Handout 1-1 Group 1:

Nine Career Fire Fighters Die in Rapid Fire Progression at Commercial Furniture Showroom — South Carolina

2017 18
Death in the line of duty... NIOSH Fire Fighter Fatality Investigation and Prevention Program
Fire Fighter Fatality Investigation and Prevention Program
A summary of a NIOSH fire fighter fatality investigation February 11, 2009

Nine Career Fire Fighters Die in Rapid Fire Progression at Commercial Furniture Showroom – South Carolina

SUMMARY

Incident Scene

(Photo courtesy of Alexander Fox, Associated Press.)

On June 18, 2007, nine career fire fighters (all males, ages 27 – 56) died when they became disoriented and ran out of air in rapidly deteriorating conditions inside a burning commercial furniture showroom and warehouse facility. The first arriving engine company found a rapidly growing fire at the enclosed loading dock connecting the showroom to the warehouse. The Assistant Chief entered the main showroom entrance at the front of the structure but did not find any signs of fire or smoke in the main showroom. He observed fire inside the structure when a door connecting the rear of the right showroom addition to the loading dock was opened. Within minutes, the fire rapidly spread into and above the main showroom, the right showroom addition, and the warehouse. The burning furniture quickly generated a huge amount of toxic and highly flammable gases along with soot and products of incomplete combustion that added to the fuel load. The fire overwhelmed the interior attack and the interior crews became disoriented when thick black smoke filled the showrooms from ceiling to floor. The interior fire fighters realized they were in trouble and began to radio for assistance as the heat intensified. One fire fighter activated the emergency button on his radio. The front showroom windows were knocked out and fire fighters, including a crew from a mutual-aid department, were sent inside to search for the missing fire fighters. Soon after, the flammable mixture of combustion by-products ignited, and fire raced through the main showroom. Interior fire fighters were caught in the rapid fire

progression and nine fire fighters from the first-responding fire department died. At least nine other fire fighters, including two mutual-aid fire fighters, barely escaped serious injury.

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the Federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other Federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. To request additional copies of this report (specify the case number shown in the shield above), for other fatality investigation reports, or further information, visit the Program Website's article Fire Fighter Fatality Investigation and Prevention or call toll free **1-800-CDC-INFO** (1-800-232-4636). (This link is also accessible at the following URL: www.cdc.gov/niosh/fire).

NIOSH investigators concluded that, to minimize the risk of similar occurrences, fire departments should:

- ***develop, implement and enforce written standard operating procedures (SOPs) for an occupational safety and health program in accordance with NFPA 1500***
- ***develop, implement, and enforce a written Incident Management System to be followed at all emergency incident operations***
- ***develop, implement, and enforce written SOPs that identify incident management training standards and requirements for members expected to serve in command roles***
- ***ensure that the Incident Commander is clearly identified as the only individual with overall authority and responsibility for management of all activities at an incident***
- ***ensure that the Incident Commander conducts an initial size-up and risk assessment of the incident scene before beginning interior firefighting operations***
- ***train fire fighters to communicate interior conditions to the Incident Commander as soon as possible and to provide regular updates***

- ***ensure that the Incident Commander establishes a stationary command post, maintains the role of director of fireground operations, and does not become involved in fire-fighting efforts***
- ***ensure the early implementation of division / group command into the Incident Command System***
- ***ensure that the Incident Commander continuously evaluates the risk versus gain when determining whether the fire suppression operation will be offensive or defensive***
- ***ensure that the Incident Commander maintains close accountability for all personnel operating on the fireground***
- ***ensure that a separate Incident Safety Officer, independent from the Incident Commander, is appointed at each structure fire***
- ***ensure that crew integrity is maintained during fire suppression operations***
- ***ensure that a rapid intervention crew (RIC) / rapid intervention team (RIT) is established and available to immediately respond to emergency rescue incidents***
- ***ensure that adequate numbers of staff are available to immediately respond to emergency incidents***
- ***ensure that ventilation to release heat and smoke is closely coordinated with interior fire suppression operations***
- ***conduct pre-incident planning inspections of buildings within their jurisdictions to facilitate development of safe fireground strategies and tactics***
- ***consider establishing and enforcing standardized resource deployment approaches and utilize dispatch entities to move resources to fill service gaps***
- ***develop and coordinate pre-incident planning protocols with mutual aid departments***
- ***ensure that any offensive attack is conducted using adequate fire streams based on characteristics of the structure and fuel load present***
- ***ensure that an adequate water supply is established and maintained***
- ***consider using exit locators such as high intensity floodlights, flashing strobe lights, hose markings, or safety ropes to guide lost or disoriented fire fighters to the exit***
- ***ensure that Mayday transmissions are received and prioritized by the Incident Commander***
- ***train fire fighters on actions to take if they become trapped or disoriented inside a burning structure***
- ***ensure that all fire fighters and line officers receive fundamental and annual refresher training according to NFPA 1001 and NFPA 1021***
- ***implement joint training on response protocols with mutual aid departments***

- ***ensure apparatus operators are properly trained and familiar with their apparatus***
- ***protect stretched hoselines from vehicular traffic and work with law enforcement or other appropriate agencies to provide traffic control***
- ***ensure that fire fighters wear a full array of turnout clothing and personal protective equipment appropriate for the assigned task while participating in fire suppression and overhaul activities***
- ***ensure that fire fighters are trained in air management techniques to ensure they receive the maximum benefit from their self-contained breathing apparatus (SCBA)***
- ***develop, implement and enforce written SOPS to ensure that SCBA cylinders are fully charged and ready for use***
- ***use thermal imaging cameras (TICs) during the initial size-up and search phases of a fire***
- ***develop, implement and enforce written SOPs and provide fire fighters with training on the hazards of truss construction***
- ***establish a system to facilitate the reporting of unsafe conditions or code violations to the appropriate authorities***
- ***ensure that fire fighters and emergency responders are provided with effective incident rehabilitation***
- ***provide fire fighters with station / work uniforms (e.g., pants and shirts) that are compliant with NFPA 1975 and ensure the use and proper care of these garments.***

Additionally, Federal and state occupational safety and health administrations should:

- ***consider developing additional regulations to improve the safety of fire fighters, including adopting National Fire Protection Association (NFPA) consensus standards.***

Additionally, manufacturers, equipment designers, and researchers should:

- ***continue to develop and refine durable, easy-to-use radio systems to enhance verbal and radio communication in conjunction with properly worn SCBA***
- ***conduct research into refining existing and developing new technology to track the movement of fire fighters inside structures.***

Additionally, code setting organizations and municipalities should:

- ***require the use of sprinkler systems in commercial structures, especially ones having high fuel loads and other unique life-safety hazards, and establish retroactive requirements for the installation of fire sprinkler systems when additions to commercial buildings increase the fire and life safety hazards***

- ***require the use of automatic ventilation systems in large commercial structures, especially ones having high fuel loads and other unique life-safety hazards.***

Additionally, municipalities and local authorities having jurisdiction should:

- ***coordinate the collection of building information and the sharing of information between building authorities and fire departments***
- ***consider establishing one central dispatch center to coordinate and communicate activities involving units from multiple jurisdictions***
- ***ensure that fire departments responding to mutual aid incidents are equipped with mobile and portable communications equipment that are capable of handling the volume of radio traffic and allow communications among all responding companies within their jurisdiction.***

INTRODUCTION

On June 18, 2007, nine male career fire fighters (the victims), aged 27 to 56, died when they became disoriented in rapidly deteriorating conditions inside a burning commercial furniture showroom and warehouse facility. At least seven other municipal fire fighters and two mutual aid fire fighters barely escaped serious injury.

The National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research, Fire Fighter Fatality Investigation and Prevention Program, learned of the incident on June 19, 2007 through the national news media. On June 19, 2007, the U.S. Fire Administration (USFA) notified NIOSH of the fatalities. That same day, a Safety Engineer and a General Engineer from NIOSH traveled to South Carolina to initiate an investigation of the incident. The NIOSH investigators traveled to the incident site and met with representatives of the Bureau of Alcohol, Tobacco and Firearms (ATF), National Institute of Standards and Technology (NIST), South Carolina State Law Enforcement Division (SLED), and South Carolina Occupational Safety and Health Administration (SC-OSHA). The NIOSH investigators were on-site June 20-22, and the NIOSH General Engineer returned June 24th to work with representatives of NIST to collect data related to the structure's construction1 for the NIOSH investigation and for a comprehensive fire reconstruction model. Note: The NIST Building and Fire Research Laboratory is developing a computerized fire model to aid in reconstructing the events of the fire. When completed, this model will be available at the NIST website. (This link is also accessible at the following URL::http://www.bfrl.nist.gov/).

On July 9, 2007, three NIOSH investigators (Safety Engineer, General Engineer, and Safety and Occupational Health Specialist), along with representatives of NIST, returned to South Carolina. Meetings were conducted with the Fire Chief; Assistant Chief, the city's Director, Safety Management Division; and the city's Workers' Compensation administrator.

[1] The fire completely destroyed the structure and the sheet metal roof was removed at the direction of ATF before NIOSH and NIST were allowed access to the structure. Consequently, detailed information on the construction was not available and NIOSH and NIST frequently relied on photographs of the structure after the fire.

During the weeks of July 9-13, July 16-20, and August 27-31, 2007, interviews were conducted with officers and fire fighters who were on-duty and dispatched to the incident scene, as well as fire fighters who were off-duty and came to the scene to offer assistance. Fire fighters from two mutual aid departments were also interviewed during these times. NIST representatives participated in many of the NIOSH interviews to collect information for their computerized fire model.

During the course of the ensuing investigation, the NIOSH investigators met with chief officers and fire fighters from the initial responding department, two local mutual aid departments, NIST staff, the county coroner, the county emergency response dispatch center staff, city building inspectors, city water system officials, representatives of the International Association of Fire Fighters (IAFF) labor union, U.S. Fire Administration staff, ATF, and representatives of the city's Fire Review Team (FRT).

NIOSH investigators reviewed some departmental standard operating procedures,[2] the victims' training records, chief officers' training records, and floor plans and photographs of the structure. Photographs were obtained from a number of sources including NIOSH, NIST, the city police department, the FRT and national media.[3] NIOSH investigators visited the city's fire training academy, met with the training officer, and reviewed the training schedule (see Appendix I). The department's maintenance and repair facility (for in-house maintenance and repair of fire apparatus, equipment, and self-contained breathing apparatus (SCBA)) was visited and maintenance records were reviewed. An independent inspection report for one of the apparatuses involved in the incident, which had been contracted for by the city, was reviewed (see Appendix II). The city's fire and police dispatch center was visited as well as the dispatch center for the first responding mutual aid department. Other sources of information used in this investigation include state and Federal OSHA regulations, NFPA standards, fire department pre-plan information (see Appendix III), coroner's reports, copies of the fireground radio transmissions provided by the city legal department, a transcript of the dispatch audio records provided by the FRT, and the FRT Phase I and Phase II reports.[1,2]

NIOSH contracted with a leading expert in personal protective clothing to evaluate the clothing and personal protective equipment worn by the victims (see Appendix IV). This evaluation took place on August 29, 2007. The evaluation site and handling of the evidence materials was coordinated with the assistance of the county coroner's office and the city police department. The PPE evaluation was witnessed by representatives of NIOSH, NIST, the FRT, the county coroner's office, the city police department, and the state fire marshal's office.

The lead NIOSH investigator participated in a meeting convened by the U.S. Fire Administration on September 20, 2007 to discuss the status of ongoing investigations and share information not of a confidential nature. This meeting consisted of representatives of the U.S. Fire Administration, ATF, the FRT, the county coroner, NIST and NIOSH. The lead NIOSH investigator participated in a similar meeting convened by the FRT on December 18, 2007. This meeting consisted of representatives of the FRT, ATF, the county coroner, NIST, and NIOSH.

[2] NIOSH investigators reviewed two Standard Operating Procedures (SOPs) provided to NIOSH: "Standard Operating Procedures Engine Company 2" (undated) and "Fire Department Policies and Procedures Manual" dated July 25, 2005. The city reported that there were additional SOPs in place at the time of the incident.

[3] Some photographs used in this NIOSH report have been altered to remove names, faces and other identifiers.

Safety and Health Regulations

South Carolina is one of 26 states and territories that administers its own occupational safety and health program through an agreement with the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA). The South Carolina Occupational Safety and Health Administration (SC-OSHA) has jurisdiction over private and public sector employers and employees within the state. The state occupational safety and health act requires employers to provide their employees with a safe and healthy worksite free of hazards that may cause injuries and illnesses to workers. South Carolina has adopted the Federal OSHA Standards verbatim, with a few exceptions.3 Most notably, South Carolina OSHA has revised the Federal OSHA Respiratory Protection Standard paragraph 1910.134(g)(4)(ii), commonly known in the fire service as the "two in – two out" rule, to allow fire fighters to enter immediately-dangerous-to-life-or-health (IDLH) atmospheres with only one fire fighter located outside the IDLH atmosphere until additional fire fighters arrive, provided certain conditions are met.

Following the fatal fire, SC-OSHA cited the fire department for several alleged violations and assessed penalties.4 The fire department and city contested these findings and SC-OSHA and the city reached a settlement in which the fire department was cited for two violations, an inadequate fire department incident command system and failure to ensure use of personal protective equipment by some fire fighters at the incident.5 SC-OSHA also cited the furniture store employer for locked exit doors, fire doors not operating properly, and not implementing an emergency action plan at the store.4

Fire Department

At the time of the incident, the career fire department was an ISO4 Class I rated department with 19 fire companies located throughout the city. The fire department serves a population of approximately 106,000 in a geographic area of about 91 square miles. In June 2007, the fire department consisted of approximately 240 uniformed fire fighters and fire officers. The department operated 16 engine companies and 3 ladder truck companies at 14 stations in the city. Each apparatus was staffed with four fire fighters but routinely operated with three fire fighters per apparatus (a captain, engineer, and fire fighter), depending on the staffing available each shift. The standard work shift was 24 hours on-duty and 48 hours off-duty, with fire fighters assigned to one of three rotating shifts. Each shift was supervised by an Assistant Chief. On the day of the incident, the department had 61 fire fighters, 4 Battalion Chiefs and an Assistant Chief working on-duty. Note: At the time of the incident, the fire department did not have a safety

[4] ISO is an independent commercial enterprise which helps customers identify and mitigate risk. ISO can provide communities with information on fire protection, water systems, other critical infrastructure, building codes, and natural and man-made catastrophes. Virtually all U.S. insurers of homes and business properties use ISO's Public Protection Classifications (PPC) to calculate premiums. In general, the price of fire insurance in a community with a good PPC is substantially lower than in a community with a poor PPC, assuming all factors are equal. ISO's PPC program evaluates communities according to a uniform set of criteria known as the Fire Suppression Rating Schedule (FSRS). The FSRS has three main parts – fire alarm and communications (10%), the fire department (50%), and water supply (40%). The FSRS references nationally recognized standards developed by the National Fire Protection Association (NFPA) and the American Water Works Association. Rated fire departments are classified 1 through 10 with Class 1 being the best rating a fire department can receive. More information about ISO and their Fire Suppression Rating Schedule can be found at the website http://www.isogov.com/about/.

officer position and a safety officer was not designated at the incident. Since then, the fire department has hired a full-time permanent safety officer.

The fire department utilized the 911 dispatch center operated by the municipal police department (PD). The local county also maintains an emergency communications / dispatch center and provides communications for two small fire departments. Some mutual aid fire departments within the county maintain their own dispatch centers.

The first mutual aid department to respond to the scene was a career department that employs 60 fire fighters and officers. It maintains four stations and serves a population of approximately 24,000 residents in an area of approximately 30 square miles. Jurisdictional boundaries between this mutual aid department and the municipal department were intermingled. Adjoining properties in the same block could be in different jurisdictions. This led to incidents where a department would be the first to arrive at a working fire outside its jurisdiction.

The second mutual aid department to respond to the scene was a combination department with 44 fire fighters that serves a rural population of 14,000.

Training

In South Carolina, it is up to the local fire chief to decide what level of training is required for fire department personnel to obtain in order to meet SC-OSHA training requirements. At the time of the incident, this municipal fire department required fire fighters to receive basic training to at least Fire Fighter I certification from the South Carolina Fire Academy or some other source. While the South Carolina Fire Academy is accredited by the International Fire Service Accreditation Congress to provide a number of NFPA level courses, at the time of the incident, the fire department recognized training from sources other than the South Carolina Fire Academy as meeting their basic certification requirements. Note: Basic fire fighter certification required by the fire department at the time of the incident did not meet NFPA 1001, Standard for Firefighter Professional Qualifications. 6

Once hired, the recruits were assigned to the department's training center for 10 days of hands-on training after which the new fire fighters were assigned to companies throughout the city. The department's training focused on equipment use, SCBA use, ladder drills, hydrant hookup, hose lays, hose pulls, rescue drills, and live-burn exercises (see training schedule – Appendix I). A training officer supervised the recruit training and oversaw the department's training program. Individual companies normally trained from 0930 to 1130 hours each day with each company's captain responsible for the training. Training on hydrant location and hook-up was done once per month.

Driver / operator training was mainly on-the-job hands-on training. Individual fire fighters could request to receive driver / operator training. The request would then be reviewed and approved through the department's chain of command.

Training records provided by the city for the nine victims consisted of verification of the weekly in-station training, certificates indicating training on subjects such as National Incident Management System (NIMS), weapons of mass destruction (WMD) and emergency medical services – medical first responder. SCBA facepiece fit test records were also provided. Training records for the chief officers were provided, consisting mainly of copies of National Incident Management System (NIMS) training certificates.

Victims

Note: Throughout this report, the 9 victims are identified by the order in which they were located at the scene, identified by the County Coroner, removed from the structure and transported. The following table provides information on each victim.

Victims (Order located)	Rank	Apparatus	Age	Experience (yrs)
1	Engineer	Engine 19	37	9
2	Fire fighter	Engine 19	56	32
3	Fire fighter	Engine 16	46	2
4	Assistant Engineer	Ladder 5	27	1.5
5	Captain	Engine 16	49	29
6	Captain	Engine 19	48	30
7	Acting Captain	Ladder 5	40	12.5
8	Captain	Engine 15	34	11.5
9	Fire fighter	Ladder 5	27	4

Equipment and Personnel

The municipal fire department initially responded to the alarm with 3 apparatus and 9 fire fighters including Engine 11 (E-11 acting captain, acting engineer and fire fighter), Engine 10 (E-10 captain, acting engineer and fire fighter), Ladder 5 (L-5 acting captain, engineer (assistant engineer), and fire fighter), a battalion chief (BC-4) and an Assistant Chief (AC). *Note: Fire department procedures stated that where structures were 5 stories or less in height, the first alarm assignment would be 2 engines, 1 ladder truck, and a Battalion Chief. For structures over 5 stories in height, the first alarm assignment would be 3 engines, 1 ladder truck, a Battalion Chief and the Assistant Chief. Once on-scene, the Incident Commander could request additional resources as deemed necessary. Procedures also stated that a confirmed report of "smoke showing" would automatically send an additional engine. When a ranking officer arrived on-scene, that officer automatically became Incident Commander.*

Engine 16 (E-16 captain, engineer, and fire fighter) was dispatched after BC-4 (the initial Incident Commander (IC)) radioed dispatch to confirm smoke was showing at the incident site as per department procedures. E-16 was designated as the third-due engine responding to all structure fires in the western district (where the incident occurred) if not assigned on the initial dispatch. Chief Officers requested Engine 15 (E-15), Engine 12 (E-12), Engine 19 (E-19), Engine 6 (E-6), Engine 3 (E-3), Engine 13 (E-13), Engine 9 (E-9), and Ladder 4 (L-4) as the incident escalated. Additional responders included the Battalion Chief from the neighboring district (BC-5) and the Battalion Chief of training (BC-T). A large number of off-duty officers and fire fighters also responded to the incident scene. Some of the off-duty fire fighters responded with turnout gear, others did not.

Only the units directly involved in the operations preceding the fatal event are discussed in this report. The activities of the additional mutual aid departments that were dispatched after the structure collapsed are not addressed by this report.

Timeline

Note: This timeline is provided to set out, to the extent possible, the sequence of events as the fire departments responded. The times are approximate and were obtained from review of the dispatch audio records, witness interviews, photographs of the scene and other available information. In some cases the times may be rounded to the nearest minute, and some events may not have been included. The timeline is not intended, nor should it be used, as a formal record of events.

The response, listed in order of arrival (time approximate) and events, include:

- **1907 hours**
  Dispatch for possible fire behind furniture store

- **1909 hours**
  BC-4, E-10, E-11, L-5 enroute
  BC-4 confirms smoke showing while enroute
  E-10, L-5, E-16 acknowledge hearing BC-4 confirm fire
  AC enroute

- **1910 hours**
  E-16 enroute as third-due engine
  E-15 relocates to western district
  BC-4 arrives on scene and reports trash fire at side of building.
  BC-4 radios for E-10 to come down side of building

- **1911 hours**
  Assistant Chief (AC) on scene
  E-10 and E-11 on scene

- **1912 hours**
  AC radios for E-16 to come inside building when they arrive on-scene.
  (Showroom clear with no fire/smoke showing)
  Ladder 5 on scene

Fire Chief (enroute) radios E-15 to relocate to Station 11
AC radios dispatch to send Engine 12
BC-4 radios Car 2 and says he knows fire is inside
building Engine 12 dispatched to scene

- **1913 hours**
  BC-4 radios E-12 that he needs E-12 to lay a supply line to E-10
  E-11 acting captain radios “I need an 1 ½” inside this building”
  (Door connecting showroom to loading dock was opened by AC showing heavy fire in loading dock)
  AC radios E-15 to “come on”
  AC radios E-15 and says to bring 1 ½” hoseline inside to right rear of
  building E-6 begins relocating to the west side

- **1914 hours**
  AC radios BC-4 and says fire is inside the rear of the building and moving towards the showroom
  AC radios dispatch to send E-6
  E-6 dispatched to scene
  Fire Chief radios dispatch to send E-19 and have E-6 relocate to Station 11

- **1915 hours**
  AC radios E-16 to bring 2 ½” hoseline in front door
  E-16 radios AC to confirm assignment
  E-16 on-scene

- **1916 hours**
  L-5 engineer and L-5 fire fighter both radio E-11 to charge line (1 ½” line pulled by L-5 / E11 crews)
  E-19 enroute
  L-5 again requests E-11 to charge hoseline
  Fire Chief on scene

- **1917 hours**
  E-12 on scene - assigned to lay supply line to E-10
  E-15 on scene

- **1919 hours**
  Fire Chief radios E-6 and tells them to come to scene and come in front door
  E-6 responds they are enroute
  Fire Chief radios dispatch to call the power company
  E-16 captain radios “charge that 2 ½”

- **1920 hours**

E-11 engineer radios the E-11 acting captain to see if he wants the 2 ½" hoseline charged. AC replies "not until the supply line is charged"
E-19 on scene
E-12 radios E-10 … "water coming 10"
E-12 engineer radios dispatch that the police department is needed because cars are running over hoses. Dispatch replies that the police department is enroute

- **1921 hours**
  AC radios E-16 engineer - "16, what about that supply line?" E-16 engineer replies he is looking for a hydrant.
  E-6 on scene

- **1922 hours**
  E-11 engineer radios E-16 that tank water is down to half-full
  E-16 engineer replies he is looking for hydrant

- **1924 hours** (see Photo #1) Battalion Chief 5 (BC-5) on scene
  Fire Chief radios E-12 to boost water pressure on supply line by 50 pounds E-12 acknowledges
  AC radios. "We need that 2 ½" (referring to 2 ½" hoseline off E-11)
  E-3 is relocated to Station 16/19
  Mutual aid department # 1 on-scene

- **1925 hours**
  E-10 radios that tank water is down to one-quarter full
  Fire Chief radios E-12 to boost supply water pressure to E-10 by 50 more pounds
  E-12 acknowledges
  Mutual aid department # 1 radios the fire department with no response

- **1926 hours**
  E-16 engineer radios that "water coming"
  Dispatch radios Fire Chief and informs him that dispatch has received a phone call from a civilian saying he is trapped at the rear of the building
  Fire Chief acknowledges

- **1927 hours**
  Inaudible radio traffic – possibly "lost inside" or "trapped inside"
  Fire Chief radios AC and says that the warehouse door has been opened and a 2 ½" hoseline is in operation. Fire Chief also asks about the rescue attempt of the trapped civilian and tells AC to do what he can do.
  Dispatch radios AC to inform him that the trapped civilian is banging on exterior wall with a hammer

- **1928 hours**

AC radios for E-11 and gets no response. *Note: This may be when the AC is looking for fire fighters to assist with rescue of the civilian and mutual aid fire fighters are pressed into action.*

- **1929 hours**
  Broken radio traffic of fire fighter in distress asking “which way out” then “everyone out”

- **1930 hours** (see Photo #2)
  E-11 radios that 2 ½” hoseline is charged
  Several different fire fighters in distress radio “need some help out,” “need help getting out,” also “lost connection with the hose”
  AC radios Fire Chief that they are attempting to free civilian trapped in warehouse

- **1931 hours – 1934 hours** (see Photo #3)
  More broken radio traffic from fire fighters in distress
  L-5 repositioned to D-side by off-duty fire fighters
  Fire Chief asks for E-3 to come to scene and lay supply line to L-5
  BC-5 reports civilian is out of building
  E-16 engineer radios dispatch that police department is needed to prevent traffic from running over supply line. FF calls Mayday
  Fire Chief asks AC “is everyone out?” AC responds the civilian is out; Fire Chief radios AC to make sure his people are accounted for.
  E-15 FF exits building (out of air) – reports he didn’t call the Mayday
  Fire Chief radios “who called Mayday”
  Fire Chief radios “…we need to vacate the building”
  Dispatch tells Fire Chief that the L-5 engineer emergency button (on radio) has been activated
  Fire Chief radios for E-15 captain with no response
  E-15 FF changes air cylinder and goes back inside

- **1935 hours – 1936 hours** (see Photos # 4, # 5, and # 6)
  Front windows knocked out
  E-6 crew (captain, engineer, and FF) along with E-15 engineer and FF exit showroom
  Fire Chief orders mutual aid crew to search for missing fire fighters
  Fire Chief continues to radio for E-15 captain and crew with no response
  Fire Chief instructs everyone else to stay off radio
  Conditions at front of showroom change dramatically – turbulent thick dark smoke rolls out windows

- **1937 hours**
  Fire Chief continues to radio for E-15 captain and crew with no response
  E-13 is dispatched to scene
  E-7 relocates to Station 13
  Fire rolls out windows at front of showroom

- **1938 hours** (see Photos # 7 and # 8)
  Mutual aid crew exits building
  Fire Chief continues to radio for E-15 captain and crew with no response
  Fire Chief radios for everyone to abandon the building
  Training Chief (BC-T) radios for E-15 captain
  BC-T radios E-16 engineer to boost water supply pressure to E-11.

- **1939 hours**
  AC radios E-16 to “give me some more water”
  BC-T also radios E-16 for more water pressure
  E-16 engineer acknowledges and water pressure is boosted to 200 psi

- **1940 hours** E-3 on scene
  Mutual Aid Department # 2 enroute to lay water supply line to L-5

- **1942 hours**
  BC-T continues to radio for E-15 captain (no response)
  Fire Chief radios that no one is to go
  inside E-13 on scene

- **1943 hours**
  Fire Chief asks if everyone is out of front
  BC-T radios E-16 engineer that he needs more water pressure. Engineer responds that the entire hose bed has been stretched out plus two sections of 3” hose. Additional radio communications about civilian vehicle traffic driving over the supply line. BC-T radios E-16 engineer and says “I need all you can give me!”

- **1944 hours**
  AC radios dispatch to call the city water department to increase water pressure in the area.
  Fire Chief radios for E-15 captain
  E-3 engineer radios that water is coming (water supply established to L-5)

Additional crews continued to arrive on-scene and contributed to the fire suppression efforts. Engine 13 began laying a supply line to L-5 at 1947 hours. The Fire Chief radioed dispatch to send Ladder 4 to the scene at 1948 hours. The Fire Chief radioed dispatch and requested that the Mayor be notified at 1950 hours. A portion of the roof over the right side of the showroom collapsed causing the front façade to begin collapsing at 1951 hours. Eventually, almost the entire roof over the main showroom and the right side addition collapsed. Ladder 4 was put into operation in the front parking lot at approximately 2005 hours. The fire was brought under control after 2200 hours. Recovery operations continued until after 0400 hours the next morning.

Personal Protective Equipment

The fire department issued each fire fighter a full set of black turnout gear and station uniforms when they were hired and sent to the recruit training class. The department issued helmets, hoods, gloves, and boots. The Chief Officers (Battalion Chief rank and higher) wore a set of brown turnout gear from a different manufacturer. At the time of the incident, each fire fighter was allowed to purchase and wear his own turnout gear, or bring their gear from other departments they served in, if they desired, so long as it met the requirements of the department.

Following the incident, the personal protective equipment (PPE – turnout clothing, SCBA, radio, hand tools, etc.) worn by each of the nine victims was secured by the city police department. On August 29, 2007, the PPE was examined in detail by a personal protective clothing expert contracted by NIOSH. The PPE was examined, documented and photographed through a systematic process. The county coroner's office coordinated the PPE examination at the request of NIOSH.

Representatives of NIOSH, NIST, the FRT, the county coroner's office, the city police department, and the state fire marshal's office were present during the examination. Each victim's PPE was severely damaged by fire and heat exposure due to the length of time it took to locate and recover the victims. The evaluation indicated melting of polyester station uniforms (non-NFPA 19757 compliant) in the areas where the turnout clothing was degraded by the fire exposure. The PPE examination also identified examples where turnout gear was not being properly worn such as turnout coat collars not fully extended upward and helmet earflaps not deployed. A summary of the complete PPE inspection is contained in Appendix IV. A copy of the complete PPE inspection report is available upon request from the NIOSH Fire Fighter Fatality Investigation and Prevention Program.

The city fire and police departments utilized a type-2 trunked radio system (computer-aided) that automatically assigned radio frequencies as needed to different "talk groups." Each apparatus riding position was assigned a radio so that each on-duty fire fighter had access to a radio. Each radio contained an emergency notification button that, when activated, would send a signal to the dispatch center with the radio's identity. On the day of the incident, radios were available, but at least one fire fighter did not carry his assigned radio. The county in which this incident occurred maintained its own dispatch center for emergency medical services (EMS) and the smaller outlying volunteer fire departments. Some smaller fire departments operated as public service districts (PSDs) and operated their own dispatch centers. Thus, not all fire departments who were on scene could communicate directly with the city fire department due to the multiple radio systems in place.

Apparatus and Equipment Maintenance

The fire department operated a maintenance and repair facility at one of the stations, where in-house maintenance was performed on all fire apparatus, equipment and SCBA. Annual pump flow testing was conducted and recorded. During the NIOSH investigation, interviewed fire fighters reported a number of recurring maintenance problems on apparatus and power equipment to the NIOSH investigators.

During the NIOSH investigation, fire fighters reported during interviews that Engine 11 (E-11) required specific procedures to engage the pump. When interviewed by NIOSH investigators, the maintenance supervisor reported that E-11 had a hydraulic transmission and a non-electric pump, and if the engine was not throttled to full throttle before the pump was engaged, the pump would not discharge at full capacity. The city reported that there were no records or reports of operational issues with E-11 prior to this event, and that daily equipment checks were performed. In December 2008, the city contracted with a nationally recognized company to conduct independent testing and evaluation of E-11. The city indicated that no changes had been made to Engine 11 since the fire. A copy of the December 16, 2008 inspection report was provided to NIOSH for review (Appendix II). The results of this testing and evaluation indicated that Engine 11 was generally in good acceptable working order with 3 maintenance findings that were corrected during the inspection, and 8 findings needing corrective action. In addition, the report highlighted findings of the Engine 11 pump inspection. The report reads, “When shifting the [pump] lever downward from top position, proper operation calls for a pause in center (neutral) position momentarily before bringing the lever to the complete downward position. Failure to pause at the center (neutral) position can cause a long excessive delay in engaging of pump. There is an expected delay even in proper operation of this pump. Please check with manufacturer for exact acceptable delay time line.”

During the NIOSH investigation, fire fighters reported to NIOSH investigators that the fire department’s procedure was to refill cylinders when the pressure dropped to 1500 psi which is well below the required 90% level found in the OSHA Respirator Standard8 and NFPA 18529 (1500 psi is 68% of full cylinder pressure or 2216 psi). NIOSH investigators examined a small number of SCBA cylinders in service on city fire apparatus and did find some with cylinder pressures below 2000 psi.

Structure

The structure involved in this incident was a one-story, commercial furniture showroom and warehouse facility totaling over 51,500 square feet that incorporated mixed-construction types. The structure was non-sprinklered. The facility had been renovated and expanded a number of times over the past 15 years. The original structure was constructed in the 1960’s as a 17,500 square foot grocery store with concrete block walls and lightweight metal bar joists (metal roof trusses) supporting the roof to create an open floor plan. After being converted to a furniture retail store, the original structure was expanded by adding a 6,970 square foot addition on the right side (D-side) in 1994 and a 7,020 square foot addition to the left (B-side) in 1995. Both additions were attached to the original exterior walls and consisted of steel beams supporting the walls and roof. To provide access between the original structure and the two additions, the exterior walls on the B and D sides of the original structure were each penetrated in 3 locations to form six 8′ × 8′ openings that were equipped with metal roll-up fire doors. These fire doors were equipped with fusible links designed to automatically close the doors in the event of a fire. In 1996, a 15,600-square-foot warehouse was added to the rear of the main showroom. The main showroom and the warehouse were connected by an enclosed wood-framed loading dock of approximately 2,250 square feet. Double metal doors connected the rear of the right-side addition to the loading dock area. These metal doors swung outward (opened into the loading dock). Additional access to the loading dock area was available from the rear of the original structure. (See Diagram 1)

At the time of the incident, the showroom included painted sheet-metal siding on the B and D side exterior walls with a combination of sheet metal and concrete block in the rear (C-side) and a front masonry and block façade (at the A-side). The roof over the main showroom (original structure) was constructed of sheet-metal roof decking covered by foam insulation and a weather membrane. Both right and left showroom additions included roofs constructed of sheet metal roof decking over fiber glass insulation. The fire caused extensive damage to the roof structure, making an analysis of the roof construction difficult.

The warehouse was a freestanding, clear-span structure with sheet-metal walls and roof. Both structures contained concrete floors. The main showroom measured 9 feet from the floor to a suspended drop ceiling and approximately 14 feet to the roof, creating almost 5 feet of void space above the suspended ceiling. The warehouse measured 29 feet from the floor to the roof. The warehouse contained rows of metal storage shelving that contained a variety of furniture items including couches, chairs, mattresses, etc. (see Photo 9 showing storage racks in warehouse).

The roofs over the main showroom, the showroom additions on both the B and D sides of the structure, and the warehouse contained limited penetrations (ventilation ductwork, utilities, etc.). Thus, there were limited openings for smoke and hot gases to escape naturally in the event of a fire.

According to city building officials, the property was annexed into the city in 1990. The original structure and the 3 additions were considered as 4 separate structures for code enforcement purposes. Separate permits were issued for the construction of the left and right side additions and the warehouse. City building officials indicated to NIOSH investigators that after the fire, the furniture store property was determined to be “non-code compliant” (not in compliance with applicable codes). Work had been performed on the loading dock area and the maintenance shop without permits between 1996 and 2005. Other code violations included the accumulation of trash outside the loading dock, large quantities of flammable liquids, solvents, and thinners in the loading dock area, and storage of furniture and flammable materials in non-permitted areas.

At the time of the incident, city ordinances required commercial structures over 15,000 square feet to be equipped with a sprinkler system. The original structure was grandfathered (exempt from this requirement) while the left and right additions (at the B and D-sides) did not meet the threshold requirement. Thus, since the store was considered as 4 separate structures, the facility had been exempt from sprinkler system requirements.

The structure had been inspected by the fire department on a number of occasions. In 1987, fire inspection duties were transferred from the fire department to the city with the last documented fire code inspection by the city in 1998. The fire department continued to perform periodic pre-plan inspections. A building pre-plan form obtained from the fire department dated April 26, 2006 noted that store contents were “household furniture and office equipment” and that the rear warehouse contained racks approximately 30 feet high (see Appendix III). The pre-plan form did not mention the large volume of furniture and flammable materials (fuel load) contained in the structure. It was reported to NIOSH investigators by fire fighters during interviews that trash from the furniture business, including packing materials, cardboard, broken furniture and other flammable materials, were routinely stored against the building near the loading dock on the west (D) side of the structure (see Diagram 2).

Weather

At the time of the incident, the temperature was approximately 86 degrees Fahrenheit (F) with a dew point of 72 degrees F and a relative humidity of 63 percent. The sky was partly cloudy with light winds blowing from the south up to 11 miles per hour.[10]

INVESTIGATION

The furniture store fire on June 18, 2007, was originally dispatched as a possible fire behind a commercial retail furniture store. The initial Incident Commander radioed dispatch that the fire was a "bunch of trash free-burning against the side of the structure." The fire very rapidly grew into an incident of major proportions. (A computerized fire model will be available in the future from NIST.) (This link is also accessible at the following URL: http://www.bfrl.nist.gov/).

Summary of Initial Sequence of Events

On June 18, 2007, at approximately 1907 hours, the fire department was dispatched to a possible fire behind a large commercial retail furniture store. Two engines (Engine 11 and Engine 10), one ladder truck (Ladder 5), and the Battalion Chief (BC-4) were dispatched per department procedures. The on-duty Assistant Chief (AC) was at Station 11 and responded to the scene. While enroute, BC-4 observed heavy dark smoke rising into the air and radioed dispatch that smoke was coming from the direction of the store. Per department procedures, this initiated the response of the third-due engine (Engine 16) to the scene.

BC-4 arrived on scene driving east to west, pulled past the store and drove down the alley to the loading dock located on the D-side of the structure. BC-4 observed fire burning from ground level to over the roofline outside of the covered loading dock. Note: The covered loading dock connects the front showroom area to the rear 15,600-square foot warehouse facility. BC-4 radioed dispatch that the fire was a "bunch of trash free-burning against the side of the structure." The dispatcher asked the responding units if they heard BC-4's report on the fire conditions. E-10, L-5, and E-16 acknowledged.

When the AC arrived on-scene, he parked in the parking lot in front of the main showroom right addition. The AC and BC-4 briefly discussed their observations and directed Engine 10 to back down the alley to the loading dock area. The AC entered the store through the main entrance located in the center of the front of the structure (A-side). The AC walked down the center of the showroom to the rear (in the original structure) then went back outside. He did not observe any smoke or fire in the main showroom. BC-4 drove his car to the front of the showroom and observed the AC coming out of the showroom's main entrance. The AC remained at the front of the store while BC-4 returned to the D-side. Note: Departmental policy was that the highest-ranking officer on-scene was the Incident Commander. Incident Command (IC) was never formally announced at this incident.

While the E-11 crew looked for a hydrant to establish water supply, the AC and the E-11 acting captain re-entered the main showroom. The AC radioed E-16 to come inside the front door when they arrived on scene. E-16 acknowledged. Ladder 5 (L-5) arrived on-scene at 1912 hours and pulled into the parking lot in front of the furniture store, facing east. BC-4 radioed the AC and informed him that the fire was now inside the structure. The AC radioed Dispatch and requested that Engine 12 (E-12) be sent to the scene. The Fire Chief advised the dispatcher to relocate Engine 15 (E15) to Station 11. BC-4 radioed E-12 and instructed them to lay a supply line to E-10. E-12 acknowledged.

The Assistant Chief detected fire when he opened a door connecting the rear of the right showroom addition to the loading dock area. The E-11 acting captain radioed that he needed a 1 ½" hand line inside the building. When E-15 radioed that they had relocated to the west-side, the AC instructed E15 to come to the scene. The AC also instructed E-15 to bring a 1 ½" hand line inside to the rear right-side of the structure. The AC radioed that the fire was inside the rear of the structure and was moving towards the showroom.

The E-11 acting captain went outside and met the L-5 crew pulling a 1 ½" hand line off E-11. The AC radioed dispatch and requested that Engine 6 (E-6) be sent to the scene. E-6 was dispatched at 1914 hours. The Fire Chief (enroute) radioed dispatch to change the assignment to have Engine 19 dispatched to the scene and have E-6 relocate to Station 11. E-16 radioed the AC to ask if they were to go to the rear of the building. The AC instructed E-16 to come to the front door and bring a 2 ½" hand line inside. The Fire Chief arrived on-scene at 1916 hours. Note: Beginning at approximately 1916 hours, the L-5 engineer is heard over the radio asking for the 1 ½" hoseline from E-11 to be charged. Diagram 2 shows the location of Engine 10 and Engine 11 in relation to the structure and how the attack lines were deployed during offensive operations.

A mutual aid department noticed heavy black smoke in the area and self-dispatched to the scene. The fire had already spread to the warehouse when the mutual aid department arrived on-scene. After some discussion with the Fire Chief, the mutual aid department was assigned to the rear of the warehouse (C-side) to begin fire suppression.

The burning furniture quickly generated large volumes of smoke, toxic gases and soot that added to the fuel load. At approximately 1926 hours, a store employee called the city's 911 Dispatch center and reported that he was trapped inside the back of the building. Note: The employee was actually working near the front of the warehouse opposite the covered loading dock (see Diagram 3.) The employee stated he was banging on the exterior wall with a hammer. The dispatcher told the employee to continue banging on the wall and to stay calm and stay as low to the floor as he could. The dispatcher radioed the Fire Chief and informed him of the situation. This information was also relayed to the city police dispatcher and a police officer on-scene verbally informed some fire fighters of the situation. The city Assistant Fire Chief and a Battalion Chief (BC-5) quickly instructed a crew of four fire fighters from the mutual aid department to initiate the rescue attempt on the B-side of the warehouse. This crew quickly located the point where the trapped civilian was banging on the exterior wall. They were able to cut through the exterior wall (metal siding) using a Haligan bar and axe. The fire fighters were able to safely extricate the civilian at approximately 1933 hours. The civilian employee rescue was announced over the radio. The mutual aid fire fighters assisted the employee to the front parking lot where he was checked by EMTs.

As the civilian was being rescued, the fire was extending into the main showroom. The fire quickly outgrew the available suppression water supply. The interior fire attack crews could not contain the spread of the fire. Note: At this point, three hoselines were inside the main showroom – the initial 1½ inch hoseline, a 2½ inch hoseline and a 1 inch booster line. All three hoselines were pulled off Engine 11 which was being supplied by Engine 16 through a single 2 ½ inch supply line approximately 1,850 feet long. Water supply from En*gine 16 to Engine 11 was established at approximately 1926 hours.* The interior crews from Engine 11, Ladder 5, Engine 16, Engine 15, Engine 19, and Engine 6 became disoriented as the heat rapidly intensified and visibility dropped to zero as the thick black smoke filled the showroom from ceiling to floor. The interior fire fighters realized they were in trouble and began to radio for assistance. At least one Mayday was called. Another fire fighter radioed that he had lost contact with the hoseline and needed help. One fire fighter activated the emergency button on his radio.

*Note: During this incident fire fighters experienced intermittent radio communication problems and interruptions. Audio transcripts of the fireground channel recorded multiple instances where fire fig*hters inside the structure (including some of the victims) transmitted over the radio but the transmissions were not heard or not understood. The first recorded transmission of a fire fighter requesting assistance occurred at approximately 1927 hours and transmissions requesting "we need help," "lost connection with the hose," and "Mayday" continued until at least 1934 hours. The first "Mayday" was recorded at approximately 1932 hours. The first recorded transmissions indicating chief officers were aware of the fire fighters calling for assistance was at approximately 1933 hours.

The Engine 6 crew and three fire fighters from E-15 were able to find the front door and exit the showroom. The front showroom windows were knocked out to improve visibility. Fire fighters, including two fire fighters from the mutual aid crew who extricated the trapped civilian, were sent inside to search for the missing fire fighters at approximately 1936 hours. The two mutual aid fire fighters made brief contact with two disoriented fire fighters just as the flammable mixture of gases and combustion by-products in the showroom ignited, filling the showroom with flames. The two mutual aid fire fighters lost contact with the two disoriented fire fighters and were driven outside by the intense heat and flames (see Photo 7). One of the rescuers received second degree burns on his face, neck, hands, and arms. An off-duty Battalion Chief and the Engine 6 engineer also entered the structure for a rescue attempt. They also were driven out by the rapid fire spread.

While fire fighters were known to be trapped inside, the number and their identities were not known. Interior fire fighters were caught in the rapid fire progression and nine fire fighters from the first-responding fire department were killed.

The operational details of each responding apparatus company are listed below. Per department procedures, chief officers requested additional apparatus as the need was identified.

Engine 10

The E-10 crew (consisting of a captain, engineer, and fire fighter) was in-transit returning to quarters when the fire dispatch came in. The crew could see smoke billowing from the incident scene as they pulled onto the highway and they heard BC-4 report over the radio a trash fire on the side of the structure. Note: E-10 and Ladder 5 are quartered at the same station. The fire fighters on E-10 and L-5 had switched positions so that another fire fighter could train on pumping E-10.

The AC and BC-4 were already on-scene when Engine 10 arrived. The AC directed E-10 to back down the alley parallel to the D-side of the store toward the loading dock. The crew observed smoke and flames inside the loading dock area and coming out an exhaust fan in the D-side wall. The E-10

captain pulled a booster line (1" red hose) and knocked down the outside trash fire while the E-10 fire fighter pulled a 1 ½" pre-connected hand line to the loading dock. BC-4 returned to the loading dock after meeting with the AC and observed fire burning inside the structure so he radioed dispatch to report that the fire was now inside the building. The E-10 captain decided to use the 1 ½" hand line for the interior attack. The E-10 engineer charged the 1 ½" hand line from the engine's tank-water supply. Fire was readily visible inside the loading dock area as the E-10 fire fighter and captain advanced the hoseline inside the loading dock about 20 to 25 feet. At their furthest point of entry, the E-10 crew could just see the door connecting the enclosed loading dock to the showroom right-side addition. This area became fully involved in flames as the E-10 crew directed water onto the fire. The 60 gallons per minute (gpm) flow from their 1 ½" handline was insufficient to control the fire. According to the fire fighters interviewed by NIOSH, the flames appeared to float in the air and burned floor to ceiling. The water didn't appear to have any effect on the fire so the crew started to retreat. Note: The E-10 crew told NIOSH investigators that the water pattern produced by their fog nozzle just pushed the flames around the room as they attempted to extinguish the fire. After the fire, at least 28 one-gallon cans of extremely flammable solvents were found inside the loading dock suggesting that at some point a vapor fire was burning inside the loading dock. As they were backing out, the hose either burst or was burned through by the fire. Water spraying from the ruptured hose aided the fire fighters (improved visibility and provided a protective water curtain) in locating the door and moving outside.

The E-10 engineer pulled some sections of 2 ½" supply line from E-10 out to the street to meet E-12 which had been assigned to provide a water supply line. When the E-10 attack crew exited the loading dock, they asked fire fighters from Engine 12 (E-12), just arriving on-scene, to repair the damaged 1 ½" hand line. The E-10 captain and fire fighter got the 1" booster line that they had previously pulled off E-10 and advanced the booster line to the loading dock door. The booster line did not have any effect on the fire so they backed the line out, switched back to the 1 ½" hand line (that had been repaired by the E-12 crew) and moved back inside the loading dock. By this time the Fire Chief was on scene. The Fire Chief came to the loading dock and yelled inside to tell the E-10 captain not to advance any further. A few seconds later, the Fire Chief ordered the E-10 crew to back outside and operate from the doorway. Note: The E-10 crew was inside the loading dock 3 times for a total of approximately 15 minutes. BC-4 observed that the fire had extended into the warehouse. BC-4 returned to the front of the building and asked the manager if he had keys for the warehouse at the rear of the loading dock. The manager said "no," so BC-4 returned to the loading dock and directed the E-12 crew and off-duty fire fighters who had responded to the scene to cut through the warehouse's roll-up door with a power saw. The crews experienced trouble with getting the saw to run properly and used axes and Haligan bars to open the warehouse doors. BC-4 also directed the E10 crew to assist with opening up the warehouse. BC-4 then directed the E-10 crew to get a 2 ½" hand line with a stack-tipped nozzle from E-10 and pull it to the warehouse door. By this time, the warehouse was becoming well involved. A second 2 ½" hoseline was later pulled from E-10 and put into operation.

BC-4 was able to look inside the warehouse and he observed a large amount of fire inside. BC-4 went back to the front of the building and directed 2 off-duty fire fighters to move Ladder 5 to the Dside and set it up for aerial water pipe operation. BC-4 also met with an off-duty captain and asked him to take over getting L-5 set up for operation. Note: This off-duty captain is also an Assistant Chief at a neighboring mutual aid fire department located about 20 miles away. A crew from the mutual aid department responded and the captain used this mutual aid crew to assist with establishing water supply to L-5 by supplying it with tank water and then stretching supply lines to Engine 12. Per department procedures, off-duty fire fighters are allowed to respond to working fires and become involved in fire suppression activities. Off-duty fire fighters are supposed to check in with the IC, give the IC their ID card or driver's license, and get an assignment. The civilian owner of a small yellow frame building located next to the D-side of the furniture warehouse advised BC-4 that his building was full of vehicles, gasoline, oil, and other flammables (see Diagram # 2). BC-4 talked to the deputy chief of the first mutual aid department about the building and asked him to get a hand line to protect the yellow building. Once L-5 was put into operation at approximately 1944 hours, it also was used to protect this building.

Engine 11

The Engine 11 (E-11) crew (acting captain, acting engineer, and fire fighter) was in quarters at Station 11 and the engine was being washed when the fire dispatch was initiated. The AC and BC-4 were also at station 11. E-11 was the first due engine but Engine 10 was in the vicinity and arrived on-scene first. While enroute to the scene, the E-11 crew heard BC-4 radio that smoke was coming from the location of the furniture store. The original fire dispatch stated that the fire was at the rear, so E-11 turned left off the highway onto a side street and drove behind the building. The AC radioed for E-11 to come back to the front of the store and pull into the second entrance to the parking lot. E11 circled around and turned right into the parking lot in front of the store just as E-10 backed down the alley on the D side. E-11 got on scene at 1911 hours just before BC-4 radioed that the fire was inside the structure. The acting captain on E-11 directed the E-11 acting engineer and fire fighter to lay a supply line to E-10. The E-11 fire fighter (suction man) started walking down the street looking for a hydrant. The E-11 fire fighter returned to E-11 before making a hydrant connection when Ladder 5 (L-5) arrived on-scene. The E-11 acting engineer was directed by the L-5 acting captain to reposition E-11 near the front door facing northeast.

The E-11 acting captain entered the main showroom doors and walked down the center aisle to the rear of the main showroom. The showroom was clear with no smoke visible inside. The AC had preceded the E-11 acting captain inside the showroom and the two walked into the right addition and walked to the rear of the right showroom addition. They both observed a small wisp of light smoke visible at ceiling level in this area. They were not immediately alarmed by this smoke and the AC opened the double door leading to the loading dock. They reported seeing lots of fire and smoke beyond the door. The AC attempted to pull the door shut but he could not shut the door due to the air rushing from the showroom toward the fire. The E-11 acting captain helped pull the door shut and the AC told the acting captain to get a 1 ½" hand line.

At 1913 hours, the E-11 acting captain radioed that he "needed an inch-and-a-half inside the building." The E-11 acting captain then went outside and met the acting captain from Ladder 5 (L-5) pulling a 1 ½" preconnected handline off E-11. They both pulled the 1 ½" pre- connected hand line through the center doors and down the center aisle. The hand line just reached the rear of the center showroom. The E-11 acting captain told the L-5 acting captain he was going to go outside to add in another section of hose. The E-11 acting captain added 5 more sections of 1 ½" hose (the second preconnected hoseline on E-11) and dragged it inside. The L-5 acting captain and L-5 fire fighter were at the nozzle at this time. The L-5 crew pulled the nozzle toward the rear of the right side addition (the line was still not charged at this point). The E-11 fire fighter entered the main showroom flaking more slack in the hoseline. The E-11 acting captain asked him to go find out why they did not yet have water pressure on the 1 ½" hose.

After waiting a short time for water pressure, the E-11 acting captain went outside to find out why they still didn't have water pressure. The E-11 acting captain and engineer were able to get the pump in operation by cycling the engine transmission to get the pump in gear. Note: Fire fighters interviewed by NIOSH stated that E-11 required specific procedures to engage the pump; an independent inspection of the apparatus confirmed these findings. On the day of the incident, the E11 engineer was serving as the acting captain so E-11 was driven and operated by a fire fighter less experienced in its operation.

The E-11 acting captain then re-entered the structure. He had to don his facepiece and go on air because gray-colored smoke was starting to accumulate in the center of the showroom. Fire was still not visible in the showroom at this point.

The Engine 16 (E-16) captain and fire fighter entered the showroom with a 2 ½" hoseline that was uncharged at this point. The E-11 acting captain told the E-16 captain he would go find out why the 2 ½" hoseline was still uncharged. As he started to exit the showroom, the inside conditions changed very rapidly. The smoke turned very thick and grayish black. The E-11 acting captain had to find the 1 ½" hose and follow it outside. E-11 was still without a water supply at this point. After talking with the E-11 acting engineer about the water supply situation, the E-11 acting captain walked around to the loading dock area to look for the E-11 fire fighter.

While at the D-side, BC-4 asked the E-11 acting captain to help with setting up a 2 ½" hoseline to the warehouse. Note: This 2 ½" hoseline was pulled from E-10. The E-11 acting captain was just stepping up to the warehouse door when the Fire Chief ordered everyone out of the warehouse. The E-11 acting captain observed that the other fire fighters in this area had things under control so he went back to the A-side. When the E-11 acting captain returned to the front, fire was blowing out the front windows. He heard the Fire Chief give an order to evacuate. The E-11 acting captain got into the E-11 cab and sounded the airhorn 3 times for an evacuation signal.

Ladder 5

Ladder 5 (L-5) was the third apparatus to arrive on-scene and initially positioned in the parking lot in front of the furniture store just west of E-11. The L-5 crew included an acting captain (Victim # 7), an assistant engineer (Victim # 4) and a fire fighter (Victim # 9 - who had switched assignments with the E-10 fire fighter). Note: This fire department typically dispatches ladder trucks as extra manpower, and not for ventilation activities. The ladder trucks do not have their own pumps and must be supplied by an engine in order to flow a master stream.

The L-5 acting captain directed the E-11 acting engineer to reposition E-11 near the front door of the main showroom. It is assumed that the L-5 acting captain heard the E-11 acting captain radio for a hand line inside the structure so the L-5 crew started to pull a 1 ½" preconnected hand line off of E11. When the L-5 crew took this hand line inside, they met the E-11 acting captain coming outside to get a hoseline. The L-5 crew took the 1 ½" hoseline to the rear of the right-side addition (after the E-11 acting captain added additional sections to the hoseline) and after some delay in getting water, advanced into the loading dock through the double doors connecting the showroom to the loading dock. This was the last confirmed location of the L-5 crew.

Between approximately 1932 and 1934 hours, L-5 was repositioned from the front of the showroom to the D-side by off-duty fire fighters who had responded to the scene. Fire fighters from a mutual aid department along with off-duty fire fighters worked to establish water supply to L-5. Engine 3 arrived on scene at approximately 1940 hours and also worked to get a water supply established to L5. Water supply was established at approximately 1944 hours.

Engine 16

At the time of the incident, Engine 16 (E-16) was designated as the 3rd due engine on all confirmed structure fires in the department's western district if not assigned on the initial dispatch. *Note: NIOSH investigators were told that the 3rd due engine is designated as the "Safety Team" and should have been held on stand-by at the scene. However, the crew was instructed to enga*ge in fire suppression activities before they arrived on-scene.

The crew was in quarters when the fire dispatch was initiated. The E-16 crew consisted of a captain (Victim # 5), an engineer, and a fire fighter (Victim # 3). E-16 started to move toward the scene when BC-4 reported smoke in the area. At approximately 1915 hours, the AC radioed E-16 to bring a 2 ½" hoseline in the front door. E-16 arrived on scene driving west to east. The E-16 captain and fire fighter dismounted the engine and went to talk to the AC. They took a 2 ½" hoseline with a stacked-tip nozzle (uncharged) into the main showroom and advanced it to the double doors leading to the loading dock and met up with the acting captain from E-11. This was the last confirmed location of the E-16 crew.

The E-16 engineer was instructed to lay a supply line for E-11 so he drove east on the highway toward where a hydrant had been previously located. This hydrant had been removed in 2004 because it had received damage from heavy truck traffic in the immediate area. He continued east to the next hydrant located approximately 1,200 feet away. Note: 1,850 feet of a single 2 ½" supply line was stretched from E-11 to the hydrant. The E-16 engineer reported hearing the radio traffic about the civilian worker being trapped in the rear of the building just as he was pulling up to the hydrant. (see Diagram # 2)

At approximately 1919 hours, the E-16 captain radioed to charge the 2 ½" hoseline (inside the building). The E-11 engineer radioed the E-11 acting captain to ask if he wanted the 2 ½" hoseline charged. The AC responded to not charge the 2 ½" hoseline until the supply line from E-16 to E-11 was charged. Note: Water supply from E-16 to E-11 was not yet established at this point. Water supply from E-16 to E-11 was established at approximately 1926 hours. After the hose was stretched out, traffic on the highway began to drive over the supply line from E-16 to E-11. The E-16 engineer radioed dispatch that the city police were needed for traffic control. As crews attempted to battle the escalating fire, water supply became an issue. Later, during the time period from 1937 hours to 1941 hours, chief officers in front of the showroom repeatedly called the E-16 engineer to boost water pressure to E-11 as the fire escalated out of control. At approximately 1941 hours, the E16 engineer was instructed to switch to another radio channel to clear up the main channel for rescue purposes.

Engine 12

The Engine 12 (E-12) crew, consisting of an acting captain, assistant engineer, and two fire fighters were in quarters at the time of the initial dispatch. At approximately 1912 hours, the AC radioed dispatch to send E-12 to the scene. While enroute, BC-4 radioed E-12 and instructed them to lay a supply line down the alley on the D-side of the building to E-10. Engine 12 acknowledged this assignment. The Fire Chief also radioed the same instructions.

Engine 12 arrived on-scene at approximately 1917 hours and hooked up a 2 ½" supply line to E-10, then drove across the highway and down a side street to a hydrant, laying out 15 sections of supply line. The E-12 engineer hooked up to the hydrant and operated the pumps supplying E-10 throughout the incident. Water supply to E-10 was established at approximately 1920 hours. The E-12 acting captain and fire fighters assisted the E-10 crew by repairing the 1 ½" hoseline that had burst, then forced open the walk-thru door at the front of the warehouse and advanced a 2 ½" hoseline inside the warehouse about 10 feet before being ordered to withdraw. The 2 ½" hoseline was then operated through the doorway into the warehouse. The fire was reported to be burning so hot that the water immediately turned to steam and did little good in suppressing the fire.

Note: The E-12 crew reported that while forcing open the warehouse door, they experienced problems with a gasoline powered saw that had the wrong type of blade (for cutting plywood, not metal). Crews had to use axes to cut through the metal siding. The E-12 crew also cut holes in the metal siding along the D-side walls for ventilation and to direct water streams inside the building (see Photo 10).

Later in the incident, additional supply lines were stretched to E-12 so that E-12 could pump to E-11 and L-5 and L-4. Chief Officers radioed E-12 to boost the water pressure to E-10 at least 3 times during the incident. The E-12 engineer also radioed dispatch to have the city police department stop traffic on the highway from running over the supply lines.

Engine 15

The Engine 15 crew was in quarters when the first alarm crews were dispatched. The E-15 crew consisted of a captain (Victim # 8), engineer, and two fire fighters. One of the E-15 fire fighters (fire fighter # 2) was newly hired and was responding to his first working structure fire with the department. Per department procedures, E-15 began to relocate from downtown to the west side. The E-15 crew reported that smoke was visible from a couple of miles away as they relocated so they began running hot (Code 3 - lights and sirens on). At approximately 1912 hours, the Fire Chief radioed dispatch to have Engine 15 relocate to Station 11. Almost immediately, the AC radioed for E-15 to come to the scene. Then the AC radioed E-15 to bring a 1 ½" hoseline to the right rear of the building.

Engine 15 arrived on-scene at approximately 1917 hours just as Engine 16 began dropping a supply line for Engine 11. The E-15 captain instructed the E-15 engineer to get dressed to go inside the building. Note: During the NIOSH interviews, numerous fire fighters reported that most fire fighters responding after the first alarm would be expected to enter a structure fire for additional interior support. Coordinated ventilation and ladder truck operations reportedly were seldom initiated.

The E-15 captain and two fire fighters donned their SCBA and proceeded to Engine 11. One fire fighter took a pike pole and Haligan bar while the other fire fighter took an axe. They briefly talked with the E-11 engineer. They observed two hoselines going through the front entrance and followed the hoselines (one 1 ½" and one 2 ½") inside. Visibility at the front of showroom was still good at this time and the crew did not go on air until they were about 10 feet inside the door. As the E-15 crew advanced further, the visibility decreased. They were aware of other crews working to their right. The E-15 captain discussed with his crew that he wanted to work a hoseline to the center and left rear of the main showroom to cut the fire off from spreading in that direction (contain fire to the right rear corner). The E-15 captain instructed fire fighter # 2 to go outside and get a hoseline.

Fire fighter # 2 went outside and pulled a booster line (1" red hose) as far as he could down the center walkway through the main showroom. By this point, the visibility had decreased to where it was difficult to distinguish other fire fighters moving nearby. Fire fighter # 2 moved as far as he could and then began to flow water from the booster line toward a red glow overhead. He ran low on air and followed the hoseline toward the front entrance. Once outside he changed his air cylinder, then followed the hoseline back inside. He heard airhorns sounding (evacuation signal) and followed the hoseline back outside.

The E15 engineer donned his PPE and went to the front door where he assisted fire fighter # 2 in pulling the booster line through the front door. The E15 engineer advanced inside the showroom about 10 feet where he encountered thick black smoke from ceiling to floor. He could see a red glow at the rear of the showroom but no distinct flames. He ran low on air and went outside and changed his SCBA cylinder then re-entered the main showroom. It was noticeably hotter inside the showroom as the E15 engineer entered the second time. The engineer heard three airhorn blasts then heard radio traffic about evacuating the building so he followed the hoseline outside.

After the E-15 captain (Victim # 8) and fire fighter # 1 moved deeper into the showroom, the E-15 captain instructed fire fighter # 1 to go get another hoseline. Note: This was the last confirmed location of the E-15 captain. Fire fighter # 1 found a charged booster hose and dragged this hose as far as he could in the direction of where he had last seen the E-15 captain. Fire fighter # 1 did not encounter the E-15 captain or his other crew members when he returned to the rear of the showroom. Fire fighter # 1 opened the hoseline nozzle a couple of times but couldn’t see much fire. Fire fighter # 1 noticed that it was starting to get really hot and the thickening smoke was reducing visibility to near zero. His low air alarm began to go off so he started to follow the hoseline outside. He came to a point where the hoseline ran underneath furniture and he couldn’t follow the hoseline any further so he jumped over the furniture. Once on the other side of the furniture, he searched for the hoseline but could not locate it. As he searched for hoselines, he saw the bright flashing light of a PASS device and moved toward the light. He encountered the engineer from Engine 6 who was looking for his crew. The E-6 engineer guided the E-15 fire fighter to the front of the showroom and when they got close enough to the front entrance to hear the sound of Engine 11 running outside, the E-15 fire fighter bolted through the door (shortly after 1931 hours). The E-15 fire fighter went to Engine 11 and asked the E-11 engineer to switch out his SCBA cylinder. At approximately 1934 hours, while changing his cylinder, the E-15 fire fighter was asked if he had radioed a Mayday and he reported that he had not.

While changing cylinders, the E-15 fire fighter heard that fire fighters were missing inside the building. Note: During the timeframe of approximately 1935 to 1936 hours, fire fighters outside the main entrance knocked out the showroom windows to improve visibility inside the building. After changing cylinders, he followed the hoselines back inside the main showroom to search for his crew.

He advanced about 50 feet into the showroom and encountered intense heat and could see fire burning everywhere around him. He met the E-6 crew (captain, engineer, and fire fighter) following the hoseline to exit the showroom. The E-6 engineer told the E-15 fire fighter he couldn’t go any further and he needed to get out. These four fire fighters exited the showroom with the E-15 fire fighter jumping through a showroom window to the right of the doorway. The E-15 engineer and fire fighter # 2 also exited the main entrance at approximately the same time. The E-15 captain did not exit the building.

Engine 19

The Engine 19 crew was in quarters when the fire dispatch was initiated. The Engine 19 crew consisted of a captain (Victim # 6), engineer (Victim # 1), and one fire fighter (Victim # 2). Engine 6 had just been dispatched to the scene when, at approximately 1914 hours, the Fire Chief radioed dispatch to send Engine 19 to the scene and to have Engine 6 relocate to Station 11.

Engine 19 arrived on scene at approximately 1920 hours and parked in the middle of the highway in front of the furniture store. The E-19 crew entered the main showroom through the front entrance. There are few details about their activities after this point.

Engine 6

The Engine 6 crew, consisting of a captain, engineer, and one fire fighter were in quarters when they heard the initial fire dispatch. Engine 6 is the second engine to relocate to the western district per fire department procedures. At approximately 1914 hours, the AC radioed dispatch to send Engine 6 to the scene. When Engine 6 was dispatched, the Fire Chief radioed for Engine 6 to relocate to Station 11 and for Engine 19 to come to the scene. At approximately 1919 hours, the Fire Chief radioed for Engine 6 to come to the scene and to come in the front door. Engine 6 was already enroute (relocating to the west side) and acknowledged that they were enroute.

Engine 6 arrived on scene at approximately 1921 hours. The E-6 captain and E-6 fire fighter went to the front door and donned their SCBA masks. They followed the 1 ½" hoseline into the building. The E-6 captain observed light smoke coming out the front door and also at the connection of the main showroom and the right side addition (exterior wall). Visibility was initially about 5 to 10 feet but visibility was reduced as they advanced into the showroom interior. There was little heat and the E-6 captain and fire fighter were able to walk into the showroom standing upright as they followed the hoseline to the rear of the main showroom then into the right side addition. The E-6 engineer entered the showroom a couple of minutes later after donning his turnout gear, SCBA, and grabbing a pike pole from E-6. He reported the smoke at the front of the showroom was intensifying and beginning to bank down. He followed the 1 ½" hoseline to the rear of the main showroom. A booster line reached only to the right rear side of the main showroom. He could hear other fire fighters talking in the direction the 1 ½" hoseline was running (into the right addition) and began opening up sheetrock walls and pushing up ceiling tiles to look for fire extension.

The E-6 captain and fire fighter met other crews near the double doors to the loading dock. The other fire fighters stated they were going to get another hoseline so the E-6 captain worked the nozzle of the 1 ½" hand line for approximately 5-6 minutes while the E-6 fire fighter attempted to pull slack in the line so they could advance closer to the fire in the loading dock area. The water pressure on the 1½" hoseline fluctuated and at one point water pressure dropped to near zero. The E-6 captain attempted to radio outside to ask what happened to the water pressure but the on-off button on his radio had broken off during his entry so he couldn't turn on his radio. The E-6 crew noticed that the interior conditions suddenly deteriorated very rapidly with visibility decreasing and in less than 30 seconds, the heat became unbearable.

As the E-6 engineer was opening the walls and ceiling at the rear of the main showroom, three or four unidentified fire fighters approached him and frantically stated that they were running out of air and couldn't find the way outside. The E-6 engineer heard their low-air alarms sounding as they bumped into him then pulled away from him and disappeared into the smoke. This happened in a matter of seconds. During the short contact with the other fire fighters, the E-6 engineer was turned around several times and became separated from the hoseline. He moved in short circles until he found the hoseline and began following it. Almost immediately, the E-6 engineer encountered another fire fighter (later identified as the E-15 fire fighter # 1) who also stated he was out of air and couldn't find his way outside. The E-6 engineer led the E-15 fire fighter along the hoseline (at one point having to reverse directions) until they got within a few feet of the front door. They could hear the sound of Engine 11 running outside and the E-15 fire fighter ran outside, followed by the E-6 engineer. After checking on the condition of the E-15 fire fighter, the E-6 engineer re-entered the main showroom.

As the E-6 fire fighter was pulling slack in the 1 ½" hoseline, another fire fighter, searching for the way out, ran into him and momentarily knocked him off the hoseline. As the E-6 fire fighter regained the hose and stood up, water pressure in the hose was lost. At this point, the heat began to intensify and the E-6 fire fighter decided it was time to retreat. At the same time, he began hearing radio traffic of the Mayday followed by attempts by the Fire Chief and the dispatcher to identify who was calling Mayday and who had activated their emergency button.

As the heat rapidly intensified, the E-6 captain began following the hoseline outside. His low air alarm started to sound and he burned his hands feeling for the hoseline. His facepiece began to pull down onto his face as he exhausted his remaining air supply. He encountered the E-6 fire fighter who told the E-6 captain he had the hoseline and they began moving toward the front of the building. By this time, the E-6 captain was almost completely out of air and he bolted toward the front of the building. The E-6 engineer was following the hoseline back into the showroom looking for his crew and encountered the E-6 captain who was now out of air and becoming disoriented. The engineer grabbed his captain and guided him toward the front door until they could hear the sound of Engine 11 running outside. They made their way outside followed seconds later by the E-6 fire fighter and the E-15 fire fighter # 1. The front showroom windows were just being knocked out when the E-6 crew exited the showroom (see Photo 4).

Engine 9

The Engine 9 (E-9) crew, consisting of a captain, engineer, and fire fighter were in quarters at Station 9 when they heard the fire dispatch. The crew monitored the fireground radio traffic and knew that a serious situation was developing. They heard the Fire Chief calling for additional resources and Engine 9 was dispatched to relocate to Station 10 and arrived at 1946 hours. At 1951 hours, E-9 was directed to drive past the incident site and stretch a 2 ½" supply line from the hydrant west of the site back to the site to Engine 13 to supply Ladder 4 before it arrived. After stretching the supply line, the E-9 crew worked on the D-side of the structure supporting fire suppression activities.

Engine 13

The Engine 13 (E-13) crew consisting of a captain, engineer, and fire fighter were in quarters when they heard the fire dispatch. E-13 was dispatched to the scene at approximately 1937 hours and arrived on-scene at 1942 hours. The E-13 crew worked to help establish water supply to Ladder 5 by stretching a 2 ½" supply line from E-12 to L-5. The E-13 crew then assisted with fire suppression activities.

Engine 3

The Engine 3 (E-3) crew consisting of a captain, engineer and fire fighter was out of service at a special event several miles outside of the city when they heard radio traffic about the fire. When they heard the incident was a confirmed structure fire, they began moving back to the city. At approximately 1924 hours, E-3 was directed to relocate to cover Station 16/19. At approximately 1931 hours, the Fire Chief called dispatch and requested the next closest engine company. E-3 was still enroute to Station 16/19 so the Fire Chief requested that E-3 come to the scene and lay a supply line to Ladder 5. At approximately the same time, L-5 was repositioned from in front of the structure to the D-side by off-duty fire fighters who had arrived at the scene.

E-3 arrived on-scene at 1940 hours. The E-3 suction man (fire fighter) took their 5" adaptor to connect to the hydrant, but E-19 (driven by the acting captain of E-11) arrived at the hydrant first. E3 stretched a 2 1/2" supply line from E-19 (the next hydrant west of the structure) to L-5 and water supply was established at 1944 hours. After establishing water supply, the E-3 engineer stayed at the engine and the rest of the E-3 crew worked on the D-side of the structure operating a 2 ½" hand line. Fire fighters cut holes into the sheet metal siding and at one point, the E-3 fire fighter and an off-duty fire fighter attempted to advance a hoseline inside the showroom by crawling under the metal shelving located along the D-side wall. They were only able to advance 5 or 6 feet and had to withdraw because of the intense fire and heat inside the burning showroom.

Ladder 4

The Ladder 4 crew consisting of an acting captain, engineer, and fire fighter were in-quarters at the time of the initial dispatch. The crew monitored the radio traffic and knew things were escalating. The Fire Chief radioed dispatch at approximately 1948 hours and requested that Ladder 4 be dispatched to the scene. At approximately 1952 hours, the Fire Chief radioed dispatch and requested Engine 9 be sent from Station 10 to lay supply line for L-4.

Ladder 4 was on scene at approximately 1956 hours and BC-4 directed the crew on where to position in the front parking lot. Portions of the showroom roof had already collapsed when L-4 got set up. Engine 19 began supplying water to L-4 at approximately 2002 hours through one 2 ½" supply line. At approximately 2006 hours, L-4 radioed the Fire Chief and requested another supply line be set up to L-4 so that both nozzles on the bucket could be put into operation. The mutual aid department laid a 4" supply hose to L-4. L-4 initially operated with 300 gpm flowing through one nozzle. L-4 operated at 750 gpm when the second supply line was set up.

Mutual Aid

Jurisdictional boundaries separating the municipal fire department from surrounding fire departments were irregular and often intermingled. As commercial areas were annexed into the city, jurisdictional boundaries often split blocks. For example, the furniture store involved in this incident was within the city’s jurisdiction. Residential structures directly behind the furniture store property that were within the same block were in the jurisdiction of a mutual aid fire department that operates as a public service district (PSD). This mutual aid fire department had 60 fire fighters operating from 4 stations and served a population of approximately 24,000 in an area of approximately 30 square miles. Note: This fire department operated its own dispatch system. This fire department routinely used positive pressure fans for ventilation purposes and routinely deployed thermal imaging cameras at structure fires.

Two crews from the mutual aid department were in close vicinity to the incident scene for a special event and noticed heavy smoke. The acting battalion chief (BC) for the mutual aid department (who was at the special event with the crews) radioed his dispatch and said the mutual aid crews were going to the scene. The dispatcher reported that the municipal fire department was already on scene. The acting battalion chief (BC), Engine 2 (E-2) with a crew consisting of an acting captain and an engineer / fire fighter, and Rescue 1 (R1) with a crew of an engineer and a fire fighter, proceeded to the scene and arrived at approximately 1924 hours. The BC radioed dispatch that they were on-scene and also requested that Engine 1 (E-1) be dispatched.

The BC immediately went to the D-side of the furniture showroom and talked with the city Fire Chief. The BC informed the Fire Chief he had two crews on scene and another crew on the way. The BC also offered the use of their thermal imaging camera and their large diameter (4”) supply hose (LDH). According to the acting battalion chief, the city Fire Chief initially told him that the mutual aid department’s assistance would not be needed. The BC asked the Fire Chief if he wanted the mutual aid department to cover the rear of the warehouse and the Fire Chief said “yes.”

At approximately 1925 hours, the BC directed E-1 to drive down the street at the rear of the warehouse and set up operations there. The BC also radioed dispatch to send Truck 1 (T-1). E-1 arrived on scene at approximately 1926 hours with a captain, engineer, and two fire fighters. E-1 connected to a hydrant located just east of the warehouse. The E-1 captain and fire fighters advanced a 1 ¾" preconnected hand line inside the warehouse through a door located on the B-side at the rear near the B-C corner at approximately 1930 hours.

Engine 2 (E-2) and Rescue 1 (R-1) parked in the middle of the highway in front of the main showroom. The two crews (two fire fighters on each apparatus) donned their turnout gear and proceeded to the D-side of the showroom to join up with their BC when a city police officer stopped them and said a male employee was trapped in the rear of the structure and had telephoned 911 for assistance. They proceeded to the front of the showroom and were directed by the city AC and BC-5 to assist them in rescuing the trapped employee. They radioed their dispatch at approximately 1928 hours that the city fire department wanted them to assist in rescuing the employee, then proceeded around the B-side of the showroom to the rear after knocking a lock off a wooden gate at the B-C corner to gain access (see Diagram 3).

The fire fighters located the area where the employee was banging on the exterior wall. The fire fighters used a Haligan bar and axes to cut through the metal siding and opened a hole large enough for the employee to crawl through. The mutual aid department’s dispatch was notified at approximately 1931 hours that the employee had been rescued. The fire fighters assisted the employee to the front parking lot to receive medical attention. Note: The Assistant Chief of the municipal fire department radioed for an ambulance after the employee was extricated. Dispatch reported an ambulance was already in route.

The fire fighters returned to the front entrance and observed heavy black smoke filling the showroom and pushing out the door, but no visible fire. They observed city fire fighters yelling about fire fighters missing inside the structure. They reported hearing orders for the front showroom windows to be knocked out to improve visibility inside the showroom. The E-2 acting captain and R-1 engineer knocked out the windows to the right of the doorway while the city BC-5 knocked out the windows to the left of the doorway. The fire fighters noted that air rushed inside the showroom after the windows were knocked out. The E-2 acting captain cut his hand (requiring time off) while knocking out the windows. The E-6 and E-15 fire fighters (from the city department) exited the building at approximately 1935 hours while the windows were being knocked out. Some of the city fire fighters were completely out of air. At approximately 1936 hours, the Fire Chief instructed the mutual aid fire fighters to go inside and search for the missing city fire fighters. Two city fire fighters (an off-duty battalion chief and the E-6 engineer) also entered the showroom. The R-1 engineer and the E-2 fire fighter teamed up and followed the hoselines inside the front door a short distance. They encountered two fire fighters who were in distress. One was down on his hands and knees screaming for help and also attempting to drag the other fire fighter. The R-1 engineer attempted to assist the fire fighters while the E-2 fire fighter guided them back to the hoseline. The showroom erupted in flames and the heat knocked the fire fighters to the floor, causing them to become separated. Both rescue teams were forced to evacuate. The E-2 fire fighter found the door first and assisted the R-1 engineer outside at approximately 1938 hours. They both reported hearing PASS devices going off inside the structure. The R-1 engineer received second degree burns to his face, hands, and arm.

The R-1 engineer reported that other fire fighters were just inside the door so another rescue attempt was made. An off-duty captain from the mutual aid department, along with city fire fighters, attempted to advance a 2 ½" hoseline back inside the door, but their progress was quickly halted by the intense heat and fire and they were forced to retreat. At 1938 hours, the city Fire Chief radioed for everyone to stay outside and to abandon the building. One last attempt to enter the front entrance (by the off-duty battalion chief and the E-6 engineer) was stopped at the doorway by the intense fire and heat.

At approximately 1935 hours, the mutual aid BC requested that Engine 7 (E-7) be dispatched and come to the rear (C-side) of the warehouse with E-1. At approximately 1943 hours, the mutual aid BC requested Engine 4 (E-4) come to the scene. The BC directed E-4 to go the rear of the warehouse and set the deck gun. At approximately 1948 hours, the BC requested Truck 1 (T-1) to come to the scene.

The mutual aid BC radioed E-4 to hold up at the highway to let T-1 come down the back street first. T-1 arrived on scene at approximately 1950 hours and was set up at the rear of the warehouse to direct a master stream of water down onto the roof of the warehouse. At approximately 1952 hours, E-4 radioed the BC that the city fire department wanted E-4 to set up water supply to the city fire department’s Ladder 4 (L-4) in the parking lot at the front of the main showroom. At approximately 2000 hours, the E-4 acting captain announced E-4 was pumping water to the city’s L-4.

Water Supply

Water supply was a critical factor in the sequence of events leading up to the nine fatalities. Engine 10 should have been the second due engine and established the water supply to Engine 11. However, E-10 arrived first at 1911 hours and was directed to back down the alley to the loading dock on the D-side of the structure since that was where visible fire was located. Engine 11 positioned in front of the main showroom and the E-11 acting captain went inside the showroom while the E-11 fire fighter looked for a hydrant so E-11 could supply water to E-10. Engine 11 re-positioned closer to the main entrance when L-5 arrived in front of the showroom.

Pre-plan information indicated the closest hydrant was located on the street behind the warehouse but this information was not utilized.

Engine 12 was dispatched at 1912 hours and directed to lay a single 2 ½"supply line to Engine 10.

Engine 16 was already enroute as the third-due engine. Engine 16 arrived on scene at 1915 hours and Engine 12 arrived on scene at 1917 hours. Engine 12 stretched approximately 750 feet of 2 ½" supply line and had water supply established to E-10 at approximately 1920 hours. Engine 16 stretched approximately 1,850 feet of supply line and had water supply established to E-11 at approximately 1926 hours.

Both E-10 and E-11 put 1 ½" pre-connected hand lines into operation using tank water while waiting for supply lines to be established. The E-11 engineer reported experiencing problems with water pressure after water supply was established. The E-12 and E-16 engineers both radioed that vehicle traffic running over the supply lines were causing problems. Pressure had to be boosted by both E-12 and E-16 well above the 200-psi working limit of the supply hoses being used in order to accommodate for the friction losses and low water volume.

Adequate water supply for the size of the structure and fuel loads inside was never established and hoselines capable of attacking the fire with adequate fire streams were not deployed. Ladder 5 was not put into master stream operation until after the fire had escalated. Additional supply lines for Engine 11, Ladder 5 and Ladder 4 were laid after the fire had escalated.

E19 / E3 laid a second 2 ½" supply line to L-5 at approximately 1944 hours. BC-5 directed the acting captain on E-11 to drive E-15 west to the next hydrant to lay another supply line back to E-11. Then BC-5 told him to take E-19 instead. Engine 3 arrived on scene just as E-19 was positioning to the hydrant.

A small mutual aid department (mutual aid # 2) supplied L-5 with tank water at approximately 1940 hours until a supply line was established at approximately 1944 hours. A second supply line from E12 to L-5 was also put into service after 2000 hours.

Ladder 4 was put into operation at approximately 2001 hours with a 2 ½" supply line laid by E-9. The first responding mutual aid department (mutual aid # 1) stretched a 4" supply line to L-4 at approximately 2005 hours so that both fire nozzles could be put into operation.

The mutual aid departments utilized 4" supply lines. After the larger diameter supply lines were put into service, the water pressure issues with L-4 and L-5 improved.

ADDITIONAL PHOTOS

Additional photos pertaining to the incident are available in Appendix V.

CAUSE OF DEATH

According to the county coroner's report, the cause of death for all nine victims was carbon monoxide toxicity, smoke inhalation and thermal injury due to fire. Diagram 4 shows the approximate location where each of the nine victims was located inside the structure per the city.

RECOMMENDATIONS

Recommendation # 1: Fire departments should develop, implement and enforce written standard operating procedures (SOPs) for an occupational safety and health program in accordance with NFPA 1500.

Discussion: The risk for fatal injury among fire fighters is high compared to other occupations.[11] There is an increasing body of scientific literature demonstrating that organizational practices that demonstrate top level management commitment to safety, establish and foster compliance with safety policies and practices, and involve workers in identifying safety hazards and promoting solutions are effective in reducing worker injuries.[12-17] Many of these concepts are embodied in *NFPA 1500, Standard for a Fire Department Occupational Safety and Health Program*.[18] Implementation of a strong fire department occupational safety and health program following written procedures and policies such as those outlined by *NFPA 1500* can foster and improve the overall safety climate of a fire department, as well as improve specific safety and health areas, such as respiratory protection, risk management, training and competency in fireground operations, tactics, and equipment and apparatus use.

During this investigation, NIOSH investigators reviewed some written departmental SOPs. While these documents contained some individual SOPs, they mainly contained administrative guidelines and did not contain detailed fireground operational procedures that would enhance fire fighter safety and health, such as a risk management plan, a fire department occupational safety and health policy, and other components of a fire department occupational safety and health program as outlined in *NFPA 1500*.[18]

It is important to understand the difference between a policy and a procedure. A department ***policy*** is a guide to decision-making that originates with or is approved by top management in a fire department. Policies define the boundaries within which the administration expects department personnel to act in specified situations. A procedure is a written communication closely related to a policy. A ***procedure*** describes in writing the steps to be followed in carrying out organizational policies. SOPs are standard methods or rules in which an organization or a fire department operates to carry out a routine function. Usually these procedures are written in a policies and procedures handbook and all fire fighters should be well versed as to their content.[19] Operational procedures that are standardized, clearly written, and mandated to each department member establish accountability and increase command and control effectiveness.[19] The benefits of having clear, concise, and practiced SOPs are numerous. For example, they can become a training outline and a tool to guide fire department members. Above all, a well-applied SOP improves departmental safety.[20]

Recommendation #2: Fire departments should develop, implement and enforce a written Incident Management System to be followed at all emergency incident operations.

Discussion: National Fire Protection Association (NFPA) 1500 *Standard on Fire Department*

Occupational Safety and Health Program, 2007 Edition,[18] and NFPA 1561 *Standard on Emergency Services Incident Management System*, 2008 Edition,[21] both state that an Incident Management System (IMS) should be utilized at all emergency incidents (including but not limited to training exercises). The U.S. Department of Labor, Occupational Safety and Health Administration has issued a guidance document intended to be used by agencies to prepare emergency response plans. The intent of the National Response Team (NRT) guidance is to provide a mechanism for consolidating multiple agencies' plans into one functional emergency response plan or integrated contingency plan (ICP). [22]

NFPA 1561, Chapter 3.3.29 defines the Incident Management System (also known as the Incident Command System (or ICS) as "A system that defines the roles and responsibilities to be assumed by responders and the standard operating procedures to be used in the management and direction of emergency incidents and other functions.[21] Chapter 4.1 states "The incident management system shall provide structure and coordination to the management of emergency incident operations to provide for the safety and health of emergency services organization (ESO) responders and other persons involved in those activities." Chapter 4.2 states "The incident management system shall integrate risk management into the regular functions of incident command." Each fire department or emergency services organization (ESO) should adopt an incident management system to manage all emergency incidents. The IMS should be defined and in writing and include standard operating procedure (SOPs) covering the implementation of the IMS. The IMS should include written plans that address the requirements of different types of incidents that can be anticipated in each fire department's or ESO's jurisdiction. The IMS should address both routine and unusual incidents of differing types, sizes and complexities. The IMS covers more than just fireground operations. The IMS must cover incident command, accountability, risk management, communications, rapid intervention crews (RIC), roles and responsibilities of the Incident Safety Officer (ISO), and interoperability with multiple agencies (police, emergency medical services, state and Federal Government, etc.) and surrounding jurisdictions (mutual aid responders).

NIOSH investigators identified several examples in this incident in which recognized guidelines for IMS were not followed. Specific examples include multiple chief officers serving in command roles in an uncoordinated manner, lack of an established accountability system to track fire fighters on scene, a RIC was not established, an ISO was not assigned, and the fire department and police department did not work effectively together to control traffic and protect hoselines delivering water to the scene.

Recommendation # 3: Fire departments should develop, implement, and enforce written SOPs that identify incident management training standards and requirements for members expected to serve in command roles.

Discussion: NFPA 1561, Chapter 4.8.3 states, "Responders who are expected to perform as incident commanders or to be assigned to supervisory levels within the command structure shall be trained in and familiar with the incident management system and the particular levels at which they are expected to perform." [21] NFPA 1001,[6] 1021,[23] 1500[18] and 1521[24] are just a few examples of recognized standards addressing fire fighter and officer qualifications.

One of the fire officer's primary responsibilities is safety both on the fireground and during normal operations. A partial list of officer qualifications (knowledge, skills, and abilities) necessary to accomplish the primary responsibility of fireground safety identified in these standards include: fire behavior; building construction; conducting pre-incident planning; inspection and incident report development; applicable codes, ordinances, and standards; identification of fire and life safety hazards; supervising emergency operations; and, deploying assigned resources in accordance with the local emergency plan. Training records for the chief officers who initially responded to this incident were provided to NIOSH by the city's Safety Management Division. These records consisted mainly of NIMS certifications with little additional records to document specific training related to fire fighter and fire officer qualifications.

Recommendation #4: Fire departments should ensure that the Incident Commander is clearly identified as the only individual with overall authority and responsibility for management of all activities at an incident.

Discussion: NFPA 1561, Chapter 5 identifies the responsibilities and overall duties of the Incident Commander (IC).[21] Chapter A.3.3.28 states, "The IC has overall authority and responsibility for conducting incident operations and for managing all incident operations at the incident site." There should be one, clearly identifiable Incident Commander for the duration of the incident, from the arrival of the first fire department unit until the incident is terminated. The Incident Commander must clearly be in charge of all fireground operations to ensure successful completion. If there is no established or single Incident Commander, fireground operations and incident conditions can break down.

Some of the key responsibilities of the Incident Commander, as detailed in NFPA 1561, Chapter 5.3, which are relevant to this incident include:

- Overall authority for the management of the incident (Chapter 5.3.1)
- Ensuring adequate safety measures are in place (Chapter 5.3.2)
- Establishing a stationary command post (Chapter 5.3.7.1)
- Continually conducting a thorough evaluation of the situation (Chapter 5.3.8)
- Maintaining an awareness of the location and function of all companies or units at the scene (Chapter 5.3.10)
- Overall responder accountability for each incident (Chapter 5.3.11)
- Initiating an accountability / inventory worksheet at the beginning of operations and maintaining that system throughout operations (Chapter 5.3.12)
- Evaluating the risk to responders with respect to the purpose and potential results of their actions in each situation (Chapter 5.3.17)
- Utilizing risk management principles (Chapter 5.3.19) o Activities presenting significant risk to the safety of responders should be limited to situations having the potential to save endangered lives.
    - Activities employed to protect property should be recognized as inherent risks to the safety of the responders, and actions should be taken to reduce or avoid these risks.
    - No risk to the safety of responders should be acceptable where there is no possibility to save lives or property.

- Developing the command organization for the incident (Chapter 5.3.20)
- Assigning intermediate levels of supervision and organizing resources following SOPs based on the scale and complexity of operations (Chapter 5.10.1.2)
- All supervisory personnel assigned to operations functions shall support an overall strategic plan, as directed by the Incident Commander, and shall work toward the accomplishment of tactical objectives (Chapter 5.10.1.3)

Chief Officers at the scene of an incident who are not officially a part of the command structure should refrain from giving tactical directions**.** One of the clear tenets of the Incident Command System is "unity of command." By directing units outside of a role in the IMS, chief officers, by virtue of their rank, can create uncoordinated efforts outside the IMS that may not benefit the operational strategy and can actually have negative impacts upon the operational strategy. The resources that are taken from the operational structure to achieve the goals of the chief officers operating outside the IMS are lost to the tactical level operations or management elements that count on these resources to achieve their tactical objectives. During this incident, formal incident command was never formally announced or transferred as ranking officers arrived on scene. Fire attack operations at the loading dock (D-side) and the main showroom (A-side) were directed by different chief officers and were not coordinated.

Recommendation #5: Fire departments should ensure that the Incident Commander conducts an initial size-up and risk assessment of the incident scene before beginning interior firefighting operations.

Discussion: Among the most important duties of the first officer on the scene is conducting an initial size-up of the incident. This information lays the foundation for the entire operation. It determines the number of fire fighters and the amount of apparatus and equipment needed to control the blaze, assists in determining the most effective point of fire extinguishment attack, the most effective method of venting heat and smoke, and whether the attack should be offensive or defensive. A proper size-up begins from the moment the alarm is received and it continues until the fire is under control. The size-up should also include assessments of risk versus gain during incident operations.[19, 25-29] Retired Chief Alan Brunacini recommends that the arriving IC drive partially or completely around the structure whenever possible to get a complete view of the structure. While this may delay the IC's arrival by a few seconds, this drive-by may provide significant details not visible from the command post.[27] The size-up should include an evaluation of factors such as the fire size and location, length of time the fire has been burning, conditions on arrival, occupancy, fuel load and presence of combustible or hazardous materials, exposures, time of day, and weather conditions. Information on the structure itself including size, construction type, age, condition (evidence of deterioration, weathering, etc.), evidence of renovations, lightweight construction, loads on roof and walls (air conditioning units, ventilation ductwork, utility entrances, etc.), and available pre-plan information are all key information which can effect whether an offensive or defensive strategy is employed. The size-up and risk assessment should continue throughout the incident.

Fires in commercial structures are typically more dangerous than residential building fires. Retired Assistant Chief Vince Dunn states that defensive operations should be used more often at special occupancy and commercial buildings. Chief Dunn cites statistics that 4 fire fighters die for every 100,000 residential fires, compared to 9 fire fighter deaths for every 100,000 commercial structure fires.[30]

Interior size-up is just as important as exterior size-up. Since the IC is staged at the command post (outside), the interior conditions should be communicated to the IC as soon as possible. Interior conditions could change the IC's strategy or tactics. For example, if heavy smoke is emitting from the exterior roof system, but fire fighters cannot find any fire in the interior, it is a good possibility that the fire is above them in the roof system. Other warning signs that should be relayed to the IC include dense black smoke, turbulent smoke, smoke puffing around doorframes, discolored glass, and a reverse flow of smoke back inside the building. It is important for the IC to immediately obtain this type of information to help make the proper decisions. Departments should ensure that the first officer or fire fighter inside the structure evaluates interior conditions and reports them immediately to the IC.

In this incident, arriving officers concentrated on the A and D-sides of the structure. A complete 360 degree size-up was never conducted. Pre-plan information did not identify the potential hazards associated with the lightweight metal roof trusses, and the excessive fuel loads associated with the contents. Only one hydrant location was noted on the pre-plan form but it was not used. Smoke emitting from the connection between the original structure and the right-side addition, the deteriorating conditions in the main showroom, a rapid decrease in visibility coupled with a rapid rise in temperature, heavy smoke stains on windows, no visible fire in the showroom with a build-up of smoke and heat, and delays in establishing water supply, were all indicators that could have prompted consideration of switching from offensive to defensive strategies.

Recommendation #6: Fire departments should train fire fighters to communicate interior conditions to the Incident Commander as soon as possible and to provide regular updates.

Discussion: Proper size-up and risk versus gain analysis requires that the Incident Commander have a number of key pieces of information and keep informed of the constantly changing conditions on the fireground. New decisions must be made and old ones revised based upon increased data and improved information. Decisions can be no better than the information on which they are based. The Incident Commander must use an evaluation system that considers and accounts for changing fireground conditions in order to stay ahead of the fire. If this is not done, the attack plan will be out of sequence with the phase of the fire and the IC will be constantly surprised by changing conditions.[27, 29, 31] Interior size-up is just as important as exterior size-up. Since the IC is staged at the command post (outside), the interior conditions should be communicated by interior crews as soon as possible to the IC. Interior conditions could change the IC's strategy or tactics. Interior crews can aid the IC in this process by providing reports of the interior conditions as soon as they enter the fire building and by providing regular updates. According to Chief Dunn, one such example would be whenever a suspended ceiling is discovered in a commercial structure, this information should be immediately communicated to the IC.[31]

Based on a review of the training curriculum and available fire department SOPs, fire fighters and officers at this department were not trained to communicate interior conditions to the outside. During the initial attack, the interior conditions in the front show room (lack of fire) did not match the exterior conditions on the D-side (loading dock area fully involved and also the amount of smoke overhead). During NIOSH interviews, fire fighters and officers who had operated inside the structure reported signs of deteriorating conditions to the NIOSH investigators. However, no interior condition reports were broadcast over the radio (to the chief officers or other fire fighters) during this incident. Verbal exchanges between the attack crews and chief officers took place but this information did not impact the tactics being used. Information concerning the interior conditions could have been used to consider changing from a fast attack mode to a more cautious defensive operation.

Recommendation #7: Fire departments should ensure that the Incident Commander establishes a stationary command post, maintains the role of director of fireground operations, and does not become involved in fire-fighting efforts.

Discussion: According to NFPA 1561, §5.3.1, "The incident commander shall have overall authority for management of the incident." [21] In addition to conducting an initial size-up, the Incident Commander must establish and maintain a command post outside of the structure to assign companies and delegate functions, and continually evaluate the risk versus gain of continued firefighting efforts. In establishing a command post, the Incident Commander shall ensure the following (NFPA 1561, §5.3.7.2):

(1) The command post is located in or tied to a vehicle to establish presence and visibility.
(2) The command post includes radio capability to monitor and communicate with assigned tactical, command, and designated emergency traffic channels for that incident.
(3) The location of the command post is communicated to the communications center.
(4) The incident commander, or his or her designee, is present at the command post.
(5) The command post should be located in the incident cold zone.

The use of a tactical worksheet can assist the IC in keeping track of various task assignments on the fireground. It can be used along with pre-plan information and other relevant data to integrate information management, fire evaluation and decision making. The tactical worksheet should record unit status, benchmark times, and include a diagram of the fireground, occupancy information, activities checklist(s), and other relevant information. This can also aid the Incident Commander in continually conducting a situation evaluation and maintaining accountability. [27] To effectively coordinate and direct firefighting operations on the scene, it is essential that the IC does not become involved in firefighting efforts. A delay in establishing an effective command post may result in confusion of assignments and lack of personnel and apparatus coordination which may contribute to rapid fire progression. The involvement of the initial IC in firefighting also hampers the collection and communication of essential information as command is transferred to later arriving officers. In this incident, a stationary command post was never established and separate and uncoordinated activities were taking place in multiple locations. This contributed to a failure to size-up the overall incident scene, to properly evaluate risk versus gain, and to maintain accountability on the fireground.

Recommendation #8: Fire departments should ensure the early implementation of division and group command into the Incident Command System.

Discussion: The early establishment of divisions and groups allows the command structure of an incident to grow more effectively than simply deploying resources and assigning division or group supervisors after units are in place. Delegating division / group command to other officers makes the management of a large incident more feasible by relieving the Incident Commander of these responsibilities which allows the IC to focus on the bigger picture while still maintaining the ability to react to progress reports and other information provided by the division / group commanders. The Model Procedures Guide for Structural Firefighting describes the application of the National Fire Service Incident Management System (NIMS) to structure fire incidents. These procedures recommend the establishment of division and group command.[32] In this incident, a strategy of coordinated division and group command was not employed.

Recommendation #9: Fire departments should ensure that the Incident Commander continuously evaluates the risk versus gain when determining whether the fire suppression operation will be offensive or defensive.

Discussion: The initial size-up conducted by the first arriving officer allows the officer to make an assessment of the conditions and to assist in planning the suppression strategy. The following general factors are important considerations during a size-up: occupancy type involved, potential for civilians in the structure, smoke and fire conditions, type of construction, age of structure, exposures, and time considerations such as the time of the incident, length of time fire was burning before arrival, and time fire was burning after arrival.[33,34] The Incident Commander must perform a risk analysis to determine what hazards are present, what the risks to personnel are, how the risks can be eliminated or reduced, and the benefits to be gained from interior or offensive operations.[35] The size-up must include continued assessment of risk versus gain during incident operations. According to NFPA 1500 §A-8.3.3, "The acceptable level of risk is directly related to the potential to save lives or property. Where there is no potential to save lives, the risk to the fire department members must be evaluated in proportion to the ability to save property of value. When there is no ability to save lives or property, there is no justification to expose fire department members to any avoidable risk, and defensive fire suppression operations are the appropriate strategy."[18,36] Retired New York City Fire Chief Vincent Dunn states, "When no other person's life is in danger, the life of the firefighter has a higher priority than fire containment."[25]

The first-responding officer, as well as the IC, needs to make a judgment as to what is at risk – people or property. This will help determine the risk profile for the incident. Many fire fighters stand by the notion that all incidents are "people" events until proven otherwise. Some fire fighters are willing to concede that a fire environment has become too hostile to sustain life and therefore, the only thing left to save is property. Historically, the fire service has a poor history of changing risk-taking based upon the people/property issue.[37]

In this incident, the store manager was present to inform the chief officers on the status of employees and patrons who had been inside the business. The fire department utilized offensive strategies focused on fire suppression. Truck company operations (search and rescue, ventilation, etc.) were not utilized until the fire department received word that an employee was trapped at the rear of the structure. As conditions inside deteriorated, offensive strategies were continued even as problems with establishing water supply mounted and the civilian was rescued.

Recommendation #10:Fire departments should ensure that the Incident Commander maintains close accountability for all personnel operating on the fireground

Discussion: Personnel accountability on a fireground means identifying and tracking all personnel working at the incident. A fire department should develop its own system and standardize it for all incidents. Accountability on the fireground can be maintained by several methods: a system using individual tags assigned to each fire fighter, a riding list provided by the company officer, a SCBA tag system, or incident command board.[18,19,21] Modern radio systems also incorporate a means of tracking the identity of fire fighters at an incident scene.

As the incident escalates, additional staffing and resources will be needed, adding to the burden of tracking personnel accountability. An incident command board should be established at this point with an assigned accountability officer or aide. The Incident Commander should also utilize the Incident Management System (IMS). Additionally, fire fighters should not work beyond the sight or sound of their supervising officer unless equipped with a portable radio.

In this incident, the only accountability system used was the daily work roster. Several off-duty fire fighters and mutual aid companies responded without being dispatched. Not all fire fighters entering the structure had their designated hand held radio. Fire fighters were known to be trapped inside the structure, but the number and their identities were not determined until their bodies were recovered.

Recommendation #11: Fire departments should ensure that a separate Incident Safety Officer, independent from the Incident Commander, is appointed at each structure fire.

Discussion: According to NFPA 1561 *Standard on Emergency Services Incident Management System, 2008 Edition*, paragraph 5.3, “The Incident Commander shall have overall authority for management of the incident (5.3.1) and the Incident Commander shall ensure that adequate safety measures are in place (5.3.2).” This shall include overall responsibility for the safety and health of all personnel and for other persons operating within the incident management system. While the Incident Commander (IC) is in overall command at the scene, certain functions must be delegated to ensure adequate scene management is accomplished.[21] According to NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program, 2007 Edition*, “as incidents escalate in size and complexity, the Incident Commander shall divide the incident into tactical-level management units and assign an incident safety officer (ISO) to assess the incident scene for hazards or potential hazards (8.1.6).”[18] These standards indicate that the IC is in overall command at the scene, but acknowledge that oversight of all operations is difficult. On-scene fire fighter health and safety is best preserved by delegating the function of safety and health oversight to the ISO.

Additionally, the IC relies upon fire fighters and the ISO to relay feedback on fireground conditions in order to make timely, informed decisions regarding risk versus gain and offensive versus defensive operations. The safety of all personnel on the fireground is directly impacted by clear, concise, and timely communications among mutual aid fire departments, sector command, the ISO, and IC.

Chapter 6 of NFPA 1521, *Standard for Fire Department Safety Officer*, defines the role of the ISO at an incident scene and identifies duties such as: recon of the fireground and reporting pertinent information back to the Incident Commander; ensuring the department's accountability system is in place and operational; monitoring radio transmissions and identifying barriers to effective communications; and ensuring established safety zones, collapse zones, hot zones, and other designated hazard areas are communicated to all members on scene.[24] Larger fire departments may assign one or more full-time staff officers as safety officers who respond to working fires. In smaller departments, every officer should be prepared to function as the ISO when assigned by the IC. The presence of a safety officer does not diminish the responsibility of individual fire fighters and fire officers for safety. The ISO adds a higher level of attention and expertise to help the fire fighters and fire officers. The ISO must have particular expertise in analyzing safety hazards and must know the particular uses and limitations of protective equipment.[26]

A designated safety officer could have assisted at this incident with continual size-up, accountability, and timely communications regarding safety on the fireground and the rapidly deteriorating conditions inside the structure. *Note: Since the fatal incident, the fire department has hired a full time, permanent Safety Officer.*

Recommendation #12: Fire departments should ensure that crew integrity is maintained during fire suppression operations.

Discussion: Fire fighters should always work and remain in teams whenever they are operating in a hazardous environment.[19] Team continuity means team members knowing who is on their team and who is the team leader; team members staying within visual contact at all times (if visibility is low, teams must stay within touch or voice distance of each other); team members communicating needs and observations to the team leader, and team members rotating together to rehabilitation, staging as a team, and watching out for each other (practicing a strong buddy system). Following these basic rules helps prevent serious injury or even death by providing personnel with the added safety net of fellow team members. Teams that enter a hazardous environment together should leave together to ensure that team continuity is maintained.[25] In this incident, there were numerous instances where fire fighters were working independently, entering and exiting the structure alone, operating hoselines, pulling walls and ceiling, and other related activities. Working alone increases the risk for themselves, and possibly to others during search and rescue efforts. Federal regulations [the OSHA 2-in-2-out rule, 29 CFR 1910.134 (g)(4)(i)] states, "…at least two employees enter the immediately dangerous-to-life-or-health (IDLH) atmosphere and remain in visual or voice contact with one another at all times."[8]

Recommendation #13: Fire departments should ensure that a rapid intervention crew (RIC) / rapid intervention team (RIT) is established and available to immediately respond to emergency rescue incidents.

Discussion: A rapid intervention crew (RIC) or team (RIT) should be designated and available to respond during all fireground operations. [18,19, 21] The rescue crew should report to the Incident Commander (IC) and be available within the incident's staging area. The rescue crew should be comprised of fresh, well-rested fire fighters, and be positioned and ready to respond when a fire fighter(s) is down or in trouble.[18] NFPA 1500, Chapter 8.8, Rapid Intervention for Rescue of Members, provides detailed guidelines for the deployment of rescue teams at emergency incidents. Chapter 8.8.1 states, "The fire department shall provide personnel for the rescue of members operating at emergency incidents." During the initial stages of an incident, the rescue crew members may be engaged in support operations outside the structure. Once the incident expands in size or complexity and the IC requests additional resources, the rescue crew must be dedicated to stand-by in case rescue operations are needed.[18] The rapid intervention crew or team should have all tools necessary to complete the job, e.g., search and rescue ropes, Haligan bar and flat-head axe combo, first-aid kit, resuscitation equipment, extra SCBA cylinders and/or transfill hoses, etc. RIC or RIT teams should have specialized rescue training to prepare them for rescue operations. RIC or RIT teams can intervene quickly to rescue a fire fighter who becomes disoriented, lost in smoke filled environments, trapped by fire, involved in a structural collapse, or has run out of breathing air. In this incident a dedicated rescue crew was never employed and no crews were held outside in standby or rescue mode. Once it was realized that fire fighters were trapped inside the structure, fire fighters from the first-responding mutual aid department as well as off-duty city fire fighters who came to the scene were pressed into service to attempt search and rescue operations at the front entrance.

Recommendation #14: Fire departments should ensure that adequate numbers of staff are available to immediately respond to emergency incidents.

Discussion: NFPA 1710 Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments (2004 Edition*)* contains recommended guidelines for minimum staffing of career fire departments.[38] NFPA 1710 § 5.2.2 (Staffing) states the following: "On-duty fire suppression personnel shall be comprised of the numbers necessary for fire-fighting performance relative to the expected fire-fighting conditions. These numbers shall be determined through task analyses that take the following factors into consideration:

1. Life hazard to the populace protected
2. Provisions of safe and effective fire-fighting performance conditions for the fire fighters
3. Potential property loss
4. Nature, configuration, hazards, and internal protection of the properties involved
5. Types of fireground tactics and evolutions employed as standard procedure, type of apparatus used, and results expected to be obtained at the fire scene."

The NFPA standard states that both engine and truck companies shall be staffed with a minimum of four on-duty personnel. The standard also states that in jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, geographical restrictions, or other pertinent factors identified by the authority having jurisdiction, these companies shall be staffed with a minimum of five or six on-duty members.

NFPA 1710 also states that the fire department's fire suppression resources shall be deployed to provide for the arrival of an engine company within a 4-minute response time and/or the initial full alarm assignment within an 8-minute response time to 90 percent of the incidents as established in Chapter 4. The fire department shall have the capability to deploy an initial full alarm assignment within an 8-minute response time to 90 percent of the incidents as established in Chapter 4. The initial full alarm assignment shall provide for the following (Chapter 5.2.4.2):

1. Establishment of incident command outside of the hazard area for the overall coordination and direction of the initial full alarm assignment. A minimum of one individual shall be dedicated to this task.
2. Establishment of an uninterrupted water supply of a minimum 1520 L/min (400 gpm) for 30 minutes. Supply line(s) shall be maintained by an operator who shall ensure uninterrupted water flow application.
3. Establishment of an effective water flow application rate of 1140 L/min (300 gpm) from two hand lines, each of which shall have a minimum of 380 L/min (100 gpm). Each attack and backup line shall be operated by a minimum of two individuals to effectively and safely maintain the line.
4. Provision of one support person for each attack and backup line deployed to provide hydrant hookup and to assist in line lays, utility control, and forcible entry.
5. A minimum of one victim search and rescue team shall be part of the initial full alarm assignment. Each search and rescue team shall consist of a minimum of two individuals.
6. A minimum of one ventilation team shall be part of the initial full alarm assignment. Each ventilation team shall consist of a minimum of two individuals.
7. If an aerial device is used in operations, one person shall function as an aerial operator who shall maintain primary control of the aerial device at all times.
8. Establishment of an Incident Rapid Intervention Crew (IRIC) that shall consist of a minimum of two properly equipped and trained individuals.

The municipal fire department involved in this incident routinely operated with three fire fighters per apparatus depending on the staffing available during each shift. During this incident, many of the routine and necessary fireground operations were not initiated—e.g., establishment of Incident Command outside the hazard area overseeing all operations, search and rescue, a staged rapid intervention crew (RIC), hydrant connection and water supply, and coordinated ventilation. All resources on scene were engaged in attacking the interior fire. Due to the limited staffing, several fire fighters were operating alone inside the burning structure instead of pairing up with other fire fighters.

Recommendation #15:Fire departments should ensure that ventilation to release heat and smoke is closely coordinated with interior fire suppression operations.

Discussion: Ventilation is the systematic removal and replacement of heated air, smoke, and gases from inside a structure with cooler air. The cooler air facilitates entry by fire fighters and improves life safety for rescue and other firefighting operations. Ventilation improves visibility and reduces the chance of flashover or backdraft.[19] The ventilation opening may produce a chimney effect causing air movement from within a structure toward the opening. This air movement helps facilitate the venting of smoke, hot gases and products of combustion, but may also cause the fire to grow in intensity and may endanger fire fighters who are between the fire and the ventilation opening. For this reason, ventilation should be closely coordinated with hoseline placement and offensive fire suppression tactics. Close coordination means the hoseline is in place and ready to operate so that when ventilation occurs, the hoseline can overcome the increase in combustion likely to occur. If a ventilation opening is made directly above a fire, fire spread may be reduced, allowing fire fighters the opportunity to extinguish the fire. If the opening is made elsewhere, the chimney effect may actually contribute to the spread of the fire.[19,39] Proper ventilation during a structure fire will reduce the tendency for rising heat, smoke, and fire gases, trapped by the roof or ceiling, to accumulate, bank down, and spread laterally to other areas within the structure. Proper ventilation reduces the threat of flashover by removing heat before combustibles in a room or enclosed area reach their ignition temperatures. Proper ventilation reduces the risk of a backdraft by reducing the potential for superheated fire gases and smoke to accumulate in an enclosed area.

The Incident Commander must consider many variables when deciding upon the plan of attack at a structure fire. Ventilation is just one of the many variables that must be considered. Before initiating the fire attack, the IC should ask the following questions:[19]

- **Is there a need for ventilation at this time?**
  The need must be based upon the heat, smoke, and gas conditions within the structure, the structural conditions, and the life hazard

- **Where is ventilation needed?**
  This involves knowing the construction features of the building, the contents, exposures, wind direction and strength, extent of the fire, location of the fire, location of top or vertical openings and location of cross or horizontal openings

- **What type of ventilation should be used?**
  Horizontal (either natural or mechanical) or vertical (natural or mechanical)?

- **Do fire and structural conditions allow for safe roof operations?**
  Knowledge of the building is paramount.

In this incident, the fire department did not attempt to coordinate ventilation with the offensive interior attack. Chief officers interviewed by NIOSH stated they would not ventilate the type of structure involved in this fire. Crews were directed to attack the fire with hoselines at the loading dock (D-side) and inside the showroom at the right rear addition. Every fire fighter interviewed by NIOSH who was inside the showroom area reported rapidly deteriorating conditions as thick gray and black smoke banked down to floor level reducing visibility to near zero with rapidly intensifying heat. Different ventilation techniques such as cutting holes in the roof or high on the D-side wall may have helped reduce the accumulation of smoke and hot gases inside the showroom. The use of a positive pressure fan at the front entrance along with adequate openings to vent the introduced air, may have helped reduce the amount of accumulating smoke in the front showroom and improved visibility, possibly allowing the disoriented fire fighters inside to find the front entrance.

All ventilation techniques have both a positive and negative aspect. Venting can be a very effective life safety procedure. When venting for life safety purposes, the principle is to pull the fire, heat, smoke and toxic gases away from victims, stairs, and other egress routes. A vent opening made between the fire fighter or victims and their path of egress could be fatal if the fire is pulled to their location or cuts off there path of egress.[39] *Note: The NIST Fire Dynamic Simulator, a computational fire model, will examine the possible impact of different ventilation strategies and their effect on this incident. The NIST fire model will be available in the future at http://www.bfrl.nist.gov/.*

Recommendation #16: Fire departments should conduct pre-incident planning inspections of buildings within their jurisdictions to facilitate development of safe fireground strategies and tactics.

Discussion: National Fire Protection Association (NFPA) 1620 *Recommended Practice for PreIncident Planning, 2003 Edition,* § 4.4.1 states, "the pre-incident plan should be the foundation for decision making during an emergency situation and provides important data that will assist the Incident Commander in developing appropriate strategies and tactics for managing the incident." This standard also states that "the primary purpose of a pre-incident plan is to help responding personnel effectively manage emergencies with available resources. Pre-incident planning involves evaluating the protection systems, building construction, contents, and operating procedures that can impact emergency operations." [40] A pre-incident plan identifies deviations from normal operations and can be complex and formal, or simply a notation about a particular problem such as the presence of flammable liquids, explosive hazards, modifications to structural building components, or structural damage from a previous fire.[29, 30, 40]

In addition, NFPA 1620 outlines the steps involved in developing, maintaining, and using a preincident plan by breaking the incident down into pre-, during- and post-incident phases. In the preincident phase, for example, it covers factors such as physical elements and site considerations, occupant considerations, protection systems and water supplies, hydrant locations, and special hazard considerations. Building characteristics including type of construction, materials used, occupancy, fuel load, roof and floor design, and unusual or distinguishing characteristics should be recorded, shared with other departments who provide mutual aid, and if possible, entered into the dispatcher's computer so that the information is readily available if an incident is reported at the noted address. Since many fire departments have tens and hundreds of thousands of structures within their jurisdiction, making it impossible to pre-plan them all, priority should be given to those having elevated or unusual fire hazards and life safety considerations.

The fire department had conducted several pre-plan inspections of the structure involved in this incident. A building pre-plan form obtained from the fire department dated April 26, 2006 noted that store contents were "household furniture and office equipment" and that the rear warehouse contained racks approximately 30 feet high (see Appendix III). A more thorough building inspection and pre-incident plan for this single-story commercial building could have potentially identified the flat roof supported by lightweight metal bar joists (metal roof trusses), the immense fuel load considerations (i.e. large quantity of furniture and associated highly flammable furnishings in the showroom as well as stored in various locations throughout the facility), the presence of a drop ceiling and hydrant locations. Evaluating the size and construction features of the structure allows the fire department the opportunity to determine a response protocol for the specific identified hazards and to develop fireground strategies and tactics (hoseline placement, water flow calculations, ventilation strategies, etc.) before an incident occurs. The hydrant location closest to the structure was noted on the April 2006 form (on the street to the rear of the warehouse), but was not used until the first mutual aid department set up operations at the rear of the warehouse. The construction features, occupancy (furniture retail), and fuel load present suggested large volumes of water would be necessary to fight a major fire at the site, which should have prompted the need to identify additional nearby hydrants. A more complete pre-planning process could have noted this information which may have aided the Incident Commander in developing a safer and more effective defensive strategy. Individual fire companies should be involved in pre-plan inspections outside their firstalarm territories so that they can become familiar with hazardous structures they may respond to on second and subsequent alarm assignments.

Recommendation #17: Fire departments should consider establishing and enforcing standardized resource deployment approaches and utilize dispatch entities to move resources to fill service gaps.

Discussion: On-scene commanders need to focus on the events occurring at the incident scene. Preplanned resource deployment can be delegated to the dispatch system. Computer-aided dispatch can make this process automatic. Without a standardized deployment approach, on-scene commanders spend time making decisions that could have already been made. The movement of resources around the jurisdiction to fill coverage gaps should be delegated to others who do not have to focus their attention on the safety of the responders in the hazard zone, such as the dispatch center. According to retired Chief Alan Brunacini, "The IC must be highly familiar with dispatch / communications procedures and stay actively connected to the details of how that system works throughout operations. … The com center knows what resources are available, where they are, and directly controls the status keeping and dispatch system that can move and manage them. The IC must always use the IMS to get the right resources (closest to the incident / appropriate type) in the right place, doing the right things. Having com work in concert with the IC many times makes a huge difference in the overall command and control."[41] For example, the dispatch center can advise the incident commander of time intervals since the initial dispatch (i.e. 10 minute or 15 minute intervals). Another example would be for dispatch to monitor fireground traffic or signs of problems, such as a Mayday call. The Incident Command System (ICS) Module Procedures Guide provides guidelines for managing major incidents and providing support to the IC by the establishment of a Planning Section to handle duties such as maintaining resource status and evaluating future resource requirements.[42]

In this incident, the fire department's procedure was for chief officers to call for additional resources as they deemed necessary. Delegating the tactical deployment and relocation of resources to dispatch or chief officers backfilling at other locations within the jurisdiction will allow Incident Commanders to focus on the fireground events. Using a standardized resource deployment approach, any Mayday should trigger the dispatcher to initiate additional measures in response to the emergency, such as notifying the Fire Chief and chief officers of the Mayday transmission and sending additional resources to the incident scene.

Recommendation #18: Fire departments should develop and coordinate pre-incident planning protocols with mutual aid departments.

Discussion: NFPA 1620 provides guidance to assist departments in establishing pre-incident plans. Pre-incident planning that includes agreements formed by a coalition of all involved parties including mutual aid fire departments, emergency medical services companies, and police, will present a coordinated response to emergency situations, and may save valuable time by a more rapid implementation of pre-determined protocols.[40] Examples of such pre-incident planning for this incident include better coordination with the police department concerning traffic control and better utilization of the resources available from mutual aid departments, such as large diameter supply hoses.

Recommendation #19: Fire departments should ensure that any offensive attack is conducted using adequate fire streams based on characteristics of the structure and fuel load present.

Discussion: The objective of the offensive fire attack is to apply enough water directly to the burning fuel to achieve extinguishment.[39] Determining the number and size of hoselines to deploy at a fire can be estimated by first estimating the size of the structure and applying various flowrate calculations such as what is taught at the U.S. National Fire Academy (area divided by 3) or by estimating the size of the fire. Retired Chief Alan Brunacini in his book *Fire Command* states, "Big Fire = Big Water, Little Fire = Little Water."[27] In addition to the location and extent of the fire, factors affecting selection and placement of hoselines include the building's occupancy, construction, and size. In addition, fire load and material involved, mobility requirements, and number of persons available to handle the hoselines are important factors. Regardless of the choice of attack method or the type of fire stream used, successful fire suppression depends upon discharging a sufficient quantity of water to remove the heat being generated, and ensuring that it reaches the fire rather than being turned into steam or being carried away by convective currents. A back-up line, at least as large as the initial attack line, should be in place and charged to protect the initial attack crew before interior firefighting efforts begin.[30] Some experts recommend that a 2 ½inch attack hoseline routinely be used with commercial and industrial structures if a sizable body of fire is present. The rational is that, compared to a residence, the fire load in commercial structures is usually heavier, will burn longer, and in need of harder hitting streams. In this incident, the loading dock area contained approximately 2,300 square feet of floor space, the right showroom addition contained approximately 7,000 square feet, and the main showroom contained approximately 17,000 square feet of floor space. Applying the National Fire Academy rule (area divided by 3), a minimum of 800 gallons per minute (gpm) of water would have been required at the loading dock. Crews operating at both the loading dock and the right showroom addition initially employed 1 ½" preconnected hand lines capable of flowing 90 gpm. 1-inch booster lines were also deployed. As the fire progressed, 2 ½" hand lines capable of flowing 350 gpm were put into operation, but their use was hindered by inadequate water supply so that the actual flow rates likely never approached these capacities during the incipient fire stage due to the small diameter of the supply lines. Table 1 provides examples of hose sizes and the corresponding flow rates.

Table 1: Example Hose Sizes and Corresponding Flow Rates.[5]

Generic 2 ½" supply hose

Discharge Pressure = 175 psi
Intake Pressure = 20 psi Distance = 750 feet

Hose Size	**Flow Available**
2 ½ inch	*321 gallons per minute*
(2) 2 ½ inch	*643 gallons per minute*
4 inch	*1, 017 gallons per minute*
5 inch	*1, 607 gallons per minute*

Recommendation #20: Fire departments should ensure that an adequate water supply is established and maintained.

Discussion: Establishing adequate water supply on the fireground is an integral part of fire suppression. A supply hose is used to move large volumes of water between a pressurized water source and a pump that is supplying attack hoselines. It is also used to maintain a water system as a continuous conduit or by connecting water supply sources. Usually, the pressure in supply hoselines are lower than those used for the attack fire hose. According to *Fire Hose Practices* by *IFSTA,* the use of a 2 ½ inch hose was once considered the minimum diameter for a supply line, but is no longer recognized as an adequate supply hose. A 3 ½" supply line is now considered the minimum. In most instances, fire departments and industrial establishments have gone to a larger diameter supply line: 3 ½, 4, 4 ½, 5, 6, 8, 10 or 12 inches. In most cases, a short length of 5" or 6" diameter hose is used. With the ever-increasing demand for greater fire flow (water supply) over long distances, large diameter hoses (LDH) are used as above-ground water mains to allow for greater flow of water available for fire suppression, and to decrease friction loss due to a smaller diameter hose.[44]

5 Partial Table 13.15 courtesy of IFSTA Pumping Apparatus Driver/Operator Handbook (1999).[43]

The fire department involved in this incident routinely deployed 2 ½" hose as the main water supply line. In this incident, 23 50-foot sections of 2 ½" supply line were laid to a hydrant capable of supplying 1,256 gpm at 56 psi. Engine 16, stationed at the hydrant, pumped through the 23 sections of supply hose to supply Engine 11 located near the front entrance. Difficulties with the Engine 11 pump delayed the establishment of a constant water supply to the initial attack line (500 feet of 1 ½" hoseline), causing the Engine 11 engineer to switch between tank water and the supply line. Crews also attempted to deploy a 1" booster line and a 2 ½" attack line (200 feet) from Engine 11. The deployment of a 1 ½" attack line over 250 feet increased the friction loss and lowered the water flow below safe and acceptable levels (150 gpm minimum). As the fire progressed and the need for additional water increased, chief officers radioed to the E-16 engineer to increase the water pressure. The officers ordered the E-16 engineer to go to 300 psi which was well over the maximum limit of 200 psi working pressure for the hose. It is likely that every time the 1" or the 2 ½" line nozzles were opened, the 1 ½" line pressure would drop. The 1 ½" line was the only one that was in position to effectively attack the fire at the rear of the showroom. To offset the reduced water flow (perceived as lack of water pressure at the nozzle), the engine operator was instructed to increase the pressure to pump more water, but this action would only increase the friction losses in the small diameter hose. A similar scenario developed on the D-side of the structure where Engine 12 was stationed at a hydrant pumping water through a single 2 ½" supply hose over 600 feet to Engine 10 which was pumping to multiple attack hoses. Additional supply hoses, increasing the volume of water available to both Engine 10 and Engine 11, were not added until after the fire fighters were determined to be missing. As the fire intensified and the need for additional water flow increased, the use of large diameter hoses for supply lines would have increased the water available at the pumps (E-10 and E-11).

Recommendation #21: Fire departments should consider using exit locators such as high intensity floodlights, flashing strobe lights, hose markings, or safety ropes to guide lost or disoriented fire fighters to the exit.

Discussion: The use of high-intensity floodlights, flashing strobe lights, or other high visibility beacons can be set up at the entry portals of burning structures as an aid to assist fire fighters in situations requiring emergency escape.[39] If staffing permits, a fire fighter can be stationed at the doorway to assist with flaking hose through the entrance and to assist exiting fire fighters. Hoselines can be marked with raised chevrons pointing in the direction of the pump (to the outside). Another option for locating exits is the deployment of safety rope lines as crews enter a structure. The end of the safety rope is secured outside the doorway and the rope is laid out as the crew advances inside. During this incident, several fire fighters inside the structure became disoriented as the conditions deteriorated. Most of the fire fighters working inside the structure ran out of air. During the NIOSH interviews, fire fighters stated they had to search for a hoseline to follow outside. Other fire fighters reported hearing the sound of Engine 11 running in the parking lot and then moving toward the sound. Safety ropes were not deployed by the initial crews who entered the structure.

Recommendation #22: Fire departments should ensure that Mayday transmissions are received and prioritized by the Incident Commander.

Discussion: The Incident Commander must monitor and prioritize every message, but only respond to those that are critical during a period of heavy communications on the fireground. A radio transmission reporting a trapped fire fighter is the highest priority transmission that Command can receive. Mayday transmissions must always be acknowledged and immediate action must be taken.[45,46] As soon as fire fighters become lost or disoriented, trapped or unsuccessful at finding their way out of the interior of a structural fire, they must initiate emergency radio transmissions. A Mayday call should receive the highest communications priority from dispatch, the IC, and all other units on-scene. In this incident, there were multiple radio transmissions of fire fighters asking for assistance in finding the exit. There was no reaction to these radio transmissions for several minutes, possibly due to the large volume of radio traffic and/or the chief officers being distracted by engaging in fireground activities. The sooner the IC is notified and a RIT is activated, the greater the chance of the fire fighter(s) being rescued.

Recommendation # 23: Fire departments should train fire fighters on actions to take if they become trapped or disoriented inside a burning structure.

Discussion: Fire fighters must act promptly when they become lost, disoriented, injured, low on air, or trapped.[45-50] First, they must transmit a distress signal while they still have the capability and sufficient air, noting their location if possible. The next step is to manually activate their PASS device. To conserve air while waiting to be rescued, fire fighters should try to stay calm, be focused on their situation and avoid unnecessary physical activity. They should survey their surroundings to get their bearings and determine potential escape routes such as windows, doors, hallways, changes in flooring surfaces, etc.; and stay in radio contact with the IC and other rescuers. Additionally, fire fighters can attract attention by maximizing the sound of their PASS device (e.g. by pointing it in an open direction); pointing their flashlight toward the ceiling or moving it around; and using a tool to make tapping noises on the floor or wall. A crew member who initiates a Mayday call for another person should quickly try to communicate with the missing member via radio and, if unsuccessful, initiate another Mayday providing relevant information on the missing fire fighter’s last known location.

In this incident, fire fighters radioed that they had lost contact with the hose, needed assistance getting out, and at least one fire fighter radioed “Mayday” then activated the emergency button on his radio. None of these radio transmissions gave any information regarding the fire fighters’ locations – i.e. “rear of the main showroom,” “near the loading dock,” etc. At least one fire fighter entered the structure without a radio.

Recommendation #24: Fire departments should ensure that all fire fighters and line officers receive fundamental and annual refresher training according to NFPA 1001 and NFPA 1021.

Discussion: Initial and continual training provides an opportunity to ensure that all fire fighters and line officers are proficient in their knowledge and skills in recognizing and mitigating hazards. Training on structural firefighting should include, but not be limited to, departmental standard operating procedures, fire fighter safety, building construction, and fireground tactics. NFPA 1500, Chapter 5, requires that the fire department provide an annual skills check to verify minimum professional qualifications of its members.[18] *NFPA 1001 Standard for Fire Fighter Professional Qualifications* was established to facilitate the development of nationally applicable performance standards for uniformed fire service personnel.[6] *NFPA 1021 Standard for Fire Officer Professional Qualifications* was developed in the same way to determine that an individual possesses the skills and knowledge to perform as a fire officer.[23] The intent of both of these standards is to develop clear and concise job performance requirements (JPRs) that can be used to determine that an individual, when measured to the standard, possesses the skills and knowledge to perform as a fire fighter or a fire officer, and that these JPRs can be used by any fire department in the country.

Training is an ongoing process, whether held daily, weekly or monthly, it allows members to maintain proficiency at their present levels, meet certification requirements, learn new procedures, and keep up with emerging technology. This fire department required fire fighters to receive basic fire fighter training certification before being considered for employment. Once recruits were hired they were put through a ten day hands-on training and then assigned to their station. This ten day training included equipment use, SCBA use, ladder drills, hydrant hookup, hose lays, hose pulls, rescue drills, and live-burn exercises. The training provided for basic hoseline operations was minimal. Hands-on training should also include topics such as hazard recognition, ventilation tactics, ICS/NIMS, scene size-up, and basic hoseline operations. The basic training certification required by the fire department at the time of this incident did not meet NFPA Fire Fighter I requirements.

Recommendation #25: Fire departments should implement joint training on response protocols with mutual aid departments.

Discussion: Mutual aid companies should train together and not wait until an incident occurs to attempt to integrate the participating departments into a functional team. Differences in equipment and procedures need to be identified and resolved before an emergency occurs when lives may be at stake. Procedures and protocols that are jointly developed, and have the support of the majority of participating departments, will greatly enhance overall safety and efficiency on the fireground. Once methods and procedures are agreed upon, training protocols must be developed and joint-training sessions conducted to relay appropriate information to all affected department members.

Fire departments should develop and establish good working relationships with surrounding departments so that reciprocal assistance and mutual aid is readily available when emergency situations escalate beyond response capabilities. During this incident, there was little coordination and communication between the municipal and the mutual aid departments, although fire fighters from the mutual aid department played key roles in rescuing the trapped employee, attempting to search the main showroom for missing fire fighters, and establishing water supply. Coordination of fireground efforts could have been enhanced if protocol planning, communication procedures (such as radio frequency/channel selection), and prior training had taken place among mutual aid departments.

Recommendation #26: Fire departments should ensure apparatus operators are properly trained and familiar with their apparatus

Discussion: Modern fire apparatus are complex equipment. Fire fighters require considerable knowledge, skills and abilities in order to properly and safely operate fire apparatus. *NFPA 1002 Standard for Fire Apparatus Driver/Operator Professional Qualifications*, Chapter 5 lists the requisite knowledge and skills necessary to safely operate fire apparatus equipped with fire pumps.[51] Prior to this incident, the fire department provided driver / operator training that consisted mainly of on-the-job training. Individual fire fighters could request to be trained as a driver / operator and this request would be approved through the fire department chain-of-command. Fire fighters then received hands-on training during normal work hours. During this incident, an operator who was not experienced with one of the engines encountered trouble getting the pump to go into gear for pump operations. A detailed inspection report provided by the city (see Appendix II) demonstrates that specialized training and experience was needed to properly engage the pump.

Recommendation #27: Fire departments should protect stretched hoselines from vehicular traffic and work with law enforcement or other appropriate agencies to provide traffic control.

Discussion: In urban settings, fire hose is commonly used on the fireground to transfer water from the distribution system (usually from a hydrant) to the fire apparatus supplying water to the attack lines. Fire hose is often stretched across roadways and through parking lots. Fire hose may be damaged in a variety of ways while being used on the fireground. Fire departments should avoid laying or pulling hose over rough terrain, sharp edges or objects. A damaged hose may impede fire suppression activities or put fire fighters in an unsafe position by reducing the water needed for fire suppression while attacking the fire. Fire departments should provide protection for deployed hoselines that may potentially be run over by vehicular traffic or be damaged by vibration. This can be done by the use of chafing blocks, hose ramps, or hose bridges.[19] Many commercial versions are available or these items can be custom made. Fire departments should also position someone at these protective devices so vehicular traffic can be properly guided across or re-routed, and to make sure the hose does not move around. Fire departments should work with the local police and law enforcement agencies to ensure adequate traffic control, warning barricades, and traffic re-direction takes place. During this incident, fire apparatus engineers radioed dispatch multiple times requesting public safety assistance for traffic control because civilian vehicle traffic was running over the 2 ½" supply lines, disrupting the water supply. During the incipient stage of the fire, traffic was not being redirected and protective devices were not in use (see Photo 11).

Recommendation #28: Fire departments should ensure that fire fighters wear a full array of turnout clothing and personal protective equipment appropriate for the assigned task while participating in fire suppression and overhaul activities.

Discussion: NFPA 1500 Standard on Fire Department Occupational Safety and Health Program, Chapter 7 contains the general recommendations for fire fighter protective clothing and protective equipment.[18] Chapter 7.1.1 specifies that "the fire department shall provide each member with protective clothing and protective equipment that is designed to provide protection from the hazards to which the member is likely to be exposed and is suitable for the tasks that the member is expected to perform." Chapter 7.1.2 states, "Protective clothing and protective equipment shall be used whenever the member is exposed or potentially exposed to the hazards for which it is provided." Chapter 7.1.3 states, "Structural fire-fighting protective clothing shall be cleaned at least every 6 months as specified in NFPA 1851 *Standard on Selection, Care, and Maintenance of Structural Firefighting Protective Ensembles*." [52] Chapter 7.2.1 states, "Members who engage in or are exposed to the hazards of structural firefighting shall be provided with and shall use a protective ensemble that shall meet the applicable requirements of NFPA 1971 *Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting*." [53] Chapter 7.9.7 states, "When engaged in any operation where they could encounter atmospheres that are immediately-dangerous-to-life-or-health (IDLH) or potentially IDLH, or where the atmosphere is unknown, the fire department shall provide and require all members to use SCBA that has been certified as being compliant with NFPA 1981 *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services*." [54] Additionally, the OSHA Respirator Standard requires that all employees engaged in interior structural firefighting use SCBAs.[8] During this incident, there were multiple instances where fire fighters were observed working in close proximity to the burning structure with incomplete personal protective ensembles including incomplete turnouts (i.e. no turnout pants, turnout coats unfastened, suspenders improperly worn, no gloves, no hoods), entering the burning structure without an SCBA, and off-duty fire fighters actively working in street clothing with no personal protection at all. The evaluation report of the PPE worn by the nine victims identified instances where the PPE was not properly worn such as turnout coat collars not fully extended upward and helmet ear flaps not deployed (see Appendix IV).

It is important to note that the 2007 revision to NFPA 1982 *Standard on Personal Alert Safety Systems (PASS)* includes new heat and flame resistance requirements resulting from documented reports where PASS devices were not heard during fatal fireground incidents.[55] Laboratory testing conducted by NIST determined that exposure to high temperature environments caused the loudness of the tested PASS alarm signal to be reduced. This reduction in loudness can cause the alarm signal to become indistinguishable from background noise at an emergency scene. Initial laboratory testing by NIST highlighted that this sound reduction may begin to occur at temperatures as low as 300°F. Thus the use of PASS devices meeting NFPA 1982, 2007 Edition requirements is highly recommended.

***Recommendation #29: Fire departments should ensure that fire fighters are trained in air management techniques to ensure they receive the maximum benefit from their* self-contained breathing apparatus (SCBA).**

Discussion: SCBA air cylinders contain a finite volume of air, regardless of the size. Air consumption will vary with each individual's physical condition, the level of training, the task performed, and the environment. Depending on the individual's air consumption and the amount of time required to exit an immediately-dangerous-to-life-and-health (IDLH) environment, the low air alarm may not provide adequate time to exit. Working in large structures (high rise buildings, warehouses, and supermarkets) requires that fire fighters be cognizant of the distance traveled and the time required to reach the point of suppression activity from the point of entry. When conditions deteriorate and the visibility becomes limited, fire fighters may find that it takes additional time to exit when compared to the time it took to enter the structure.[46, 56] NFPA 1404 *Standard for Fire Service Respiratory Protection Training* Paragraph 5.1.4.2 requires fire departments to train fire fighters on air management techniques so that the individual fire fighter will develop the ability to manage his or her air consumption while wearing an SCBA. NFPA 1404 specifies that the individual air management program should include the following directives:

(1) Exit from an IDLH atmosphere should be before consumption of reserve air supply begins.
(2) Low air alarm is notification that the individual is consuming the reserve air supply.
(3) Activation of the reserve air alarm is an immediate action item for the individual and the team.[57]

Fire departments and fire fighters should regularly conduct training exercises in which fire fighters perform various exercises and work tasks at different work rates until their SCBA cylinder air is exhausted so that fire fighters become familiar with the time they can expect to work before the low air alarm sounds, and how long they have to exit once the low air alarm sounds. In order to comply with NFPA 1404, fire departments and fire fighters should follow the Rule of Air Management which states "*Know how much air you have in your SCBA and manage that air so that you leave the hazardous environment before your low-air alarm activiates*."[57, 58] By being aware of these time parameters, fire fighters can make educated decisions on the time they can safely spend in IDLH atmospheres. In this incident, the majority of fire fighters who entered the main showroom ran out of air. Some of the fire fighters were able to exit. The nine victims are all believed to have run out of air.

Recommendation #30: Fire departments should develop, implement and enforce written SOPs to ensure that SCBA cylinders are fully charged and ready for use.

Discussion: During this incident, many of the fire fighters who entered the main showroom became disoriented due to the rapidly deteriorating conditions and ran low or completely exhausted their air supply. The examination of the remains of the SCBA used by the 9 victims suggested that all 9 SCBA were out of air. The SCBA used by this fire department include cylinders that are rated for a 30-minute duration when fully charged to 2216 psi. During the NIOSH interview process, several fire fighters stated that the fire department's procedures were to refill cylinders when the pressure dropped to 1500 psi which is well below the required 90% level (1500 psi is 68% of full cylinder pressure). Although NIOSH did not examine all department SCBAs or a scientific sample of SCBAs, examination of a small convenience sample of in-service SCBAs did identify some below 2000 psi. Cylinders designed to be fully charged at 2,216 psi should be refilled whenever the pressure falls to 1,994 psi. Due to gauge accuracy and the type of scale used on the face of the cylinder pressure gauge, any cylinder at or below 2000 psi should be topped off to ensure fire fighters are entering IDLH conditions with a full cylinder. The OSHA Respirator Standard, 29 CFR 1910.134(h)(3)(iii) states,"Air and oxygen cylinders shall be maintained in a fully charged state and shall be recharged when the pressure falls to 90% of the manufacturer's recommended pressure level."[8] NFPA 1852 and good SCBA practice dictate that SCBA air cylinders be refilled whenever the cylinder pressure falls to 90% of the manufacturer's recommended pressure level.[9, 59] A 30-minute cylinder typically holds 1,200 liters of air when fully charged. A cylinder charged to 1,500 psi would hold approximately 812 liters of air. A fire fighter working at a moderate work rate (40 liter per minute air consumption rate) would exhaust a cylinder holding 1500 psi in approximately 20 minutes (812 liters divided by 40 liters per minute). Fire fighters working at a higher work rate or breathing under duress (such as in an emergency situation) would exhaust a cylinder much quicker. During extreme exertion, the actual service time can be reduced by 50 percent or more.[9] A number of fire fighters inside the showroom were running low on air within 20-25 minutes.

Recommendation #31: Fire departments should use thermal imaging cameras (TICs) during the initial size-up and search phases of a fire.

Discussion: Thermal imaging cameras (TIC) can be a useful tool for initial size up and for locating the seat of a fire. Infrared thermal cameras can assist fire fighters in quickly getting crucial information about the location of the source (seat) of the fire from the exterior of the structure which can help plan an effective and rapid response. Knowing the location of the most dangerous and hottest part of the fire may help fire fighters determine a safer approach and avoid exposure to structural damage in a building that might have otherwise been undetectable. Ceilings and floors that have become dangerously weakened by fire damage and are threatening to collapse may be spotted with a thermal imaging camera. A fire fighter about to enter a room filled with flames and smoke can use a TIC to assist in judging whether or not it will be safe from falling beams, walls, or other dangers. The use of a thermal imaging camera may provide additional information the Incident Commander can use during the initial size-up. Thermal imaging cameras (TICs) should be used in a timely manner, and fire fighters should be properly trained in their use and be aware of their limitations.[60]

The use of a TIC during initial size-up and entry into the structure might have confirmed the presence of hot smoke and gases in the concealed space above the suspended ceiling, which would have been an indicator that more defensive tactics should be considered. TICs were available on the fireground but never put into service.

Recommendation #32: Fire departments should develop, implement and enforce written SOPs and provide fire fighters with training on the hazards of truss construction

Discussion: Fire departments should develop, implement and enforce SOPs or SOGs concerning safe fireground tactics when operating in structures containing truss construction and then train fire fighters to recognize the hazards of lightweight truss construction and the appropriate actions to take.[61,62] Fire departments should use pre-incident planning and building inspections to identify structures within their jurisdiction that contain truss construction. Pre-plan information should be entered into the dispatcher's computer so that when a fire is reported at pre-planned locations, the dispatcher can notify by radio all first responders with critical information.[61,62] Fire departments should ensure that the Incident Commander conducts an initial size-up and risk assessment of the incident scene before beginning interior fire-fighting operations. Hidden voids within truss construction provide large areas for smoke and hot gases to accumulate unseen. These hidden voids provide the potential for rapid fire spread, which may go unnoticed by fire fighters working below. The Rapid Intervention Team should be immediately notified when truss construction is identified. Fire departments should use defensive strategies whenever trusses have been exposed to fire or structural integrity cannot be verified. Unless life-saving operations are under way, fire fighters should immediately be evacuated and an exterior attack should be used.[61,62] Fire fighters performing fire-fighting operations under or above trusses should be evacuated as soon as it is determined that the trusses are exposed to fire (not according to a time limit). A collapse zone should be established when operating outside a burning building, since truss roof collapses can push out on the walls, causing a secondary collapse of the exterior walls. The collapse zone should be equal to the height of the building plus allowance for scattering debris, usually at least 1½ times the height of the building.[39, 61, 63] Defensive overhauling procedures should be used after fire extinguishment in a building containing truss construction. Outside master streams should be used to soak the smoldering truss building and prevent rekindling.[39, 61, 63]

Recommendation #33: Fire departments should establish a system to facilitate the reporting of unsafe conditions or code violations to the appropriate authorities.

Discussion: In 1987 the responsibility for fire code inspections was transferred from the fire department to the city. In order to facilitate open communication, fire department personnel and building code officials should be cross-trained on each-others' duties and responsibilities. Fire fighters should have a basic understanding of what a code violation is and building code inspectors should have a basic understanding of fire fighter safety issues. The fire department conducted a number of pre-plan inspections at the structure involved in this incident. However, unsafe conditions and code violations were not noted on the pre-plan inspection form presented to NIOSH. The preplan form did note the presence of the warehouse with storage shelves approximately 30 feet high, but did not note the lightweight metal roof trusses and the excessive fuel loads associated with the contents. Such information could be used to facilitate safer conditions for employees, the public and fire fighters and emergency responders called to the scene. The accumulation of trash outside the loading dock, large quantities of flammable liquids, solvents, and thinners in the loading dock area and storage of furniture and flammable materials in non-permitted areas were determined to be code violations after the incident. The identification and reporting of these conditions to the responsible authorities prior to the incident could potentially have resulted in corrective actions.

Recommendation #34: Fire departments should ensure that fire fighters and emergency responders are provided with effective incident rehabilitation

Discussion: Effective emergency incident rehabilitation is an important element of fire fighter health and safety. Quoting Gregory Cade, former U.S. Fire Administrator, "Emergency responder rehabilitation is designed to ensure that the physical and mental well-being of members operating at the scene of an emergency do not deteriorate to the point where it effects their safety. It can prevent serious and life-threatening conditions such as heat stroke and heart attacks from occurring. Fireground rehab is the term often used for the care given to fire fighters and other responders while performing their duties at an emergency scene. Fireground rehab includes monitoring vital signs, rehydration, nourishment, and rest for responders between assignments."[64, 65] During this incident, the municipal fire department did not practice fireground rehab. While fireground rehab was not a direct contributing factor in the deaths of the nine fire fighters, fireground rehab is an important part of a fire department occupational safety and health program.

Recommendation #35: Fire departments should provide fire fighters with station / work uniforms (e.g., pants and shirts) that are compliant with NFPA 1975 and ensure the use and proper care of these garments.

Discussion: Fire fighters involved in structural firefighting and other emergency activities should be provided, at a minimum, station / work uniforms that are certified and compliant with NFPA 1975 in order to avoid the potential for burn injuries that are more severe as the result of using thermally unstable or rapidly deteriorating materials (e.g., fabrics that contain a significant portion of polyester or other synthetic fabrics that easily melt at low temperatures). Ideally, the prescribed station / work uniforms should also be flame resistant certified to the optional requirements specified in NFPA 1975.[7] The use of NFPA 1975-compliant station / work uniforms is specified in NFPA 1500 (paragraphs 7.1.5 and 7.1.6), which also recommends that departments provide for the adequate cleaning of station / work uniforms provided to their members (7.1.7).[18] According to Appendix A.5.3.10 of NFPA 1500, clothing that is made from 100 percent natural fibers or blends that are principally natural fibers should be selected over other fabrics that have poor thermal stability or ignite easily. Appendix A.5.3.10 further states,"The very fact that persons are fire fighters indicates that all clothing that they wear should be flame resistant (as children's sleepwear is required to be) to give a degree of safety if unanticipated happenings occur that expose the clothing to flame, flash, sparks, or hot substances. This would include clothing worn under their structural fire-fighting protective ensemble." While compliance with NFPA standards is voluntary, in many instances NFPA standards represent fire service "best practices" available for ensuring fire fighter safety and health, especially where state and Federal laws are silent on health and safety issues.

In this incident, the fire fighters were not supplied with nor were they wearing station/work uniforms that were compliant with NFPA 1975. Although the use of polyester work clothing was not a direct contributing factor to the nine fatalities that occurred in this incident, the wearing of polyester-based uniforms can contribute to significant potential for severe burn injury.

Recommendation #36: Federal and state occupational safety and health administrations should consider developing additional regulations to improve the safety of fire fighters, including adopting National Fire Protection Association (NFPA) consensus standards.

Discussion: Fire fighters have a high rate of injury death compared to other occupations,[11] yet federal and state regulations addressing the risks of firefighting are sparse. In September 2007, the federal Occupational Safety and Health Administration (OSHA) requested information from the public to evaluate what action, if any, the US Department of Labor should take to further address emergency response and preparedness, including the safety of fire fighters during common responses such as structural fires, as well as rare and unexpected events, such as natural disasters and terrorist attacks.[66] In this request for information, OSHA noted that elements of emergency responder health and safety are currently regulated by a number of standards, many of which were promulgated decades ago, and none designed as a comprehensive emergency response standard. Consequently, existing standards do not address the full range of hazards or concerns currently facing emergency responders, including fire fighters.

NIOSH provided comments in response to this request.[67] NIOSH expressed support for this information gathering process, and provided data, information, and recommendations from NIOSH fire fighter fatality investigations and research. NIOSH suggested that OSHA consider regulating all types of emergency incidents, both common and rare events, and that OSHA consider the full continuum of emergency response activities, from pre-planning for emergency response activities through recovery and post-incident treatment. NIOSH provided information from fire fighter fatality investigations, including large numbers of investigations in which NIOSH recommended that fire departments: comply with NFPA standards for personal protective clothing and equipment,[52,53] require the use of Personal Alert Safety Systems,[55] require minimum standards for safety and health training, require the use of an Incident Management System to manage emergency events,[21] require a designated Safety Officer at emergency events, require the use of thermal imaging cameras at structure fires, require that fire departments have written SOPS and a written safety and health program, and require that RIT teams be established at emergency events before fire fighters enter IDLH environments. NIOSH referenced several NFPA standards in these comments.

Compliance with existing Federal and state occupational safety and health regulations may not be adequately protecting fire fighters, and is inconsistent with industry “best practices” developed through the NFPA consensus process. In addition to OSHA considering additional regulations to protect fire fighters, state occupational safety and health agencies that cover public employees should similarly consider enhancing the protection of fire fighters through their state regulations.

Recommendation #37: Manufacturers, equipment designers, and researchers should continue to develop and refine durable, easy-to-use radio systems to enhance verbal and radio communication in conjunction with properly worn SCBA.

Discussion: The use of Personal Protective Equipment (PPE) and an SCBA make it difficult to communicate, with or without a radio.[68,69] Faced with the difficult task of communicating while wearing a SCBA, fire fighters sometimes momentarily remove their face pieces to transmit a message directly or over a portable radio. Considering the toxic and oxygen-deficient hazards posed by a fire and the resulting products of combustion, removing the SCBA face piece, even briefly, is a dangerous practice that should be prohibited. Even small exposures to carbon monoxide and other toxic agents present during a fire can affect judgment and decision making abilities. To facilitate communication, equipment manufacturers have designed face piece-integrated microphones, intercom systems, throat mikes and bone mikes worn in the ear or on the forehead.[69,70]

Recent testing of portable radios in simulated firefighting environments by the National Institute for Standards and Technology (NIST) has identified that radios are vulnerable to exposures to elevated temperatures. Some degradation of radio performance was measured at elevated temperatures ranging from 100^{O}C to 260^{O}C, with the radios returning to normal function after cooling down. Additional research is needed in this area.[71]

During this incident fire fighters experienced intermittent radio communication problems and interruptions. Audio transcripts of the fireground channel recorded multiple instances where fire fighters inside the structure (including some of the victims) transmitted over the radio, but the transmissions were not heard or could not be understood. Effective radio communication is an important part of safe fireground operations.

Recommendation #38: Manufacturers, equipment designers and researchers should conduct research into refining existing and developing new technology to track the movement of fire fighters inside structures.

Discussion: Fire fighter fatalities often are the result of fire fighters becoming lost or disoriented on the fireground. The use of systems for locating lost or disoriented fire fighters could be instrumental in reducing the number of fire fighter deaths on the fireground. The National Institute for Standards and Technology (NIST) has been evaluating the feasibility of real-time fire fighter tracking and locator systems.[68,72] Research into refining existing systems and developing new technologies for tracking the movement of fire fighters on the fireground should continue.

Recommendation #39: Code setting organizations and municipalities should require the use of sprinkler systems in commercial structures, especially ones having high fuel loads and other unique life-safety hazards, and establish retroactive requirements for the installation of fire sprinkler systems when additions to commercial buildings increase the fire and life safety hazards.

Discussion: This recommendation focuses on fire prevention and minimizing the impact of a fire if one does start. The NFPA *Fire Protection Handbook* states,"throughout history there have been building regulations for preventing fire and restricting its spread. Over the years these regulations have evolved into the codes and standards developed by committees concerned with fire protection. The requirements contained in building codes are generally based upon the known properties of materials, the hazards presented by various occupancies, and the lessons learned from previous experiences, such as fire and natural disasters."[73] Although municipalities have adopted specific codes and standards for the design and construction of buildings, structures erected prior to the enactment of these building laws may not be compliant. Such new and improved codes can improve the safety of existing structures.[73] Sprinkler systems are one example of a safety feature that can be retrofitted into older structures. Sprinkler systems can reduce fire fighter fatalities since such systems can contain and may even extinguish fires prior to the arrival of the fire department. In this incident, this structure incorporated mixed-used construction types and was non-sprinklered. The original structure was built in the 1960s (17,500 square feet), with additions added in 1994 (6,970 square feet) and 1995 (7,020 square feet). The structure was annexed into the city in 1990. City ordinances required commercial structures over 15,000 square feet to have a sprinkler system. The original structure was grandfathered, and the subsequent additions were treated as separate buildings so the facility was never sprinklered. The additions were treated as separate structures with the end result being that each addition did not meet the threshold at which a sprinkler system would be required.

Recommendation #40: Code setting organizations and municipalities should require the use of automatic ventilation systems in commercial structures, especially ones having high fuel loads and other unique life-safety hazards.

Discussion: The use of automatic ventilation systems in roofs and enclosed void spaces that would open in the event of a fire and allow smoke, hot fire gases and heat to escape could aid fire fighters by helping control fire spread. Smoke venting through these openings would also give Incident Commanders and fire fighters very useful information related to the fire's size, location and stage of growth. Many European standards such as the UK legislation requirements of BS7346 part 1 (European National (EN) 12101) & BS 5588 part 5 require automatic roof ventilation systems that automatically open to ensure rapid dispersal of smoke, heat and toxic gases.[74]

Recommendation #41: Municipalities and local authorities having jurisdiction should coordinate the collection of building information and the sharing of information between building authorities and fire departments.

Discussion: Municipalities and local authorities having jurisdiction should develop a questionnaire or checklist to ensure that pre-plan inspections collect the appropriate information. The questionnaire or checklist could focus on building characteristics including the type of construction, materials used, occupancy, fuel load, roof and floor design, and unusual or distinguishing characteristics. Once obtained, this information should be recorded, shared with all departments who provide mutual aid, and if possible, entered into the dispatcher's computer so that the information is readily available if an incident is reported at the noted address. Municipalities and local authorities having jurisdiction should also include experienced fire personnel throughout any zoning or building code developmental process concerning life safety to the public and fire department members. Typically, pre-incident planning focuses on commercial buildings and the specific hazards they have due to their size, construction, and contents.

Recommendation #42: Municipalities and local authorities having jurisdiction should consider establishing one central dispatch center to coordinate and communicate activities involving units from multiple jurisdictions.

Discussion: An effective radio communication system is a key factor in fire department operations. The communication system, or central dispatch center, is used for receiving notification of emergencies, alerting personnel and fire apparatus, coordinating the activities of the units engaged in emergency incidents, and providing non-emergency communications for the coordinating fire departments. The dispatch system must be able to identify the type and number of units due to respond to the type of incident in advance based on risk criteria and unit capabilities. The central dispatch center should also monitor fireground activity and inform command of time intervals or of possible missed transmissions such as Maydays. A central dispatch center equipped with regional mutual aid channels could serve multiple jurisdictions.[38,70] This type of system would provide operational advantages in the communication system, reflect a more functional mutual aid system, and reduce overall costs of operating centers in individual jurisdictions. Having a pre-determined response for apparatus arranged by district, address or by type of incident, makes the job of the Incident Commander and the dispatcher much easier. The pre-determined assignment lists the apparatus slated to respond to the incident and should take into account apparatus that are out of service by filling in for such units with similar units. In this incident, the municipal fire department maintained its own dispatch center in cooperation with the city policy department. The neighboring departments either had their own dispatch centers or were serviced by the county dispatch system. The municipal fire department relied upon the chief officers to request companies as the need was identified, instead of having predetermined response assignments.

Recommendation #43: Municipalities and local authorities having jurisdiction should ensure that fire departments responding to mutual aid incidents are equipped with mobile and portable communications equipment that are capable of handling the volume of radio traffic and allow communications among all responding companies within their jurisdiction.

Discussion: Units responding to or engaged at incidents should have the necessary radio frequencies/channels to be in contact with other units providing mutual aid. These units should also have the capability to monitor the fireground activities while en-route.[38] During this incident, some mutual aid departments could not communicate with the IC or the municipal dispatch center on either their portable or mobile radios.

REFERENCES

1. Routely JG, Chiaramonte M, Crawford B, Piringer P, Roche K, Sendelbach T [2007]. City of Charleston Post Incident Assessment and Review Team: Phase 1 Report. October 16, 2007.

2. Routely JG, Chiaramonte M, Crawford B, Piringer P, Roche K, Sendelbach T [2008]. City of Charleston Post Incident Assessment and Review Team: Phase II Report. May 15, 2008.

3. South Carolina Department of Labor, Licensing and Regulation [2009]. S. C. Occupational Safety and Health Administration (OSHA) http://www.llr.state.sc.us/Labor/Osha/index.asp?file=suba.htm Date accessed: February 5, 2009.

4. South Carolina Department of Labor, Licensing and Regulation [2007]. Report of S.C. OSHA findings in June 18, 2007 Charleston Super Sofa Fire. Columbia, SC: Department of Labor, Licensing and Regulation. http://media.charleston.net/pdf/OSHAreport.pdf Date accessed: February 5, 2009.

5. State of South Carolina [2007]. Settlement Agreement. Columbia, SC: State of South Carolina, County of Richland.

   http://media.charleston.net/2007/pdf/settlement_agreement_120307.pdf Date accessed: February 5, 2009.

6. NFPA [2008]. NFPA 1001: Standard for Firefighter Professional Qualifications. 2008 ed. Quincy, MA: National Fire Protection Association.

7. NFPA [2004]. NFPA 1975 Standard on station / work uniforms for fire and emergency services. Quincy, MA: National Fire Protection Association.

8. OSHA [1998]. 29 CFR Parts 1910 and 1926 Respiratory Protection; Final Rule. Federal Register Notice 1218-AA05. Vol. 63, No. 5. January 8, 1998. U.S. Department of Labor, Occupational Safety and Health Administration. Washington DC.

9. NFPA [2008]. NFPA 1852 Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA). Quincy, MA: National Fire Protection Association.

10. Weather Underground [2008]. Weather history for incident location in SC, June 18, 2007.http://www.weatherunderground.com/history/airport/KCHS/2007/6/18/DailyHistory.html?req _city=Charleston&req_state=SC&req_statename=South+Carolina Date accessed: October 29, 2008. (This link is also accessible at the following URL: http://www.weatherunderground.com/history/airport/KCHS/2007/6/18/DailyHistory.html?req _city=Charleston&req_state=SC&req_statename=South+Carolin)

11. Clarke C, Zak MJ [1999]. Fatalities to law enforcement officers and firefighters, 1992-1997. Compensation and Working Conditions, 1999.

12. Arocena P, Nunez I, Villanueva M [2008]. The impact of prevention measures and organizational factors on occupational injuries. Safety Science 46: 1369-1384.

13. Aksom T, Hadikusumo [2008]. Critical success factors influencing safety program performance in Thai construction projects. Safety Science 46: 709-727.

14. Mearns K, Whitaker SM, Flin R [2003]. Safety climate, safety management practice and safety performance in offshore environments. Safety Science 41: 641-680.

15. Shannon HS, Robson LS, Sale JM [2001]. Creating safer and healthier workplaces: role of organizational factors and injury rates. American Journal of Industrial Medicine 40: 319-334.

16. Vredenburgh A [2002]. Organizational safety: which management practices are most effective in reducing employee injury rates? J Safety Research 33: 259-276.

17. Shannon HS, Mayr J, Haines T [1997]. Overview of the relationship between organizational and workplace factors and injury rates. Safety Science 26: 201-217.

18. NFPA [2007]. NFPA 1500: Standard on Fire Department Occupational Safety and Health Program. Quincy, MA: National Fire Protection Association

19. IFSTA [2008]. Essentials of firefighting, 5th ed. Oklahoma State University. Stillwater, OK: Fire Protection Publications, International Fire Service Training Association.

20. Dodson D [2007]. Fire Department Incident Safety Officer. 2nd Edition. New York: Thomson Delmar Learning.

21. NFPA [2008]. NFPA 1561 Standard on Emergency Services Incident Management System, 2008 Edition. Quincy, MA: National Fire Protection Association.

22. OSHA [1996]. The National Response Team's Integrated Contingency Plan Guidance; Federal Register Notice 61:28641-28664, June 5, 1996. Posted as a guidance document on the Occupational Health and Safety Administration website http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER &p_id=13550. Date accessed: October 29, 2008.

23. NFPA [2008]. NFPA 1021: Standard for Fire Officer Professional Qualifications. 2003 ed. Quincy, MA: National Fire Protection Association.

24. NFPA [2008]. NFPA 1521. Standard for Fire Department Safety Officer. 2008 Edition. Quincy, MA: National Fire Protection Association.

25. Dunn V [1992]. Safety and Survival on the Fireground. Saddle Brook NJ: Fire Engineering Books and Videos.

26. Dunn V [2000]. Command and Control of Fires and Emergencies. Saddle Brook NJ: Fire Engineering Book and Videos.

27. Brunacini AV [1985]. Fire command. Quincy, MA: National Fire Protection Association.

28. Dunn V [1998]. Risk management and lightweight truss construction. New York: WNYF, Official training publication of the New York City Fire Department, 1st issue.

29. NIOSH [1999]. NIOSH Alert: Request for assistance in preventing injuries and deaths of fire fighters due to structural collapse. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. (NIOSH) Publication No. 99-146.

30. Dunn, V. [2007]. Strategy of Firefighting. Saddlebrook NJ: Penn Well Publishing Co. p- 162.

31. Dunn, V. [1988]. Collapse of Burning Buildings: A Guide to Fireground Safety. Saddle Brook, NJ: Fire Engineering Books and Videos.

32. International Fire Service Training Association (IFSTA) [2000]. Model Procedures Guide for Structural Firefighting. 2nd Edition. Stillwater, OK: Fire Protection Publications.

33. NIOSH [2005]. Career fire fighter dies and two career captains are injured while fighting night club arson fire – Texas. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2004–14, p. 6.

34. International Fire Service Training Association (IFSTA)[2002]. Fireground support operations. 4th Edition. Stillwater, OK: Fire Protection Publications.

35. Kipp JD and Loflin ME [1996]. Emergency incident risk management. New York, NY: Van Nostrand Reinhold, p. 253.

36. Foley S. [1998]. NFPA 1500, Fire department occupational health and safety standards handbook. 1st ed. Quincy, MA: National Fire Protection Association (chapter 3).

37. Dodson, D [2005]. The art of first-due. Fire Engineering. March 2005, pp. 135-141.

38. NFPA [2004]. NFPA 1710 Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. 2004 Edition. Quincy, MA: National Fire Protection Association.

39. Klaene BJ and Sanders RE [2000]. Structural firefighting. Quincy, MA: National Fire Protection Association.

40. NFPA [2003]. NFPA 1620: Recommended practice for pre-incident planning. Quincy, MA: National Fire Protection Association.

41. Brunacini A, Brunacini N [2004]. Command Safety: The IC's role in protecting firefighters. Peoria, AZ: Across the Street Productions, Inc.

42. National Incident Management System Consortium [2007]. Incident Command System (ICS) Model Procedures Guide for Incidents Involving Structure Firefighting,

High-Rise, MultiCasualty, Highway, and Managing Large-Scale Incidents Using NIMS-ICS. First Edition. Oklahoma State University. Fire Protection Publications.

43. IFSTA [1999]. Pumping Apparatus Driver/Operator Handbook. 1st ed. Fire Protection Publications. International Fire Service Training Association.

44. IFSTA [2004]. Fire Hose Practices. 8th ed. Stillwater, OK: Fire Protection Publications, Oklahoma State University. International Fire Service Training Association.

45. Carter W, Childress D, Coleman R, et al. [2000]. Firefighter's Handbook: Essentials of firefighting and emergency response. Albany, NY: Delmar Thompson Learning.

46. Hoffman, JJ [2002]. MAYDAY-MAYDAY-MAYDAY. Fire Department Safety Officers Association Health and Safety for Fire and Emergency Service Personnel 13(4):8.

47. Angulo RA, Clark BA, Auch S [2004]. You called Mayday! Now what? Fire Engineering, Sept 2004, Vol. 157, No. 9, pp. 93-95.

48. DiBernardo JP [2003]. A missing firefighter: Give the Mayday. Firehouse, Nov 2003, pp. 6870.

49. Sendelbach TE [2004]. Managing the fireground Mayday: The critical link to firefighter survival. http://cms.firehouse.com/content/article/article.jsp?sectionId=10&id=10287. Date accessed: October 29, 2008.

50. Miles J, Tobin J [2004]. Training notebook: Mayday and urgent messages. Fire Engineering, April 2004, Vol. 157, No. 4, pp. 22.

51. NFPA [2008]. NFPA 1002 Standard for Fire Apparatus Driver/Operator Professional Qualifications. 2009 ed. Quincy, MA: National Fire Protection Association.

52. NFPA [2008]. NFPA 1851 Standard on Selection, Care, and Maintenance of Structural Firefighting Protective Ensembles. Quincy, MA: National Fire Protection Association.

53. NFPA [2007]. NFPA 1971 Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting, 2007 Edition. Quincy, MA: National Fire Protection Association.

54. NFPA [2007]. NFPA 1981 Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services, 2007 Edition . Quincy, MA: National Fire Protection Association.

55. NFPA [2007]. NFPA 1982 Standard on Personal Alert Safety Systems (PASS), 2007 Edition. Quincy, MA: National Fire Protection Association.

56. NIOSH [2001]. Supermarket Fire Claims the Life of One Career Fire Fighter and Critically Injures Another Career Fire Fighter – Arizona. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and

Prevention, National Institute for Occupational Safety and Health, Fatality Assessment and Control Evaluation (FACE) Report F2001-13.

57. NFPA [2006]. NFPA 1404 Standard for Fire Service Respiratory Protection Training. Quincy, MA: National Fire Protection Association.

58. Bernocco S, Gagliano M, Phippips C, and Jose P. [2008]. Is your department complying with the NFPA 1404 air management policy? Fire Engineering. Vol 161, No 2. February. Pp 103108.

59. Peterson JA and Merinar TR [1997]. Respirator Maintenance Program Recommendations for the Fire Service. Journal of the International Society for Respiratory Protection. Vol 15, Issues III & IV. Fall/Winter 1997.

60. Corbin DE [2000]. Seeing is believing. Dallas, TX: Occupational Safety and Health, Aug 69(8): 60-67.

61. NIOSH [2005]. NIOSH alert: preventing injuries and deaths of fire fighters due to truss system failures. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-132.

62. Dunn V [2001]. The deadly lightweight truss. Firehouse. Jan:16-20.

63. Brannigan FL [1999]. Building construction for the fire service. 3rd ed. Quincy, MA: National Fire Protection Association, pp. 517-563.

64. USFA [2008]. Emergency Incident Rehabilitation Manual for Firefighters and Other Emergency Responders. U.S. Department of Homeland Security, U.S. Fire Administration. February 2008.

65. USFA [2008]. Press Release: USFA Releases New Emergency Incident Rehabilitation Manual for Firefighters and Other Emergency Responders http://www.usfa.dhs.gov/media/press/2008releases/031208.shtm. Date accessed: October 29, 2008.

66. 72 Fed Reg 51735 [2007]. Emergency Response and Preparedness. Occupational Safety and Health Administration, Request for Information. Federal Register: September 11, 2007. Volume 72, Number 175. Page 51735-51743.

67. NIOSH [2007]. Comments of the National Institute for Occupational Safety and Health on the Occupational Safety and Health Administration Request for Information: Emergency Response and Preparedness, Docket No. H-010. November 26, 2007. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

68. NIST [2007]. Advanced fire service technologies program. Proceedings of the 2007 NIST Annual Fire Conference. National Institute of Standards and Technology, Building and Fire Research Laboratory. Gaithersburg, MD.

69. USFA/FEMA [1999]. Improving firefighter communications. USFA-TR-099. Emmitsburg. MD: United States Fire Administration.

70. TriData Corporation [2003]. Current status, knowledge gaps, and research needs pertaining to fire fighter radio communication systems. Report prepared for NIOSH. Arlington, VA: TriData Corporation.

71. Davis WD, Donnelly MK, and Selepak MJ [2006]. Testing of portable radios in a firefighting environment. NIST Technical Note 1477. National Institute of Standards and Technology. Gaithersburg, MD. Building and Fire Research Laboratory.

72. NIST [2008]. Wireless Sensor Research at NIST. National Institute of Standards and Technology, Building and Fire Research Laboratory. Gaithersburg, MD http://www.bfrl.nist.gov/WirelessSensor/. Date accessed October 29, 2008. (This link is also accessible at the following URL: http://www.bfrl.nist.gov/WirelessSensor)

73. NFPA [1997]. Fire Protection Handbook, 18th ed. Quincy, MA: National Fire Protection Association. 1-42.

74. BSRIA [2008]. New European standard for smoke extraction fans. Press Release. http://www.bsria.co.uk/services/testing/standard-testing/fans Building Services Research and Information Association of Great Britain. Date accessed: October 29 2008.

INVESTIGATOR INFORMATION

This investigation was conducted by Timothy Merinar, Safety Engineer, Matt Bowyer, General Engineer, Jay Tarley, Safety and Occupational Health Specialist, and J. Scott Jackson, Occupational Nurse Practitioner, with the NIOSH Fire Fighter Fatality Investigation and Prevention Program. Stacy Wertman, Safety and Occupational Health Specialist, NIOSH, Division of Safety Research, provided technical support. This report was authored by Timothy Merinar. Jeffrey O. Stull, President, International Personnel Protection, Inc., conducted a forensic evaluation of the personal protective equipment (PPE), protective clothing and station uniforms worn by the victims. Expert technical reviews were provided by Chief Alan Brunacini (retired), Phoenix Fire Department; I. David Daniels, Fire Chief / Emergency Services Administrator, Renton Washington; Assistant Chief Vincent Dunn (retired), Fire Department of New York; Battalion Chief John Salka, Fire Department of New York and President of Fire Command Training; Gordon Routley, fire service consultant and FRT Project Leader; Kevin Roche, Phoenix Fire Department and FRT member; Nelson Bryner, National Institute of Standards and Technology (NIST), and Ken Farmer, U.S. Fire Administration (USFA).

Special thanks to Nelson Bryner, Paul Fuss, and Glenn Forney of NIST for their assistance during this investigation and to Lee Baughman, South Carolina OSHA, for his assistance at the site. The investigators would also like to thank the fire department, the International Association of Fire Fighters local union, local mutual aid departments, the county coroner, the city Director, Safety Management Division, and the city police department for their assistance during this investigation. Finally, a very special “thank you” to all the fire fighters who provided valuable information during this investigation.

Photo 1. Time approximately 1924 hours. Fire is visible over showroom roof. Smoke is dark gray in color and becoming turbulent. The flames may not have been visible from front parking lot or close to the building on the D-side. *(Photo courtesy of Dan Folk.)*

Photo 2. Time approximately 1930 hours. Note how smoke has changed to dark black color indicating it is rich with products of incomplete combustion. Note Ladder 5 and Engine 11 in front of structure as well as fire department vehicle in lower left corner. The top of Engine 10 is just visible over the fence at the lower right. *(Photo courtesy of Associated Press, Alexander Fox photographer.)*

Photo 3. Time approximately 1934 hours. Note lack of any fire personnel in front of structure. At this point, the E-11, L-5, E-16, E-15, E-19, and E-6 crews are inside the showroom. Also note how the color of smoke column appears different from previous photo which may be due to the angle of the photograph and position of the sun. *(Photo courtesy of Police Department, Bill Murton, photographer.)*

Photo 4. Last surviving members of the initial attack crews exit showroom at approximately 1935 hours. *(Photo courtesy of Police Department, Bill Murton, photographer.)*

Photo 5. Time approximately 1935 hours. Mutual aid fire fighter breaking showroom front window. Photo taken just prior to mutual aid department making rescue attempt in front showroom. Note the heavy tar stains on the windows indicating the smoke inside the showroom is rich with flammable products of incomplete combustion. *(Photo courtesy of Police Department, Bill Murton, photographer.)*

Photo 6. Time approximately 1936 hours. Note turbulent dark gray smoke rolling out of the showroom as the front windows are being knocked out. Mutual aid crew is assembling for search and rescue attempt. *(Photo courtesy of Associated Press, Alexander Fox, photographer.)*

Photo 7. Time approximately 1938 hours. Photo shows conditions at front of showroom just before the interior search and rescue attempts were halted due to the interior conditions.
(Photo courtesy of the Charleston Post and Courier.)

Photo 8. Time approximately 1938 hours. Photo taken less than a minute after rescue crews are forced out of the showroom by the interior conditions. Note fire rolling out the showroom windows. *(Photo courtesy of the Charleston Post and Courier.)*

Photo 9. Storage racks in warehouse post fire. Storage racks were filled with various furniture and mattress items. Note the extent to which the storage racks filled the warehouse which gives an indication of the volume of merchandise and the fuel load inside the 15,600 square foot warehouse. The warehouse measured approximately 130 ft. by 120 ft. and was 29 ft from floor to roof. *(Photo – NIOSH.)*

Photo 10. Time approximately 1942 hours. Engine 10 and Engine 12 crews battle fire in warehouse from outside. *(Photo courtesy of police department, Bill Murton, photographer.)*

Photo 11. Time approximately 1925 hours. Note traffic on major highway in front of incident site driving over 2 ½ inch supply line. The hoseline runs from Engine 12 (to left of photo) to Engine 10 (to right of photo. Photo shows mutual aid crew members arriving on scene. *(Photo courtesy of Dan Folk.)*

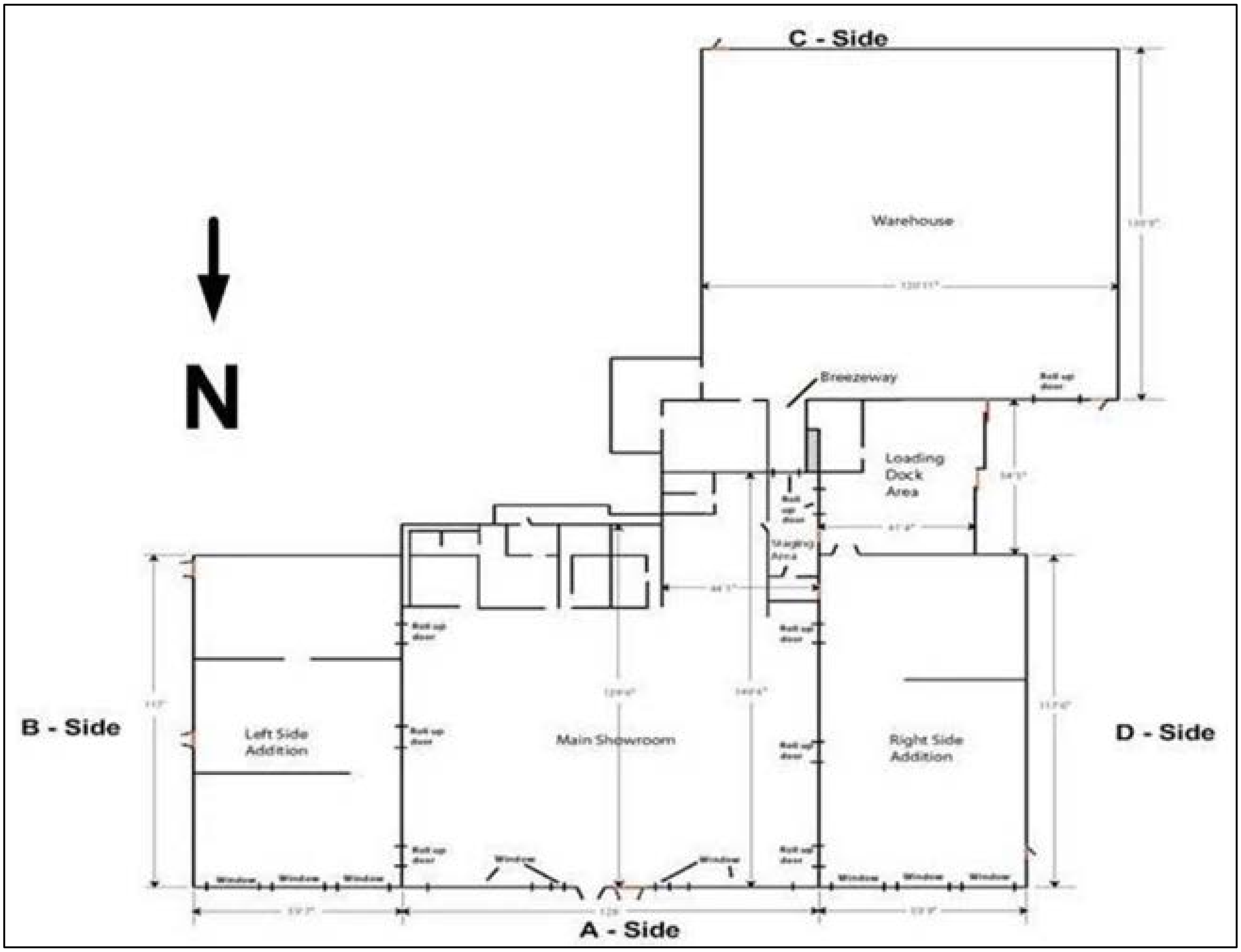


Diagram 1. Floor plan of furniture store and warehouse

[Fire Fighter Fatality Investigation](https://www.cdc.gov/niosh/fire/reports/face200718.html) This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Diagram 2. Location of Engine 10 and Engine 11, supply lines and hoselines pulled at different times during the incident. Note accumulation of trash at loading dock on the day photo was taken, 3 months prior to the incident. Note the absence of ventilation ductworks or other roof penetrations over the showroom, thus no path for smoke and hot gases to escape. From aerial photo taken in March 2007 *(copyright Pictometry International – used with permission of Pictometry)*

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Diagram 3: Note location where mutual aid crew cut through exterior wall to extricate male employee trapped inside the warehouse. From aerial photo taken in 2007.

(copyright Pictometry International – used with permission of Pictometry).

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

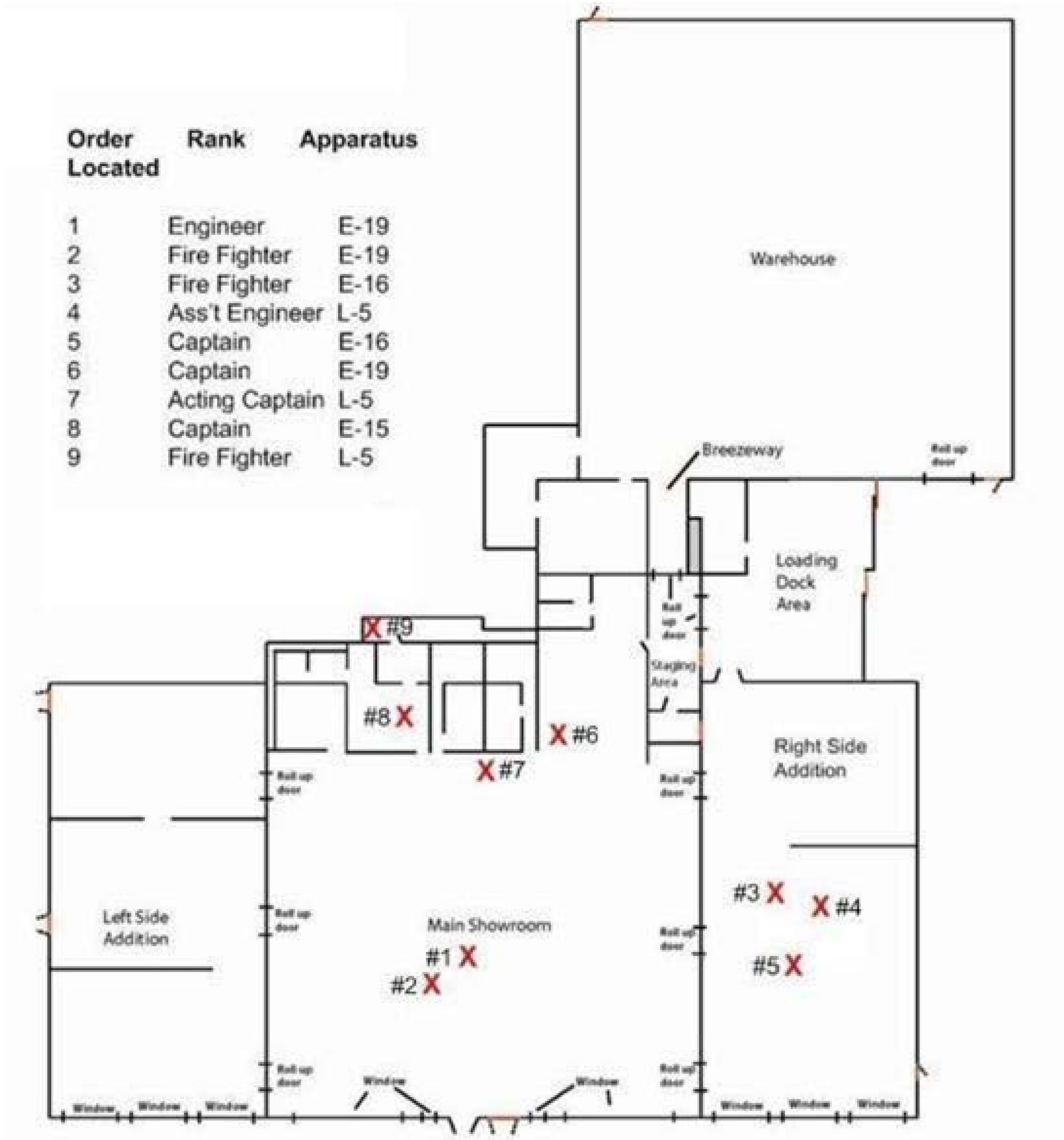


Diagram 4. Approximate Location of 9 Victims. Vistims 1, 2, 6 and 7 are located in the Main showroom. Victims 3, 4, and 5 are locate in the Right Side Addition. Victims 8 and 9 are located behind the main Showroom.

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Appendix I

Recruit Class Schedule

PROBIE SCHEDULE

Monday	Tuesday	Wednesday
SHIFT_____	SHIFT_____	SHIFT____
CHIEF'S OFFICE	EQUIPMENT	EQUIPMENT
H.R. 8:30 4:30	S.C.B.A.	S.C.B.A.
LECTURS	LADDERS	LADDERS
	CONFIND SPACE	HYDRANT HOOKUP
		HOSE LAYS
		HOSE PULLS
		2 ½ HANDLIND

Thursday	Friday	Monday
SHIFT____	SHIFT___	SHIFT___
EQUIPMENT	EQUIPMENT	EQUIPMENT
S.C.B.A.	S.C.B.A.	S.C.B.A.
LADDERS	LADDERS	LADDERS
HYD.HOOKUPS	HYD.HOOKUPS	HYD.HOOKUPS
35' LADDER	LADDER RESCUE	HIGH RISE
1 ½ UP LADDER	NIGHT DRILLS	STAND PIPE

Tuesday	Wednesday	Thursday	Friday
SHIFT____	SHIFT ____	SHIFT____	SHIFT____
EQUIPMENT	EQUIPMENT	CUT GRASS	WRITTEN TEST
S.C.B.A	S.C.B.A.	WAX CARS	STESS TEST
LADDERS	LADDERS	BURNS	GRADUATION
HYD.HOOKUPS	HYD.HOOKUPS		CLEAN ENG
LADDER TRUCK			
SMALL WINDOW			

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Appendix II

Engine 11 Inspection Report
Dated
December 16, 2008.

The fire department reported that no change had been made to Engine 11 since the day of the fire.

Jan 08 2009 11:35AM HP LASERJET FAX p.1

Memo

First Vehicle Services

Page 1

Unit: __Engine 11
Date inspection completed: 12/16/2008
Unit Mileage: 72092
EVT inspection completed by: Employee # 77177

Findings corrected on sight during Inspection:
1- Lower rear step light replaced, all light housings cleaned.
2- Left high beam head light had high moisture, headlight replaced.
3- Sprayed penetrating oil on pump packing gland lock.

Findings needing corrective action: No findings needing immediate corrective action, truck can remain in service at current state. The following should be addressed at or before next scheduled PM.

1- Schedule repair / replacement of air compressor, oil found in 2 air tanks.
2- Cab lift hydraulic pump is in need of replacement; manual cab lift is working properly and is in good working condition.
3- Power steering fluid is dark and in need of changing – PM scheduled for Jan 09.
4- Transmission fluid in need of changing– PM scheduled for Jan 09.
5- Cab lift safety bar is in good working order; however rubber bumper has hardened and should be replaced to remove rattling noise when driving.
6- Pump packing drip rate is excessive – gland lock is stuck in housing, should be addressed at next scheduled PM.
7- Left rear upper compartment light inop. should be addressed at next scheduled PM.
8- Shackle shims and bushings show wear on front springs, should be addressed at next scheduled PM.

Findings not needing corrective actions / comments:
1- Class 1 leak (acceptable amount of weeping) found at pump transfer case output seal.
2- Class 2 leak (minor, amount seepage) of right accessory drive oil seal. This item should be monitored for increase.

Page 2

First Vehicle Services
P.O. box 2016
Mt. Pleasant, SC 29405

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Jan 08 2009 11:35AM HP LASERJET FAX p.2

Memo

First Vehicle Services

3- Right Front (officer's seat) seatbelt shows signs of slight wear from contact with door latch. This item is in acceptable condition and should be monitored periodically for signs of increased wear over time.

Engine 11 Pump Findings:
Overall the engine 11 pump appears to be in good acceptable working order. Close inspection found no cause to replace or repair this item. When shifting the lever downward from top position, proper operation calls for a pause in center (neutral) position momentarily before bringing the lever to the complete downward position. Failure to pause at the center (neutral) position can cause a long excessive delay in engaging of pump. There is an expected delay even in proper operation of this pump. Please check with manufacturer for exact acceptable delay time line.

Technician Signature [redacted], date: 12-17-08

General Manager Signature [redacted] date 12-17-08

First Vehicle Services
P.O. box 2015
Mt. Pleasant, SC 29405

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Appendix III

Pre-plan Inspection Form

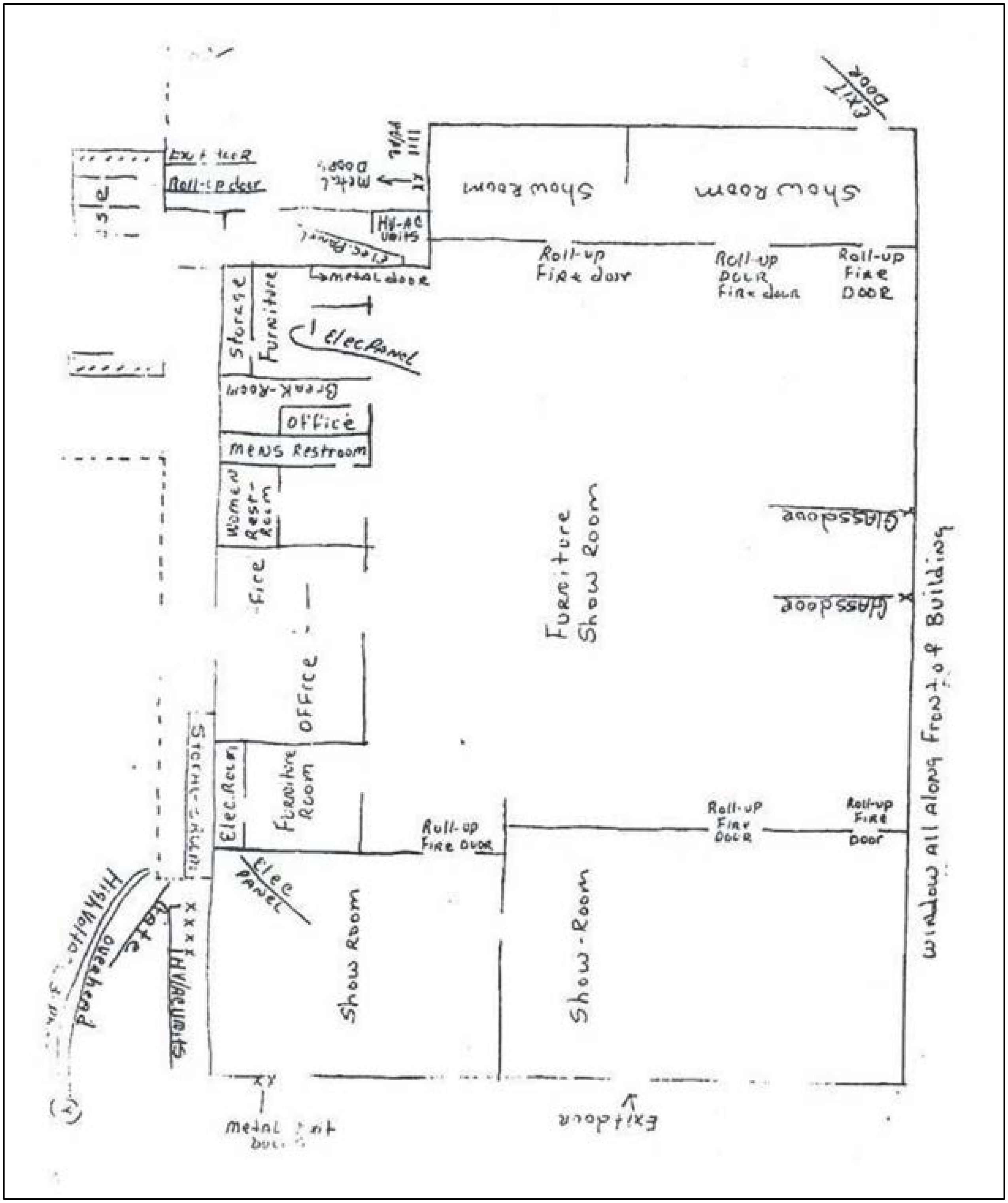
Pre-plan inspection form for the incident location. Note that names, addresses, phone numbers and other identifiers have been removed. Page 1 of 2.

City of [redacted] Fire Department [redacted]
PRE-PLANNING BUILDING INSPECTIONS

Company Eng 11, Eng 10 + L5 Date 04/26/06 Officer [redacted]
Address [redacted]
Occupant [redacted]
Owner [redacted]
Emergency # (Key Holder) [redacted]
Lives Involved: Day 15 - 18. Night 0
Type of Building Metal, Block No. Floors 1
Type of Roof Comp. Construction Metal Block.
F.D. Connections N/A Standpipes N/A
Auto Sprinkler N/A Location Main Valve N/A
Fire Alarm Indicator N/A
Location Main Elec. Switch Left Rear of Building
Location Main Gas Shut-Off Right Rear of Building.
Stairways N/A
Elevators N/A
Fire Escapes N/A Scuttle Holes N/A.
Vertical Openings ~~N/A~~ 7 Hallways 1
Fire Doors 11 Exits 8
Best Way To Enter Building: Day Front. Night Front.
Hydrant Location [redacted] st. [redacted] Rd.
Contents House hold furniture + office Equipment

Exposures to be Covered [redacted] gas station + Car dealership.
Date of Last Extinguisher Recharged May 2006.
CO2 Dry Chemical ✓
Additional Comments and/or Concerns Warehouse in rear Taller Roofs
Approx. 30' ~~hight~~ high.

Pre-plan inspection form, page 2 of 2.
Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.



[Fire Fighter Fatality Investigation](https://www.cdc.gov/niosh/fire/reports/face200718.html) This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Appendix IV

PPE Evaluation Report

For a copy of the complete PPE Evaluation Report, contact NIOSH Fire Fighter Fatality Investigation and Prevention Program 304-285-5916

International Personnel Protection, Inc.
Jeffrey O. Stull, President and Grace G. Stull, Vice President

August 5, 2008

Timothy R. Merinar, Safety Engineer
Surveillance and Field Investigations Branch
Division of Safety Research
1095 Willowdale Road
Morgantown, WV 26505-2888

Dear Mr. Merinar:

Enclosed please find my report to the examination of the protective clothing worn by nine fire fighters involved in the [redacted] fire.

Please contact me if you have any questions.

Sincerely,

Jeffrey O. Stull

Jeffrey O. Stull

Enclosure

P.O. Box 92493 • Austin, TX 78709 • Office (512) 288-8272 • Fax (512) 344-9588 • EMail: Intlperpro@aol.com

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

EXAMINATION OF FIRE FIGHTER PROTECTIVE CLOTHING AND EQUIPMENT WORN IN THE SUPER SOFA STORE FIRE

Final Report
July 31, 2008

Summary

This report covers my examination of the protective clothing and equipment worn by nine different fire fighters that died during their involvement in the [redacted] Fire in [redacted], South Carolina on June 18, 2008. This examination was carried out with the cooperation of the [redacted] Coroner's Office that had retained the clothing and equipment, which was removed from either removed from the individual deceased firefighters or recovered from the scene. Photographs were taken by the Chief Photographer of [redacted] Police Department.

The majority of clothing sets showed extensive damage with many items only available as remnants. Several portions of clothing were readily destroyed beyond recognition and could not be handled without further disintegration of the respective items. The lapse in time between the collapse of the structure and the recovery of the firefighter bodies significantly contributed to the continued degradation of the protective clothing and equipment and therefore does not represent the condition of the clothing at the time of each firefighter's demise. An examination of sets of clothing for firefighters that had escaped just prior to the collapse revealed that exposure conditions were relatively extreme but still in the ordinary range of fireground conditions. This information indicates that it may have been possible for some firefighters to sustain burn injuries at the time of collapse; however, other evidence suggests that several firefighters had removed the facepieces of their self-contained breathing apparatus after running out of air, suggesting that asphyxiation may have been the primary cause of death rather than burn injury.

Objective

I was asked by Mr. Timothy R. Merinar of the National Institute for Occupational Safety and Health (NIOSH) Surveillance and Field Investigations Branch to examine the protective clothing and equipment worn by the nine deceased fire fighters to determine if there were any deficiencies in the gear that could have caused their fatalities.

Description of the Incident and Fire Fighter Injuries

A complete description of the incident and specific injuries and burns sustained by the fire fighters is provided in the comprehensive Fire Fighter Field Investigative Program report. All fire fighters died at the fire scene with their bodies recovered after the fire was brought under control. For this reason, much of the clothing and equipment was damaged to a greater extent following the actual time that each fire fighter succumbed to the extreme conditions of their exposures.

1

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Items Examined and Observations

Protective clothing and equipment items were provided for each fire fighter and laid on examination tables for viewing. Given the extreme damaged condition of the clothing and equipment, minimal manipulation of items was undertaken. The following types of items were examined for each fire fighter, where identified and recovered:

- Protective coat
- Protective pants
- Protective helmet
- Protective hood
- Protective gloves
- Protective footwear
- Self-contained breathing apparatus
- Personal Alert Safety System (PASS) device
- Radio
- Station/work uniform pants and shirt
- Underwear
- Socks
- Tools or other items carried by each firefighter or found in proximity to the location of their recovered bodies

In some cases, some items could not be readily identified, or were so damaged to make a complete assessment impractical. A complete inventory of clothing, equipment and other items available for examination by firefighter is provided in Appendix A.

For the purpose of this examination, each fire fighter is identified as a number with this numbering system consistent with that used in the FFFIPP report. This information is provided with the designations of Victim #1 through Victim #9.

Specific observations and findings by victim are provided in Appendices B through J. Selected photographs are provided as needed to illustrate the condition and damage of the gear, where specific items were identified.

Additional items of protective clothing and equipment were provided for two firefighters who escaped just prior to the collapse. These included a fire fighter from the [redacted] Fire Department and a fire fighter from the [redacted] Fire Department. The purpose of examining these gear items was to determine the nature of exposure conditions inside the building that the victims may have been exposed to. It is understood that the activities, time on scene, and other factors are likely to be different, but nonetheless, this information was used to help frame the exposure conditions at the time of collapse. It is understood that these two fire fighters escaped with a minimum of injuries. Photographs and observations for the clothing and equipment examined for these firefighters are provided in Appendix K.

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

The Fireground Environment

One manner of analyzing the protective clothing and equipment is to examine industry information that shows the range of fireground conditions that can be experienced and relate these conditions to the types of damage that can occur to clothing and equipment.

The relationship between increasing thermal radiation (expressed in cal/cm^{2}s) and the resulting rise in air temperature (expressed in degrees Celsius and degrees Fahrenheit) is presented in Figure 1. Possible structural fire fighting situations are illustrated in this figure:[1,2]

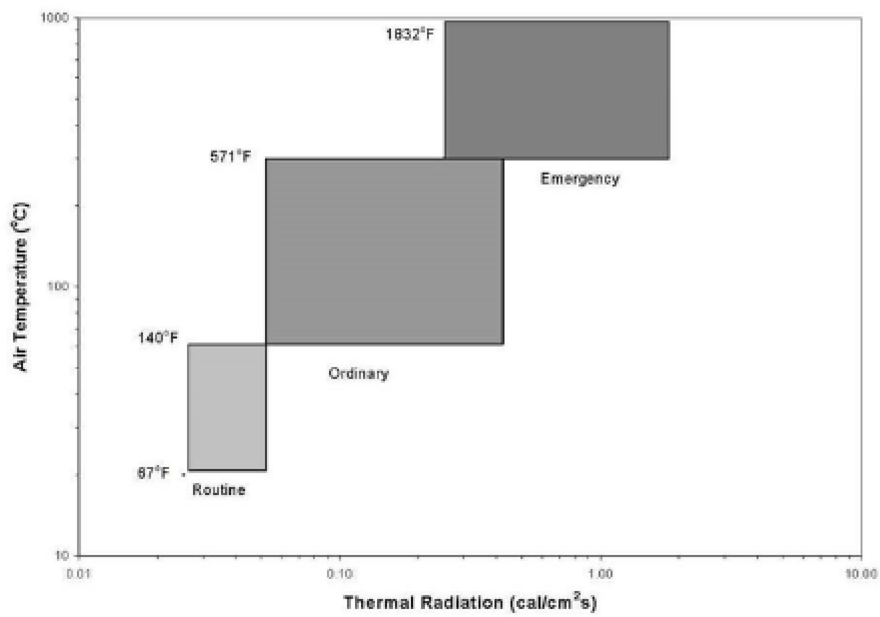


Figure 1– Classification of Fireground Conditions

- The ***Routine*** region describes conditions where one or two objects, such as a bed or waste basket, are burning in a room. The thermal radiation and the air temperatures are virtually the same as those encountered on a hot summer day. As shown in Figure 161, ***Routine*** conditions are accompanied by a thermal radiation range of 0.025 to 0.05 cal/cm^{2}s and by air temperatures ranging from 68 to 140°F. Protective clothing for fire

[1] N. J. Abbott and S. Schulman, "Protection from Fire: Nonflammable Fabrics and Coatings, *Journal of Coated Fabrics*, Vol. 6, July 1976, pp. 48-64.
[2] H. P. Utech, "High Temperatures vs. Fire Equipment," *International Fire Chief*, Vol. 39, 1973, pp. 26-27.

3

[Fire Fighter Fatality Investigation](https://www.cdc.gov/niosh/fire/reports/face200718.html) This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

fighters typically provides protection under these conditions, but excessively long exposure times may create a burn injury situation.

- The ***Ordinary*** region describes temperatures encountered in fighting a more serious fire or being next to a "flash-over" room. ***Ordinary*** conditions are defined by a thermal range of 0.05 to 0.6 cal/cm^{2}s, representing an air temperature range of 140 to 571°F. Under these conditions, protective clothing may allow sufficient time to extinguish the fire or to fight the fire until the nominal air supply is exhausted (usually less than 30 minutes).

- The ***Emergency*** region describes conditions in a severe and unusual exposure, such as those caused inside a "flash-over" room or next to a flame front. In ***Emergency*** conditions, the thermal load exceeds 0.6 cal/cm^{2}s and temperatures exceed 571°F. In such conditions, the function of firefighters' clothing and equipment is simply to provide protection during the short time needed for an escape without serious injury.

Burn injuries are sustained with the energy absorbed by the skin can no longer be dissipated in the body. In essence, the rate of heat (energy) transfer into the body at a particular location overwhelms the body's capacity to remove that heat to other portions of the body. In general, when the energy transferred through the clothing to the skin is able to cause the skin temperature to rise to 111°F (44°C), pain is felt by the average individual person. If the skin temperature increases to 131°F (55°C), the onset of second degree burn injury occurs.

Any number of reasons can exist for burn injury to occur in selective locations over the fire fighter's body or for the severity of the injury to vary at different locations. Unexposed or less protected areas of the firefighter's body are more susceptible to burn injury than other areas. The specific layout of the fire scene can cause shielding to the fire fighter's body depending on their orientation and position. These areas may include the portions of the head or ears. Where clothing compresses against the skin either by fit or wearing position, heat transfer to the skin can occur at higher rates. The phenomenon of stored energy can also be a factor where heat energy that accumulates in clothing from continued radiant exposure can quickly transfer to the skin when the clothing is compressed suddenly. This compression can happen simply from bending a joint (a knee or elbow) or otherwise positioning the body to stretch the clothing across the body so that more intimate contact is made with the skin. If shrinkage of an item occurs, which effectively reduces the insulating air layer between the clothing and the skin, increased heat transfer to the skin will occur. This type of heat transfer can occur when a glove, constructed of leather, shrinks from a high, extended heat exposure. Finally, wherever damage occurs that causes severe charring, embrittlement, and break open of materials or components, protection is lessened and the potential for burn injury is increased.

Analysis and Findings

Tables 1 and 2 provide an overview of the condition of clothing and equipment that was examined for each of the fire fighters. This table lists the surviving portions of each item. In nearly all cases, the majority of each item was destroyed due to the intensity of the fire and delay in recovering the fire fighters.

4

Table 1 – Overview of Clothing and Equipment Condition for Each Fire Fighter (Victims 1- 5)

Clothing or Equipment Item	Victim #1	Victim #2	Victim #3	Victim #4	Victim #5
Protective coat	Remnants: left front side and part of back; Collar down; Severe charring and embrittlement	Remnants: left front side, small portion of left sleeve, right side of closure; Severe charring and embrittlement	Remnants: top of coat with right sleeve and portions of left side; Collar down; Severe charring and embrittlement	Remnants: front closure area, left arm, lower portion of right sleeve; Severe charring and embrittlement	Remnants: portions of left front closure area, left arm, and back; Severe charring and embrittlement
Protective pants	Remnants: left leg; Severe charring and embrittlement	Remnants: most of right leg, portions of left leg; Severe charring and embrittlement	Remnants: portions of both legs and waist area; Severe charring and embrittlement	Remnants: back of pants, majority of liner; Severe charring and embrittlement	Remnants: portions of both legs and part of waist area; Severe charring and embrittlement
Protective helmet	Intact; most heat damage to reflective markings and ear covers	Not available for examination	Not available for examination	Remnants: majority of shell, faceshield; Heavy heat damage; portion of shell missing; ear covers not deployed	Not available for examination
Protective hood	Remnants: part of face opening, bottom bib; Severe charring and embrittlement	Not available for examination	Intact: severe charring around face opening and portions of bib	Intact: severe charring at face opening and portions of bib	Remnants: portions of face opening and front bib; Severe charring and embrittlement
Protective gloves	Remnants: left glove only, outer layer disintegrated; Severe charring and embrittlement	Remnants: Thumb side of left glove; Severe charring and embrittlement	Remnants: portions of left glove; Severe charring and embrittlement	Remnants: both gloves; Moderate charring and embrittlement	Not available for examination

5

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Clothing or Equipment Item	Victim #1	Victim #2	Victim #3	Victim #4	Victim #5
Protective footwear	Remnants: left boot only; right side dis-integrated; Severe charring and embrittlement	Remnants: right boot with portion of left side missing; only hardware remains for left boot; Severe charring and embrittlement	Remnants: right boot is intact; portions of left boot; Severe charring and embrittlement of both boots	Remnants: both boots; portions showing severe charring and embrittlement	Remnants: majority of right boot and bottom half of left boot; Severe charring and embrittlement
Station/work shirt	Pieces only, not examined	Unavailable for examination	Not examined	Not examined	Not examined
Station/work pants	Pieces only, not examined	Remnants: majority of left leg, portions of right leg; Melted to protective pants	Not examined	Remnants: majority of pants intact; Melted to protective pants	Remnants: portions of both legs and part of waist; Severe charring and embrittlement
Socks	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination
SCBA facepiece	Intact: lenses melted through; Severe melting	Unavailable for examination	Unavailable for examination	Intact: heavily distorted	Unavailable for examination
SCBA frame	Back frame mainly intact; Severe damage	Remnants: most of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: portions of hardware
SCBA cylinder	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; valve missing
PASS device	Severely melted onto belt	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Table 2 – Overview of Clothing and Equipment Condition for Each Fire Fighter (Victims 6- 9)

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
Protective coat	Remnants: majority of back area and parts of each sleeve; Severe charring and embrittlement	Remnants: left side of coat and top portion of collar along with entire front closure and part of left sleeve; Severe charring and embrittlement	Remnants: right side of coat; left side completely missing; microphone melted to coat; Severe charring and embrittlement	Remnants: majority of front with portions of left sleeve; Collar down; Severe charring and embrittlement
Protective pants	Remnants: majority of both legs and waist area; Severe charring and embrittlement	Remnants: left side of pants and portions of right leg and liner; Severe charring and embrittlement	Remnants: majority of pants including lining; Severe charring and embrittlement	Remnants: majority of pants except parts of right leg; Severe charring and embrittlement
Protective helmet	Not available for examination	Remnants: front half of helmet; Severe charring and embrittlement	Not available for examination	Not available for examination
Protective hood	Remnants: part of face opening; Severe charring and embrittlement	Remnants: portions of front part of hood; Severe charring and embrittlement	Not available for examination	Remnants: entire front of hood; back of hood missing; Severe charring and embrittlement
Protective gloves	Not available for examination	Remnants: Majority of right glove; left glove without fingers; Severe charring and embrittlement	Not available for examination	Remnants: both gloves; portions of palm side missing; Severe charring and embrittlement

7

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
Protective footwear	Remnants: both boots primarily intact, but portions are missing from upper; Severe charring and embrittlement	Remnants: both boots; however, several portions of upper missing; Severe charring and embrittlement	Remnants: both boots; however, several portions of upper missing; Severe charring and embrittlement	Remnants: both boots; portions showing severe charring and embrittlement
Station/work shirt	Not examined	Unavailable for examination	Not examined	Remnants: portions of shirt including collar; Severe charring and embrittlement
Station/work pants	Remnants: majority of both legs and waist area; Melted to protective pants	Remnants: part of waist band, portions of legs; Severe charring and embrittlement	Remnants: left leg and portions of right side; Severe charring and embrittlement	Not available for examination
Socks	Unavailable for examination	Unavailable for examination	Unavailable for examination	Unavailable for examination
SCBA facepiece	Unavailable for examination	Remnants: portion of front, majority of lenses; severe damage	Unavailable for examination	Remnants: all components in place; severe melting and damage
SCBA frame	Back frame most of frame and pieces of hardware; Severe damage	Remnants: some parts of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage	Remnants: part of frame and pieces of hardware; Severe damage

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Clothing or Equipment Item	Victim #6	Victim #7	Victim #8	Victim #9
SCBA cylinder	Wrapping exposed; Valve inoperable	Wrapping exposed; Valve operable (found open); Burst disk intact	Wrapping partly exposed; Valve operable (found open); Burst disk intact	Wrapping exposed; Valve operable (found open); Burst disk intact
PASS device	Severe melting	Unavailable for examination	Severely melted to waist strap of SCBA	Unavailable for examination

9

Fire Fighter Fatality Investigation This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

In the majority of cases, all gear that was examined was found to be available in remnants with significant large portions of the gear thermally decomposed or disintegrated from intensive, long-term heat exposure. Those items of clothing or equipment that were relatively intact were generally believed to have somehow been shielded from the fire conditions through the relative position of the item on the body or through some part of the structure at the fire scene. For example, the helmet for Victim #1 was in a relatively undamaged condition. It is speculated that the helmet was recovered early at the fire scene and was underneath the victim when the victim was found.

Very little can be learned about the relative protective performance of the clothing or equipment worn by the individual fire fighter victims. In some cases, it is possible to determine if the clothing was properly deployed, for example charring patterns on the protective coats of some victims show that their collars were not extended upward. Similarly, when helmets were available for inspection, it did not appear for at least one victim that the ear covers were deployed. Nevertheless, this wearing practices are immaterial to the fatalities that occurred as the clothing and equipment characteristics were completed overwhelmed during the extended entrapment in the fire structure of the fire fighter victims.

Where station/work uniforms were recovered, it was found that the fire fighters worn clothing items that were primarily polyester in composition. Given the extreme, extended circumstances of the exposure, these uniforms often were melted to the interior of the protective clothing. In one case, suspender straps were melted to the fire fighter's protective coat. While not likely contributory to the burns sustained to the fire fighters, the use of polyester-based station/work clothing does pose a hazard to fire fighters and should not be worn. Uniforms that are either 100% cotton or those constructed of flame-resistant materials should be used.

A detailed examination of the SCBA for each victim revealed that those SCBA cylinders with functioning valves were generally fully open. Moreover, the burst disk in these cylinders, where they could be examined, was intact. This information suggests that the fire fighters probably ran out of air before succumbing to the high heat burn injuries that were sustained over much of their bodies.

An examination of clothing and equipment from two fire fighters that were able to escape the fireground just before the structure collapse does show very extensive heat conditions suggestive of high ordinary fire ground conditions. In both cases, the damage to the clothing was primarily sustained to the back of the clothing where dye sublimnation of the protective coat outer shell occurred on both sides of the SCBA cylinder. There was also mild charring on the moisture barrier side of the protective coat liner. The reflective markings on both fire fighters' helmets showed charring on the rear side as did some portions of the trim on the back of the fire fighters' clothing. These conditions are generally produced at temperatures exceeding 500°F for several minutes and absorbed heat energies of greater than 5.0 calories per square centimeter. These conditions are highly survivable, meaning that the fire fighters were able to escape due to the protective qualities of their clothing and equipment.

10

[Fire Fighter Fatality Investigation](https://www.cdc.gov/niosh/fire/reports/face200718.html) This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Conclusions

Based on the examination of the clothing and equipment worn by the fire fighters, I could not find any defects of the clothing or equipment as manufactured or worn by the fire fighters that would have contributed to their burn injuries and fatalities. It is impossible to determine with absolute certainty whether the fire fighters first ran out of air before receiving burn injuries, but the condition of the SCBA show that running of air probably occurred before the majority of burn injuries were sustained. Fire fighters that were able to escape the fireground before the collapse had gear that showed damage consistent with high ordinary fireground conditions. The majority of damage to the clothing and equipment was sustained after the fire fighter victims were entrapped on the fireground and due to the extensive lapse of time before the recovery of their bodies.

I could not find any defect or problems with the any of clothing or equipment items that I examined. All of the protective clothing and equipment appeared to function as intended. However, it is important that fire fighters wear station/work uniforms that do not contain high levels of polyester and that these uniforms meet the requirements of NFPA 1975, *Standard on Station/Work Uniforms for Fire and Emergency Services.* Although not a specific factor in this event, the *wearing of polyester-based uniforms can contribute to significant potential for severe burn injury.*

The clothing and equipment for all fire fighters should be retained because of its involvement in a situation where injuries were sustained. The clothing should retained be retained by the department for a period of at least 2 years with an appropriate chain of custody. Records should be kept of any further evaluations.

Respectfully submitted,

Jeffrey O. Stull

Jeffrey O. Stull, President
International Personnel Protection, Inc.
Austin, Texas

11

[Fire Fighter Fatality Investigation] This link is accessible at https://www.cdc.gov/niosh/fire/reports/face200718.html.

Appendix V
Additional Photos

Photo A-1. Time is approximately 1923 hours. Fire is visible over showroom roof. Smoke is dark gray in color and becoming turbulent. The flames may not have been visible from front parking lot or close to the building on the D-side. *(Photo courtesy of Dan Folk.)*

Photo A-2. Time is approximately 1936 hours. Loading dock area approximately 20 minutes after first crews arrived on scene. There is heat damage to metal siding on loading dock and warehouse. There are two Loading dock doors. There is an approximate orgin of fire in the corner. *(Photo courtesy of Police Department, Bill Murton, photographer.)*

Photo A-3. Time approximately 1939 hours. Fire fighters near front entrance to showroom. Note lack of water pressure on the red booster line and the 2 ½" hand line. Also note lack of gloves and hood. *(Photo courtesy of the Charleston Post and Courier.)*

Photo A-4: Time approximately 1951 hours. Front façade beginning to collapse. *(Photo courtesy of the Charleston Post and Courier.)*

Handout 1-1 Group 2:

Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation — Maryland

2014 24

Death in the line of duty... NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation September 21, 2015

Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland

Executive Summary

On November 12, 2014, a 62-year-old male career lieutenant, serving as the shift safety officer, died after falling through a hole in the floor of a vacant row house. At approximately 0019 hours, the career fire department was dispatched to a report of smoke in a vacant row house. Fire fighters began arriving on scene starting at 0022 hours and encountered a fire on the rear stairway that extended up the stairwell to the second floor. Battalion Chief 2 arrived on-scene at 0024 hours and assumed Incident Command. He quickly upgraded the dispatch to a working fire dispatch which sent additional engine and truck companies, an additional battalion chief, and the shift safety officer. The fire was quickly brought under control and the Incident Commander began releasing companies around 0046 hours. Remaining crews used ventilation fans to clear smoke from the fire structure and the vacant row house on side Delta.

Crews working inside the Delta exposure observed that the ground-level floor at the rear of the structure had been completely removed but did not report this hazard to Incident Command when they exited. Hole in floor at rear of vacant row house. The shift safety officer entered the Delta exposure alone

The victim fell approximately 7 feet onto and apparently fell through the hole, receiving face and **the basement floor.** head injuries. All remaining personnel cleared the incident ***(Photo***

NIOSH) scene by 0223 hours. The fire department dispatch center began receiving phone calls reporting the shift safety officer's unattended vehicle blocking traffic around 0647 hours. Fire department resources were dispatched at 0748 hours to investigate the unattended vehicle. The shift safety officer was discovered in the basement of the Delta exposure at 0824 hours and was pronounced dead at the scene. The cause of death was determined to be smoke inhalation.

Contributing Factors

- *Floor system at rear of the Delta exposure completely removed prior to incident*
- *Hole in floor (fireground hazard) not reported to the incident commander*
- *Smoke accumulation in the unventilated basement of the Delta exposure*
- *Ventilation in the Delta exposure was not completed*
- *Shift safety officer entered Delta exposure alone*
- *Fireground accountability was ineffective*
- *Crew integrity was not maintained and single unit resources operated alone*
- *Fire Communications Bureau placed shift safety officer in service without verbal confirmation of his location.*

Key Recommendations

- *Fire departments should utilize a functional personal accountability system requiring a checkin and check-out procedure with the designated accountability officer or the incident commander*
- *Fire departments should ensure that the incident commander accounts for all resources before dissolving command*
- *Fire departments should train fire fighters on the principles of situational awareness*
- *Fire departments should train and empower all fire fighters to report unsafe conditions to Incident Command*
- *Fire departments should train all fire fighters and officers to report when tasks are completed or cannot be completed to their officer or the incident commander*
- *Fire departments should ensure that every fire fighter on the fire ground utilizes a Personal Alert Safety System (PASS) device including the ability to provide PASS devices for personnel operating in a potentially dangerous environment not requiring the use of self-contained breathing apparatus*
- *Fire departments should provide Battalion Chiefs and Chief Officers with a staff assistant or chief's aide to help manage information and communication*
- *Fire departments should ensure that single resource units (e.g. safety officers, fire investigators, etc.) do not function alone in IDLH environments at emergency scenes*
- *Fire departments should ensure that dispatch centers forward all reports of suspicious or unusual events to the appropriate authorities in a timely manner*
- *Fire departments should ensure that Mayday training program(s) are developed and implemented so that they adequately prepare fire fighters to call a Mayday.*

2014 24

Death in the line of duty...

NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

September 21, 2015

Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland

Introduction

On November 12, 2014, a 62-year-old male career lieutenant, serving as the shift safety officer, died after falling through a hole in the floor of a vacant row house. The shift safety officer fell into the basement, suffered minor face and head injuries, and died from smoke inhalation. On November 13, 2014, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. The fire department also contacted NIOSH and requested NIOSH's assistance in conducting an investigation of the incident. At the request of the fire department, the NIOSH investigation was initiated on December 8, 2014. A safety engineer and an investigator from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Maryland and met with the Fire Chief, the Assistant Fire Chief, members of the fire department's Safety and Health Office, and the department's Investigation Review Board. The NIOSH investigators traveled to the incident site to obtain photographs and measurements. They inspected the personal protective clothing and equipment worn by the victim. The NIOSH investigators traveled to the fire department's training academy to discuss training requirements and obtain training records and also visited the fire department's air mask maintenance shop. The NIOSH investigators interviewed fire fighters and fire officers who were involved in the November 12 incident. The NIOSH investigators also met with a representative of the Maryland Department of Labor, Licensing and Regulation (DLLR), Occupational Safety and Health (MOSH) who was investigating the incident.

At the request of the fire department, the NIOSH investigators arranged for representatives from the National Institute of Standards and Technology (NIST), Building and Fire Research Division, to conduct airflow velocity and pressure measurements at the incident site on December 11, 2014 to evaluate the use of the ventilation fans that had been deployed during the incident.

Fire Department

This career fire department serves an estimated population of 622,104 in an area covering 80.8 square miles and 11.3 square miles of water over a total area of 92.1 square miles.
The fire department has over 1,700 members who are divided into three management branches – Emergency Operations, Safety and Member Services, and Community Risk Reduction. On average the department responds to more than 235,000 calls for service per year.

The Assistant Chief of Operations oversees the work of four (4) shift commanders and the emergency medical services (EMS) deputy chief. Operations personnel work out of 38 neighborhood fire stations. These stations house approximately 100 firefighting, emergency medical, and special operations companies. These units include 31 engine companies, 17 truck companies, 24 first-line advanced life support medic units, 3 peak time and 9 critical alert transport units, 4 squad companies (similar to a rescue engine) and a heavy rescue unit. Specialty units include hazmat trucks, special rescue vehicles, mobile command vehicles and fire boats. The department operates six emergency operations battalions and one EMS battalion, on four shifts. The work schedule for suppression is comprised of one 24 hour shift on, 24 hours off, 24 hours on followed by 5 days off. Once every 4 weeks members work an impact shift (24 hours). The work schedule for EMS is comprised of two 10 hour days, two 14 hour nights followed by 4 days off. Minimum staffing for engines, trucks, squads and the heavy rescue is four personnel per unit and a total of 292 members per shift.

A first-alarm assignment for a structure fire includes the dispatch of the five closest engine/squad companies, the two closest truck companies, the closest medic unit and the two closest battalion chiefs. The heavy rescue will also respond in a predetermined area of the city. Utilizing predetermined tactical assignments outlined in written standard operating procedures (SOPs), the first engine/squad will secure a continuous water supply and reports to the front (side Alpha), of the reported address. The second engine/squad will cover the water supply of the first engine/squad. The third engine/squad will assume the role of rapid intervention team (RIT) upon their arrival. The fourth engine/squad will secure a continuous water supply and report to the rear (side Charlie), of the reported address. The fifth engine/squad will cover the water supply of the fourth engine/squad. The first truck reports to side Alpha and the second to side Charlie. Assignments may be altered by responding units via the fire ground radio channel. A working fire assignment will dispatch the next closest engine or squad company, the next closest truck company, the closest AIRFLEX unit, the on-duty shift safety officer and the shift commander. A second alarm assignment will add the next three closest engine/squad companies, the next closest truck company, the heavy rescue, if it is not already on the incident, the next closest battalion chief, the next closest medic unit, the on duty fire investigator and the closest EMS District Supervisor. Additional alarms are the next four closest engines/squads and the next two closest trucks. As alarms increase, staff officers and specialty units are also added.

Battalion chiefs have all been trained as Incident Safety Officers (ISO). Two suppression battalion chiefs are dispatched on a first alarm assignment. The second dispatched battalion chief serves as the Incident Safety Officer until relieved by the shift safety officer. Captains who act as battalion chiefs will also have the same responsibilities even though they may not yet have been fully trained as an ISO. Chief officers at the shift commander rank and above are assigned chief aides who perform administrative duties, drive the chief officer's vehicle, and assist on the fire ground with communications and accountability as necessary. Battalion chiefs are not assigned aides.

The city is divided into predetermined "Box Areas" which are geographic areas within a station's first due territory and are numbered using the engine in the station's number as a prefix. For example, the station of engine 8 has box areas 8-1, 8-2, etc. Station order to the box areas have been recorded into the Computer Aided Dispatching system, to allow dispatchers the ability to send the closest units more efficiently.

The Assistant Chief of Safety and Member Services oversees the Fire Department Human Resources, Safety Division, Education and Training Academy, Fiscal Office, and the Office of Legal Counsel.

Safety Division

The fire department Safety and Health Office is an independent function within fire department headquarters. The Assistant Chief of Safety and Member Services manages the operations of the Safety Division. At the time of this incident, three safety officers were assigned to the Safety and Health Office, each working 40 hours per week. In addition, each of the four operational shifts had an assigned shift safety officer, working the 24-hour shift rotation. The lieutenant who died in this incident was the A-shift safety officer. *Note: B-Shift was on duty at the time of the incident. The lieutenant was assigned to A-Shift and was working his monthly impact shift on B-Shift at the time of the fire.*

Each operational shift has a number of lieutenants trained to fill-in as the shift safety officer when necessary. Requirements to be a shift safety officer include achieving the rank of lieutenant, attending the 2-day Incident Safety Officer (ISO) course through the U.S. Fire Administration National Fire Academy, and hands-on training that includes riding with a shift safety officer until deemed to be adequately qualified.

The duties of the shift safety officer include assisting the Chief of Safety in maintaining the function of the Safety and Health Office, line-of-duty injury investigation and reporting, fire department vehicle accident investigation, and serving as the Incident Safety Officer (ISO) at hazardous materials incidents, technical rescues and fireground operations. The shift safety officer responds to emergency incidents that involve a high risk to fire department personnel including:

- Working Fires
- Full Rescue Assignments
- Mass Casualty Incidents
- Hazmat Task Force Response
- Dive/Rescue Team / Water Rescue
- Special Rescue Operation Team
- Cave-in / Confined Space

The shift safety officer is dispatched on a working fire but can self-dispatch any time it is deemed necessary. The Chief of Safety is dispatched on all third-alarm fires.

Once the shift safety officer is dispatched and arrives at the scene of a working fire, the shift safety officer dons the necessary personal protective clothing and equipment, including a portable radio, and reports to the incident commander for a face-to-face conference. After receiving a briefing and any assignments specific to the incident, the shift safety officer performs a 360-degree size-up of the incident scene, looking for specific safety hazards. The shift safety officer also meets with the acting incident safety officer (the second-due battalion chief) and assumes the role of ISO. The shift safety officer would then brief the incident commander on any obvious hazards present, and then go to the area of most activity. The shift safety officer wears an orange fire helmet for visibility and easy identification. The shift safety officer has the authority to alter, suspend or terminate any unsafe act or operation. The shift safety officer may also serve as a liaison with other agencies that respond to fires or emergencies in matters that pertain to safety. Examples of the specific duties and types of hazards the ISO would look for include: walking the fireground and establish a fireground perimeter; surveying incidents and personnel for the following:

- Proper donning and use of protective clothing and safety gear
- Fatigued personnel (heat and cold related problems)
- Structural conditions (roof, walls, floors, windows, etc.)
- Utilities (overhead wires, gas lines, liquid propane (LP) gas tanks, etc.)
- Safe apparatus placement (outside of potential collapse zone, properly secured, wheel chocks).
- Ladders (footing, placement)
- Operations (opposing hoselines, use of portable master streams, proper equipment use)
- Rapid intervention team placement
- Adequate lighting
- Safe operating procedures.

The ISO is responsible for reporting unsafe acts and corrective actions to the incident commander and working with the incident commander to ensure personnel on the incident are aware of any special circumstances or dangers.

The Assistant Chief of Community Risk Reduction oversees three support divisions which are the Office of the Fire Marshal, Information Technology Services, and Logistics. All of these divisions help in supporting the operational functions of the fire department. The Office of the Fire Marshal provides public fire safety and educational resources. Logistics is responsible for the procurement of all fire department apparatus, equipment, and supplies while overseeing the maintenance of all facilities. Information technology helps to support the fire department's internal communications infrastructure and fire dispatch system.

Training and Experience

The fire department maintains a Division of Education and Training to help ensure that each member of the fire department receives the appropriate instructions and information needed to properly perform duties and prepare for advancement. The Division of Education and Training designs, develops and provides programs for probationary training, company level training, battalion level training, officer candidate training, continuing education training and special training (hazmat, technical rescues, etc.).

The city fire department recruits fire fighters through a civil service examination process. After passing the civil service examination, potential candidates are placed on hiring list. Potential candidates must complete a candidate physical ability test (CPAT). Candidates are assigned to a recruit class. The fire department operates a training academy where recruits attend a 6-month nonresident academy. Recruits do not reside at the academy during the 6-month training class. The recruit class covers Emergency Medical Technician (EMT) Basic, Fire Fighter I, Fire Fighter II, Hazmat Operations, Vehicle Operator and fire department-specific skills classes covering subjects such as self-contained breathing apparatus (SCBA) and personal protective equipment (PPE) training, ladder training, interior firefighting, and other subjects. Recruits receive ProBoard certification for Firefighter I, Firefighter II, Hazmat Awareness and Hazmat Operations through the Maryland Fire and Rescue Institute (MFRI).

Graduates from the 6-month recruit class are assigned to a company. Each battalion has specific training requirements that address the battalion's unique geographical needs. Recruits assigned to a company wear a yellow helmet and are assigned a training manual booklet with specific tasks that must be checked off by the recruit's supervisor. Once all tasks are completed and checked off, the recruit gets a black helmet.

In addition, each fire fighter must complete 16 hours of company level training per month. Fire fighters can also take outside training classes at their own expense. Every fire fighter receives live fire training once each year. Two engine companies and one ladder company are sent to the fire academy for live fire training where they drill on various training scenarios. Each fire fighter also receives annual training in rapid-intervention-team (RIT) operations.

Fire fighters with 1 year of experience can test for pump operator (PO) and emergency vehicle driver (EVD) certification. Fire fighters with a minimum of 3 years of experience can test for the lieutenant position. Lieutenants with at least one year of experience as a lieutenant can test for the captain position. The fire department maintains pre-requisite training and experience requirements for each level of rank. Since 2011, the fire department has provided funding for fire fighters to receive ProBoard certification.

The incident commander at this incident had over 16 years of experience as a fire fighter and held the rank of Battalion Chief since 2010. He had been a fire officer with the department since being promoted to lieutenant in 2002. The fire department's training records showed that he had completed training in subjects including: Responder to Hazardous Materials/WMD Incident – Awareness; Responder to Hazardous Materials/WMD Incidents – Operational; Fire Fighter I; Fire Fighter II, Emergency Medical Technician, Basic; Vehicle & Machinery Technical Rescuer I & II; Fire Service Instructor I; Fire Service Instructor II; Fire Service Instructor III; Health & Safety Officer; and others.

The shift safety officer who died in this incident had over 40 years of experience as a fire fighter and held the rank of lieutenant since 2004. He had worked in the Safety Office for the past 10 years and was the senior shift safety officer. The fire department's training records showed that he had completed training in subjects including: Hazardous Materials/WMD Incident – Awareness; Hazardous Materials Operations; Responder to Hazardous Materials/WMD Incidents – Operational;
Hazardous Materials: Recognizing and Identifying; Self-contained Breathing apparatus (SCBA)

Training; Protective Envelope Foam Training; Fire Investigator; Fire/Arson Investigation; IS-00100.a Introduction to the Incident Command System (ICS-100); IS-00200.a ICS for Single Resources and Initial Action Incidents (ICS-200); IS-00700.a National Incident Management System (NIMS) – An Introduction (ICS 700); IS-00800.b National Response Framework, An Introduction (ICS-800); EMS Basic Life Support Skills Training; EMS Advanced Life Support Skills Training; Fire Suppression
Skills Training; City Driver Permit Training; Fire Department Driver Training; 2-Minute Drill (donning personal protective clothing and SCBA); Maze Training; Lead Off (supply hose and hydrant connection); One-man Ladder Carry; Two-man Ladder Carry; Charged Hoseline; and several others.

Equipment and Personnel

The fire department follows established procedures for responding to emergency calls dispatched by the Fire Communications Bureau (fire dispatch or FCB) based upon the size and nature of the incident reported. Assignments are made based upon defined response protocols for each alarm level.

One lists the different alarm types and defined assignments. Both the Fire Communication Bureau (FCB) and the incident commander have the flexibility to modify the alarm assignments when necessary.

Table One – Alarm Types and Assignments

Alarm Type	Alarm Level	Units Assigned
Silent Alarm	1st Alarm	1 engine or 1 truck or both as dictated by incident
Tactical Box Alarm	1st Alarm	2 engines, 1 truck
Task Force Box Alarm	1st Alarm	3 engines, 1 truck, 1 Battalion Chief
Box Alarm	1st Alarm	5 engines, 2 trucks, 2 Battalion Chiefs, Rescue 1(if near downtown, 1 Medic Unit, Fireboats (if near waterfront), 3rd due engine is designated RIT.
Working Fire	1st Alarm Upgrade	1 engine, 1 truck, Shift Commander, Shift Safety Officer, 1 AirFlex unit.
2nd Alarm	2nd Alarm Assignment	4 engines, 2 truck, 1 EMS Officer, 1 Medic Unit, 1 Battalion Chief, 1 Fire Investigation Bureau officer
3rd Alarm	3rd Alarm Assignment	4 engines, 2 trucks, Mobile Command Unit, EMS Battalion Chief
4th Alarm	4th Alarm Assignment	4 engines, 2 trucks
5th Alarm and up	5th Alarm Assignment	4 engines, 2 trucks

This incident initially involved a dispatch for a report of smoke in a row house. Per established fire department procedures, the following equipment and personnel were dispatched for a box alarm assignment:

Box Alarm

Engine Number	Personnel
Engine 31:	(E31; Acting Lieutenant, pump operator, 2 fire fighters)
Engine 6:	(E6; Lieutenant, pump operator, 2 fire fighters)
Engine 13:	(E13; Acting Lieutenant, pump operator, 2 fire fighters – per procedures, assigned as the RIT)
Engine 33:	(E33; Lieutenant, pump operator, 2 fire fighters)
Engine 23:	(E23; Lieutenant, pump operator, 2 fire fighters)
Truck 5:	(T5; Lieutenant, 2 emergency vehicle drivers, fire fighter)
Truck 1:	(T1; Acting Lieutenant, emergency vehicle driver, 2 fire fighters)
Medic 16:	(M16; ambulance unit with 2 paramedics)
Battalion Chief 2:	(BC 2 – *Incident Commander*)
Battalion Chief 6:	(BC 6)

The fire department maintains two support vehicles, called AIRFLEX units that carry extra SCBA air cylinders, portable lights, compressed-air foam and other support items. AirFlex units are normally dispatched on a working fire alarm but in this incident, AirFlex 2 was dispatched on request of the incident commander prior to requesting the working fire alarm. Shortly after arriving on-scene, and after confirming that smoke was showing, the incident commander (BC2) radioed dispatch to request an AirFlex unit and shortly after that, upgraded the incident to a working fire.

Per fire department procedures, the following additional units were dispatched for the working fire alarm.

Working Fire Alarm

Engine 8:	(E8; Lieutenant, pump operator, 2 fire fighters)
Truck 16:	(T16: Lieutenant, 2 emergency vehicle drivers, fire fighter)
Safety Officer 2:	(Shift safety officer (*the victim*))
Shift Commander:	(Car 5: Acting Deputy Chief and chief's aide –*Acting Shift commander*)
Fire Investigation Unit:	(Captain – arson investigator)

Structure

This incident occurred in two adjoining vacant row houses. The row houses were located near the middle of a city block containing 12 row houses sharing common side walls that were constructed in the 1920 era. This type of construction is common throughout the city and the regional area. A row house is a style of medium-density urban housing that originated in Europe in the 16th century, where a row of identical or mirror-image houses share common side walls.[1] The exterior walls and common side walls were brick and mortar construction. The fire occurred in the fifth house from the western end of the block. Most of the row houses in the block were vacant.

The side Bravo exposure was occupied. The fire structure was vacant and boarded up and was commonly used for drug and other illegal activities. The side Delta exposure where this fatality occurred was also vacant and boarded up. In this particular block of row houses, the common side walls were constructed of brick but did not extend into the attic void space. The structure included a flat roof covered with multiple layers of asphalt paper and shingles. Electrical and gas utilities were shut off to both row houses.

The row houses measured approximately 14 feet 2 inches wide by 55 feet long. Each row house had three stories above ground and a full basement partially below grade. Two small basement windows were located at street level in the front of each row house (see Photo 1 (entire block) and Photo 2 (close-up of basement windows)). The structure was located to the north of a major city street running east and west with two lanes of traffic in each direction plus a parking lane on the north side of the street.

Photo 3 shows the orientation of the fire structure in the middle of the row. The shift safety officer was found in the Delta exposure. At some point, the side Delta exposure had undergone some refurbishment work. The complete floor system had been partially removed at the rear of the first (ground level) floor. All the floor boards and floor joists had been removed between the two common side walls, leaving a hole approximately 13 feet wide and 7 feet long at the rear of the structure (see Photo 4). The hole was located just past the basement steps. A hallway located on side Bravo led from the front room to the rear (side Charlie).

Photo 1. View of the city block were the incident occurred. Row houses fronting the entire city block are typical in this neighborhood.
(Photo adapted from Google Earth Street View. Imagery date: 9/2014)

Photo 2. View of the front door to the Delta exposure building. Note the small basement windows on both sides of the steps. Also note that this photo was taken during post-incident flow path testing by NIST *(Photo NIOSH)*

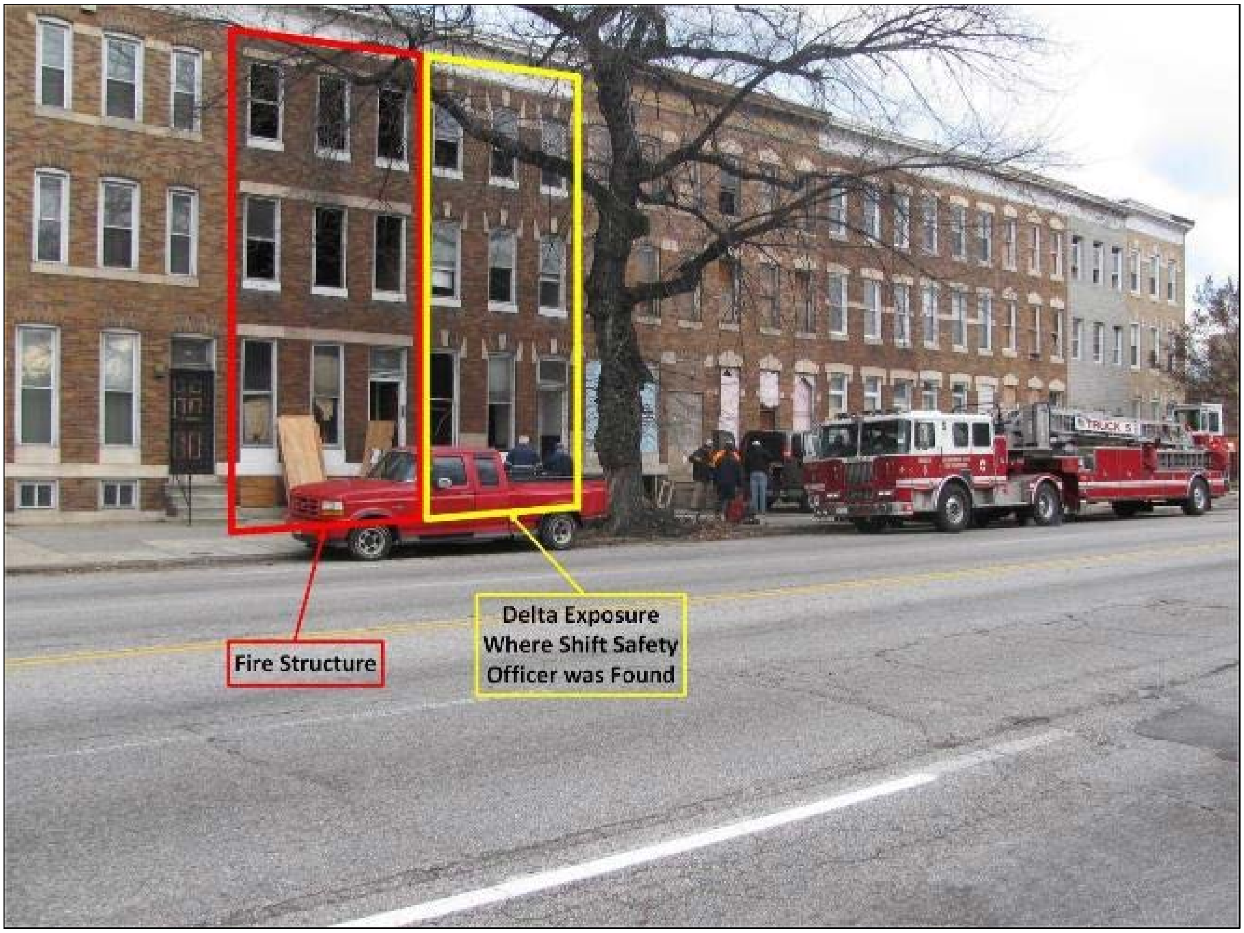


Photo 3. View of the row houses where incident occurred. The shift safety officer was found in the Delta exposure. The shift safety officer's fire department vehicle was parked to the left (to the west) just out of view. Row houses fronting the entire city block are typical in this neighborhood. Photo taken during the NIST pressure and ventilation testing on December 11, 2014

(Photo courtesy of Fire Department / Fire Investigation Bureau)

Photo 4. View of the missing floor taken from near the approximate location where the shift safety officer likely landed on the basement floor. It is believed he stepped off the first floor at the area highlighted by the arrow.
(Photo courtesy of Fire Department / Fire Investigation Bureau)

Timeline

Note: This timeline is provided to set out, to the extent possible, the sequence of events as the fire department responded. The times are approximate and were obtained from review of the dispatch audio records, witness interviews, photographs of the scene and other available information. In some cases the times may be rounded to the nearest minute, and some events may not have been included. The timeline is not intended, nor should it be used, as a formal record of events.

- **0019:08 Hours**
  911 Call to fire communications bureau (FCB or fire dispatch).

- **0019:32 Hours**

FCB initiates box alarm dispatch for a report of smoke in a structure (row house). Engine 31, Engine 6, Engine 13, Engine 33, Engine 23, Truck 5, Truck 1, Medic 16, Battalion Chief 2, Battalion Chief 6 were dispatched on the first alarm.

- **0020:16 – 0022:02 Hours**
  All units enroute. Engine 13 acknowledges they are RIT.

- **0022:10 Hours**
  Truck 5 radios on scene. Reports smoke showing and assumes command.

- **0022:19 Hours**
  FCB (fire dispatch) acknowledges Truck 5 is on scene and has command.

- **0022:24 Hours**
  Medic 16 on scene

- **0022:55 Hours**
  Engine 31 radios they have hydrant

- **0023:00 – 0024:00 Hours**
  Engine 6, Engine 13, Engine 33, Engine 23, and Truck 1 arrive on scene. Engine 13 is RIT.

- **0024:14 Hours**
  Battalion Chief 2 on scene and radios size up – "3 story brick, middle of the group, looks like we've got smoke showing 3rd floor, alpha side. Units are initiating an interior attack. You can make Battalion Chief 2 command."

- **0026:31 Hours**
  AirFlex 2 support vehicle dispatched on the direction of the incident commander (BC 2).

- **0028:22 Hours**
  IC radios FCB and requests that incident be upgraded to a working fire.

- **0028:32 Hours**
  Engine 8, Truck 16, Car 5 and Shift Safety Officer dispatched.

- **0029:11 Hours**
  Battalion Chief 6 on scene and assumes safety officer duties (goes to side Charlie).

- **0030:53 Hours**
  Shift Safety Officer enroute.

- **0032:17 Hours**

IC radios Safety (BC 6) and asks for a report from side Charlie.

- **0032:48 Hours**
  BC 6 (Safety) radios IC and reports that side Charlie is opened up, all visible fire has been knocked down, just light smoke showing on the 2nd floor.

- **0042:01 Hours**
  IC radios BC 6 to advise him that Shift Safety Officer will be Safety and BC 6 will be Charlie Division.

- **0042:09 Hours**
  BC 6 acknowledges transfer of assignments

- **0045:35 Hours**
  IC radios FCB and places fire under control. Soon after, working fire units in staging were put back into service.

- **0047:17 Hours**
  IC radios Truck 1 to open up Delta exposure. IC says he is sending in a company with hoseline into the front just in case. The RIT crew (Engine 13) is sent in the front door of the Delta exposure to search for fire extension.

- **0047:30 Hours**
  Truck 1 acknowledges order to open up Delta exposure (rear).

- **0056:14 Hours**
  Shift Safety Officer radios to crew “second floor Delta”

- **0056:26 Hours**
  Engine 13 radios command and reports… “Right now we don’t have any fire, just trapped smoke, we’re opening up now checking it out.”

- **0056:38 Hours**
  Shift Safety Officer radios “copy.”

- **0057:14 Hours**
  IC radios Truck 5 to set up ventilation fans to clear out smoke from fire building and Delta exposure.

- **0057:21 Hours**
  Truck 5 radios “copy Chief”.

- **0058:42 – 0058:48 Hours**
  Shift Safety Officer's radio was turned off then back on.

- **0104:00 Hours (approximate time)**
  Shift Safety Officer was observed talking to IC in street in front of row houses. (see Photo 5). ***Note: Shortly after this photo was taken, the Shift Safety Officer entered the Delta exposure alone. Photo 5 represents his last documented location and time.***

- **0152 Hours**
  Incident Commander (BC 2) radios the Fire Communications Bureau (FCB) and transfers command to Truck 5

- **0154 Hours**
  BC 2 leaves fireground and returns to quarters

- **0203 - 0023 Hours**
  All remaining crews leave fireground and go back into service, except for the Shift Safety Officer.

- **0334 Hours**
  Fire Communications Bureau places the Shift Safety Officer in service without verification of his location.

- **0525 Hours**
  On-coming Shift Safety Officer reports for work and notices Safety Officer vehicle is not in quarters.

- **0647 Hours**
  FCB receives phone call from civilian reporting that fire department vehicle is parked in street facing the wrong way and blocking traffic lane (at scene of row house fire).

- **0650 Hours**
  On-coming Shift Safety Officer calls victim's cell phone with no answer.

- **0708 Hours**
  FCB receives another phone call from civilian reporting that fire department vehicle is parked in street.

- **0710 Hours**
  On-coming Shift Safety Officer calls victim's cell phone again with no answer

0715 Hours
Deputy Chief receives the first of several calls from FCB concerning fire department vehicle parked in street blocking traffic lane.

- **0748 Hours**
  Engine company sent on administrative detail assignment to investigate fire department vehicle parked in street blocking traffic lane.

- **0824 Hours**
  Victim's body found in basement of Delta exposure.

- **0852 Hours**
  Victim pronounced dead at the scene by the EMS supervisor.

Photo 5. Photo taken at approximately 0104 hours showing shift safety officer in street with the incident commander and another fire fighter. Photo was taken shortly before the shift safety officer entered the Delta exposure alone. ***(Photo courtesy of Fire Department)***

Personal Protective Equipment

At the time of the incident, the shift safety officer was wearing his station uniform, work boots, turnout coat and pants, gloves and fire helmet. He was not wearing a self-contained breathing apparatus. He was wearing his left glove and his right glove was found with his helmet. Police took possession of all personal protective equipment and clothing following the incident. He was carrying a personal light attached to his turnout coat. It could not be verified whether the light was turned on or off at the time he was found. He was carrying a fire department-issued radio designated as the shift safety officer's radio. The radio was turned on and the battery was charged at the time the shift safety officer was located. The radio was found in his coat pocket with the lapel microphone attached to the upper left side (lapel) of his turnout coat. He had used the radio at least two times prior to his last documented time on the fireground (at approximately 0104 hours (see Photo 5)). These transmissions were recorded on fireground channel A-16, the correct fireground channel for this incident. The radio was equipped with an emergency activation button which was not utilized during this incident.

At the request of the fire department, NIOSH took possession of the shift safety officer's radio and fire helmet. The NIOSH National Personal Protective Technology Laboratory (NPPTL) coordinated the evaluation and testing of both the radio and the fire helmet. Both the radio manufacturer and the helmet manufacturer provided assistance to NPPTL during the evaluation process.

Radio Evaluation Summary

The radio evaluation was conducted on January 6, 2015 under the direction of NIOSH NPPTL. As part of the evaluation process, the radio was first evaluated at one of the fire department's stations and then transferred to the manufacturer's testing facility for additional evaluation and testing. This evaluation consisted of testing the radio for proper programing and operation to determine if there were any faults in its operation that may have contributed to the fatality.

During this process, the radio operated properly. No faults or programming issues were noted during the inspection and evaluation that would have contributed to the fire fighter fatality.

Note: Prior to the NPPTL radio evaluation, the fire department evaluated the radio's performance by operating the radio from within the Delta exposure basement on December 11, 2014 during the NIST pressure and ventilation testing. Fire department personnel radioed the Fire Communication Bureau and received acknowledgement. At that time, the radio performed as expected.

Helmet Evaluation Summary

The helmet worn by the shift safety officer was less than one year old and in very good condition.

NIOSH investigators observed a scuff mark and stress crack in the helmet's outer shell to the left of the helmet emblem. A quantity of what appeared to be dried blood was observed on the outer shell. The scuff mark and stress crack in the helmet suggest a glancing impact from the fall. The disposition of the suspension system is consistent with a directional force suffered during the fall. The interior impact cap showed no signs of damage from a direct or glancing impact. See Photo 6 and Appendix One for more information.

The helmet involved in this incident, while structurally identical to the NFPA version of the helmet, only met the requirements of OSHA US-OSHA Standard 29 CFR 1910.156. This helmet did not meet the minimum visibility and color requirements specified in the National Fire Protection Association (NFPA) 1971 *Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting* (2013 Edition).[2]

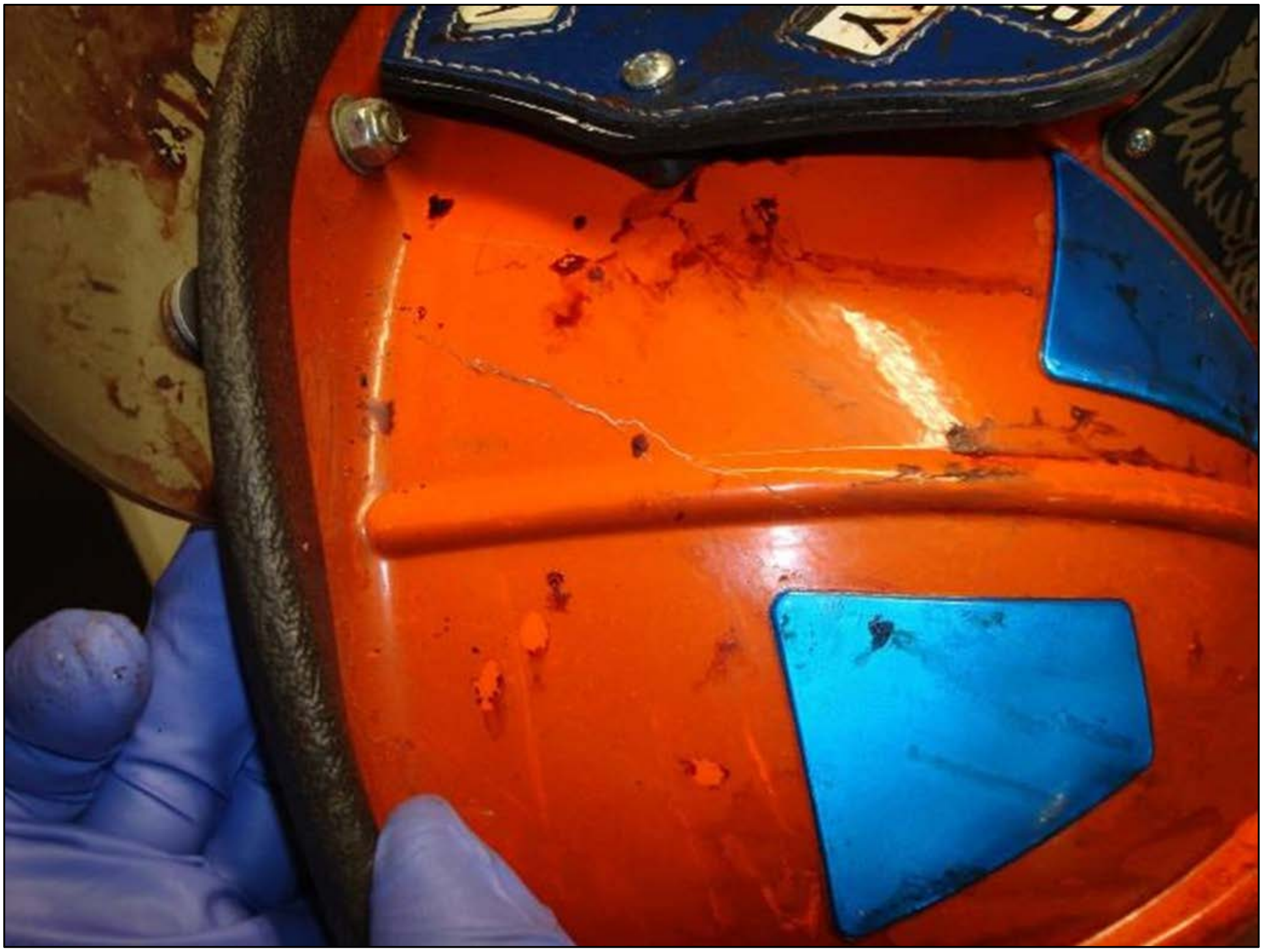


Photo 6. Close up view of the shift safety officer's helmet. Note the crack in the helmet's outer shell near the center of the photo. Also note the blue tetrahedrons on the helmet and the blue shield. (Photo NIOSH)

Based on the inspection, the protective helmet performed as intended for the event and it is not believed to have contributed to the fatality of this incident.

The complete NPPTL evaluation reports covering the radio and helmet are available upon request.

Weather Conditions

At the time of the incident, the weather was overcast with an approximate temperature of 59 degrees Fahrenheit (59°F). The relative humidity was approximately 94-96 percent with a dew point of 57°F. Winds were calm and a light drizzle was reported at nearby locations.[3]

After the incident, the fire department consulted with local meteorologists about the possibility of thermal inversion conditions contributing to the smoke accumulation in the basement of the Delta exposure were the shift safety officer died. In meteorology, a temperature inversion occurs when warm air at high altitude traps colder air near the ground surface. Under normal conditions, the atmospheric temperature decreases with altitude. This allows dust, smoke and other pollutants to rise and be dispersed. In urban areas, a temperature inversion can trap smoke and other pollutants near the surface, producing smog.[4] A temperature inversion likely occurred at the time of this incident. However, the weather conditions on the night of the incident are not believed to have contributed to the smoke accumulation within the basement of the vacant row house where the shift safety officer was found.

Investigation

On November 12, 2014, a 62-year-old male career lieutenant, serving as the shift safety officer (SO2), died after falling through a hole in the floor of a vacant row house. The shift safety officer fell into the basement, suffered face and head injuries, and died from smoke inhalation.

At approximately 0019 hours, the city's Fire Communication Bureau (FCB) began receiving telephone calls reporting smoke in a structure. The caller was not sure where the smoke was coming from. At 0019:32 hours, a box alarm was sounded. Following standard fire department procedures, the closest five engine companies and two truck companies along with two battalion chiefs and a medic unit were dispatched. Engine 31 (E31), Engine 6 (E6), Engine 13 (E13), Engine 33 (E33), Engine 23 (E23), Truck 5 (T5), Truck 1 (T1), Battalion Chief 2 (BC 2), Battalion Chief 6 (BC 6) and Medic 16 (M16) were dispatched. While enroute, the third-due engine company, E13, was designated as the rapid intervention team (RIT) per standard procedures. E13 acknowledged the assignment to be RIT. Companies began to arrive on scene at 0023 hours. The first due engine company, E31, dropped 3inch supply line at a hydrant and then proceeded to the front of the structure (side Alpha), approximately one and a half blocks to the east. The second due engine, E6, connected to the hydrant and pumped to E31 establishing a continuous water supply. Truck 5 staged in the street behind E31 and raised their aerial ladder to the roof of the three-story structure. Engine 13 arrived on scene and all four crew members reported to the front of the structure for RIT assignment. Battalion Chief 2 arrived on scene at 0024 hours and assumed Incident Command. Battalion Chief 2 reported a three-story brick structure with smoke showing on side Alpha. Engine 33, and Truck 1 were deployed to side Charlie. Engine 23 covered a hydrant to provide a continuous water supply to Engine 33.

The fire structure shared common brick and mortar walls with an occupied row house on side Bravo and a vacant row house on side Delta. The T5 crew used hand tools to force open the front door of the fire structure. The T5 lieutenant and fire fighter entered the structure and began to search for the location of the fire. As the E31crew was advancing a five-section (250 feet) 1¾ inch preconnected handline through the front door, the T5 lieutenant radioed that he had found fire on the second floor. The E31 crew advanced their handline up the front stairway located on side Bravo. As they were advancing to the second floor, a section of the handline burst so the E31 crew had to pull a second 1¾ inch preconnected handline off E31 and advance it up the front stairway. At approximately 0027 hours, Battalion Chief 6 (BC6) arrived on scene, radioed to FCB that he would be "Safety" and checked in with the Incident Commander. Per department procedures, the second due battalion chief assumes the duties of the Incident Safety Officer (ISO) until relieved by the shift safety officer. Battalion Chief 6 walked around the block to side Charlie.

At approximately 0028 hours, BC2 (the Incident Commander) radioed FCB and upgraded the incident to a working fire. Per standard procedures, one additional engine company, Engine 8 (E8), one additional truck company, Truck 16 (T16), the shift safety officer (SO2), the shift commander, and the AIRFLEX unit, a vehicle that carries additional air cylinders, portable lighting, and other equipment were dispatched. Battalion Chief 5 (BC5) was working as the acting shift commander at the time of the fire.

The T1 crew forced entry at the rear of the fire structure and the E33 advanced a 1¾ inch preconnected hand line through the rear door. The E33 crew observed fire in the rear stairwell extending up to the second floor. They used their handline to knock down the fire. Hose streams were operated at approximately 150 gallons per minute at 100 psi.

At approximately, 0032 hours, the IC radioed for the working fire units (E8 and T16) to stage west of the structure. At 0033 hours, BC6 radioed that just light smoke was showing on side Charlie. At 0034 hours, the IC radioed that the bulk of the fire was knocked down with moderate smoke conditions on all sides.

At approximately 0042 hours, the shift safety officer (SO2) arrived on-scene and reported to the IC. The IC radioed that the shift safety officer was taking over as "Safety" and BC 6 would be "Charlie Division." The shift safety officer then began a 360 degree walk-around of the incident scene. He walked around the block from side Alpha to side Bravo and down the alley to side Charlie. The shift safety officer talked to BC6 about the conditions at the rear of the structure and BC6 transferred the safety officer responsibilities to the shift safety officer.

At 0046 hours, the IC declared the fire under control and began to release crews. The crews dispatched for the working fire (E8 and T16) had remained in staging and were released without having been deployed. The acting shift supervisor (Car 5) returned to service at 0047 hours. The IC ordered the side Delta exposure to be opened up and checked for fire extension. Truck 5 forced open the front door and two fire fighters from Truck 1 began to force open the rear (side Charlie) of the side Delta exposure building. As the T1 fire fighters were working to force open the rear door and window, the shift safety officer directed them to stop. Reportedly, the shift safety officer stated they were in an unsafe condition and that crews were working inside the structure. The shift safety officer did not state what the unsafe condition was. During interviews, the T1 fire fighters stated that they thought it was because glass was falling down from the second story windows where the T5 and T1 crews were knocking out the side Charlie windows of the side Delta exposure building for ventilation.

When T5 forced open the front door of the side Delta exposure, heavy smoke pushed out. The IC directed the RIT crew (E13) to take a handline into the side Delta exposure in case fire had extended into the structure. The E13 crew advanced the hoseline into the Delta exposure and up the steps to the second floor. They did not find any fire in the Delta exposure. *Note: The E13 crew had an experienced fire fighter serving as the acting lieutenant.* The T5 and T1 crews were already inside working on ventilation.

After returning from the second floor, the E13 crew walked to the rear of the first floor. They observed that all the floor boards and the floor joists had been removed at the rear of the first floor from the basement steps to the back wall, leaving a large hole in the floor (see Diagram 1). The E13 crew walked back outside to the front (side Alpha) but did not report the missing floor boards to the IC or the shift safety officer.

An electric smoke ejector (exhaust ventilation fan) was placed in the front doorway of the fire structure to clear the structure of smoke. An electric positive pressure ventilation (PPV) fan was also placed in the front doorway of the side Delta exposure by an unknown fire fighter. A T5 fire fighter observed that the PPV fan was improperly positioned so he moved the fan back to the sidewalk in front of the doorway and turned it so that it was blowing toward the front door of the Delta exposure building. The T5 fire fighter checked to make sure that there was positive pressure at the doorway by feeling for air movement from the fan.

T1 never reported to the IC that due to the shift safety officer stopping their efforts to open the rear door and window, they were not able to complete their assignment to ventilate the rear of the delta exposure.

The shift safety officer returned to side Alpha and was observed talking face-to-face with the IC. At approximately 0056 hours, the shift safety officer radioed the E13 crew for a report on the conditions on the second floor of the Delta exposure building. A E13 crew member radioed command that there was no fire, just some trapped smoke and they were working to open up the structure. The E13 crew reported that when they returned outside, they saw the shift safety officer (SO2) at side Alpha. Photographs taken at approximately 0104 hours showed the shift safety officer in the street at Side Alpha near the incident commander (see Photo 5).

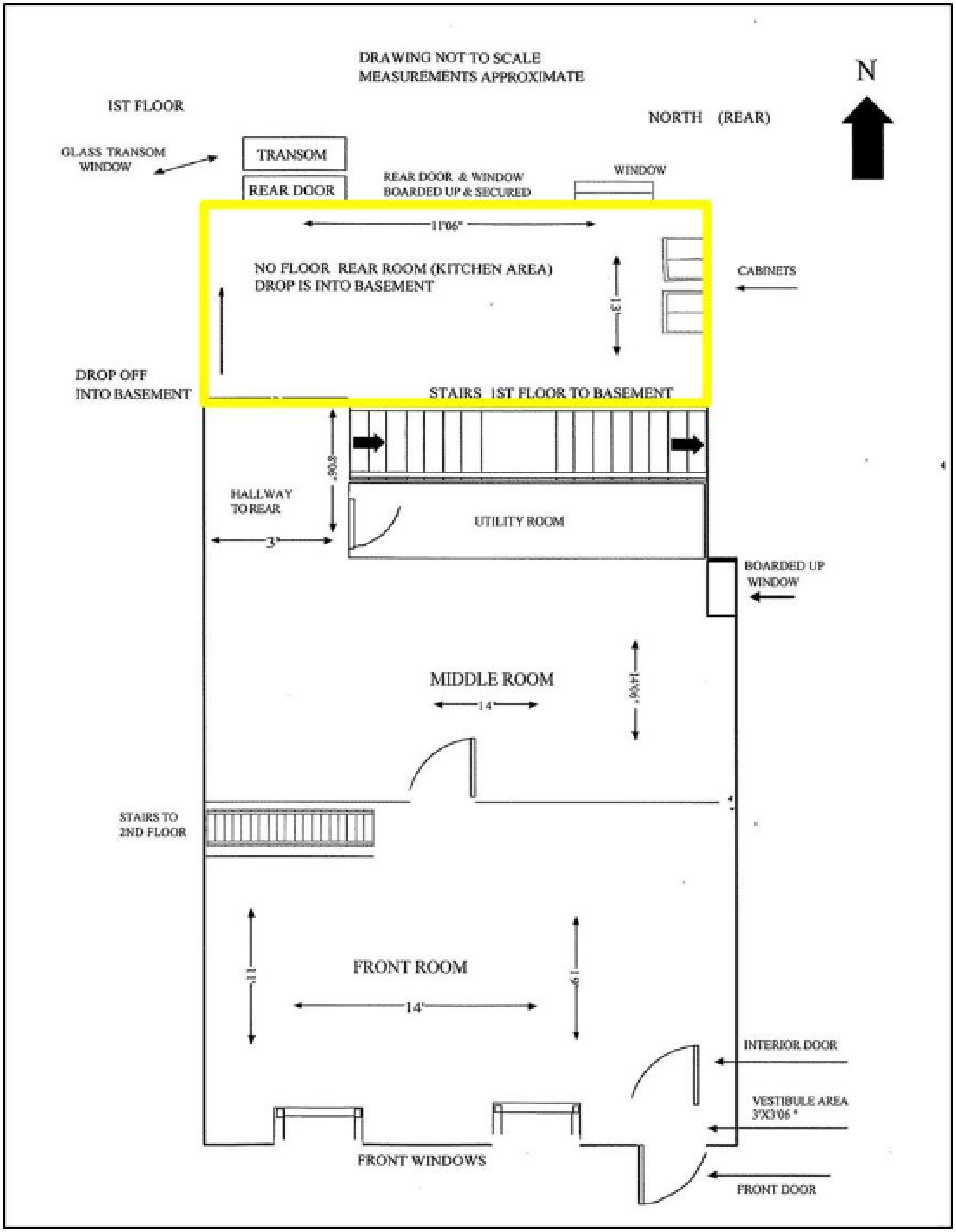


Diagram 1. First floor layout of the Delta exposure where the shift safety officer was found. The highlighted area at the rear of the first floor is the area where all flooring and joists had been removed. ***(Adapted from drawing provided by Fire Department)***

[Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland](https://www.cdc.gov/niosh/fire/pdfs/face201424.pdf#page=24)This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201424.pdf#page=24.

One of the T5 fire fighters reported moving the PPV fan in the doorway of the Delta exposure so that the shift safety officer (SO2) could enter the Delta exposure. The shift safety officer entered the structure alone. There were no confirmed sightings or contact with the shift safety officer after this time. The safety officer's vehicle carried gas detection equipment that was not utilized at this incident.

The IC began releasing crews to return to service. BC6 returned to service at approximately 0116 hours. At approximately 0152 hours, the IC radioed dispatch that he was transferring command to Truck 5. The IC (BC2) departed the scene at approximately 0154 hours. The remaining crews worked to secure the fire structure and the Delta exposure by boarding up doors and windows. All remaining fire department staff, excluding the shift safety officer, departed the scene by 0223, which was confirmed by radio transmissions.

At approximately 0334 hours, the Fire Communication Bureau placed the shift safety officer in service without verification of his location.

At approximately 0643 hours, the city communication center received a 911 phone call from a male caller who asked to be connected to the Fire Communication Bureau. The caller reported that a fire department vehicle was parked on the wrong side of the street and in the middle of the street. He reported that he had been at the location approximately 20 minutes and nobody was around. He described the vehicle markings and the vehicle license plate number. He also identified the vehicle location by the block number and street intersection. The call ended at approximately 0646 hours. No case number was entered into the computer-aided dispatch (CAD) system.

At approximately 0647 hours, the city call taker called FCB and reported what the caller had said. The fire department dispatcher asked for the vehicle's color, license plate number and other identifying markings along with the vehicle's location. After this call ended, the fire department dispatcher discussed the call with another fire department dispatcher. The discussion ended at approximately 0653 hours and the fire dispatchers returned to their duties.

At approximately 0700 hours, the fire dispatcher who received the call realized he hadn't reported the call to his supervisor. He briefly discussed the call with the shift lieutenant but they were interrupted by calls to the FCB dispatch center and never finished the conversation.

At approximately 0708 hours the same caller called dispatch again and asked if the fire department had a vehicle at the location. The shift lieutenant took the call. The caller reported that he hadn't seen anyone around the vehicle and the back window was slightly open and he was concerned that someone might try to steal equipment from the fire department vehicle. After more discussion, the shift lieutenant attempted to contact the fire department apparatus coordinator and at 0711 the apparatus coordinator called back to fire dispatch. The fire dispatch shift lieutenant and the apparatus coordinator discussed the information provided by the caller but the vehicle was not immediately identified by the apparatus coordinator.

At approximately 0732 hours, the caller called fire dispatch again to ask about the vehicle. The shift lieutenant took the call and asked the caller for the vehicle's license plate number. The caller provided the license plate number again. The shift lieutenant called the apparatus coordinator and gave him the license plate number. At approximately 0736 hours, the apparatus coordinator identified the vehicle as being assigned to the shift safety officer (SO2). The shift lieutenant immediately radioed over fire bands A1 and A2 for the shift safety officer 2. This was broadcast a number of times with no response. The shift lieutenant also checked the daily staff roster to identify the shift safety officer. *Note: the shift safety officer normally works a 24 hour shift from 0700 to 0700 hours. A new shift safety officer (on C shift) came on duty and noticed that the safety vehicle SO2 was not in quarters. He assumed the missing shift safety officer (the lieutenant working B-shift) was out on a call.*

At 0743 hours, the on-duty shift safety officer (C shift) called fire dispatch and asked where SO2 was located. The call taker told the on-duty shift safety officer to hold because the shift lieutenant was working on locating the vehicle. The shift lieutenant answered the phone and spoke directly to the onduty C-shift safety officer. She asked him if he was where the vehicle was located. He stated that he was still in quarters waiting for the missing shift safety officer (the victim working B-shift) to return with the vehicle. The shift lieutenant told the on-duty shift safety officer that dispatch had received a number of phone calls reporting that the safety officer's vehicle SO2 was parked on the wrong side of the street blocking traffic and the windows were partially open, with no fire service personnel around the vehicle. *Note: The shift safety officer coming on duty had previously called the missing shift safety officer's cell phone in an attempt to determine his location.*

At approximately 0745 hours, the fire dispatch shift lieutenant called the fire operations shift commander and reported that there was a problem with the safety officer's vehicle being parked on the wrong side of the street blocking traffic and the missing shift safety officer could not be located. After some discussion with dispatch and the on-duty shift safety officer, at approximately 0748 hours, the shift commander directed Engine 6 to be placed out of service so that the E6 crew could go to the location and investigate.

At approximately 0824 hours the E6 crew located the missing shift safety officer in the basement of the Delta exposure. He was in a sitting position near the Side Bravo wall slumped over on his right side against a pile of debris (see Diagram 2). Emergency medical services personnel were dispatched to the scene and the shift safety officer was pronounced dead at the scene at approximately 0852 hours.

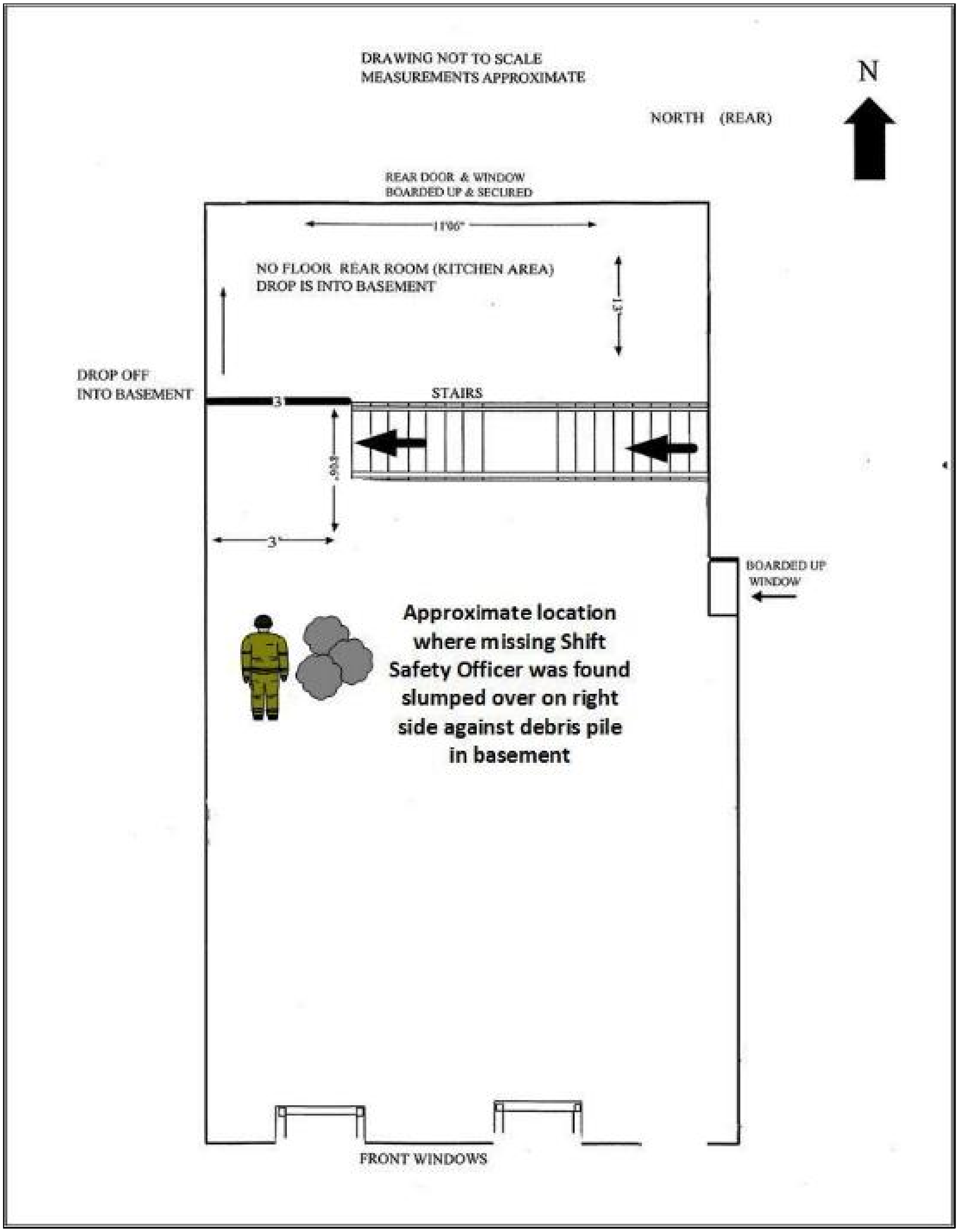


Diagram 2. Basement floor layout showing the location where the shift safety officer was found in the basement of the Delta exposure.
(Adapted from drawing provided by Fire Department)

Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201424.pdf#page=27.

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 that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatalities:

- Floor system at rear of the Delta exposure completely removed prior to incident
- Hole in floor (fireground hazard) not reported to the incident commander
- Smoke accumulation in the unventilated basement of the Delta exposure
- Ventilation in the Delta exposure was not completed
- Shift safety officer entered the Delta exposure alone
- Fireground accountability was ineffective
- Crew integrity was not maintained and single unit resources functioned alone
- Fire Communication Bureau placed shift safety officer in service without verbal confirmation of his location.

Cause of Death

The medical examiner's report listed the victim's cause of death as smoke inhalation. The manner of death was an accident. The autopsy identified a blood carbon monoxide level of 73.5 percent. Noted injuries included a broken nose and lacerations and abrasions on the forehead and nose. There was no evidence of internal head trauma.

Evaluating the Effects of Ventilation

At the request of NIOSH and the fire department, the National Institute of Standards and Technology (NIST) Fire Research Division was invited to examine and evaluate several air movement / ventilation scenarios involving the two vacant row houses involved in this incident. The vacant row houses included the fire structure and the adjoining Delta exposure structure where the shift safety officer was ultimately found. Since the cause of death was determined to be smoke inhalation and the fatality occurred in the Delta exposure building which had no fire involvement, this evaluation was conducted to determine what effect the use of the ventilation fans on the night of the fire could have contributed to the accumulation of smoke and fire gases within the basement of the Delta exposure building.

Gases flow from one space to another as a result of pressure differences, i.e. move from a space of higher pressure to a space at a lower pressure. If there is no pressure difference between one space and another, then the gases will not flow between the spaces.

Several different scenarios were examined by NIST to see if a flow path could be created through the Delta exposure building in such a way that would hold smoke in the basement of the row house or evacuate smoke out of the basement of the row house. This evaluation was conducted by NIST on December 11, 2014. Representatives of the fire department, Maryland Department of Labor, Licensing and Regulation, NIOSH and NIST were present during the evaluation.

Introduction

When a fire occurs in a room, the combustion products (fire gases/smoke) from the fire are hotter and less dense than the surrounding air. As the fire gases get hotter they continue to expand and flow away from the fire. Once the heated fire gases have filled the upper portion of a room (hot gas layer), the gas pressure in the hot gas layer increases. This increased pressure allows the fire gases to push through openings in the room into adjacent spaces with a lower pressure.

After a fire, when the fire gases have cooled to ambient conditions, rooms in a structure may be filled with visible "cold" smoke. Because the gases have cooled and equalized with the surroundings, there is no difference in pressure to move the cold smoke out of the space. Many times fire departments will use a fan to increase the pressure of the smoke filled room and push the smoke to a lower pressure outside of the room. For this to work, a flow path must be created with the fan pressurizing the inlet to the smoke filled room to force the flow through another opening which serves as the lower pressure exhaust vent. This is the principle behind the use of positive pressure ventilation (PPV) fans.

Instrumentation and Flow Path Evaluation

Differential pressure transducers were located at various positions in the basement and on the first floor of the Delta exposure building where the victim was found. The purpose of the testing was to determine if pressure differences could be generated between the first floor and the basement in such a way that air from the basement would be exhausted. The same fans used during the night of the fire were used during the evaluation process.

An electric smoke ejector fan was located in the front doorway of the fire building and an electric PPV style fan was set up blowing at the front doorway of the Delta exposure building (see Photo 7).

Findings

In most scenarios evaluated, no pressure differences were generated with either the smoke ejector in the doorway of the fire building and/or the PPV fan blowing at the doorway of the Delta exposure building. The reason for this is that there was no flow path from either the basement or the first floor to a lower pressure vent. Given that there was a large section of the floor assembly missing from the rear of the 1st floor, the basement and the first floor effectively behave as one large compartment. The open volume of the basement/first floor and uncontrollable openings to the second and third floors, limited the ability of the electric PPV fan to create a high pressure in any part of the Delta exposure structure.

The only ventilation condition that enabled flow through the basement occurred when one of the basement windows at the front (Side Alpha) of the Delta exposure building was opened (see Photo 8). Since the first floor and the basement were similar but at slightly higher pressures (approximately 5 pascals (Pa) than the outside), air flowed from the basement out of the basement window opening. An anemometer positioned in the basement window opening showed an exhaust flow of 1 to 2 mph. This window was not opened on the night of the fire.

Opening the rear door of the Delta exposure building created a flow path from the front door through the house to the rear. With a flow path open from the front to the rear of the row home, air movement was observed on the first floor by the stairway to the basement in excess of 5 mph, even without the PPV fan running, as a result of the pressure created by the wind outside. With the flow through the structure, air in the rear area of the basement would experience some amount of mixing with the air moving through the structure.

It should also be noted that both of the fans used in these tests, despite differences in design, had similar air velocities at the face of the fan. As a result the PPV fan did not have the capacity to create a pressure increase of 20 Pa or higher in the large, open structure. In other words, the PPV fan was too small to create effective positive pressure ventilation under these conditions.

Summary

A flow path with a higher pressure at the inlet vent and a lower pressure at the exhaust vent is required to move gases through the flow path. In cases where there was no clear flow path with a lower pressure exhaust vent, there was no air movement within the row home. Only when the rear door was opened did a functional flow path exist across the first floor. Even with the front and rear doors open, the air flow in the basement would still be largely unaffected. The potential for flow to move through the basement existed with the front door open and the basement windows open. However significantly higher pressures (e.g. larger fan) would be required to develop a condition to clear the basement with the basement windows open. Neither fan was properly sized to provide proper ventilation and did not contribute to the environment in the basement

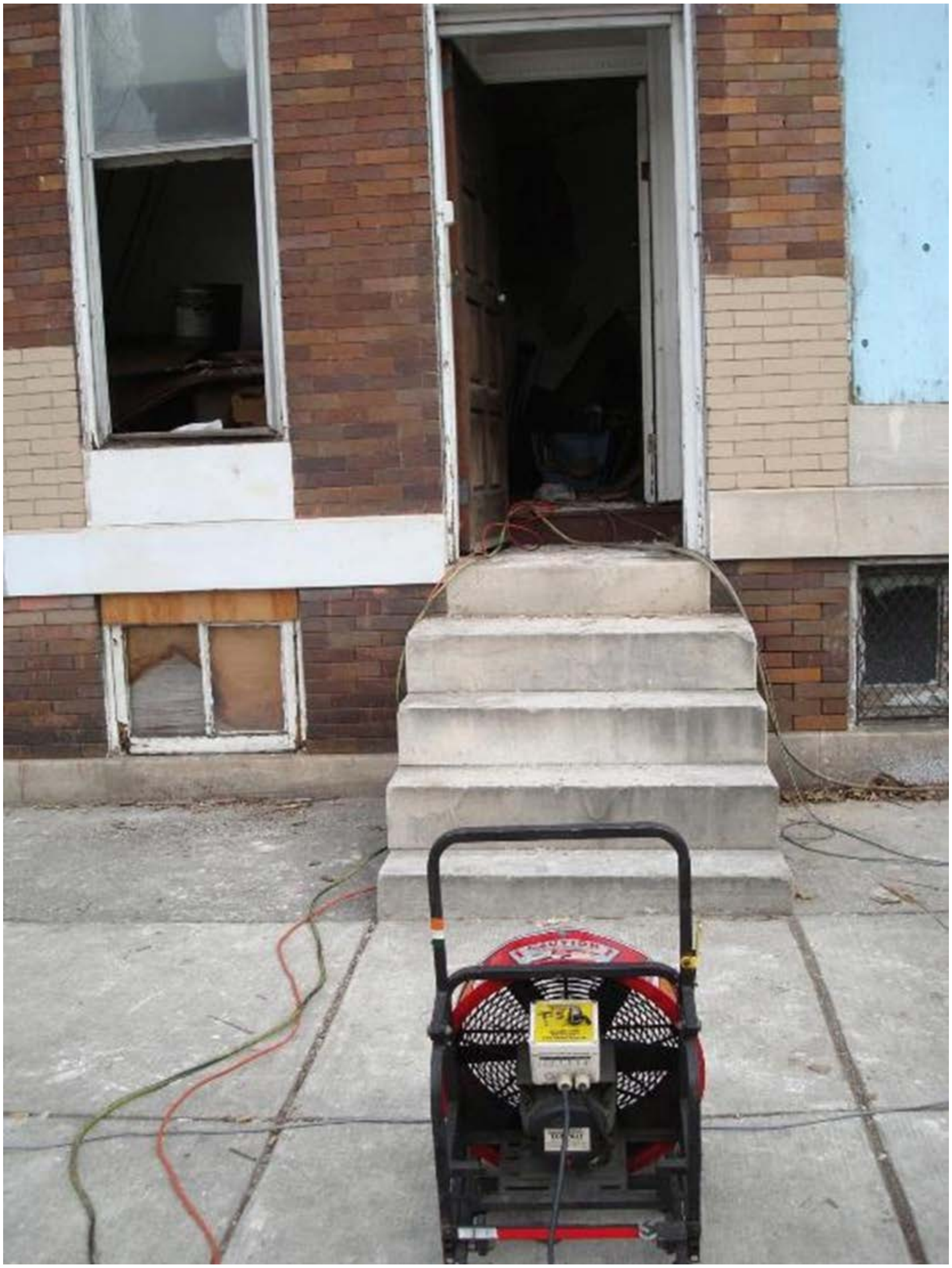


Photo 7. Ventilation fan in front of Delta exposure. Photo taken while NIST was collecting pressure and ventilation data. (Photo NIOSH)

Photo 8. Photo shows basement window at Side Alpha of the Delta exposure building removed as part of the NIST data collection process. This window was not opened the night of the incident. ***(Photo NIOSH)***

Recommendations

Recommendation #1: Fire departments should utilize a functional personnel accountability system, requiring a check-in and check-out procedure with the designated accountability officer or Incident Commander.

Discussion: Fire departments should review existing personnel accountability procedures to ensure that they are functional and effective. If no personnel accountability procedures exist, the fire department should develop, implement and enforce standard operating procedures that ensure a personnel accountability system is utilized at all emergency operations. The National Fire Protection Association (NFPA) 1561 *Standard on Emergency Services Incident Management System* (2008 edition), Section 4.5.1 states that the emergency services organization (ESO) shall develop and routinely use a system to maintain accountability for all resources assigned to the incident with special emphasis on the accountability of personnel. Section 4.5.3 states that the system shall include a specific means to identify and keep track of responders entering and leaving hazardous areas, especially where special protective equipment is required. Section 4.5.10 states that responders who arrive at an incident in or on marked apparatus shall be identified by a system that provides an accurate accounting of the responders on each apparatus.[5] NFPA 1500, Section 8.4 identifies requirements for personnel accountability during emergency operations. Section 8.4.1 states that the fire department shall establish written standard operating procedures for a personnel accountability system that is in accordance with NFPA 1561, Standard on Emergency Services Incident Management System.[5, 6] Section 8.4.4 states that the Incident Commander shall maintain an awareness of the location and function of all companies or crews at the scene of the incident.

Personnel accountability systems can range in complexity from simple identification tags to complex electronic tracking systems. A variety of different personnel accountability systems have been used at emergency operations across the country.

The fire department involved in this incident had written standard operating procedures defining a personnel accountability system intended to meet the requirements of NFPA 1500 and NFPA 1561. The written procedures specified that the Incident Commander shall be responsible for overall personnel accountability for the incident and that the Incident Commander shall maintain an awareness of the location and function of all companies or units at the scene of the incident. The procedures also stated that the Incident Commander shall provide the use of additional accountability officers based on the size, complexity, or needs of the incident.

During this incident, the personnel accountability function remained with the IC until after the fire was placed under control and crews were placed back into service. The shift safety officer (SO2) was dispatched on the Working Fire Alarm and arrived on-scene just minutes before the fire was placed under control. SO2 reported to the Incident Commander for a briefing as per the department's procedures for the Shift Safety Officer. A photograph taken at approximately 0104 hours documented SO2 talking to the Incident Commander in the street in front of the row houses (see Photo 5). Soon after, SO2 entered the Delta exposure alone. The Incident Commander radioed dispatch that he was transferring command to Truck 5 at approximately 0152 hours. The Incident Commander left the incident scene at 0154 hours. All remaining fire department staff excluding the SO2 left the incident scene by 0223 hours. Dispatch marked the shift safety officer in station at 0334 hours without attempting to verify his location. At some point after 0104 hours, Incident Command lost accountability of SO2. Fire departments should ensure that personnel accountability procedures are functional so that accountability is maintained for all personnel dispatched to an emergency incident.

Recommendation #2: Fire departments should ensure that the Incident Commander accounts for all resources before dissolving command.

Discussion: As noted above, personnel accountability at an emergency response is of the utmost importance. The Incident Commander and any designated accountability officers need to be aware of the location and job assignment for all fire department personnel at the emergency incident scene at all times. Fire departments should have procedures in place to ensure that personnel accountability is maintained at all times during an emergency response. This includes from the initial dispatch until the last fire department personnel leaves the incident scene. During this incident, the personnel accountability function remained with the IC until after the fire was placed under control and crews were placed back into service. A separate accountability officer was not designated.

This fire department has written procedures detailing fireground operations and incident command functions including the transfer of command. These procedures focus on the transfer of command as an incident grows in size and complexity. These procedures provide limited guidance on fireground personnel accountability as the incident is winding down. The Shift Safety Officer was seen talking with the Incident Commander at approximately 0104 hours and entered the Delta exposure alone soon after. The Incident Commander radioed dispatch that he was transferring command to Truck 5 at approximately 0152 hours. The Incident Commander left the incident scene at 0154 hours. All remaining fire department staff excluding the shift safety officer left the incident by 0223 hours. Dispatch marked the shift safety officer in station at 0334 hours without attempting to verify his location.

Recommendation #3: Fire departments should train fire fighters on the principles of situational awareness.

Discussion: All fire fighters operating at an incident should maintain situational awareness and conduct a continuous risk assessment throughout the incident, reporting unsafe or changing conditions to the Incident Commander. Fire fighters need to understand the importance of situational awareness and personal safety on the fire ground. *Essentials of Firefighting and Fire Department Operations*[7] defines situational awareness as an awareness of the immediate surroundings. On the fire ground, every fire fighter should be trained to be constantly alert for changing and unsafe conditions. This applies not only to the conditions found within a burning structure, but to exposure buildings and the exterior fireground as well. Even though a safety officer may have been designated for an incident, all personnel are obligated to remain alert to their immediate surroundings.

The ability to maintain situational awareness is reliant on a fire fighter's training, judgment and personal condition. These factors must come together every time a fire fighter goes to an emergency incident especially those involving a low-frequency, high risk event such as structural fire-fighting, wildland fire-fighting, trench rescue, high angle rescue, or any of the wide arrays of emergencies fire fighters are called upon to mitigate. A lack of competency, or even a temporary lack of focus, can lead to a chain of events that may be catastrophic or even fatal.[8-9]

To properly train personnel to maintain situational awareness on the fireground or at any emergency incident, a fire department has to develop and utilize effective scenario based training. Training fire fighters to maintain situational awareness on the fireground needs to include building construction, fire behavior, fireground tactics and strategy, ventilation, and other fireground operations. This is a continuous process that is initiated in recruit school and continues through a fire fighter's entire fire service career.[8-9]

Fire fighters need to understand the importance of situational awareness, personal safety, and company/crew accountability on the fireground. The fireground dangers and hazards can and do change as an incident evolves and the event duration increases. Situational awareness is defined as recognition of the immediate surroundings. On the fireground, every fire fighter should be trained to be constantly alert for changing and unsafe conditions related to their immediate surroundings. Each and every fire fighter needs to be responsible and accountable for their own safety, as well as team members and others working in the immediate area. This applies not only to the conditions found within a burning structure, but to the exterior fireground as well.[7]

The United States Coast Guard says that, "Situational Awareness is the ability to identify, process, and comprehend the critical elements of information about what is happening to the team with regards to the mission." In other words in order to have "situational awareness" you must constantly know what is happening around you, and where you are in relation to threats.[8] The need for fire fighters to maintain situational awareness is paramount. A loss of situational awareness can lead directly to disorientation. Disorientation far too often leads to a fire fighter line of duty death. In addition, a perceived lack of a threat can lead directly to complacency or an unrealistic feeling of comfort in one's environment. Situational awareness is a cognitive skill; it can be taught. In order to have situational awareness, you must be able to perceive the threat, comprehend the threat and predict what effect that threat may have on you. These elements: Perceive, Comprehend and Predict form the cornerstone of maintaining complete situational awareness.[8]

In this incident, the shift safety officer (SO2) entered the Delta exposure building as crews were finishing up operations and preparing to leave the scene. He entered the structure alone sometime shortly after 0104 hours. He was not wearing an SCBA or a PASS device. It is likely that he was unaware of the hazard of the missing floor located at the rear of the exposure building and subsequently fell into the basement. The shift safety officer was alive after his fall and continued to breathe, eventually succumbing to smoke inhalation with an autopsy blood carbon monoxide level of
73.5%

Recommendation #4: Fire departments should train and empower all fire fighters to report unsafe conditions to Incident Command.

Discussion: The International Association of Fire Chiefs (IAFC), Safety, Health and Survival section developed the "Rules of Engagement for Structural Firefighting." The rules of engagement have been developed to assist both the fire fighter and the Incident Commander (as well as command team officers) in risk assessment and "Go or No-Go" decisions. The fire ground creates a significant risk to fire fighters and it is the responsibility of the Incident Commander and command organization officers to minimize fire fighter exposure to unsafe conditions and stop unsafe practices.[10]

The IAFC Rules of Engagement can assist the Incident Commander, company officers, and fire fighters (who are at the highest level of risk) in assessing their situational awareness. One principle applied in the rules of engagement is that fire fighters and the company officers are the members most at risk for injury or death and will be the first to identify unsafe conditions and practices. The rules integrate the fire-fighter into the risk assessment decision making process. These members should be the ultimate decision makers as to whether it's safe to proceed with assigned objectives. Where it is not safe to proceed, the rules allow a process for that decision to be made while still maintaining command unity and discipline.

One of the IAFC Rules of Engagement for Firefighter Survival states, "**You Are Required to Report Unsafe Practices or Conditions That Can Harm You. Stop, Evaluate, and Decide.**" This Rule applies the principles of crew resource management by encouraging all firefighters to apply situational awareness and be responsible for their own safety and that of other firefighters. In a sense all firefighters become the additional eyes and ears of the incident commander and alerting him (or the immediate supervisor) to unacceptable situations. No fire attack or building is worth the life of a firefighter or a preventable (sometimes career ending) injury. The intent of this Rule is to allow any member to report a safety concern through a structured process without fear of penalty.

One of the key tenants of the National Fallen Firefighter Foundation (NFFF) is their 16 Life Safety Initiatives. The 16 Firefighter Life Safety Initiatives (FLSI) were jointly developed by representatives of the major fire service constituencies in 2004 at a Firefighter Safety Summit in Tampa, FL. At that time, the National Fallen Firefighters Foundation was tasked with promulgating the Initiatives throughout the fire service, and developing material to support their implementation.[11]

Live Safety Initiative number 4 is "Empowerment - All firefighters must be empowered to stop unsafe practices." While this may appear to be a challenging or even controversial statement, it simply means that every organization should provide an environment that allows its members to speak up regarding personal and organizational safety; without negative consequences for doing so (within a prescribed context), and without decentralizing the authority of the formal leader. The goal is to have every member fully engaged during an emergency incident with a focus on doing the work in a proficient manner and looking out for one another to avoid injuries and potential line of duty death.[11]

Every firefighter is responsible for their individual safety and the safety of other firefighters. Each firefighter is responsible for identifying risks and hazards and reporting them. Supervisors are responsible for accepting reports regarding safety concerns without penalizing the firefighter and properly acting on the report to ensure the safety of firefighters.

In this incident, fire fighters working inside the Delta exposure observed the missing floor at the rear of the structure but this information was never reported to Incident Command or the shift safety officer.

This information could have allowed the IC and/or the shift safety officer to take action to prevent exposure to this hazard by establishing a hazard control zone. Late in the incident, the shift safety officer entered the structure alone. It is believed that he fell through the hole into the basement and later succumbed to smoke inhalation.

Recommendation #5: Fire departments should train all fire fighters and officers to report when tasks are completed or cannot be completed to their officer or the Incident Commander.
Discussion: The Incident Commander depends upon two-way communication and continual feedback at emergency incidents in order to manage the incident. This aids the Incident Commander in the decision making process and is especially true at structure fires and large

incidents where the IC may not have visual contact with all fire fighters and may not be able to view the entire incident scene from the command post.

This incident occurred in the middle of a series of 12 connected row houses that filled an entire city block. The Incident Commander was positioned in the street on side Alpha facing the block of row houses. In order to facilitate incident management, the second-due battalion chief was designated Charlie Division and also the incident Safety Officer per standard departmental procedures on the first alarm. He operated on the Charlie side throughout the incident. When the shift safety officer (SO2) arrived on-scene, he assumed the incident Safety Officer role. After the fire was brought under control in the fire building, the IC directed crews to open the rear of the Delta exposure to release trapped smoke and help clear the structures. Members of a truck company were working to open the rear door and window at ground level on the Delta exposure when SO2 ordered them to stop because they were in an unsafe position. The truck company members moved to complete other assignments and SO2 returned to side Alpha. The IC was not aware that the rear of the structure was not opened for ventilation. If the rear of the Delta exposure had been opened, the truck company members and also the shift safety officer may have observed the missing floor section and taken action to prevent exposure to this hazard by establishing a hazard control zone. SO2 later entered the Delta exposure alone through the front door and fell into the basement, succumbing to smoke exposure.

Additionally, NFPA 1561 Standard for an Emergency Services Incident Management System, Section 5.9.6.11 of Chapter 5 states, “At an emergency incident where activities are judged by the incident safety officer as posing an imminent threat to responder safety, the incident safety officer shall have the authority to stop, alter, or suspend those activities.” Section 5.9.6.11.1 states, “The incident safety officer shall immediately inform the incident commander of any actions taken to correct imminent hazards at the emergency scene.”[5]

Ventilation testing by NIST determined that the only condition where a functional flow path across the first floor of the Delta exposure occurred when both the front and rear doors were open. Even with the front and rear doors open, the NIST testing determined that the air flow in basement would still be largely unaffected. See Pages 25-28 for more information.

Recommendation #6: Fire departments should ensure that every fire fighter on the fire ground utilizes a Personal Alert Safety System (PASS) device including the ability to provide PASS devices for personnel operating in a potentially dangerous environment not requiring the use of selfcontained breathing apparatus.

Discussion: Every fire fighter who may be required to enter an immediately dangerous-to-life-or health (IDLH) environment should be equipped with a personal alert safety system (PASS) device meeting the requirements of the *NFPA 1982 Standard on Personal Alert Safety Systems* (2013 edition or the latest edition).[12]

NFPA 1500 Standard on Fire Department Occupational Safety and Health Program (2013 edition), Chapter 7.1 states the fire department shall provide each member with protective ensembles, ensemble elements, and protective equipment designed to provide protection from hazards to which the member is likely to be exposed and that is suitable for the tasks the member is expected to perform.[6] Chapter 7.2.1 states that members who engage in or are exposed to the hazards of structural firefighting shall be provided with and shall use a protective ensemble that shall meet the applicable requirements of NFPA 1971 Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting.[2] NFPA 1500, Chapter 7.16.2 states that each member shall be provided with, use, and activate his or her PASS devices in all emergency situations that could jeopardize that person's safety due to atmospheres that could be IDLH, in incidents that could result in entrapment, in structural collapse of any type, or as directed by the incident commander or the incident safety officer. Annex A to NFPA 1500 (A7.16.2) states that the mandatory use and operation of a PASS by fire fighters involved in rescue, fire suppression, or other hazardous duty is imperative for their safety. The primary intent of this device is to serve as an audible device to warn fellow fire fighters in the event a fire fighter becomes incapacitated or needs assistance. Past fire fighter fatality investigation reports document the critical need to wear and operate PASS devices when fire fighters operate in hazardous areas. Investigation results show that fire fighters often failed to activate the PASS unit prior to entering a hazardous area. Training and operational procedures are imperative to ensure activation of the PASS whenever PASS devices are used.

In this incident the shift safety officer was dressed in turnout gear including structural firefighting pants, coat, boots, and helmet. He was not wearing a self-contained breathing apparatus and did not have a stand-alone PASS device. The presence of an activated and properly functioning PASS device would have sounded an alarm tone after he became motionless in the basement, potentially alerting fire fighters still on the scene to his location. The shift safety officer arrived on-scene after fire suppression operations had begun and did not enter the structure until the fire had been extinguished. However, as noted in NFPA 1500, it is good practice to wear a full protective ensemble (including SCBA) whenever members are engaged in or exposed to the hazards of structural firefighting. In cases where it is determined that an SCBA is not necessary but fire fighters could be exposed to other common fireground hazards such as collapse and entrapment, fire fighters should be provided with stand-alone PASS devices. This incident highlights why the use of PASS devices meeting the requirements of NFPA 1982 (2013 Edition, or the most current edition), by all fire service members is highly recommended.

Recommendation #7: Fire departments should provide Battalion Chiefs and Chief Officers with a staff assistant or chief's aide to help manage information and communication.

Discussion: A chief's aide, staff assistant, or command technician is a position designed to assist an IC with various operational duties during emergency incidents. The chief's aide can be an essential element for effective incident management. At an emergency incident, the staff assistant can assist with key functions such as: managing the tactical worksheet; maintaining personnel accountability of all members operating at the incident (resource status and deployment location); monitoring radio communications on the dispatch, command, and fireground channels; control information flow by computer, fax, or telephone; and, access reference material and pre-incident plans. The personnel accountability system is a vital component of the fire fighter safety process. The system is designed to account and track personnel as they perform their fireground tasks. In the event of an emergency or "Mayday," the personnel accountability system must be able to provide the rapid accounting of all responders at the incident. This is one of the chief's aide's essential responsibilities. Another important function is the role of a driver in addition to their role as part of the command team. Chief Officers are required to respond quickly to emergency incidents. In their response, they have to be fully aware of heavy traffic conditions, construction detours, traffic signals, and other conditions. More importantly, the chief officer must also monitor and comprehend radio traffic to assess which companies are responding, develop a strategy for the incident based upon input from first arriving officers, develop and communicate an incident action plan which defines the strategy of the incident. A chief's aide can assist the battalion chief or chief officer in processing information without distraction and complete the necessary tasks enroute to the scene.[13]

The fire department involved in this incident assigned aides to Chief officers at the Shift Commander rank and above who perform administrative duties, drive the chief officer's vehicle, and assist on the fire ground with communications and accountability as necessary. Battalion Chiefs are not assigned chief aides. Thus, the Battalion Chief is responsible for the operation of their vehicle during emergency responses, in addition to collecting and analyzing information about the incident for a number of sources. Departments should consider the aide to be an individual that has the experience and authority to conduct the required tasks. Other potential roles for the chief's aide include assisting with the initial size-up, completing a 360-degree size-up, coordinating progress reports from sector/division officers and many others. The aide position can be used as a training position to help facilitate officer development. There are non-emergency functions for the chief's aide that are vital to the daily operations of the department. Some jurisdictions assign a chief's aide to command officers to perform daily administration functions (such as position staffing and leave management). In this incident, the Acting Shift Commander was dispatched on the "working fire" alarm, arrived on-scene at approximately 0034 hours and went back in service at 0154 hours after the fire was placed under control. A chief's aide or staff assistant could have helped the Incident Commander with tasks such as driving to the scene, accountability, radio communications, and scene size-up.

Recommendation #8: Fire departments should ensure that single resource units (e.g. safety officers, fire investigators, etc.) do not function alone in IDLH environments at emergency scenes

Discussion: From the moment a fire fighter enters the fire service, they are taught that they should never work alone. Fire fighters are trained to work in teams of two or more and functioning as a single resource is strongly discouraged. The OSHA *Respiratory Protection Standard,* Title 29, Code of Federal Regulations (CFR) Part 1910.134 includes language establishing procedures for interior structural firefighting. Paragraph 1910.134(g)(4)(i) requires that at least two employees enter the IDLH atmosphere and remain in visual or voice contact with one another at all times.[14]

The publication *Fire Department Incident Safety Officer* by David W. Dodson serves as a guide for the incident safety officer (ISO) to help achieve the goal of preventing fire fighter injuries and deaths. This publication states that as part of this process, "Effective ISOs always try to set a good example while performing their duties. Often, it is the habits and self-discipline that an incident safety officer displays that influence others - a passive trigger to safe behavior. To illustrate, ISOs should always, without fail, participate in the crew accountability system.

Likewise, they should use appropriate PPE, follow department policies, and obey zone markers. Because ISOs often work alone—contrary to most fire service tenets—they are usually outside the hazard area and looking in, and this practice is acceptable.

However, to set a good example, ISOs working alone should follow basic guidelines:

- Always be in sight of another responder.
- Always be within shouting distance of another responder.
- Let somebody know where you are going if you are taking a tour of the incident scene.
- Don't walk into, or breathe, smoke.

It is counterproductive for the ISO to be viewed as working unsafely. ISOs should evaluate their own environment and exposure, making the adjustments necessary to act safely. Here are some examples: • In the unusual case where ISO need to go into an IDLH environment or into a hot zone, they should request a partner, use appropriate PPE and SCBA, and be tracked just like any other assigned crew.

- When performing reconnaissance around a building, ISOs are likely to walk into an area where no responder is visible (if you cannot see anyone, then nobody can see you). In these cases, ask for a partner to go with you. If no one is available, walk to the Bravo-Charlie corner, then walk back around the A-side to see the Charlie-Delta side —and have someone on the Aside keep you in their vision.
- ISOs need to self-monitor their rehab needs: Stay hydrated and eat something if you have been on-scene longer than two hours. Take steps to minimize the effects of thermal stress on your thinking ability."[15]

These recommendations apply to all single resource units including safety officers, fire investigators, division / group supervisors and anyone working on the fireground or at an emergency incident. Although fire fighters may be permitted to operate independently and in many cases alone, every repetition of the act of working alone reinforces the false belief that it is safe to do so, or that the inherent level of risk is low and therefore acceptable. Incident commanders should require that single resource units to be partnered with another similar single resource and/or be supported by a crew of other responders whose primary role is to ensure the safety of such resources. The responsibility of the IC to ensure the safety of all personnel is paramount. They must ensure that sufficient resources are summoned to ensure that all functions can be safety completed.

Recommendation #9: Fire departments should ensure that Mayday training program(s) are developed and implemented so that they adequately prepare fire fighters to call a Mayday.

Discussion: The first and foremost priority for fire fighter safety is not getting oneself into a situation that could potentially cause injury or death. The fire fighter must maintain situational awareness at all times while operating on the fireground. Fire fighters must understand that when they are faced with a life-threatening emergency, there is a very narrow window of survivability, and any delay in egress and/or to transmission of a Mayday message reduces the chance for a successful rescue. Knowledge and skill training on how to prevent a mayday situation and how to call a mayday should begin and be mastered before a fire fighter engages in fireground activities or other immediately dangerous to life and health environments. Beginner fire fighter training programs should include training on such topics as air management; familiarity with an SCBA, a radio, or PPE; crew integrity; reading smoke, fire dynamics, and fire behavior; entanglement hazards; building construction; and signs of pending structural collapse. Fire fighters must be able to recognize when they find themselves in a questionable position (dangerous or not) and be trained on procedures for when and how a mayday should be called. A fire fighter's knowledge, skill, and ability to declare a mayday must be at the mastery level of performance. This performance level should be maintained throughout their career through training offered more frequently than annually.[16]

Fire departments must understand that each fire fighter may have a different interpretation of what is life-threatening. The ability of a fire fighter to call a Mayday is a complicated behavior that includes the affective, cognitive, and psychomotor domains of learning and performance.[17, 18] Any delay in calling a Mayday reduces the chance of survival and increases the risk to other fire fighters trying to rescue the downed fire fighter. This incident illustrates the need for fire fighters to be given specific training on mayday procedures for determining when a Mayday must be called.

No rules are established for determining when a mayday must be called, and mayday training is not included in the job performance requirements in NFPA Fire Fighter 1 or 2 standards. It is up to the authority having jurisdiction to train members for emergency operations[6, 19] and to develop rules and performance standards for a fire fighter to call a mayday. The National Fire Academy (NFA) has two courses addressing the fire fighter mayday doctrine: Q133 Firefighter Safety, Calling the Mayday, a 2hour program covering the cognitive and affective learning domain of the fire fighter Mayday doctrine; and H134 Calling the Mayday: Hands-on Training, an 8-hour course covering the psychomotor learning domain of the fire fighter Mayday doctrine. These courses are based on the military methodology used to develop and teach ejection doctrine to fighter pilots. A training CD is available to fire departments free of charge from the U.S. Fire Administration Publications Office[17,20] The NFA Mayday courses present specific mayday parameters or rules for determining when a fire fighter must call a mayday. The courses may help fire departments in developing and teaching mayday procedures for fire fighters. Also, NFPA 1001 *Standard for Fire Fighter Professional Qualifications*, includes job performance requirements related to the fire fighter calling for assistance (such as a mayday situation).[18]

The IAFF Fire Ground Survival program is another resource fire departments can use and was developed to ensure that training for mayday prevention and mayday operations are consistent between all fire fighters, company officers, and chief officers.[16] No Mayday was called during this incident, even though the shift safety officer had a functional radio.

Any Mayday communication must contain the location of the firefighter in as much detail as possible and, at a minimum, should include the division (floor) and quadrant. It is imperative that firefighters know their location when in IDLH environments at all times to effectively be able to give their location in the event of a Mayday. Once in distress, firefighters must immediately declare a Mayday. The following example uses LUNAR (Location, Unit, Name,nAssignment/Air, Resources needed) as a prompt: "Mayday, Mayday, Mayday, Division 1 Quadrant C, Engine 71, Smith, search/out of air/vomited, can't find exit." When in trouble, a firefighter's first action must be to declare the Mayday as accurately as possible. Once the IC and

RIT know the fire fighter's location, the firefighter can then try to fix the problem, such as clearing the nose cup, while the RIT is enroute for rescue.[21]

A fire fighter who is breathing carbon monoxide (CO) quickly loses cognitive ability to communicate correctly and can unknowingly move away from an exit, other fire fighters, or safety before becoming unconscious. Without the accurate location of a downed fire fighter, the speed at which the RIT can find them is diminished, and the window of survivability closes quickly because of lack of oxygen and high CO concentrations in an IDLH environment.[17, 20-21]

Recommendation #10: Fire departments should ensure that dispatch centers positively confirm the status of all resources before clearing an event.

Discussion: The dispatch center is an important part of any emergency operation and provides valuable assistance and support to the incident commander. The dispatch center can provide assistance to the incident commander to help with accountability and resource tracking. The dispatch center can remind the incident commander at regular intervals how much time has transpired since crews first arrived on scene and can also prompt the IC to conduct personnel accountability rollcalls at predetermined regular intervals such as every 10 or 20 minutes. The dispatch center should mark the time that units go enroute, arrive on scene and the time that units are placed back into service.

In this incident, the incident commander IC began releasing crews to return to service shortly after the fire was brought under control at approximately 0046 hours. BC6 returned to service at approximately 0116 hours. At approximately 0152 hours, the IC radioed dispatch that he was transferring command to Truck 5. The IC (BC2) departed the scene at approximately 0154 hours. All remaining fire department staff excluding the shift safety officer departed the scene by 0223, which was confirmed through radio transmissions.

At approximately 0334 hours, the Fire Communication Bureau placed the shift safety officer in service without verification of his location. A process requiring positive verbal confirmation that a unit has cleared an event could have identified that the shift safety officer was missing much sooner.

Recommendation #11: Fire departments should ensure that dispatch centers forward all reports of suspicious or unusual events to the appropriate authorities in a timely manner.

Discussion: During this incident, the dispatch center began receiving phone calls around 0647 hours reporting a fire department vehicle was parked in a travel lane of a busy street facing the wrong direction and the vehicle appeared to be unattended. At least one caller provided dispatch with the vehicle's license plate number and other identifying information. The fire department's shift supervisor was notified at approximately 0715 hours and following a series inquiries, an engine company was dispatched to investigate at approximately 0748 hours. The shift safety officer (SO2) was already deceased when he was located at approximately 0824 hours in the basement of the Delta exposure structure.

All units that responded to the row house fire communicated with dispatch when they left the scene by 0223 hours except for SO2. At some point, dispatch realized that SO2 hadn't cleared the scene. Dispatch marked the shift safety officer in station at 0334 hours without attempting to verify his location. The shift safety officer entered the structure alone at some time after 0104 hours and succumbed to smoke exposure in the basement sometime before being located at 0824 hours.

Recommendation #12: Fire departments should consider conducting evaluations of their emergency incident activities to determine the role complacency contributes to unsafe actions and develop strategies to combat such complacency.

Discussion: Fire departments need to consider the conduct regular evaluations of their emergency incident activities to identify areas in which the department may be vulnerable to the risk of fire fighter injury and death. This process should include determining the role that complacency contributes to unsafe actions. The National Fallen Firefighters Foundation (NFFF), in coordination with the U.S. Fire Administration (USFA), has developed an online Vulnerability Assessment Tool that will provide fire departments with a systematic process to evaluate risk and ultimately reduce the threat of firefighter injuries and deaths.[22]

Vulnerability is a term used in the insurance and technology industries, and refers to an aspect of an organization's culture or operations that is likely to result in a negative outcome. In fire service operations, that negative outcome can include a firefighter injury or fatality. A vulnerability assessment is the process of identifying, quantifying and prioritizing the vulnerabilities within an organizational system, such as a fire department. For instance, your firefighters may be at risk because you do not have or do not enforce a mandatory seat-belt policy. Resources will help you develop and support enforcement of such a policy.[22]

At the end of the process, users have a customized report identifying areas of vulnerability linked to firefighter injuries and deaths. Each report contains suggestions for "risk reduction alternatives" specific to identified vulnerabilities and provides pertinent industry standards and guidelines to address the identified concerns. Fire departments can then use this analysis to develop operational and strategic plans to implement the risk reduction recommendations necessary to minimize or eliminate predictable causes of line-of-duty injuries and deaths.[22]

In this incident, the shift safety officer's vehicle carried gas detection equipment that could have been used to sample for the presence of carbon monoxide in the fire building and the Delta exposure, but was not used during the incident. The use of a gas detector could have warned the shift safety officer of the dangerous accumulation of carbon monoxide in the building.

Recommendation #13: Fire departments should ensure that when Rapid Intervention Teams (RIT) are moved into operational roles, they are replaced with another functional Rapid Intervention Team.

Discussion: Although there is no evidence that this recommendation would have prevented this fatality, it is being provided as a reminder of a good safety practice. During this incident, the fire department followed established procedures in dispatching a third engine company to serve as the Rapid Intervention Team. While enroute, the Fire Communication Bureau radioed Engine 13 to advise them of their assignment and Engine 13 acknowledged that they were the RIT. Upon arrival, Engine 13 assumed the RIT function. These actions are necessary to ensure that a team of fire fighters is on location to support incident operations as required by the OSHA 2-in 2-out rule in the Respiratory Protection Standard[14] and in NFPA 1500 *Fire Department Occupational Safety and Health Program, Chapter 8.8 Rapid Intervention for Rescue of Members*.[6] The timely dispatch of sufficient resources to provide for a dedicated RIT as part of the first alarm assignment is critical given that empirical evidence suggests that a significant percentage of fireground-related emergencies occur within the first 20-minutes after fire fighters arrive at a working fire.

After the fire was placed under control and standby resources were released to go back into service, the RIT was given an operational assignment to deploy an attack hoseline into the Delta exposure building and search for possible fire extension. At this point, there was no longer a functional RIT in place. It is equally important for the incident commander to replace a RIT team that has been deployed to another function.

Recommendation #14: Fire departments should ensure that the proper personal protective equipment meeting the applicable requirements of the National Fire Protection Association (NFPA) is used at all times.

Discussion: Although there is no evidence that this recommendation would have prevented this fatality, it is being provided as a reminder of a good safety practice. NFPA 1561, *Standard on Emergency Services Incident Management System*, Chapter 5.9.6 defines the role and responsibility of the Safety Officer within the structure of command. Chapter 5.9.6.5 states that the safety officer and assistant safety officer(s) shall be specifically identifiable on the incident scene. Annex A, section A.5.9.6.5 states that this can be accomplished by wearing a highly visible vest, helmet, or other indicator. A specific color or design is not identified.[5]

The publication *Fire Department Incident Safety Officer* by David W. Dodson notes that while no standard exists for the safety officer's visibility requirements, most people associate the color green with safety. The National Safety Council uses a green cross as their symbol and the Fire Department Safety Officer's Association uses a green Maltese cross as its symbol. This publication states that the incident safety officer should wear a high-visibility vest that clearly states "SAFETY". Upon seeing the safety vest, fire-fighting crews often stop an unsafe action or withdraw from an unsafe position. This self-correction is desirable on-scene; the ISO can then concentrate on other items of concern. To maximize this trigger, the SAFETY vest should be instantly recognizable from a distance.[15]

In this incident, the shift safety officer `responded on the working fire dispatch per fire department procedures. The shift safety officer wore an orange fire helmet that had a blue shield marked "Safety Officer" and blue colored reflective tetrahedrons around the crown of the helmet. The helmet was also labeled "SO2" on the back. He did not wear any type of reflective vest.

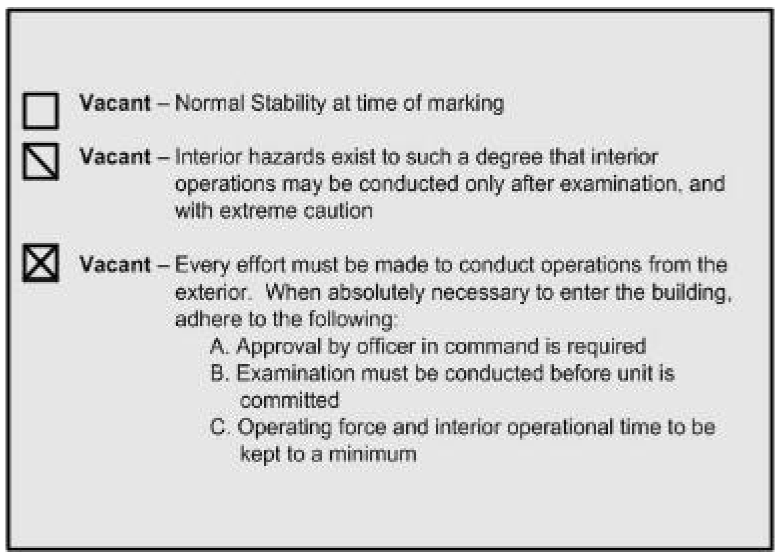
It should also be noted that the blue colored tetrahedrons around the crown of the fire helmet worn by the shift safety officer did not meet the helmet visibility marking requirements of NFPA 1971 Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting (2013 edition). NFPA 1971, Section 7.5.9 states that helmet visibility markings shall be tested for retroreflectivity and fluorescence as specified in Section 8.45….and shall have the color be fluorescent yellow-green, fluorescent orange-red, or fluorescent red.[2]

Recommendation #15: Fire departments and city building departments should work together to identify and mark buildings that present hazards to fire fighters and the public.

Discussion: Abandoned buildings can and do pose numerous hazards to fire fighters' health and safety as well as the general public.[23] Hazards should be identified and warning placards affixed to entrance doorways or other openings to warn fire fighters of the potential dangers. Such hazards can be structural as the result of building deterioration or damage from previous fires. Gutted interiors also increase the amount of exposed flammable materials and contain open pathways for rapid flame spread. Structural hazards can occur when building owners or salvage workers remove components of the building such as supporting walls, doors, railings, windows, electric wiring, utility pipes, etc.

Abandoned materials such as wood, paper, and flammable or hazardous substances, as well as collapse hazards, constitute additional dangers fire fighters may encounter. Collapse hazards can include chimney tops, parapet walls, slate and tile roof shingles, metal and wood fire escapes, HVAC or other mechanical equipment, solar electrical collectors and cells, advertising signs, and entrance canopies. A warning placard may be a 12-inch-square piece of metal painted reflective yellow so that it reflects light in the dark and indicates to fire fighters that hazards exist inside the building. Figure 1 illustrates symbols used on warning placards developed and used by the New York City Fire Department (FDNY).[24] *Note: The checkbox with one slash indicates the building is vacant and there are interior hazards that fire fighters need to be aware of. The checkbox with an X in it indicates the building is seriously compromised and fire fighters should not enter, but rather initiate an exterior attack.*

Fire departments should work with city and local authorities to develop and implement a strategy to identify, mark, secure, and where possible demolish unsafe structures within their jurisdictions. The IAAI / USFA Abandoned Building Project, conducted by the International Association of Arson Investigators and the US Fire Administration, is one example of a program that can be utilized to aid and assist fire fighter safety and health by identifying, marking, and removing unsafe structures.[23] (this link can also be accessed at the following URL: http://www.interfire.org/features/AbandonedBuildingProjectToolBox.asp



Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201424.pdf#page=46.

Figure 1. Warning placard used by FDNY to identify hazards in vacant buildings. The placard has three categories. The first one is Vacant with an unchecked box – Normal Stability at time of marking. The next is Vacnt with half of an ‘x’. – Interior hazards exist to such a degree that interior operations may be conducted only after examination, and with extreme caution. Last category has a full ‘X’ next to Vacant – Every effort must be made to conduct operations from the exterior. When absolutely nexessaety to enter the building, adhere to the following:

A. **Approval by officer in command is required.**
B. **Examination must be conducted before unit is committed**
C. **Operating force and interior operational time to be kept to a minimum.**

The toolbox contains the Abandoned Building Project report *Managing Vacant and Abandoned Properties in Your Community* and other reference materials. This report includes recommendations on how fire departments can work with governmental authorities to reduce the public safety hazard created by unsafe and abandoned buildings. A number of locations across the country have developed laws and regulations that address the public safety hazards created by vacant and abandoned buildings. Examples are the *Commonwealth of Massachusetts, Abandoned or Dangerous Building Regulations 780 CMR and 527 CMR*[25] and the City of Cincinnati Vacated Building Maintenance License.[26] The NFPA 1 *Fire Code, Annex Q Fire Fighter Safety Building Marking System* makes direct reference to the potential resolution to identifying hazardous structures and contents through building marking programs.[27]

This incident occurred in a city block containing a mixture of both inhabited and vacant row houses. Some of the vacant row houses had been abandoned and were in various states of disrepair. The row house where the shift safety officer was found had a large opening in the floor at the rear of the first floor. Some time prior to this event, a large portion of the floor at the rear of the building had been removed. If this hazard had been identified by a building marking program, a different outcome might have occurred.

References

1. Wikipedia [2015]. Row House. http://en.wikipedia.org/wiki/Terraced_house. Date accessed: March 6, 2015. (This link is also accessible at the following URL: https://en.wikipedia.org/wiki/Terraced_house)
2. NFPA [2013]. *NFPA 1971 Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting,* 2013 ed. Quincy, MA: National Fire Protection Association.
3. Weather Underground [2014]. Weather conditions for November 12, 2014. http://www.wunderground.com/history/airport/KBWI/2014/11/12/DailyHistory.html?req_city= NA&req_state=NA&req_statename=NA . Date accessed: December 16, 2014. (This link is also accessible at the following URL: https://www.wunderground.com/history/airport/KBWI/2014/11/12/DailyHistory.html?req_city=NA&req_state=NA&req_statename=NA)
4. Merriam-Webster [2014]. Merriam-Webster online dictionary: weather inversion. http://www.merriam-webster.com/dictionary/temperature%20inversion . Date accessed: December 16, 2014. (This link is also accessible at the following URL: https://www.merriam-webster.com/dictionary/temperature%20inversion)
5. NFPA [2013]. *NFPA 1561 Standard on Emergency Services Incident Management System*, 2013 ed. Quincy, MA: National Fire Protection Association.
6. NFPA [2013]. *NFPA 1500 Standard on Fire Department Occupational Safety and Health Program,* 2013 ed. Quincy, MA: National Fire Protection Association.
7. IFSTA [2008]. Essentials of firefighting, 5th ed. Oklahoma State University. Stillwater, OK: Fire Protection Publications, International Fire Service Training Association.
8. Brennan, C. [2009]. Fire Service Warrior: Situational awareness. November 3, 2009. http://thefireservicewarrior.blogspot.com/2009/11/situational-awareness.html . Date accessed, April 2015. (This URL is accessible at the following URL: http://thefireservicewarrior.blogspot.com/2009/11/situational-awareness.html)
9. Gasaway, R.B. [2013]. Situational Awareness for Emergency Response. Tulsa, OK: PennWell.
10. IAFC [2012]. Rules of engagement for structural firefighting. Fairfax VA: International Association of Fire Chiefs, Safety, Health and Survival Section. http://websites.firecompanies.com/iafcsafety/files/2013/10/Rules_of_Engagement_short_v10_2 .12.pdf]. Date accessed: March 2015.
11. National Fallen Firefighters Foundations [2004]. 16 Life Safety Initiatives. http://www.everyonegoeshome.com/16-initiatives/4-empowerment/ . Date accessed: April 2015. (This URL is accessible at the following URL: https://www.everyonegoeshome.com/16-initiatives/4-empowerment/)
12. NFPA [2013]. *NFPA 1982 Standard on Personal Alert Safety Systems*, 2013 ed. Quincy, MA: National Fire Protection Association.
13. Ciarrocca M & Harms T [2011]. Help on the scene. FireRescue Magazine. February 2011, vol 29, issue 2. Pp 40-48.

14. OSHA [1998]. 29 CFR Parts 1910 and 1926 Respiratory Protection; Final Rule. Federal Register Notice 1218-AA05. Vol. 63, No. 5. January 8, 1998. U.S. Department of Labor, Occupational Safety and Health Administration. Washington DC.
15. Dodson D. [2007]. Fire Department Incident Safety Officer, 2nd Edition. Clifton Park, NY. Thomson Delmar Learning.
16. IAFF. IAFF Fire Ground Survival Program. Washington, DC: International Association of Fire Fighters [http://www.iaff.org/HS/FGS/FGSIndex.htm]. Date accessed: April 2014.
17. Clark, BA [2005]. 500 Maydays called in rookie school. Firehouse.com. http://www.firehouse.com/topic/strategy-and-tactics/500-maydays-called-rookie-school . Date accessed: July 2015. (This URL is accessible at the following URL: http://www.firehouse.com/article/10498807/firefighter-mayday-training-500-maydays-called-in-rookie-school)
18. Grossman D, Christensen L [2008)]. On combat: the psychology and physiology of deadly conflict in war and peace, 3rd ed. Millstadt, IL: Warrior Science Publications.
19. NFPA [2013]. NFPA 1001 standard for fire fighter professional qualifications. 2013 ed. Quincy, MA: National Fire Protection Association.
20. Clark BA [2008]. Leadership on the line: Firefighter Mayday doctrine where are we now? Firehouse.com. http://www.firehouse.com/podcast/leadership-line/leadership-line-firefightermayday-doctrine-where-are-we-now. Date accessed: July 2, 2015. (This link is also accessible at the following URL: http://www.firehouse.com/podcast/10459336/leadership-on-the-line-firefighter-mayday-doctrine-where-are-we-now).
21. U.S. Fire Administration [2006]. Mayday CD Q133 Firefighter safety: calling the Mayday and H134 Calling the Mayday: hands on training. Emmitsburg, MD: U.S. Department of Homeland Security, U.S. Fire Administration, National Fire Academy.
22. NFFF [2014]. Vulnerability Assessment Program. National Fallen Firefighters Foundations. https://www.firevap.org/system/overview . Date accessed: July 2, 2015. (This link is also accessible at the following URL: https://www.firevap.org/system/overview)
23. IAAI / USFA [2006]. Abandoned Buildings Project: Managing Vacant and Abandoned Properties in your Community. 2006 revision. International Association of Arson Investigators / U.S. Fire Administration joint report. http://www.interfire.org/features/pdfs/Background%20Paper_2006.pdf . Date accessed: July 2, 2015. (This URL is also accessible at the following URL: http://www.interfire.org/features/pdfs/Background%20Paper_2006.pdf)
24. NIOSH [2010]. *NIOSH ALERT: Preventing Deaths and Injuries of Fire Fighters using Risk Management Principles at Structure Fires*. July 2010. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH), Publication No. 2010-153. http://www.cdc.gov/niosh/docs/2010-153/ . (This link is also accessible at the following URL: http://www.cdc.gov/niosh/docs/2010-153/).

25. Commonwealth of Massachusetts [2008]. Abandoned or Dangerous Building Regulations 780 CMR and 527 CMR. Commonwealth of Massachusetts, Executive Office of Public Safety and Security. Memorandum to all Heads of Fire Departments. February 1, 2008. http://www.mass.gov/eopss/agencies/dfs/dfs2/osfm/fire-prev/advisories/2000/abandonedbuildings-regulations.html Date accessed: July 2, 2015.
26. City of Cincinnati [2006]. Vacant Building Maintenance License Ordinance. Cincinnati Municipal Code 1101-77. March 2006. http://www.cincinnati-oh.gov/communitydevelopment/linkservid/2B9F59F3-CC02-4520-ACF7D7A0042FF04E/showMeta/0/ Date accessed: July 2, 2015.
27. NFPA [2009]. NFPA 1 Fire Code. 2015 ed. Quincy, MA: National Fire Protection Association.

Investigator Information

This incident was investigated by Timothy R. Merinar, Safety Engineer and Murrey Loflin, Investigator, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, WV. An expert technical review was provided Matthew Tobia, Assistant Chief, Loudoun County Virginia Combined Fire Rescue System and David W. Dodson, Response Solutions, LLC. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Additional Information

Maryland Fire and Rescue Institute

The Maryland Fire and Rescue Institute (MFRI) of the University of Maryland is the State's comprehensive training and education system for emergency services. The Institute plans, researches, develop, and delivers quality programs to enhance the ability of emergency services providers to protect life, the environment, and property. MFRI is the State's fire and emergency service training agency. The Institute has more than 80 years of experience in providing training to protect the citizens of Maryland. Over four hundred certified instructors serving as part-time faculty support more than fifty full-time faculty and staff members. MFRI programs rely on the knowledge and resources of the University of' Maryland system to obtain service and assistance to serve you. The University of Maryland is a not-for-profit governmental agency of the State of Maryland. (This link is also accessible at the following URL: http://www.mfri.org).

IAFC Rules of Engagement for Firefighter Survival

The International Association of Fire Chiefs (IAFC) is committed to reducing fire fighter fatalities and injuries. As part of that effort, the nearly 1,000 – member Safety, Health and Survival Section of the IAFC has developed DRAFT “Rules of Engagement for Structural Firefighting” to provide guidance to individual fire fighters and incident commanders, regarding risk and safety issues when operating on the fireground. The intent is to provide a set of model

procedures for structural firefighting to be made available by the IAFC to fire departments as a guide for developing their own standard operating procedure.
http://www.iafcsafety.org/downloads/Rules_of_Engagement

IAFF Fireground Survival Program.

The purpose of the Fire Ground Survival program is to ensure that training for Mayday prevention and Mayday operations are consistent between all fire fighters, company officers and chief officers. Fire fighters must be trained to perform potentially life-saving actions if they become lost, disoriented, injured, low on air or trapped. Funded by the IAFF and assisted by a grant from the U.S. Department of Homeland Security (DHS) through the Assistance to Firefighters (FIRE Act) grant program, this comprehensive Fire Ground Survival training program applies the lessons learned from fire fighter fatality investigations conducted by the National Institute for Occupational Safety and Health (NIOSH) and has been developed by a committee of subject matter experts from the IAFF, the International Association of Fire Chiefs (IAFC) and NIOSH.
(This link is also accessible at the following URL: http://www.iaff.org/HS/FGS/FGSIndex.htm).

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). In addition, citations to Web sites 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 Web sites.

Appendix One

Personal Protective Equipment Evaluation

Summary and Conclusions

Radio Evaluation Summary

The radio evaluation was conducted on January 6, 2015. As part of the evaluation process, the radio was first evaluated at one of the fire department's stations and then transferred to the manufacturer's testing facility for additional evaluation and testing. This evaluation consisted of testing the radio for proper programing and operation to determine if there were any faults in its operation that may have contributed to the fatality.

During this process, the radio operated properly. There weren't any faults or programming issues noted during the inspection and evaluation that would have contributed to the fire fighter fatality.

Note: Prior to the NPPTL radio evaluation, the fire department evaluated the radio's performance by operating the radio from within the Delta exposure basement on December 11, 2014 during the NIST pressure and ventilation testing. Fire department personnel radioed the Fire Communication Bureau and received acknowledgement. At that time, the radio performed as expected.

Helmet Evaluation Summary

The helmet worn by the shift safety officer was less than one year old and in very good condition. NIOSH investigators observed a scuff mark and stress crack in the helmet's outer shell to the left of the helmet emblem. A quantity of what appeared to be dried blood was observed on the outer shell. The scuff mark and stress crack in the helmet suggest a glancing impact from the fall. The disposition of the suspension system is consistent with a directional force suffered during the fall. The interior impact cap showed no signs of damage from a direct or glancing impact. See Photo 6 and Appendix One for more information.

The helmet involved in this incident, while structurally identical to the NFPA version of the helmet, only met the requirements of OSHA US-OSHA Standard 29 CFR 1910.156. This helmet did not meet the minimum visibility and color requirements specified in the National Fire Protection Association (NFPA) 1971 *Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting* (2013 Edition).[2]

To meet the NFPA visibility requirements, the helmet visibility markings must be both retro-reflective and fluorescent (Section 6.5.3). The approved colors are fluorescent lime-yellow, fluorescent redorange and fluorescent red (Section 7.5.9). The tetrahedrons on the helmet involved in this incident were blue and thus did not meet the color requirements of NFPA Section 7.5.9. To meet the eye and face protection requirements of NFPA 1971 the helmet must be equipped with either goggles or a faceshield. This helmet was equipped with flip down eye shields that do not meet the requirements for NFPA Section 6.4.5. The helmet did not contain an NFPA approval label.

There are many factors that are needed to calculate an accurate force generated during a fall from a certain height. In this case we must estimate the circumstances involving the speed, deceleration, impact of the body, and their relation to the incident.

***Estimated Height of First Floor from Basement Floor* -** 7 Feet (see Photo 4)
***Estimated Height of Fire Fighter*-** 6 Feet
***Estimated Weight of Shift Safety Officer* -** 230 pounds
***Estimated Stopping Distance (deceleration)* -** ½ foot (0.5)
***Estimated Force from Fall*-** In excess of 6,200 pounds

Based on the inspection, the protective helmet performed as intended for the event and it is not believed to have contributed to the fatality of this incident.

The complete NPPTL evaluation reports covering the radio and helmet are available upon request

Handout 1-1 Group 3:

Lieutenant and Fire Fighter Die and 13 Fire Fighters injured in a Wind-driven Fire in a Brownstone — Massachusetts

2014 09 **Death in the line of duty...** NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *March 2, 2016*

Lieutenant and Fire Fighter Die and 13 Fire Fighters injured in a Wind-driven Fire in a Brownstone - Massachusetts

Executive Summary

On March 26, 2014, a 43-year-old male career fire lieutenant and a 33-year-old fire fighter died during fire-fighting operations in an occupied multifamily residential structure (brownstone). Engine 33 was the first-due engine company assigned to Box 1579. Engine 33 arrived on scene and reported: “We have a four-story with smoke showing from the first floor. Engine 33 is stretching a 1¾-inch hoseline in the front doorway.” The lieutenant and the fire fighter stretched the 1¾-inch hoseline up the front steps (uncharged), through the front door, and into the front hallway. When the lieutenant was informed the fire and a possible victim were in the basement, Engine 33 took the hoseline down the steps. The Engine 33 pump operator charged the line, but the line lost its water due to the rapidly deteriorating fire conditions which compromised the hose. Engine 7 arrived on scene and stretched a 2 ½-inch hoseline as a back-up line to Engine 33. Engine 7 stretched their line in the front door following Engine 33’s hoseline. Engine 22 was on-scene and was preparing to stretch a hoseline into the basement apartment underneath the front steps. The crew from Engine 7 was moving their hoseline towards the stairwell leading to the basement, when conditions changed drastically. Fire and heat came up the steps from the basement.

A view of fireground worker leaving the rear door of the attached shed open while investigating the smoke detector activation. The conditions became untenable for the fire fighters from Engine 7. They moved out of the building to the landing of the front steps. Also, the interior door at the top of the basement stairs was open, the front exterior doors were left open by an occupant fleeing the fire, and a rear basement door or window failed. Once the rear door or window burned through, this created an unrestricted flow path from the basement to the first floor plus the floors above, thereby triggering a rapid progression of fire conditions. This trapped the officer and fire fighter from Engine 33 in the basement. The fire, heat, and smoke through the basement and first floor created untenable conditions on both floors. Due to the intense heat and fire conditions, the 1¾-inch attack hose burned through. Command then ordered the building to be evacuated. Approximately 1 minute later, the Engine 33 lieutenant called Command and said they were running out of water. The dispatcher replied, "OK Engine 33, we are going to get you water." Command immediately called a second alarm for Box 1579. Several companies tried to make entry into Side Alpha from both the basement and the first floor of the structure, but were pushed back by heavy fire and smoke. Crews pushed through the Side Bravo exposure to initiate fire attack on Side Charlie. Crews took a 2½-inch hoseline into the basement apartment on Side Charlie. Approximately 15 minutes later, crews located the fire fighter from Engine 33 in the kitchen area of this apartment. The fire fighter was removed from the apartment and immediately taken to an ambulance for transport to the hospital. The fire fighter from Engine 33 was pronounced dead at the hospital. After the fire fighter was removed, conditions changed and the structure became fully involved. Crews were removed from the structure and the strategy was changed to defensive operations. Once the fire was completely knocked down and conditions allowed fire fighters to safely re-enter the structure, a search was made for the lieutenant of Engine 33. The lieutenant was found at the bottom of the stairs near the entrance to Apartment #10 in the basement. The lieutenant was pronounced dead at the scene.

Contributing Factors

- *Delayed notification to the fire department*
- *Uncontrolled ventilation by a civilian*
- *Occupied residential building with immediate life safety concerns*
- *Staffing*
- *Scene size-up*
- *Lack of fire hydrants on Side Charlie (a private street)*
- *Lack of training regarding wind-driven fires*
- *Unrestricted flow path of the fire*
- *Lack of fire sprinkler system*

Key Recommendations

Fire departments should define fireground strategy and tactics for an occupancy that are based upon the organization's standard operating procedures. As part of the incident action plan, the incident commander should ensure a detailed scene size-up and risk assessment occurs during initial fireground operations, including the deployment of resources to Side Charlie. Scene size-up and risk assessment should occur throughout the incident.

2014 09

Death in the line of duty... NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

March 2, 2016

Lieutenant and Fire fighter Die and 13 Fire Fighters injured in a Wind Driven Fire in a Brownstone - Massachusetts

Introduction

On March 26, 2014, a 43-year-old career fire lieutenant and a 33-year-old fire fighter died during firefighting operations in a multifamily residential structure (brownstone). On April 4, 2014, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On April 8, an investigator and safety engineer from the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) traveled to Massachusetts to meet with the fire commissioner, senior staff, International Association of Fire Fighters (IAFF), and the IAFF local president to develop a plan for the investigation process. On April 10, 2014, a general engineer and two occupational health and safety specialists traveled to Massachusetts to join the investigator to begin the investigation process. During this segment of the investigation, the NIOSH Fire Fighter Fatality Investigation Team met with the fire commissioner, the chief of operations, a safety chief, the president of the IAFF local, superintendent of the Fire Alarm Office, and the county's assistant district attorney assigned to this incident. The Fire Fighter Fatality Investigation Team inspected and photographed the turnout gear and self-contained breathing apparatus (SCBA) from the lieutenant and fire fighter. The team departed on April 16, 2014.

On May 3, 2014, the same members of the NIOSH Fire Fighter Fatality Investigation Team returned to Massachusetts to complete the field investigation. Two subject matter experts joined the NIOSH Fire Fighter Fatality Investigation Team during this segment of the investigation. The Fire Fighter Fatality Investigation Team toured the incident scene, photographed the interior and exterior of the structure, and interviewed investigators with the fire investigation unit and members of the fire training division. The NIOSH Fire Fighter Fatality Investigation Team conducted interviews with fire department officers and fire fighters who operated at Box 1579 on March 26, the superintendent of the fire alarm office, the superintendent of the fire department's fleet division, and members of the city's Inspectional Services Department (Building Officials Office). A closing meeting was held on May 9, 2014, with the fire commissioner and senior staff, the president and members of the IAFF local, the subject matter experts, and the NIOSH Fire Fighter Fatality Investigation Team.

Fire Department

This career fire department has 35 stations with 1,606 members of which 1,467 are uniformed members. The department protects a population of approximately 646,000 within an area of about 48 square miles.

The fire department consists of the following members:

1 fire commissioner and chief of department
2 chiefs of operations
2 deputy fire commissioners
14 deputy chiefs
51 district chiefs (battalion chiefs)
1 fire alarm superintendent
1 assistant fire alarm superintendent
75 captains
219 lieutenants
1,092 firefighters
92 civilian personnel
56 fire alarm personnel

The rank structure for the fire department is as follows: fire commissioner/chief of the department, chief of operations, deputy fire commissioner, deputy chief, district chief, captain, lieutenant, senior fire fighter, fire fighter, and probationary fire fighter.

The fire department consists of nine divisions: Fire Suppression; Fire Prevention; Training; Special Operations; Office of Field Services; Information Technology; Personnel; Safety, Health, and Wellness; Fire Alarm Office.

Fire Suppression: The services provided include fire-fighting, medical evaluation, vehicle extrication, hazardous material response, confined space rescue, structural collapse rescue, trench collapse rescue, and more. The department operates engine companies, ladder companies, and rescue companies, each providing distinctly separate services at a fire or other emergency.

The fire department operates 33 engine companies, 20 ladder companies, 2 tower ladder companies, 2 heavy rescue companies, 9 district chiefs (battalion chiefs) (Car 1, Car 3, Car 4, Car 6, Car 7, Car 8, Car 9, Car 11, Car 12), 2 deputy chiefs (C6 [Division 1] and C7 [Division 2]), 1 marine unit, 1 fire brigade, 2 tunnel/confined space units, 2 brush units, 1 hazardous materials unit, 1 mobile air supply unit, 1 rehab unit, 1 mobile command unit, 1 mobile decontamination unit, and 1 hydrant thawing unit.
The district chief and deputy chiefs are each staffed with an incident command technician (ICT). Division 1 has District 1, District 3, District 4, District 6, and District 11. Division 2 has District 7, District 8, District 9, and District 12.

All fire stations are under the supervision of a captain (station captain) and are divided into four working groups (shifts). Three of the four working groups are under the supervision of a lieutenant.

All companies are staffed with a minimum of one officer and three fire fighters per shift. The riding assignments for each engine company, ladder company, and rescue company are as follows:

Engine Company

Engine xx Officer	(Right front seat)
Engine xx Pump	(Left front seat)
Engine xx Pipe	(Right rear seat)
Engine xx Hydrant	(Left rear seat)
Engine xx Loop	(Rear seat, as staffing allows)

Ladder Company

Ladder xx Officer	(Right front seat)	
Ladder xx Open-up Man	(Left rear seat)	(Halligan and Maul)
Ladder xx Rake	(Right rear seat)	
Ladder xx Chauffeur/Roof man	(Left front seat)	
Ladder xx Vent	(Rear seat, as staffing allows)	

Rescue Company

Rescue x Officer	(Right front seat)
Rescue x Chauffeur, Alpha	(Left front seat)
Rescue x Bravo	(Right rear seat)
Rescue x Charlie	(Rear middle seat)
Rescue x Delta	(Left rear seat)

Members assigned to the Fire Suppression Division work a 24-hour shift (0800–0800), followed by 48 hours off, then 24 hours on duty, and followed by 96 hours off.

In 2014, the fire department responded to 75,176 emergency incidents. The fire department responded to:

5,704 fire incidents
33,624 rescue/EMS incidents
3,303 hazardous incidents—no fire
11,001 service calls
7,122 good intent calls
14,139 false alarms and false calls
283 miscellaneous calls

Fire Prevention: This division is responsible for maintaining records, granting permits, conducting public education, inspecting buildings, and conducting fire investigations. The Fire Marshal's Office consists of the following:

3 fire protection engineers
1 plans reviewer (engineer)
1 chemist
45 uniformed fire inspectors
20 civilian personnel
25 uniformed fire investigators (Fire Investigation Unit)

Training: This division provides recruit training, company in-service training, live fire training, and professional development for all members of the department. Also, the division conducts research to improve techniques and equipment, evaluating new tools before their implementation. The Emergency Medical Services and the Safety Operations Unit are also within this division.

Special Operations: The Special Operations Division of the fire department is tasked with duties concerning hazardous materials, technical rescue, and marine operations. These duties include developing and delivering training and creating operational plans and standard operating procedures for the three functions with Special Operations.

Office of Field Services: The department's Office of Field Services provides for the planning and logistical needs for the fire department. This includes acting as a liaison with outside agencies, monitoring the hazardous building list, coordinating the local emergency planning committee (LEPC), managing special projects, and planning for special events.

Information Technology: This division supports staff within the fire department operations (e.g., computer-aided dispatch), operational support (e.g., training and fire prevention records), and administrative support (e.g., payroll and personnel). The Information Technology Division reports to a chief of operations.

Personnel: This division includes the Administration Section, Selection Unit, Medical Office, Personnel Assignments of Officer's Section, and the Employees Assistant Program. The division keeps the records of each fire fighter; communicates with other departments, unions, and agencies; and hears grievances, disciplinary hearings, and appeals.

Safety, Health, and Wellness: The functions of this division, established in 2014, are to monitor and research current safety procedures and policies and to promote solutions when problems are discovered. The overall goal is the reduction of fire fighter injuries and illnesses on the fireground and in training and chronic occupational health issues. The Safety, Health, and Wellness Division is also tasked with writing and revising the department's standard operating procedures. This is to promote greater safety and fireground effectiveness, injury and illness prevention, and improvements in training practices and fireground operations. This division also investigates department injuries and motor vehicle accidents.

Fire Alarm Office: The Fire Alarm Office (FAO) serves as the dispatch center and base of communications for the department. The FAO enters all calls for service from any source into the computer-aided dispatch system to initiate the proper response, deploy resources, and expedite all alarms in accordance with standard operating procedures. The FAO also reads, adjusts, and maintains fire alarm circuits and recorders. Also, FAO staff repairs and adjusts equipment in the dispatch center as needed. All FAO operators are versed in the department's fireground standard operating procedure with a special emphasis on fireground safety.

Training and Experience

The Commonwealth of Massachusetts has no mandatory minimum requirements to become a fire fighter. For cities and towns that have adopted the Commonwealth of Massachusetts civil service system, a candidate must pass the state's fire fighter civil service written examination and successfully complete the Candidate Physical Ability Test. The Commonwealth of Massachusetts Civil Service Commission administers the fire fighter written examination and physical agility exam for the municipality. The applicants are ranked and then given to the city's human resources division. The municipality conducts the following:

- Background check
- Drug screen
- Medical examination, which meets the requirements of NFPA 1582 *Standard on Comprehensive Occupational Medical Program for Fire Departments* (1997 edition) [NFPA 1997]
- Physiological exam
- City residency requirements check

Once a candidate is hired by this fire department, the candidate is required to attend a 20-week recruit school at the department's training academy. Five weeks of the academy training consists of the National Registry of Emergency Medical Technician—Emergency Medical Technician course. Upon completion of the recruit school, the recruit fire fighter will have completed more than 745 hours of instruction and will be certified (ProBoard Certification) per NFPA 1001 *Standard for Fire Fighter Professional Qualifications* [NFPA 2013c] to the level of Fire Fighter I and Fire Fighter II and per NFPA 472 *Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents* [NFPA 2013b] to the level of Hazardous Materials—Awareness Responder and Operational Responder. The recruit fire fighter becomes a probationary fire fighter and then completes a probationary period of 32 weeks. Upon the successful completion of the probationary period, the individual becomes a fire fighter.

The officer of Engine 33 was hired by the department on December 8, 2004. He completed recruit school in April 2005 and was assigned to Ladder 15 as a probationary fire fighter. He successfully completed his probation and was assigned as a fire fighter to Ladder 15. He was promoted to lieutenant on April 3, 2012. His current assignment was a lieutenant on Engine 33. His qualifications included NFPA 1001, Fire Fighter I and II; Hazardous Materials Awareness level and Operations level per NFPA 472; Massachusetts EMT/Basic; and a ProBoard-certified Hazardous Materials Technician per NFPA 472. Other training included Radio Communications; Driver/Operator Training; Mayday procedures; EMS continuing education units; hazardous materials refresher training and certifications; weekly in-service training on standard operating procedures and EMS protocols pursuant to department General Orders; and the fire department fire college.

The fire fighter from Engine 33 was hired by the department on November 5, 2007. He completed recruit school in March 2008 and was assigned to Ladder 2 as a probationary fire fighter. He successfully completed his probation and was assigned as a fire fighter to Ladder 2. His current assignment was as a fire fighter to Ladder 15. He was detailed to Engine 33 on March 26, 2014. His qualifications included NFPA 1001, Fire Fighter I and II—ProBoard certification; Hazardous Materials Awareness level and Operations level per NFPA 472—ProBoard certification; and Massachusetts EMT/Basic. Other training included IAFF Emergency Response to Terrorism Course—Operations; Hazardous Materials Training—CBRNE, Response to Radiological Incidents; Air/Gas Monitoring, Chlorine Training, and Highway Tanker Emergencies; and EMS continuing education units.

Equipment and Personnel

All 9-1-1 calls are answered by the city's police dispatch center. If the 9-1-1 call is for a fire or a medical emergency, the call is then routed to the fire department's Fire Alarm Office (FAO). In the event of a structure fire, the FAO assigns the appropriate number and type of companies to the incident. All incidents are assigned a box number based upon the location of street boxes, which are also used as a method of transmitting alarms to the FAO. The fire department communicated information from an incident to the Fire Alarm Office by a street box, which was done primarily before the radio system came into existence. The fire department still has telegraph alarm boxes located on street corners throughout the city and in various businesses and occupancies.

Types of Alarms for Structure Fires

Still Alarm. Usually any emergency call received by telephone at the Fire Alarm Office or verbal notification by a citizen at a fire station. Under certain conditions the FAO may treat a box alarm as a still alarm.

Still Alarm Assignment:

1 engine, 1 ladder

Box Alarm

First Alarm Assignment: 4 engines (1 engine for rapid intervention team [RIT]), 2 ladders, 1 rescue, 1 district chief

Downtown First Alarm Assignment: 4 engines (1 for RIT), 2 ladders, 1 tower ladder, 1 rescue, 1 district chief, and 1 division chief

High-rise Fire Response First Alarm Assignment: 4 engines (1 for RIT), 2 ladders, 1 rescue, 3 district chiefs (1 for operations, 1 for evacuation, 1 for accountability), 1 division chief, safety chief, air supply unit

Full Box Alarm/Confirmed Fire with RIT and Rehab Assignment: 1 ladder (RIT), 1 tower ladder, 1 district chief (RIT), safety chief, rehab unit

Second Alarm

Second Alarm Assignment: an additional 3 engines, 1 ladder, 2 district chiefs (1 for accountability), 1 division chief, air supply unit, fire investigation unit, and 1 public information officer

Third Alarm

Third Alarm Assignment: an additional 2 engines, 1 ladder, special unit, and field/tactical communications unit

Fourth Alarm

Fourth Alarm Assignment: an additional 2 engines

Fifth Alarm

Fifth Alarm Assignment: an additional 2 engines and 1 ladder

Sixth Alarm

Sixth Alarm Assignment: an additional 2 engines

Seventh Alarm

Seventh Alarm Assignment: an additional 2 engines and 1 ladder

Eighth Alarm

Eighth Alarm Assignment: an additional 2 engines

Ninth Alarm

Ninth Alarm Assignment: an additional 2 engines

Total apparatus on scene: 21 engine companies, 7 ladder companies, 1 tower ladder, 1 heavy rescue company, 6 chiefs (1 deputy/5 district), 1 special unit, 1 rehabilitation unit, and 1 air supply unit.

Types of Alarms for Specific Incidents

Motor Vehicle Accident

Motor Vehicle Accident Assignment: 1 engine, 1 ladder

Motor Vehicle Accident (Pin or Entrapment)

Motor Vehicle Accident (Pin or Entrapment) Assignment: 1 engine, 1 ladder, 1 district chief, 1 rescue

Vehicle Fire

Vehicle Fire Assignment: 1 engine

EMS Response

EMS Response Assignment: 1 company only (either an engine, ladder, rescue, or tower ladder company)

HazMat Level 0

HazMat Level 0 Assignment: 1 engine, 1 ladder

HazMat Level 1 (Upgrade)

HazMat Level 1 Assignment: 1 district chief, special unit, 1 HazMat inspector, 1 engine (HazMat), 1 ladder (HazMat), safety chief (H1)

HazMat Level 2 (Upgrade)

HazMat Level 2 Assignment: 1 district chief, HazMat unit, fireground rehab/mass casualty unit, field/communication tactical unit, 1 police department environmental safety group unit

HazMat Level 3 (Upgrade)

HazMat Level 3 Assignment: 2 engines (decontamination), 1 division chief, 1 public information officer, 1 fire investigation unit, fire department photography unit

Fireground Communications

Department's Fire Alarm Office

The department operates a dispatch and communication center (Fire Alarm Office), which started operation on December 27, 1925. All fire alarm circuits, along with radio and telephone communications, are controlled from the Fire Alarm Office (FAO). The radio shop for the fire department is located at the FAO. Personnel designated to maintain the street boxes and circuits are assigned to the FAO.

All 9-1-1 calls are answered by the 9-1-1 police dispatcher. Requests for fire and EMS responses are routed to the FAO, which only dispatches fire department resources. The fire department still has telegraph alarm boxes located on street corners throughout the city and in various businesses and occupancies.

The department's communication system consists of ultra-high-frequency (UHF) radios: 5 channels

42 receiver sites

4 simulcast sites

5 portable radios assigned to each fire apparatus

312 high-rise sites in the city with repeater systems

The portable radios can be used (on the fireground) with the repeater or line of site; a computer automatically selects the appropriate mode of operation. The district chiefs and deputy chiefs have repeaters in their vehicles, which boost the signal from 5 watts to 100 watts.

The staffing for the FAO is 1 superintendent, 1 assistant superintendent, and 32 dispatchers. The FAO staffs each shift (4 shifts) with 7 dispatchers with a minimum staffing of 5 dispatchers. The dispatchers work a 24-hour shift (0800–0800), followed by 48 hours off, then 24 hours on duty, and followed by 96 hours off. Each shift works with the same operational staff as members of the Fire Suppression Division, so dispatchers are familiar with the shift's deputy chiefs and district chiefs.

The FAO dispatches an average of 250–275 incidents per day. Each incident is assigned a box number based upon the street boxes located throughout the city. When an incident occurs, a dispatcher is assigned to that incident and maintains communications on the dispatch and tactical channel(s) from the beginning of the incident until the incident is terminated. If the incident goes to a fifth alarm, an additional dispatcher is called back, plus the superintendent and assistant superintendent respond to the FAO.

Role of the Dispatcher during a Mayday

Dispatchers should be the voice of calm during a Mayday. This takes practice. Dispatchers should train in performing their responsibilities so when a Mayday is called, they react instinctively and without delay. A dispatch center/communications center supports fire fighter safety best when adequately staffed. In addition to the call taker and dispatcher, at least one other dispatcher should monitor the fire ground tactical channel during working incidents. In some cases, units on the fire ground *DID NOT* hear the Mayday, but dispatchers and fire department resources did. In order to ensure fire fighter survivability, the tactical channel should be monitored at all times during working incidents.
Dispatchers should also be authorized to immediately contact Command upon hearing any Mayday or emergency traffic communications. This confirms that Command has heard the message and is taking action. The same applies if the dispatcher received an emergency activation from a fire fighter's portable radio. Command should be notified and take action to confirm whether the message is an emergency or an accidental activation.

If the fire department's radios are equipped with channels from other fire departments, the dispatcher should immediately advise these departments of the Mayday situation. Fire fighters have accidentally selected the wrong frequency, and contacted another fire department on their radio. These agencies should be advised that if they hear communications from the distressed fire fighter. This agency's dispatch center should maintain contact with them. *DO NOT* change frequencies. The other agency should immediately advise the department's dispatcher of the contact, followed by a notification to Command. Command or other designated officer should go to that tactical channel and communicate directly with the distressed fire fighter. *DO NOT* ask the fire fighter to change channels. The fire fighter may not be able to do so, or even worse, end up on another channel [IAFF 2010].

The FAO plays an integral role in the department's daily fireground operations. The FAO had a positive impact on the Mayday operation at Box 1579 on March 26, 2014. Upon transmission of the Mayday, the FAO immediately confirmed that the incident commander was aware of the Mayday transmission. Also, FAO dispatchers transmitted the alert tome and ordered radio silence, confirmed the Mayday fire fighter's location, maintained contact with the Mayday fire fighter, assigned a tactical channel for non-RIT operations, confirmed additional alarms with Command, dispatched additional RIT resources, dispatched additional technical rescue resources, ordered advanced life support from the city's emergency medical services, and assisted in conducting a personnel accountability report with Command.

Timeline

This timeline is provided to set out, to the extent possible, the sequence of events according to recorded radio transmissions. Times are approximate and were obtained from review of the dispatch records, witness interviews, and other available information. NIOSH investigators have attempted to include the potential radio transmissions. This timeline is not intended, nor should it be used, as a formal record of events.

Incident and Fireground Communications	Time	Response and Fireground Operations
March 26, 2014		
9-1-1 call reported building filled with Smoke.	**1441 Hours**	
Alert tone announcement for the transmission of Box 1579 by Fire Alarm Office (FAO): "Engine 33, Engine 7, Engine 22, Ladder 24, Ladder 26, Rescue 1 [R01], and District 4 [Car 4] dispatched for structure fire for Box 1579; Channel 2 is the fireground channel."	**1442 Hours**	
For "smoke showing," FAO dispatched District 3 (Car 3), Engine 37, Tower Ladder 3 (TL3), and Ladder 18 as RIT. Also dispatched were H1 (safety officer) and W25 (mobile air unit).	**1445 Hours**	Engine 33 (E33) reported on scene and assumed command; Command advised smoke showing from the first floor. The E33 officer and E33 Pipeman (right jumpseat) stretched a 1¾-inch hoseline (uncharged) up the front steps and into the first floor.
	1446 Hours	Car 4 arrived on scene and assumed command for Box 1579. An unknown unit radioed that occupants were trapped on the fourth floor.
H1 (safety officer) enroute.	**1447 Hours**	Rescue 1 arrived on scene.

Incident and Fireground Communications	Time	Response and Fireground Operations
Per the orders of Command, transmit a second alarm for Box 1579.	1448 Hours	Car 3, E7, E22, E37, H1, L18, L24, L26, and TL3 arrived on scene. Command reported, "We have a four-story brick residential; the fire is in the basement; the occupants of the fourth floor have selfevacuated off the fire escape." E33's 1¾-inch hoseline is charged and going down the stairs to the basement. ***Note:*** *Due to a rapid progression of fire conditions, E33 hoseline is burned through and loses pressure. The officer of E33 is unaware this has occurred. The water never reaches the nozzle.* E7 backed up E33 with a 2½-inch hoseline into the first floor. Conditions rapidly change due to a rapid progression of fire conditions and E7 was forced out to the front stoop.
FAO transmitted Box 2-1579. Engine 4, Engine 17, Engine 10, Ladder 17, Rescue 2, C6 (Division 1 Deputy Chief), District 7 (Car 7)	14:49:09 Hours	
(Accountability), and District 9 (Car 9) are dispatched for Box 2-1579.	14:49:12 Hours	E33 officer called Engine 33 to have the hoseline charged.
	14:49:22 Hours	Command radioed FAO and advised, Hours "Emergency Traffic… everyone off the first floor, everyone off the first floor."
	14:49:31 Hours	FAO advised all companies operating at Box 2-1579 to "get out of the first floor."
	14:49:45	E33 declares a Mayday. "Mayday E33, Mayday E33."

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO radioed, “E33 has a Mayday on Fireground Channel 2 in the basement; E33 has a Mayday on Fireground Channel 2 in the basement. OK Car 4?”	**14:49:57 Hours**	
FAO transmitted again, “E33 has a Command to FAO, “I want all members out of the building, all members out of the building immediately.”	**1450 Hours**	Command acknowledged the message. Mayday on Fireground Channel 2 in the basement. OK Car 4?”
Command to FAO, “I want all members out of the building, all members out of the building immediately.”	**14:50:17 Hours**	
FAO transmitted this message on Channel 1, Fireground Channel 2, and Channel 3.	**14:50:26 Hours**	
	14:50:38 Hours	FAO transmitted on Fireground Channel 2 to E33 to charge the 1¾-inch hoseline going to the crew of E33 in the basement.
	14:50:43 Hours	Ladder 26 called FAO. “Tell Command, we need a line to the back [of the building – Side Charlie]; We have fire showing on the first floor. There is a shed attached to the basement level in the rear. Have companies come around to the street in the rear. The companies can attack the fire from Side Charlie.”
	1451 Hours	The officer of E33 asked for the line to be charged.

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO transmitted the following message on Channel 1, Fireground Channel 2, and Fireground Channel 3: “All companies operating at Box 1579, switch to Fireground Channel 3. Fireground Channel 2 is the Mayday Channel. All companies operating at Box 1579, use Fireground Channel 3. Fireground Channel 2 is the Mayday Channel.”	**14:51:07 Hours**	
	14:51:42 Hours	The officer of E33 radioed, “33, we need water now, charge 33’s pipe.”
Command to FAO, “Give me a third alarm. Have the second-alarm companies report to the rear.	**14:51:45 Hours**	
	14:52:02 Hours	E33 officer radioed FAO, “Both of us are trapped in the basement towards the front of the building. We got water, but the hoseline is burnt through. You have got to charge our line.”
FOA to Command, “E33 is trapped in the basement. They are trying to head to the front of the building. They need water.”	**14:52:34 Hours**	
	14:52:50 Hours	Command acknowledged the message.
	14:52:53 Hours	FAO to E33 officer, “They are trying to get you water.”
	14:52:59 Hours	The officer of E33 radioed, “We are on the stairway and it’s getting hot down here.”

Incident and Fireground Communications	Time	Response and Fireground Operations
	14:53:30 Hours	The chauffeur of E33 radioed, “I am running out of water, I am running out of water.” ***Note:*** *E33 was operating off water from the booster tank which 750 gallons. A supply line for E33 had not been established at this time.*
FAO to Command, “E33 is in the basement heading toward the front of the building. I will verify.	**14:53:36 Hours**	
FAO transmitted Box 3-1579; Engine 29, Engine 42, and Ladder 15 are dispatched for Box 3-1579.	**14:53:58-14:54 Hours**	
	14:54:31	E33 officer radioed, “We are in the basement towards the front of the building.”
	14:55:20	E33 officer radioed FAO, “It’s getting hot down here. Getting hotter.”
	14:55:35	FAO to E33 officer, “OK 33, they are going to get you water.”
	14:56:43	FAO to E33 officer, “E33, they are coming to get you.”
Command to FAO, “We have companies in the front of the basement now. Tell E33’s officer if he can find a way out, to get out.”	**14:56:56 Hours**	
	14:57:24 Hours	The last radio transmission from E33 officer. He radioed, “Need a line in the basement, right away; a big line.”
FAO to Command, “L26 officer reports they need a line in the rear and E33 is still calling for water.”	**14:57:43 Hours**	

Incident and Fireground Communications	**Time**	**Response and Fireground Operations**
	14:57:51 Hours	L26 to FAO, "Tell Command we need a line on the backside of the building. We have heavy fire on Side Charlie."
"Per the orders of Command, transmit a fourth alarm for Box 1579." FAO transmitted: "A fourth alarm has been struck for Box 1579. The fireground channel is Channel 3. Stay off Channel 2, it is the Mayday Channel."	**14:58:51 Hours**	
	14:59:07	"Division 1 Deputy Chief (C6) on scene."
FAO transmits: "C6 is assuming Command of Box 1579. On the orders of the Deputy Chief, he is requesting a fourth and fifth alarm for Box 1579. Have the fourth and fifth alarm companies respond to the rear of the building (Side Charlie)."		
Engine 5 and Engine 3 are dispatched for Box 4-1579.	**14:59:22**	
Engine 28, Engine 55, and Ladder 14, and C1 (Commissioner) are dispatched for Box 5-1579.		
	15:00:21	Car 4 to Command, "We have heavy fire in the rear; we are trying to get water back here."
Command to FAO, "Have the third-alarm ladder companies go to the front of the building (Side Alpha) with 35's and the first-due engines on the fourth and fifth alarms to the rear of the fire building and run big lines into the basement."	**15:00:29**	

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO radioed to third-alarm ladder companies respond to the front of the building and fourth-alarm engine companies respond to the rear.	15:01:00	
Command to FAO, "We have companies trying to advance into the basement now."	15:03:48	
	15:04 Hours	C7 (Division 2 Deputy Chief) on scene. C7 assigned as Division Charlie.
	15:06: 18	C7 to Command, "We have 3 big lines Hours going in the rear moving towards the front of the building." 15:07:18
	15:07: 18	C7 to Command, "Have a couple of ambulances come to Side Charlie in case we pull these guys out the rear door."
	15:07:35	C7 to Command, "Companies are making Hours progress. They are 20 to 25 feet inside the basement and they keep going."
"Per the orders of Command strike the sixth alarm and seventh alarm for Box 1579."	15:08:16	
	15:08:59	Rescue 1 to FAO, "Have all members reset their PASS devices. We have multiple PASS devices going off."
FAO transmitted the following message on Channels 1, 2, and 3: "All companies reset PASS devices due to multiple PASS devices in alarm."	15:09:35	

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO dispatched Engine 30 for Box 6-1579. ***FAO dispatched Engine 8, Engine 21, and Ladder 4 for Box 7-1579.***	**15:09:46**	
Command to FAO, “Urgent, Urgent, I want everybody out of the building, everybody out of the building.”	**15:10:14**	A rapid progression of fire conditions occurs in the structure.
FAO transmitted the following message on Channels 1, 2, and 3. “Per the orders of Command, All companies operating at the seventh alarm for Box 1579, get out of the building, all companies out of the building.”	**15:10:28**	
	15:11:11	Command to all companies on Fireground Channel 3, “Everybody out the building.”
FAO transmitted the following message on Channels 1, 2, and 3. “Per the orders of Command, All companies operating at the seventh alarm for Box 1579, get out of the building, all companies out of the building.”	**15:11:31**	
“Per the orders of Command strike the eighth alarm and ninth alarm for Box 1579.” “Have these companies report to Command in front of the building.”	**15:13:00**	
FAO dispatched Engine 49 and Engine 24 for Box 8-1579.	**15:13:37**	
FAO dispatched Engine 39, Engine 14, and Tower Ladder 10 (TL10) for Box9-1579.	**15:13:52**	
	15:15:34	C7 to Command, “Do we still have members missing?”

Incident and Fireground Communications	Time	Response and Fireground Operations
C1 to FAO, "Yes, there is still a member unaccounted for in the basement." C7 to FAO, "Companies are going backin."	15:16:38	
C1 to FAO: "Negative. No companies are going in anywhere. Stay out and away from the building."	15:17:03	
	15:17:11	C7 to C1: "We are aware of the collapse potential. We can see in front of us. We can hear a PASS device inside the building."
C1 to FAO: "We can't put anybody in there at the front door or back door. That OK? Other than that, stay out of the building."		
C7 to FAO, "I copy the message."	15:18:30	
C7 to FAO, "Tell C1 I am pulling 07 companies back out again."	15:19:07	
	15:19:30	***C7 to Command, "We are getting the guy [fire fighter from E33] out now. Get EMS to the rear [Side Charlie]."***
FAO to C1, "Tower Ladder 3 just brought a member [fire fighter from E33] out the rear of the building."	15:20:59	
	15:21:37	C7 to Command, "Are there still members inside?"
C1 to FAO: "We are doing an accountability check right now. We are looking into that right now."	15:21:52	
C7 to FAO, "Can you ask Command if all the members of E33 are accounted for at this time?"	15:23:56	

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO to C7: “Command is doing an accountability check. They are doing an accountability check right now.”	15:24:04	
FAO dispatched Engine 32 to Box 9-1579. E32 is special called.	1531 Hours	
Command to FAO: “All first-alarm and second-alarm companies do a PAR with Accountability 7. They can do it in person or send a member. I want an accountability PAR for the first-alarm and second-alarm companies.”		
Accountability 7 to FAO, “Accountability 7 is located across the street from the fire building.”		
FAO transmitted the following message: “Engines 37, 33, 22, 3, 4, and 39, L15, L17, L26, and TL3 report your PAR to Accountability 7 who is located across the street from the fire building.”	15:37:18	
	15:40:09	C7 to Command: “We are going to defensive operations in the rear. I am getting members away from the building.”
	15:40:27	Command to C7: “The fire is through the roof. I am sure you are aware that we are trying to get ladder pipes flowing and Blitz guns in operation on adjacent roofs to try and knock down the fire.”
Command to FAO, “I want all lines shut down. I want all exterior lines shut down.” FAO repeats this message on Fireground Channel 2 and Fireground Channel 3.	15:50:18	

Incident and Fireground Communications	Time	Response and Fireground Operations
	15:51:14	Command to C7: "Give me a report. It seems that heavy fire is through the roof and coming from the rear forward. Is that accurate?"
	15:51:32	C7 to Command, "Yes, I really can't see the fire from the ground, but we know there is heavy fire on the roof in the rear."
Accountability 7 to FAO, "Can you list the third-alarm companies?" FAO replied, "Engine 10, Engine 17, and Ladder 18 for the third alarm at Box 1579."	15:54:15	
	15:57:34	C7 to Command: "The heavy fire in the rear on the third floor and fourth floor has been knocked down by the deck guns. We still have heavy fire on the second floor. We are going to hit that with the Blitz guns. I have set up collapse zones in the rear." Command acknowledged report.
FAO to Accountability 7, "All members accounted for?"	16:05	
FAO dispatched Engine 51 to Box 9-1579. E51 is special called.	16:14	
	16:24 Hours	C7 to Command, "We have everyone back 1½ times the height of the building." Command acknowledged.
Command to FAO: "I want all heavy stream appliances and exterior lines shut down. I want all exterior lines shut down." FAO transmitted the message on Fireground Channel 3.	16:29 Hours	

Incident and Fireground Communications	Time	Response and Fireground Operations
FAO dispatched Engine 16 to Box 9-1579. E16 was special called.	16:33	
FAO dispatched HazMat 1 to Box 9-1579. HazMat 1 was special called.	16:35 Hours	
"Per the orders of Command, respond a structural engineer and the medical examiner to the fire building."	17:06 Hours	
FAO dispatched Ladder 16 to Box 9-1579. L16 is special called.	17:44 Hours	
		Crews from R01 and R02 located the lieutenant of E33 near the bottom of the stairs near the rear basement apartment. The officer of Engine 33 was removed from the building and placed in an ambulance for transport to the hospital.
Command to FAO: "Place this fire under control. I am requesting 1 district chief, two engines and 1 ladder for "Fire Detail." ***FAO dispatched Engine 2, Engine 41, Ladder 19, and District 11 (Car 11) to Box 9-1579 as Fire Detail.*** ***March 27, 2014***		
Command to FAO, "I am transmitting an "All out" for Box 9-1579."	07:43	

Building Construction and History

The structure involved in this incident was called a "brownstone." Brownstone is the common name for a variety of brown, red, and pink sandstone widely used as building materials from the mid-1800s until the early 1900s [New York Landmarks Conservancy 2003]. *Note: In the city involved in this incident, the bottom or ground floor is called the basement. The floor entered by the front steps is called the first floor. The bottom or ground floor identified as basement is different from most basements as there is access from the front and rear of the structure and access by interior stairs; more than half of the basement was above street level.*

The layout of the interior apartments of the fire building (**See Photo 1**) were numbered as follows:

- Basement: the basement (e.g., partially below grade) had two apartments, Apartment #9 in the front (Side Alpha) and Apartment #10 in the rear (Side Charlie).
- First Floor: the first floor was previously two separate apartments but had been combined into a single apartment identified as Apartment #1 at the time of the fire.
- Second Floor: the apartment on the second floor has a similar floor plan as Apartment #1 and was numbered as Apartment #3.
- Third Floor: the third floor was made up of two apartments, Apartment #5 in the front (Side Alpha) and Apartment #6 in the rear (Side Charlie).
- Fourth Floor: the fourth floor was made up of two apartments, Apartment #7 in the front (Side Alpha) and Apartment #8 in the rear (Side Charlie).
- With the exception of Apartment #1 and Apartment #3, all of the apartments only had windows facing either the front or the rear, depending on the position of the apartment.

Photo 1. The fire building is the one with the bay windows from the basement to the fourth floor. The entrance to the basement apartment is under the steps.
(*Photo source: World Wide Web.*)

Extension and Spread of Fire

In order to better understand fire growth and development during this incident, it may be useful to understand how fire generally spreads in these types of buildings. A brownstone will generally be classified as Type III (Ordinary) construction, with masonry walls and combustible (i.e., dimension lumber), interior load-bearing construction.

In addition to typical problem areas associated with Type III buildings, particular points of examination inside a brownstone could include dumbwaiter shafts, hot air ducts, and registers running throughout the building. Because of the nature of mechanical systems installed at the time of construction, these interior connected voids are much larger than would be found in today's Type III buildings. Also consider that when built, any brownstone was likely to be a single-family home. It is entirely possible that these voids were not sealed off when the building was subsequently divided into apartments.

Some brownstone buildings may have open stairs in the rear of the building, which was originally for use by servants. Their existence allows for areas of fire spread that may not be recognized or known by those unfamiliar with this type of building. Additionally, the large, open, and often wood-paneled main stairway provides a continuous combustible flue from the first floor to the ceiling of the top floor and is typically terminated at a skylight. This will allow fire to spread rapidly and cut off escape routes for the occupants. Transom windows, which may be found over the interior doors, can fail under fire conditions and allow heat and smoke into the hallway areas. This also will allow fire to spread more easily [FDNY 2009a, FDNY 2013a].

The Fire Building

The structure involved in the fire was built in 1899 with a total living space of 6,376 square feet. The structure had five floors including a basement. The lot size is 3,600 square feet. The construction is Type III (Ordinary).

When built, the structure was designed as a single-family dwelling. In 1974, the owner divided the building into apartments with one apartment each on the first floor and the second floor and with two apartments each in the basement, third floor, and fourth floor. The basement was divided into two separate apartments with separate entrances. The basement unit at the front of the building (Apartment #9) could only be entered from the exterior entrance below the stairs on Side Alpha. The basement unit at the rear of the structure (Apartment #10) could be entered from the interior stairs at the center of the common hall on the first floor and from an exterior grade-level entrance on Side Charlie (**See Diagram 1**). The main entrances to the apartments on the second through fourth floors were reached by a common interior stairwell. Secondary means of egress from apartments on the first through fourth floors were provided by exterior fire escapes.

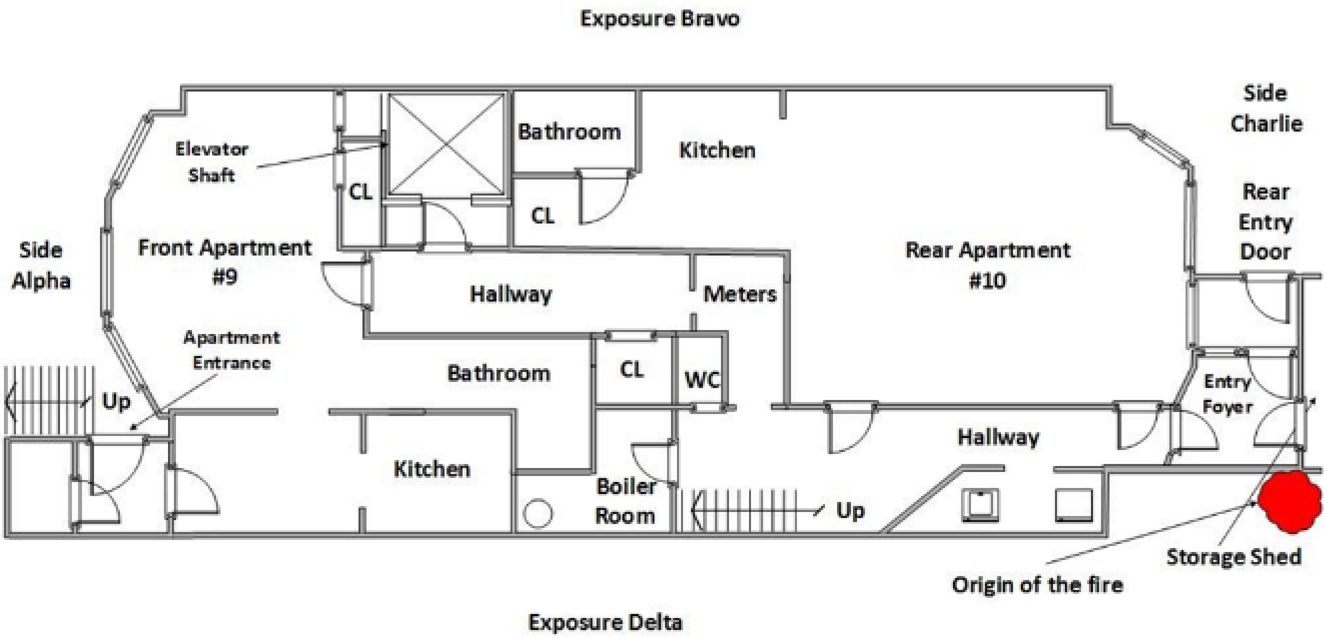


Diagram 1. The diagram of the basement of the fire building. The front apartment is #9 and the rear apartment is #10. The shed was attached to the structure on Side Charlie, behind the rear entrance doors for the rear apartment.
Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.
This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=26.

The first floor consisted of one apartment, which included a bedroom in the front (Side Alpha), a large living area in the rear (Side Charlie), a kitchen, a bathroom, another bedroom, and a common entry foyer, which had access to the basement (Apartment #10) and the apartments on the floors above (**See Diagram 2**). Prior to its conversion to apartments, the building had an elevator that went from the basement to the first floor. The elevator had been used to bring prepared food from the basement to the first floor when the structure was a single-family dwelling. The elevator was not in service at the time of the fire. The elevator was located on the Side Bravo wall.

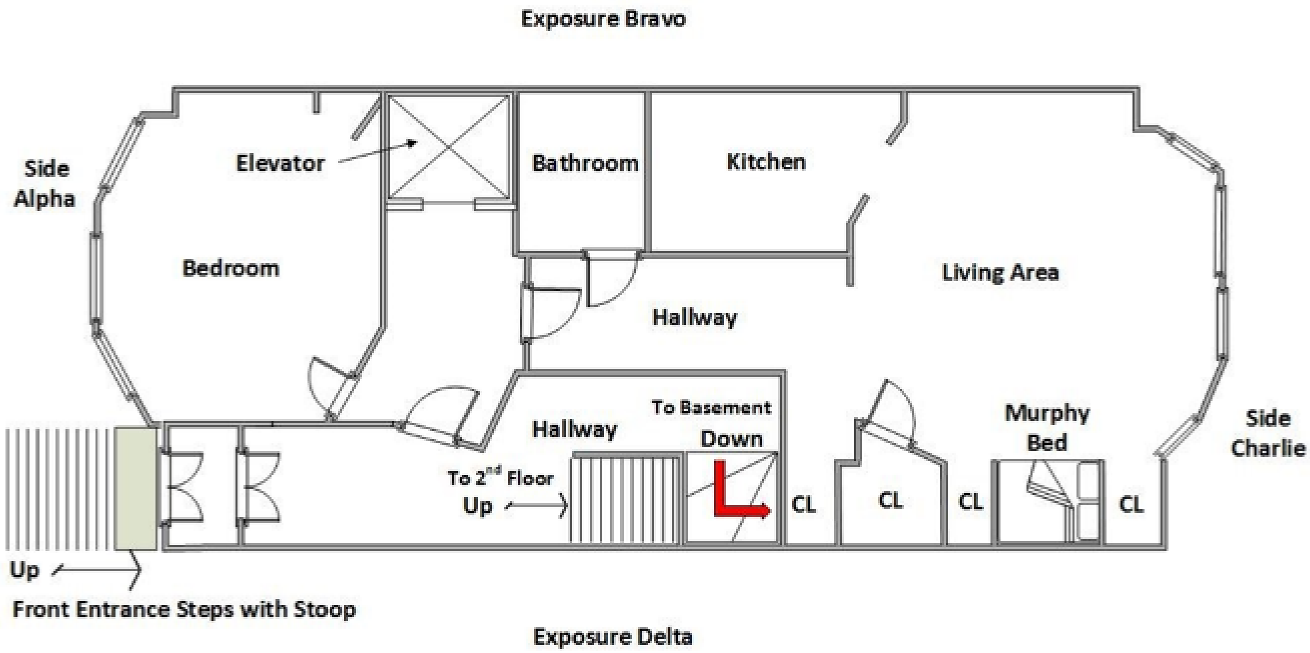


Diagram 2. The diagram of the first floor (Apartment #1) of the fire building. The stairs leading down to the basement are marked by the red arrow.

[Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.](https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=27)

This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=27.

The block where the fire occurred consisted of predominately brownstone buildings. In-fill structures abutted the buildings on either side of them, just as the original structures did. Parking was allowed on the street in front of the buildings. Parking was also allowed on a private, narrow street on the Charlie side of the building. As indicated in the diagram, several buildings had garages for tenant parking (**See Diagram 3**).

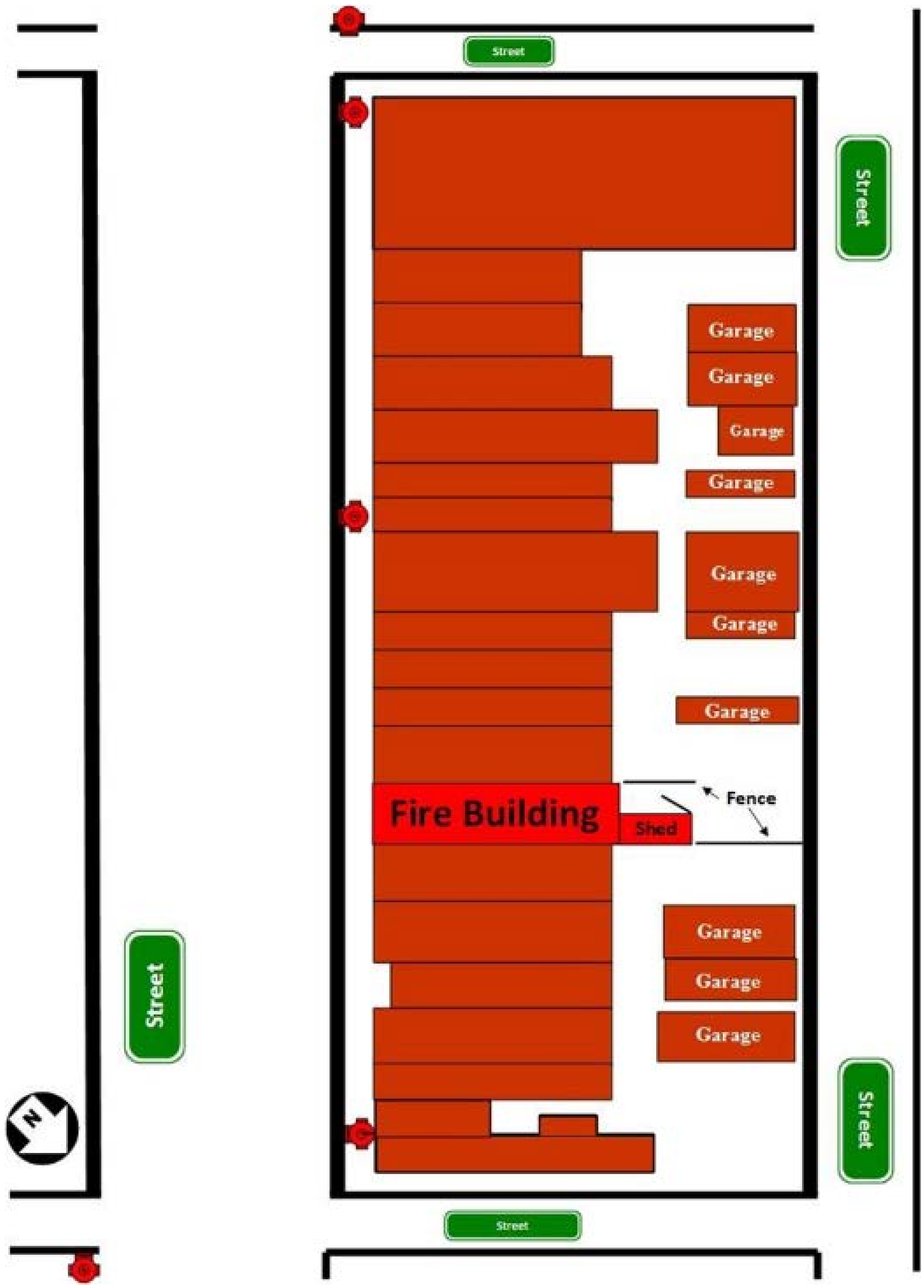


Diagram 3. The street diagram and location of the fire building.
[Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.](https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=29)
This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=29.

The fire started in a shed in the rear of the structure. The shed was attached to the building by the rear entrance. The shed served as the office, storage, and work facility for the property maintenance staff of the affected building (**See Photo 2**).

Photo 2. A view of Side Charlie and the location of the maintenance shed.
(*Photo source: Google Earth.*)

Personal Protective Equipment

At this incident, each officer and fire fighter was wearing a station/work uniform, turnout pants, turnout coat, helmet, boots, and an SCBA with integrated personal alert safety system (PASS). ***Note:*** *At the time of this incident, the department did not mandate the use of protective hoods.*

NIOSH investigators inspected and photographed each victim's personal protective equipment at the Arson Division office. The inspected SCBA and turnout gear exhibited a variety of thermal damage as the result of the exposure to the fire. Two SCBA units were shipped to the NIOSH National Personal Protection Technology Laboratory (NPPTL) in Pittsburgh, Pennsylvania, for evaluation.

On February 27, 2015, NPPTL personnel in Pittsburgh evaluated the SCBA and the summary evaluation report is included as "**Appendix One: Status Investigation Report of Two Self-contained Breathing Apparatus**."
On April 8, 2015, an independent contractor was requested to evaluate the personal protective equipment. The summary evaluation report is included as "**Appendix Two: Personal Protective Equipment Evaluation**."

Weather and Road Conditions

The weather temperature at 1454 hours was 34 degrees Fahrenheit (34^o F) with a wind chill factor of 20^o F. The humidity was 27% and the barometric pressure was 29.59 inches. Visibility was 10 miles and the winds were 32 miles per hour from the southeast. The winds gusted as high as 69 miles per hour during this incident. The skies were overcast and no precipitation was reported in the previous 24 hours [Weather Underground 2014].

Investigation

On March 26, 2014, at 1441 hours, the Fire Alarm Office (FAO) received a 9-1-1 call that reported a building was filling with smoke. At 1443 hours, the FAO dispatched Engine 33, Engine 7, Engine 22, Ladder 24, Ladder 26, Rescue 1, and District 4 (Car 4) for Box 1579**.** ***Note:*** *The first-due ladder company (Ladder 15) was out of service due to maintenance; Ladder 24 (third-due ladder company) was dispatched as the first-due ladder company. The second-due ladder company (Ladder 17) was out of service due to training; Ladder 26 (fourth-due ladder company) was dispatched as the second-due ladder company. Both Ladder 15 and Ladder 17 responded after the initial dispatch.*

Engine 33 arrived on scene at 1445 hours and parked in front of the fire building. The officer from Engine 33 advised FAO that “Engine 33 is in command and we have a four-story with smoke showing from first floor.” Due to the active and dynamic situation plus the immediate life safety concerns of an occupied residential building encountered at this incident, the Engine 33 officer assumed fast-attack mode as the command mode. ***Note:*** *Fast-attack mode can also be known as fast-action mode or mobile command. This command mode is selected in situations that require immediate action to stabilize and requires the company officer’s assistance and direct involvement in the attack.*

The Engine 33 lieutenant and Engine 33 (Pipeman) right jumpseat fire fighter stretched a 1¾-inch hoseline up the front steps and into the first floor. A civilian was coming down the front fire escape while Engine 33 was making their stretch. The Engine 33 chauffeur charged the 1¾-inch hoseline as Engine 33 moved down the steps to the rear basement apartment. At 1445 hours, Car 4 had arrived on scene and assumed command from the officer of Engine 33. Car 4 established command in front of Engine 33.

At 1446 hours, FAO dispatched District 3 (Car 3) and Engine 37 on the Rapid Intervention Team (RIT) assignment. At 1446 hours, FAO completed the RIT dispatch for Box 1579. FAO dispatched Tower Ladder 3 and Ladder 18. The safety officer (H1-Safety District Chief) assisted the RIT chief and RIT operations on Side Alpha. A concurrent RIT operation was ongoing on Side Charlie.

The fire fighter assigned to the left jump seat (Hydrant) of Engine 33 was preparing to pull the 4-inch supply line when a female civilian told him that someone might be in the basement apartment. The fire fighter took a halligan tool and went down the exterior steps and into the front basement apartment (Apartment #9). The fire fighter forced two doors and entered the front basement apartment. The fire fighter came out of the apartment and met with Command who was in the street. The fire fighter advised Command that the fire was in the rear basement apartment (Apartment #10) and a hoseline needed to be deployed to the basement.

Engine 7 arrived on scene at 1447 hours from the east and parked facing Engine 33 and laid a 4-inch supply line from the hydrant on the corner and then ran a 2½-inch supply line to Engine 33. Engine 33 was entering the front door as Engine 7 arrived on scene. The crew (officer and two fire fighters) from Engine 7 pulled a 2½-inch hoseline to the front steps. Engine 7 stretched a 2½-inch hoseline up the front steps following Engine 33's charged 1¾-inch hoseline. As Engine 7 moved the hoseline toward the stairs, the conditions started to change as the first floor became extremely hot. The Pipeman from Engine 7 asked the Engine 7 officer to call for water. The conditions became untenable and Engine 7 left the building. As Engine 7 pulled the 2½-inch hoseline out of the building, the hose was burned. The time was approximately 1449 hours (**See Diagram 4**).

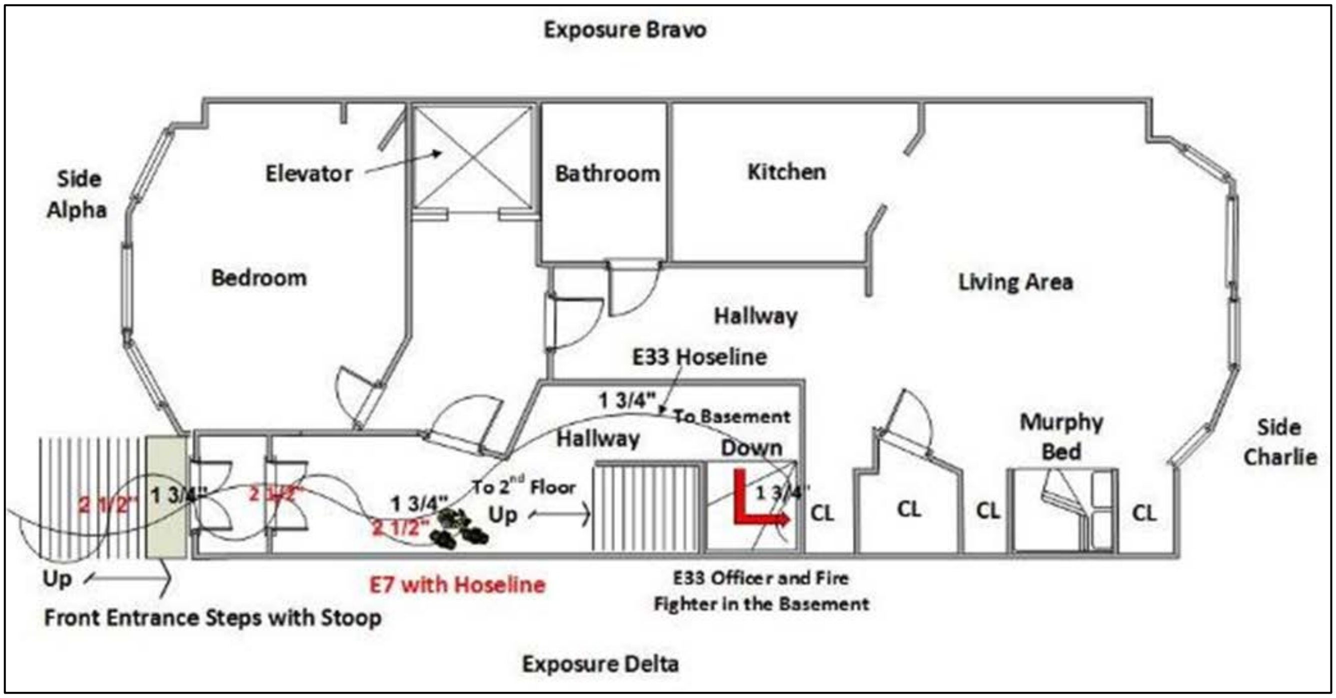


Diagram 4. The initial hoseline operations entering through the front door of the first floor.

Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.

This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=31.

Engine 33 has taken a 1¾-inch hoseline into the basement. Engine 7 is pulling a 2½-inch hoseline into the front hallway of the first floor, moving toward the basement steps. The time is approximately 1449 hours.

Engine 22 responded to Box 1579 as the third-due engine. Engine 22 laid a 4-inch supply line from a hydrant in the previous block, arrived on scene at 1448 hours, and parked behind Engine 7. The chauffeur pulled a 200-foot 2½-inch hoseline to the front walkway of the fire building. The captain and right jump seat fire fighter from Engine 7 took the 2½-inch hose into the first floor with the “Hydrant” fire fighter from Engine 33. At the same time, Rescue 1 and Engine 37 were pulling a 1¾-inch hoseline through the front door, down the steps, and into the basement. All companies were forced out of the building at this point due to a rapid progression of fire conditions. The Engine 22 “Hydrant” fire fighter went back to Engine 22 to pull another 2½-inch hoseline when conditions changed.

Ladder 24 arrived on scene at 1448 hours and parked behind Engine 33. The captain and two fire fighters entered the first floor of the fire building. Ladder 24 crawled down the hallway to the stairs going to the second floor. The captain of Ladder 24 stated they were engulfed in black smoke and the heat increased, which forced them out of the building. Crews had to pull the captain of Ladder 24 out of the building. At the same time, the chauffeur from Ladder 24 put the aerial ladder to the roof. He went to the roof and vented the roof.

Ladder 26 arrived on scene at 1448 hours and parked on Side Charlie, directly behind the fire building. The captain of Ladder 26 observed the rear door of the maintenance shed was open and fire in the shed. The captain advised his crew not to break any windows. The captain radioed Command and asked for water on Side Charlie but was unable to reach Command due to radio traffic. He instead called FAO and advised that fire was showing on the first floor in the rear of the building. He requested an engine company on Side Charlie for water. The captain of Ladder 26 then forced his way through Exposure Bravo to get to Side Alpha (**See Diagram 5**).

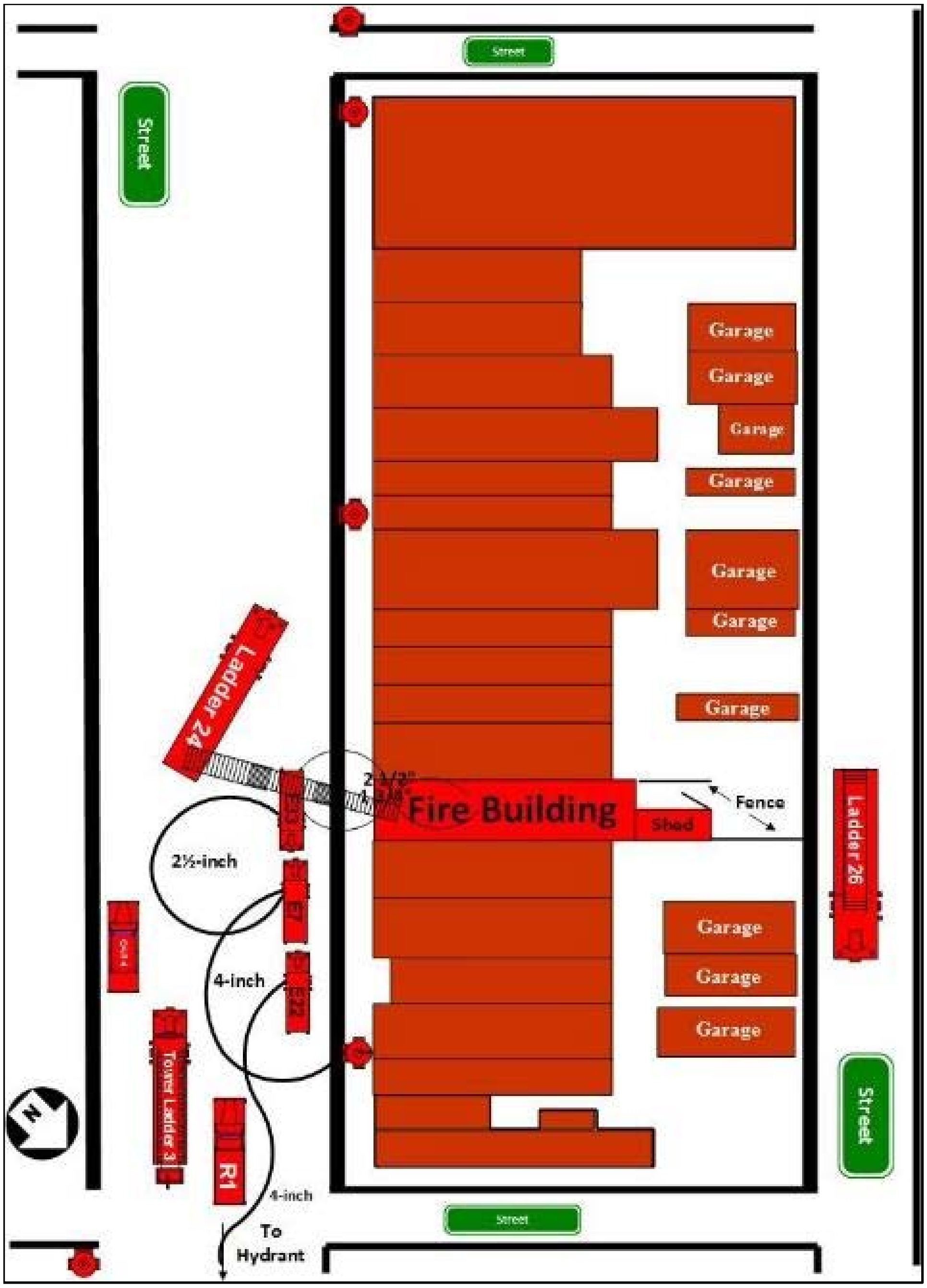


Diagram 5. The diagram of the initial engine company operations with Engine 33, Engine 7, and Engine 22 making entry into the fire building. The time is approximately 1449 hours.

[Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.](https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=33)

This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=33.

The captain of Ladder 26 met with Command on Side Alpha regarding the need for water on Side Charlie. Several members of Rescue 2 pulled a 2½-inch hoseline through Exposure Bravo to Side Charlie. The captain of Ladder 26 returned to Side Charlie and entered the rear apartment through a window. He went in with crews from Ladder 17 and Rescue 2. Prior to entering the structure, a rapid progression of fire conditions occurred. Another rapid progression of fire conditions occurred while they were operating in the rear basement apartment. The time was approximately 1511 hours.

Rescue 1 arrived on scene at 1447 hours and parked at an intersection behind Tower Ladder 3. Rescue 1 was assigned to assist companies with making entry into Side Alpha. As Rescue 1 was approaching the scene, the smoke conditions changed drastically from the time of arrival. The smoke conditions changed from brown smoke to thick, black smoke. Rescue 1 entered the basement with Engine 37. Due to the tremendous heat, both companies were forced out of the basement. Rescue 1 moved to the rear (Side Charlie) of the fire building and made entry into the rear basement apartment. The time was 1511 hours.

At 1448 hours, Command ordered a second alarm for Box 1579. C6 (Division 1 Deputy Chief), District 7 (Accountability), District 9, Engine 4, Engine 17, Engine 10, Ladder 17, Ladder 15, and Rescue 2 were dispatched on the second alarm for Box 1579 (Box 2-1579). At 1449 hours, the lieutenant from Engine 33 called Engine 33 and said "charge the line." After this radio transmission, Command ordered all companies out of the building. The lieutenant radioed a Mayday at 14:49:45. The lieutenant said, "E33 has a Mayday in the basement." At 1450 hours, the dispatcher advised Engine 33 to charge the hoseline. At 1451 hours, the lieutenant from Engine 33 called and said, "We need water now; charge E33's pipe." At 14:51:07 hours, FAO moved fireground operations to Tac Channel 3. Tac Channel 2 was assigned for the Mayday. At 1452 hours, the lieutenant from Engine 33 radioed FAO and said: "Both of us are trapped in the basement toward the front of the building. We got the water but my line is burnt through. You have got to charge our line." At 1453 hours, FAO announced, per the orders of Command, a third alarm was being struck for Box 1579 (Box 3-1579). FAO dispatched Engine 29, Engine 42, and Ladder 15 for the third alarm on Box 1579. ***Note:*** *Based upon the information from interviews with fire officers, fire fighters, and fire investigators, Engine 33 stretched an 1¾-inch into the fire building, up the front stoop, and into the first floor. Engine 33 found the stairs leading to the basement and stretched the charged hoseline into the basement. A maintenance worker opened the rear door of the shed and left it open while investigating the smoke detector activation. Also, the interior door at the top of the basement stairs was open, the front exterior doors were left open by an occupant fleeing the fire, and a rear basement door or window failed. This created an unrestricted flow path from the basement to the first floor plus the floors above, thereby triggering a rapid progression of fire conditions. This trapped the officer and fire fighter from Engine 33 in the basement. The fire, heat, and smoke through the basement and first floor created untenable conditions on both floors. Due to the intense heat and fire conditions, the 1¾-inch attack hose burned through.*
At 1453, FAO advised the officer of Engine 33 that they were trying to get water to him. At 1454 hours, the lieutenant of Engine 33 repeated his message of his location in the basement. At 1455 hours, the lieutenant stated, "It is getting hot down here and getting hotter." At 1456 hours, FAO called the lieutenant of Engine 33 and said, "They are coming

to get you." At 1457 hours, the captain from Ladder 26 made another request for water on Side Charlie. He stated, "We need a line on the backside of the building; we have heavy fire on Side Charlie." ***The last transmission from the lieutenant of Engine 33 was at 1457 hours***. He radioed, "Need a line in the basement, right away; a big line."

At 1459 hours, per the orders of Command, a fourth alarm was struck for Box 1579 (Box 4-1579). Engine 5 and Engine 3 were dispatched on the fourth alarm. At 14:59:07 hours, C6 assumed Command of Box 1579, and District 4 was assigned as Division Charlie. Command advised FAO to have the fourth-alarm and fifth-alarm companies respond to the rear of the building. At 14:59:22 hours, a fifth alarm was struck for Box 1579 (Box 5-1579). FAO dispatched Engine 28, Engine 55, Ladder 14, and C1 (Commissioner).

At 1500 hours, Engine 10 laid a supply line from Engine 4 to Side Charlie. The first attempt to enter the basement from the rear of the building had three 2½-inch hoselines operated by Engine 10, Engine 4, and Engine 24. Rescue 1 was attempting to locate the officer and fire fighter from Engine 33. Crews from Ladder 26, Ladder 15, Ladder 17, Tower Ladder 3, and Engine 42 were operating in the rear of the building at this time. The officer of Rescue 1 notified C7 of hearing a PASS Alarm as he exited the building. The crews were only able to get about 5–10 feet into the apartment when a rapid progression of fire conditions occurred in the basement and on the first floor. Crews exited the building, regrouped, and re-entered the basement apartment. The time was 1506 hours. The crews re-entered the building and continued the search for the missing lieutenant and fire fighter from Engine 33. Crews were operating about 20–25 feet in the rear basement apartment.

At 1509 hours, the sixth alarm and seventh alarm for Box 1579 were dispatched. Engine 30 was dispatched on Box 6-1579 and Engine 8, Engine 21, and Ladder 4 were dispatched for Box 7-1579. Another rapid progression of fire conditions occurred at the front of the building at approximately 1511 hours. Command contacted FAO and ordered all crews out of the building. This was done on all three channels. At 1511 hours, a rapid progression of fire conditions occurred at the rear of the first floor while crews were operating in the rear basement apartment (**See Photo 3**). At 1513 hours, Command ordered the eighth alarm and ninth alarm for Box 1579. Engine 49 and Engine 24 were dispatched for Box 8-1579. Engine 39, Engine 14, and Tower Ladder 10 were dispatched for Box 91579.

Photo 3. A rapid progression of fire conditions occurred on the first floor at approximately 1511 hours. Crews were operating on Side Charlie (upwind side) and making entry into the rear basement apartment via the windows. This photo shows the force of the rapid progression of fire conditions. ***(Photo courtesy of the fire department.)***

Command ordered defensive operations on Side Alpha due to the severity of the fire conditions. At 1515 hours, Division Charlie (C7) contacted Command regarding whether fire fighters were still missing. C1 (Commissioner) advised that a member was unaccounted for in the basement. Crews from Engine 10, Engine 4, Engine 24, Rescue 1, Rescue 2, Ladder 17, Ladder 15, Ladder 26, Tower Ladder 3, and Engine 42 were operating on Side Charlie. Members from Rescue 2 found the fire fighter from Engine 33 in the rear basement (Apartment #10) near the kitchen. The fire fighter was covered with debris. Members of Rescue 2 moved the fire fighter from Engine 33 to the rear window (**See Diagram 6**). Crews outside picked up the fire fighter and put him on a stretcher.

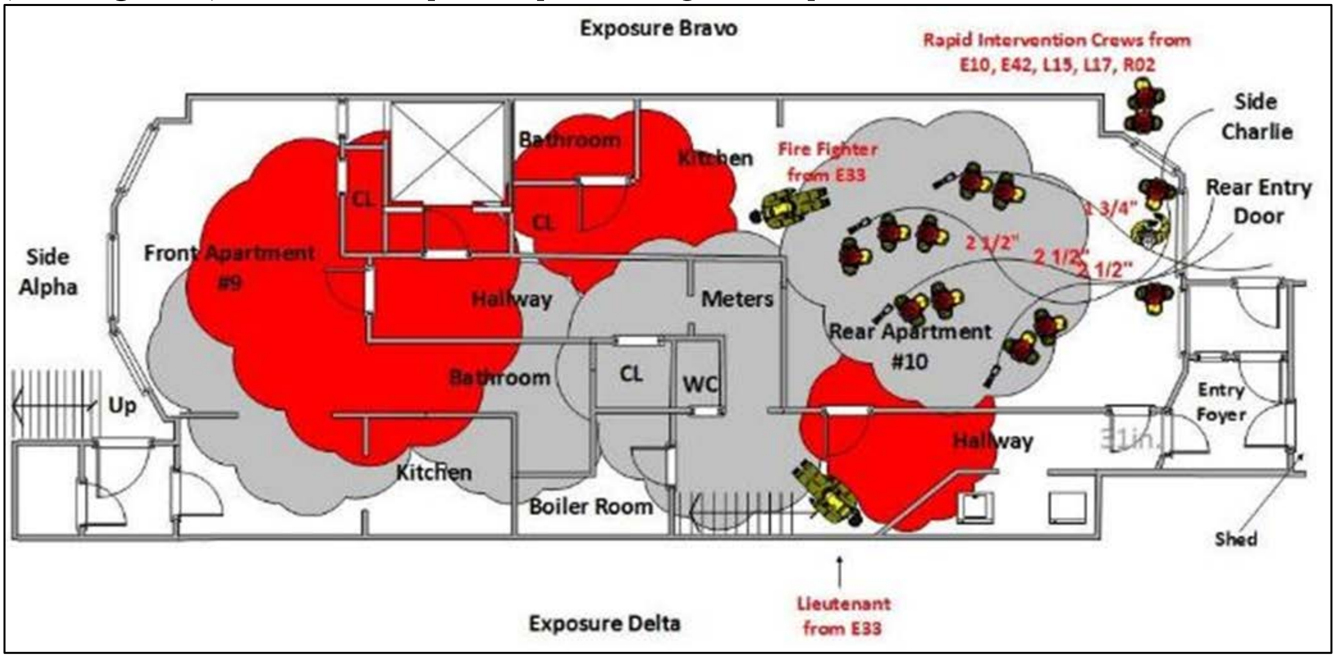


Diagram 6. Crews from Engine 10, Engine 42, Ladder 15, Ladder 17, and Rescue 2 are operating the rear basement apartment searching for the lieutenant and fire fighter from Engine 33. Rescue 2 finds the fire fighter from Engine 33 and removed him from the building. The time is 1519 hours. The lieutenant was not located until 1848 hours.

Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.

This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=37.

The time was 1519 hours when the fire fighter was removed from the structure. The fire fighter was taken on the stretcher to an EMS ambulance located at a cross street near Side Alpha. He was transported to the nearest trauma center. The fire fighter was pronounced dead at 1607 hours.

Shortly after the fire fighter from Engine 33 was removed from the structure, C7 allowed two companies—Engine 21 and Rescue 1—to re-enter the rear basement apartment for approximately 30– 60 seconds to listen for the PASS Alarm from the Engine 33 lieutenant. When no device was heard, C7 ordered the companies out of the building due to the severely deteriorating conditions.

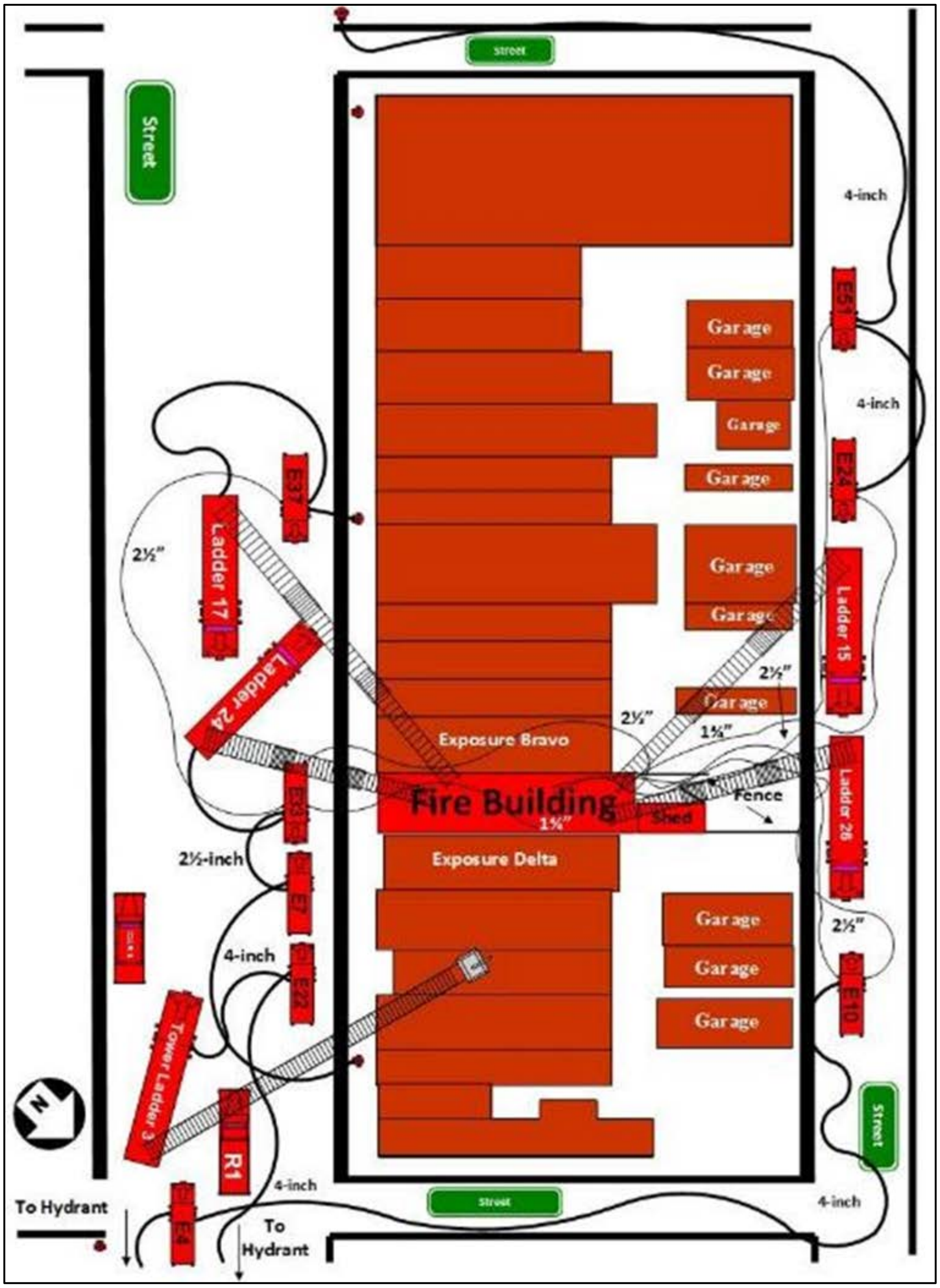


Diagram 7. Defensive operations. Ladder pipes, a tower ladder, and numerous deck guns plus hoselines are in operation. The time is approximately 1645 hours.

[Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.](https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=38)

This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=38.

The defensive operations continued on Side Alpha and Side Charlie until approximately 1635 hours (**See Diagram 7 and Photo 4**). At 1831 hours, a request was made for a chief inspector from the city's Inspectional Services Department, a structural engineer, and the medical examiner. At 1840 hours, a request was made for the structural engineer to report to Division Charlie. After consultation with a structural engineer, Command advised Division Charlie to attempt to locate the lieutenant from Engine 33.

Photo 4. Defensive operations on Side Alpha of the fire building. Three ladder pipes, a tower ladder, numerous deck guns, and hoselines are in operation. The time is approximately 1615 hours.
(Photo courtesy of the fire department.)

Division Charlie (C7) tasked Rescue 1 and Rescue 2 to make another search to locate the officer of Engine 33 in the rear basement apartment. At approximately 1848 hours, members of Rescue 1 and Rescue 2 located the officer of Engine 33. He was pronounced dead at the scene. At 1911 hours, the officer was removed from the rear basement apartment and transported by an EMS ambulance to the nearest trauma center. The fire for Box 9-1579 was declared "All Out" by Command at 0743 hours on March 27.

Fire Behavior/Wind-driven Fire

The fire was unintentionally started by welders who were installing a railing on the left side staircase at the rear entrance of Exposure Delta next to the fire building. The welders started work at approximately 1230 hours. At approximately 1439 hours, the occupant of Apartment #10 heard the building's fire alarm activate. The occupant walked out of the apartment and went up the steps and notified the occupant in Apartment #1. The occupant of Apartment #10 called 9-1-1 at 1441 hours. Another occupant telephoned the building's maintenance supervisor and advised him of the smoke in the building. The welders realized that the shed behind the fire building was on fire. They attempted to extinguish the fire with water and snow. Due to the wind, the smoke extended into the fire building.

At approximately 1445 hours, the maintenance supervisor arrived and parked on Side Charlie in the rear parking lot of the fire building. He went to the rear of the building due to fire apparatus blocking the entrance on Side Alpha. He noticed smoke coming from the shed and went to open the back exterior door going into Apartment #10. He placed his key in the door and opened the door approximately 3 inches. The maintenance supervisor stated when he opened the door, "Fire came at me." The maintenance supervisor also stated that he thought he could see fire through the window of the interior door to Apartment #10 (**See Diagram 1**). The maintenance supervisor left the door open and then moved back to the parking lot.

Engine 33 had entered the fire building through the front door and moved the hoseline to the stairwell to go down to the basement. With the rear basement doors and the front doors open, the fire had a flow path from the basement, up the stairs to the first floor and floors above. This occurred after the interior rear door or window leading into the hallway in the basement failed.

Wind has been recognized as a contributing factor to fire spread in wildland fires and large-area conflagrations. Wildland fire fighters are trained to account for the wind in their tactics. While structural fire departments have recognized the impact of wind on fires, in general, the standard operating procedures for structural fire-fighting have not changed to address the hazards created by a wind-driven fire inside a structure.

The results of the "no-wind" and "wind" fire simulations demonstrate how wind conditions can rapidly change the thermal environment from tenable to untenable for fire fighters working in a single-story residential structure fire, in a multi-family residential structure fire, and high-rise structure fire. The simulation results emphasize the importance of including wind conditions in the scene size-up before beginning and while performing fire-fighting operations and adjusting tactics based on the wind conditions [NIST 2013b].

The National Institute of Standards and Technology (NIST) has conducted research and testing on the impact of wind-driven fires and fireground operations. Adjusting fire-fighting tactics to account for wind conditions in structural fire-fighting is critical to enhancing the safety and the effectiveness of fire fighters. Studies have demonstrated that applying water from the exterior into the upwind side of the structure can have a significant impact on controlling the fire prior to beginning interior operations.
It should be made clear that in a wind-driven fire, it is most important to use the wind to your advantage and attack the fire from the upwind side of the structure, especially if the upwind side is the burned side. Interior operations need to be aware of potentially rapidly changing conditions [Fire Protection Research Foundation 2013].

The research conducted by NIST also provides potential guidance for fire fighters as a part of a scene size-up and when approaching the room of fire origin. ***Note:*** *Fire fighters should check for wind conditions in the area of the fire, look for "pulsing flames" or flames not exiting a window opening, examine smoke conditions around closed doors within the potential flow path, and maintain control of doors within the flow path. Even if flames are being forced out of adjacent windows with a high amount of energy, there could still be sufficient energy flows on the fire floor to create a hazard for fire fighters.*

The data from this research will also help to identify fire-fighting tactics to improve standard operating procedures for the fire service to enhance fire fighter safety, improve fireground operations, and to encourage the use of wind control devices. If the demonstrated technologies continue to prove effective in the field trials and pilot programs, the next step may be to examine the need for standards and standardized test methods to define a minimum level of acceptable performance of these devices [NIST 2013a].

Flow Path and Fire Control

"A flow path is composed of at least one inlet opening, one exhaust opening, and the connecting volume between the openings. The direction of the flow is determined by difference in pressure. Heat and smoke in a high pressure area will flow through openings toward areas of lower pressure." Based on varying building designs and the available ventilation openings (doors, windows, etc.), several flow paths can exist within a structure. Any operation conducted in the exhaust portion of the flow path will place members at significant risk due to the increased flow of fire, heat, and smoke toward their position [FDNY 2013a; NIST 2013a].

Fire fighters must be aware and understand that the critical first step in evaluating the potential for a wind-impacted fire is recognition of any smoke movement in the flow path, wind speed, smoke being forced under doors, and/or pulsing smoke or fire. The incident commander and company officers must be notified immediately when any of these conditions are observed. **The communication of this critical information to the incident commander and company officers operating inside the building must be acknowledged.**

Due to the doors on Side Charlie being left open or failing, the interior door at the top of the basement stairs being left open, and the front doors on Side Alpha being left open by an occupant fleeing the fire, an unrestricted flow path was created from the basement to the first floor and floors above. The fire hose that Engine 33 deployed was impacted by the fire and heat generated by the flow path.

Fire Origin and Cause

The fire was ruled accidental by the county's district attorney. According to fire investigators, employees from a welding company accidentally started a fire in the maintenance shed in the rear of the fire building. The welding company employees were installing pre-fabricated wrought-iron railings in the rear of the Delta Exposure building. It was the opinion of the Fire Investigation Unit that the area of origin of this fire was the rear of the fire building, outside the shed wall facing the rear Delta Exposure. The cause of the fire was a heat source too close to combustible material, with combustion accelerated by high winds.

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 that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatalities:

- Delayed notification to the fire department
- Uncontrolled ventilation by a civilian
- Occupied residential building with immediate life safety concerns
- Staffing
- Scene size-up
- Lack of fire hydrants on Side Charlie (a private street)
- Lack of training regarding wind-driven fires
- Unrestricted flow path of the fire
- Lack of fire sprinkler system

Cause of Death

The medical examiner listed the manner of death of the lieutenant and fire fighter from Engine 33 as accidental. The cause of death for the lieutenant was smoke inhalation and thermal injuries. The cause of death for the fire fighter was smoke inhalation and thermal injuries as well as blunt force trauma to the abdomen.

Recommendations

Recommendation #1: Fire departments should define fireground strategy and tactics for an occupancy that are based upon the organization's standard operating procedures. As part of the incident action plan, the incident commander should ensure a detailed scene size-up and risk assessment occurs during initial fireground operations including the deployment of resources to Side Charlie. Scene size-up and risk assessment should occur throughout the incident.

Discussion: Fireground standard operating procedures (SOPs) define the initial strategy and tactics for a coordinated deployment of departmental resources for specific incidents and occupancies. SOPs are based on factors not limited to but including department staffing; deployment capabilities; knowledge and skill levels; apparatus, tools, and equipment; building information including height, area, construction class, and type of occupancy; and potential life hazards. The first arriving resource will assume command and control of the incident. This ensures initial responding units understand the strategy and the operational goals and can deploy tactics at incidents with or without a chief officer on the scene. The intent is to maximize efficiencies while minimizing confusion and duplication of effort.

The incident commander develops a strategy and tactics based upon scene size-up and the risk assessment, including the factors listed above. This is a process that must be made in a short period of time involving a dynamic and fluid situation. Most importantly the strategy and tactics should include an observation and/or report from all sides of the structure, especially Side Charlie. The goal of effective fireground procedures is to increase the safety of the members, eliminate confusion, and prevent the loss of life [NIOSH 2015].

Occupancies define the space inside the class of building. Construction types/classes of construction define how the building is constructed with either combustible or non-combustible materials. Occupancies exist inside the constructed building. Fire departments must consider numerous factors that affect operations when developing these SOPs. This will ensure essential strategic-, tactical-, and task-level functions are performed by the incident commander, division/group supervisors, company officers, and fire fighters. Additionally, this process compliments the defined knowledge, skills, abilities, competencies, and fireground experience to assist:

- The incident commander to plan and implement an effective strategy and Incident Action Plan.
- Division/group supervisors to formulate and follow tactics.
- Company officers to successfully carry out assigned tasks.
- Individual members to effectively perform their duties [FDNY 2009a; FDNY 2009b; FIRESCOPE 1994].

Tasks that need to occur at any fire, regardless of the occupancy, are an initial on-scene report upon arrival, initial risk assessment, situational report, water supply, deployment of hoselines and backup hoselines, search and rescue, ventilation, initial rapid intervention crews (IRIC), ground and aerial ladder placement, fire attack and extinguishment, and salvage and overhaul.

At any incident, life safety is always the first priority, followed by incident stabilization (second priority) and then property conservation (third priority). Ensuring for the safety of fire fighters is a continuous process throughout the incident. A sound risk management plan ensures that the risks are evaluated and matched with the actions and conditions. The following risk management principles shall be use by the incident commander:

- Activities that present a significant risk to the safety of fire fighters shall be limited to situations that have the potential to save endangered lives.
- Activities that are routinely employed to protect property shall be recognized as inherent risks to the safety of fire fighters, and the actions shall be taken to reduce or avoid these risks.
- No risk to the safety of fire fighters shall be acceptable where there is no possibility to save lives or property [Brunacini 2002; NFPA 2014a].

The strategy and tactics of an incident are dictated by the size-up, initial risk assessment, and situational report by the first arriving officer. If physical barriers make the 360-degree size-up impractical for the first arriving officer, the size-up of Side Bravo, Side Charlie, and Side Delta may be delegated to another fire department resource. The priority is to get a fire department resource to the rear of the structure (Side Charlie). However, unless an obvious life safety issue exists (e.g., visible victims requiring immediate assistance), interior fire-fighting operations should not commence until a report from Side Charlie is received. A radio report of conditions, including those on Side Charlie, should be transmitted over the assigned tactical channel to the incident commander and the dispatch center. The transmission should include the following information:

- Smoke and fire conditions, with an emphasis on identifying the seat of the fire. The initial radio report from the first arriving unit for a structural fire should include the signal for a working fire, the number of stories, type of occupancy, and location of fire. This lays the foundation for additional reports and serves as notification to responding units as to the type of tactics to implement.
- If there were critical building description information through the critical incident dispatch system (CIDS) for the address, then this information would aid in implementing or adjusting SOPs. CIDS could contain information that would necessitate alternative action to fulfill said operational goals.
- Building features (e.g., number of stories), particularly if there is a difference between Side Alpha and Side Charlie.
- Basement access and type.
- Any other life or safety hazards.

Any change to operational priorities or responsibilities based on the above size-up should be clearly communicated to Command, all responding units, and the dispatch center via the assigned tactical radio channel [Township of Spring Fire Rescue 2013; FDNY 2011]. Command is then obligated to rebroadcast and receive acknowledgement from all operating companies.

The procedures developed for fireground operations should be flexible enough to allow for change if any of the following issues occur or are present:

- Life hazard (must be given first priority)
- Problems with water supply and water application
- Volume and extent of fire, requiring large caliber streams
- Location of the fire, if inaccessible for hand-line operations
- Materials involved in the fire and explosion potential compounding the problem
- Exposure problems where further fire spread would be a major concern
- Stability of the structure, which would be dependent on the condition of the structural components of the building and the intensity and duration of the fire [ISFSI 2013]

In this incident, the initial on-scene size-up and evaluation was made by Engine 33 as the first-alarm companies arrived on scene on Side Alpha. The officer of Engine 33, based upon life safety issues and smoke showing, made the decision to initiate an offensive attack (fast attack). The first fire department unit on Side Charlie was Ladder 26, which was after interior fire-fighting operations had started. It is essential that during the initial stages of an incident, at least one company (preferably an engine company) is designated to Side Charlie of a structure, even if a 360-degree walk-around is conducted. This ensures that Command has a complete initial assessment of the fireground and a continuous risk assessment and situational report from Side Charlie.

Recommendation #2: Fire departments should ensure that once command is established at an incident, the incident commander maintains control of situation status, resource status, and communications, plus ensures the completion of the tactical objectives.

Discussion: Based upon the design of the Incident Command System, the standard assumption of command establishes the organizational authority to perform the command functions starting at the very beginning of the incident. When the first officer arrives on scene, this officer has the responsibility to evaluate incident conditions, develop an incident action plan, determine how to progress toward the completion of the tactical objectives, address any safety consideration, deploy and assign operating companies, and determine if there is a need for additional resources [Brunacini 2002].
It is the responsibility of the incident commander to develop an organizational structure, using standard operating procedures, to effectively manage the incident scene. The development of the organizational structure should begin with deployment of the first arriving fire department unit and continue through a number of phases, depending on the size and complexity of the incident. The command structure must develop at a pace that stays ahead of the tactical deployment of personnel and resources. In order for the incident commander to manage the incident, they must first be able to direct, control, and track the position and function of all operating companies. Building a command structure is the best support mechanism the incident commander can use to achieve a balance between managing personnel and the needs of the incident [NFPA 2014a].

The eight basic functions of command define standard activities that are performed by the incident commander to achieve the tactical objectives. The responsibilities of an incident commander include the following:

- The first arriving fire department resource has responsibility for the incident and assumes command of the incident.
- The incident commander conducts an initial and on-going situational assessment of the incident.
- The incident commander establishes an effective communications plan.
- The incident commander develops the incident objectives from the situational assessment and forms appropriate strategy and tactics.
- The incident commander deploys available resources and requests additional resources based upon the needs of the incident.
- The incident commander develops an incident organization for the management of the incident.
- The incident commander reviews, evaluates, and revises the strategy and tactics based upon the needs of the incident.

- The incident commander provides for the continuity, transfer, or termination of command [Brunacini 2002].

As command is transferred, so is the responsibility for these functions. The first six functions must be addressed immediately from the initial assumption of command [Brunacini 2002].

At most incidents the initial incident commander will be a company officer. The company officer of the first arriving unit shall formally establish command and give an arrival report. The company officer should remain in command until properly relieved by a member of higher rank who is on scene.

The initial incident commander remains in command until command is transferred, the incident is stabilized, or command is terminated. The first arriving fire department unit initiates the command process by giving an initial radio report. A standard initial radio report (arrival report) includes the following:

- Location of the incident.
- Location of the command post.
- Title of the incident.
- Brief report (e.g., building size, construction type, and occupancy).

Other information that must be transmitted to the dispatcher and on the tactical channel are the following:

- Obvious problem/conditions
  - Nothing showing (indicates checking or investigating)
  - Smoke showing (amount and location)
  - Fire showing (amount and location)
  - Working fire
  - Fully involved
- Actions taken Assuming command
  - Laying a line, attacking with …, and so forth
  - Declaration of strategy—offensive or defensive
- Command confirmation with name
- Follow-up radio report
  - Any immediate safety concerns
  - Accountability started (announce the initial accountability location)
  - Disposition of resources (situational status)
- Define initial rapid intervention crew (IRIC) [FIRESCOPE 1994; NFPA 2014a]

The following is an example of an arrival report:

"Engine 9 is on scene at 945 Saratoga Street and Engine 9 is assuming Saratoga Command. We have fire showing from floor #2 on Side Alpha of an occupied, three-story, wood frame dwelling, which is approximately 20 feet by 30 feet. This is a working fire. Engine 9 did not lay in, Engine 19 lay a line for us. This is an offensive fire and E9 is in the fast-attack mode.

E9 is attacking the fire with a 1¾-inch hoseline. Command has established accountability at E9 and IRIC has been established."

Once the location of command has been established (e.g., Saratoga Command), the incident commander may announce that he/she is resorting to "fast-attack mode" and proceeding to the incident location with his/her company. By announcing that he/she is resorting to "fast-attack mode" the incident command retains command of the incident. Fast-attack mode is employed only in the initial stages of an incident. The initial incident commander determines which type of command mode is more appropriate based upon the specifics of the incident. The three modes of command create a standard method of getting the role of command functional during the initial stages of an incident. The three command modes are:

- Nothing Showing (Investigation) Mode
- Fast-Attack Mode
- Command Mode [FIRESCOPE 1994, Brunacini 2002]

Where fast intervention is critical, utilization of the portable radio will permit the company officer's involvement in the attack without neglecting the responsibilities of the incident commander. The fast attack mode should not last more than a few minutes and will end with one of the following:

- The situation is stabilized.
- The situation is not stabilized and the company officer must withdraw to the exterior and establish an incident command post.
- Command is transferred to another higher ranking officer (e.g., battalion chief, district chief). When a chief officer is assuming command, the chief officer may opt to return the company officer to his/her crew, or assign him/her to a subordinate position [Brunacini 2002].

When operating in the fast-attack mode, communication is a critical issue. Though this function only operates in a short period of time (e.g., 3–5 minutes), a lot can occur during this time frame.

Fireground communications is an essential element to ensure for effective command and control. The officer (Command) must maintain communications with the dispatcher plus first-alarm companies. Hopefully, this can be done on one radio channel—preferably a tactical channel. This allows the immediate access to the dispatcher to provide an update of the incident. Also, this allows Command to communicate directions to other company officers to ensure that tactical objectives are being met. The communication component allows the officer to maintain situational status (what is the incident doing) as well as resource status (what are the assigned companies doing).

All this information gathering is essential, especially when the battalion chief or district chief arrives on scene and the transfer of command must occur. When the transfer of command occurs, the optimum scenario is a face-to-face exchange of information. In this situation, the company officer has the responsibility to provide an update of:

- Incident conditions.
- The incident action plan.

- The status of tactical objectives.
- Any safety consideration.
- Deployment and assignment of operating companies (situational status).
- Personnel accountability (resource status) [Brunacini 2002; NFPA 2014a].

If the arrival of the battalion chief or district chief is more than a few minutes, the second-due resource may need to assume command in a standard position (outside the hazard zone) monitoring communications, updating, reviewing, and reinforcing the initial size-up, backing-up the initial attack, and verifying the safety, welfare, and accountability of crews.
At this incident, the officer of Engine 33 gave his scene size-up and assumed command of the incident at 1445 hours. Car 4 (District 4) arrived on scene 40 seconds later and assumed command of the incident. There was no communications from the officer of Engine 33 to Car 4 during the transfer of command. The next resources didn't arrive on scene until 1448 hours. The next communications from the officer of Engine 33 was at 1449 hours when he called Engine 33 to charge the hoseline. The Mayday was called 45 seconds later.

Recommendation #3: Fire departments should develop and implement standard operating procedures, training programs, and tactics for wind-driven fires.

Discussion: Based on the analysis of this fire incident and results from current research and field studies, adjusting fire-fighting tactics to account for wind conditions in structural fire-fighting is critical to enhancing the safety and the effectiveness of fire fighters. A wind-driven fire may be one of the most dangerous operations fire fighters will encounter. The term "wind-driven" fire is used to describe a fire in which the wind has the potential to, or is already causing, a dramatic and sudden increase in fire, heat, and smoke conditions. Experienced fire officers and fire fighters who have survived wind-driven fires have all described the following:

- Upon arrival, conditions appeared to be routine.
- Within seconds, fire, heat, and smoke conditions changed without warning "from routine to life threatening."
- An operating 2½-inch hoseline flowing from the downwind position or into the exhaust portion of the flow had little or no effect on the incredible heat being produced; flowing water into the intake or inlet side of the flow path is very effective.
- Directly attacking these fires with one or even two 2½-inch hoselines proved ineffective and ultimately led to fire fighters incurring serious injuries [FDNY 2013a].

When responding to a reported structure fire, an overriding consideration concerning size-up must be wind conditions and its potential effect on the fire. The key to successfully operating at wind-impacted fires in a structure depends on recognizing the wind-impacted fire conditions that may change a seemingly routine fire into a "blowtorching" fire. "Blowtorching" is the appropriate description of what will occur when fire conditions are impacted by wind conditions.

The impact of the wind will be affected by the size of the window opening, the fuel load, and the stage of the fire when the window failed. **When wind-impacted fire conditions exist in a structure, the incident commander should notify the dispatcher so this information can be relayed to all responding units. Also, the incident commander needs to make an**

announcement on the tactical channel as well. Once the contributing factors are identified, steps can be taken to minimize the hazards to fire fighters [FDNY 2013a].

Fire departments should develop standard operating procedures for incidents with high-wind conditions ad for areas where high-wind conditions are likely. It is important that fire officers and fire fighters develop an understanding of how wind conditions influence fire behavior and impact fireground tactics that may be necessary under wind-driven conditions. Wind conditions can have a major influence on structural fire behavior. When wind speeds exceed 10 mph (16 km/hr.) the incident commander, division/group supervisors, company officers, and fire fighters should use caution and take wind direction and speed into account when selecting a strategy and developing tactics. The National Institute of Standards and Technology (NIST) has determined that wind speeds as low as 10 mph (16 km/hr.) are sufficient to create wind-driven fire conditions if the flow path is uncontrolled [NIST 2013a]. NIST, in a recent study on wind-driven fires in structures, has shown that wind speeds as low as 10 mph can turn a routine “room and contents fire” into a floor to ceiling fire storm or “blowtorch effect,” generating untenable conditions for fire fighters, even outside of the room of origin. Temperatures in excess of 600 ºC (1100 ºF) and total heat fluxes in excess of 70 kW/m^2 were measured at 4 feet above the floor along the flow path between the fire room and the downwind exit vent. These conditions were attained within 30 seconds of the flow path being formed by an open vent on the upwind side of the structure and an open vent on the downwind side of the structure [NIST 2013a].

Fire departments are encouraged to develop and implement a standard operating procedure addressing such issues as obtaining the wind speed and direction, considering the possible fuel load associated with a particular occupancy, determining proper strategy and tactics for fireground operations, consideration of ventilation, and establishing possible scenarios associated with the wind speed based upon risk assessment. Under wind-driven conditions, an exterior attack from the upwind side of the fire may be necessary to reduce fire intensity to the extent that fire fighters can gain access to the involved compartments [Fire Protection Research Foundation 2013].

The strategy and tactics of an incident are dictated by the size-up, initial risk assessment, and situational report by the first arriving officer. If physical barriers make the 360-degree size-up impractical for the first arriving officer, the size-up of Side Charlie may be delegated to another fire department unit. However, unless an obvious life safety issue exists (e.g., visible victims requiring immediate assistance), interior fire-fighting operations should not commence until a report from Side Charlie is received [Fire and Rescue Departments of Northern Virginia 2013].

In simulations and in previous full-scale experiments, it has been demonstrated that wind can increase the thermal hazards of a structure fire [Fire Protection Research Foundation 2013; ISFSI 2013]. Therefore, wind must be considered as part of the initial size-up of the fire conditions and must be monitored and reported throughout the fire incident. It is critical for fire fighters to not be in the exhaust portion of the fire flow path. The directional nature of the fire gas flow path results in higher temperatures than the area adjacent to the flow path or upwind of the fire. The flow path can be controlled by limiting ventilation. Previous studies demonstrated that applying water from the exterior into the upwind side of the structure can have a significant impact on controlling the fire prior to beginning interior operations [Fire Protection Research Foundation 2013; ISFSI 2013].

Current fire control training guides state, “Whenever possible, approach and attack the fire from the unburned side to keep it from spreading throughout the structure.” It should be made clear that in a wind-driven fire, it is most important to use the wind to your advantage and attack the fire from the upwind side of the structure, especially if the upwind side is the burned side. The unexpected ventilation from a broken window can suddenly change the interior thermal conditions. Interior operations must be aware of potentially rapidly changing conditions.

A fire department should incorporate the following into their training and education component on wind-impacted fires:

- Ensure that an adequate initial size-up and risk assessment of the incident scene is conducted before beginning interior fire-fighting operations.
- Ensure that fire fighters, company officers, division/group supervisors, and the incident commander have a sound understanding of fire behavior and the ability to recognize indicators of fire development and the potential for extreme fire behavior (such as smoke [color, velocity, and density], visible fire, and heat).
- Ensure that fire fighters and company officers are trained to recognize the potential impact of windy conditions on fire behavior and implement appropriate tactics to mitigate the potential hazards of wind-driven fire.
- Ensure the incident commander’s strategy considers high-wind conditions, if present.
- Ensure that fire fighters understand the influence of ventilation on fire behavior and effectively apply ventilation and fire control tactics in a coordinated manner.
- Ensure that fire fighters and officers understand the capabilities and limitations of thermal imagers.
- Ensure a thermal imager is used as part of the size-up process.
- Ensure that fire fighters are trained to check for fire in overhead voids upon entry and as charged hoselines are advanced.
- Develop, implement, and enforce a comprehensive Mayday standard operating procedure and train and educate fire fighters to ensure they understand the process and know how to initiate a Mayday.
- Ensure fire fighters are trained in fireground survival procedures.
- Ensure all fire fighters on the fire ground are equipped with radios capable of communicating with the incident commander and the dispatch center [FDNY 2013b].

At this incident, the wind was blowing against the fire building on Side Charlie. Due to the doors on Side Charlie being left open or failing, the interior doors at the top of the basement steps being left open, and the front doors on Side Alpha being left open by an occupant fleeing the fire, an unrestricted flow path was created from the basement to the first floor and the floors above. This allowed the fire to spread from Side Charlie to Side Alpha. One of the key issues was the captain of Ladder 26 recognized the conditions of a wind-driven fire and ordered no windows to be broken on Side Charlie.

Recommendation #4: Fire departments should ensure adequate staffing for deployment to urban incidents involving high hazard occupancies and concentrated population.

Discussion: Interdependent and coordinated activities of all fire-fighting personnel deployed are required to meet these priority objectives. A number of tasks are related to each of the priorities, and these tasks (e.g., stretching a hoseline to the fire, ventilation, search and rescue) can be conducted simultaneously, which is the most efficient manner, or consecutively (one after the other), which delays some task(s) thereby allowing risk escalation to occur. A number of resources, such as the International Association of Fire Fighters, the National Fire Protection Association, and National Institute of Standards and Technology, can assist policy makers and fire service leaders in planning for adequate resource deployment in their community to ensure that fire fighter intervention in a risk event occurs in a timely and coordinated manner to limit risk escalation and negative outcomes.

NFPA 1710 *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments* contains recommended guidelines for minimum staffing of career fire departments [NFPA 2013e]. NFPA 1710 states the following: “On-duty fire suppression personnel shall be comprised of the numbers necessary for fire-fighting performance relative to the expected fire-fighting conditions. These numbers shall be determined through task analyses that take the following factors into consideration:

- Life hazard to the populace being protected.
- Provisions of safe and effective fire-fighting performance conditions for the fire fighters.
- Potential property loss.
- Nature, configuration, hazards, and internal protection of the properties involved.
- Research by NIST and UL on methods for strategically ventilating and isolating fires to delay or prevent flashover by use of manual door control (requires additional staffing).
- Types of fireground tactics and evolutions employed based on standard operating procedures, staffing, type of apparatus used, and results expected to be obtained at the fire scene [NFPA 2013e].

Following a community hazard/risk assessment, fire service leaders prepare a plan for timely and sufficient coverage of all hazards and the adverse risk events that occur. This plan is often referred to as a ***Standard of Response Coverage***. Standards of response coverage can be defined as those written policies and procedures that establish the *distribution* and *concentration* of fixed and mobile resources of an organization [NIST 2013a].

Resource distribution is associated with geography of the community and travel time to emergencies. Distribution is typically measured by the percent of the jurisdiction covered by the first-due units within a specified time frame [NFPA 2013e]. Concentration is also about geography and the arranging of multiple resources, spacing them so that an initial “effective response force” can arrive on scene within the time frames established by community expectation and fire service leadership. Response time goals for first-due units (distribution) and for the total effective on-scene emergency response force (concentration) drives fire department objectives like fire station location, apparatus deployed and staffing levels. The service level objectives established in any community drives response time performance by all responding resources and the assembly of effective on-scene fire-fighting (or EMS) response force. Both response time performance and assembly times subsequently drive resource distribution and concentration. If response times and force assembly times are low, it is more likely that sufficient resources have been deployed, which is associated with more positive outcomes from risk events. Conversely, if response times and force assembly times are high, it is more likely that insufficient resources have been deployed, which is associated with more negative outcomes. Fire service leaders must take into account several other considerations when preparing a standards of response coverage. These considerations should include an assessment of the probability or likelihood that a particular event will occur [NFPA 2013a].

In many departments, company officers are primarily responsible for crew management, crew safety, crew accountability, and communication with other operating units on scene and with the incident commander. These company officers do not directly engage in stretching hoselines, advancing and operating hose streams, normal truck company operations including ventilation, or related tasks. The officer can be available to focus on crew management, situational awareness and crew accountability. However, officers will assist in conducting searches and removing victims when necessary. These officer tasks are essential to fire fighter and civilian life safety, since studies show that situational awareness and human error are contributing factors in nearly 20% of the fireground line-of-duty deaths, and that 40% of fire fighter injuries are attributed to situational awareness [NIST 2013a].

Urban fire departments should staff companies commensurate with the tactical hazards, high-hazard occupancies, high incident frequencies, geographic restrictions, and other pertinent factors as are common in urban environments. For example, the Fire Department of New York (FDNY) staffs rescue companies and ladder companies with a minimum of one officer and five fire fighters. FDNY engine companies are staffed with one officer and four fire fighters. The Chicago Fire Department staffs rescue companies with one officer and five fire fighters. Also, Chicago Fire Department ladder companies and engine companies are staffed with one officer and four fire fighters [NIST 2013b].

At this incident, engine and ladder companies operated with an officer and three fire fighters. The heavy rescues are staffed with an officer and three fire fighters. The staffing levels are consistent throughout the city. Based upon the workload of the fire department (call volume, working fires, and deployment criteria), the staffing allows for tasks to be completed based upon the capabilities of the company. At the beginning of the incident, Engine 33 arrived on scene, but the 4-inch supply line could not be stretched to the hydrant due to the lack of staffing. Also, first-alarm companies had to perform the rescue of building occupants, which required companies to be split.

Recommendation #5: Fire departments should ensure that a tactical worksheet is used by Command during initial fireground operations and maintained throughout the incident.

Discussion: The tactical worksheet is a vital piece of equipment because it helps the incident commander organize the incident from the initial onset of the incident. The benefit of using a tactical worksheet is that critical information is documented as well as providing reminders, prompts, and a convenient workspace for tracking companies and apparatus. For fire departments that provide a staff assistant or incident command technician, the district chief or battalion chief has the ability of starting the tactical worksheet enroute to the incident. The incident commander has the ability to record vital information that may help them make future operational decisions. By documenting the assignments of division/group supervisors, and division/group resources, the incident commander creates a visual reference of the overall fireground organization and deployment [NFPA 2014a].

The use of a tactical worksheet can assist the incident commander to track various task assignments on the fireground. It can be used along with preplan information and other relevant data to integrate information management, fire evaluation, and decision making. The tactical worksheet should record unit status and benchmark times and include a diagram of the fireground, occupancy information, activities checklist(s), and other relevant information. The tactical worksheet can also help the incident commander in continually conducting a situation evaluation and maintaining personnel accountability [NFPA 2014a].

The advantages of using a tactical worksheet are:

- Includes a location to quickly note individual assignments.
- Provides prompts for the incident commander, such as time, air management and strategy.
- Provides tactical benchmarks, such as “primary search complete,” “fire under control,” and “loss stopped.”
- Facilitates consistent, organized information.
- Documents assignments and responsibilities.
- Expedites passing of command or support for the incident commander.
- Provides resource status [NFPA 2014a].

The tactical worksheet is also an excellent tool when the "passing of command" must occur. On the fireground, the officer taking over command can quickly check the worksheet and obtain a strong understanding of the initial deployment of resources, the need for additional apparatus and equipment, and the status of units in the staging area.

The department in this incident has Standard Operating Procedure (SOP) #207 *Personnel Accountability System*, which states, “All District and Deputy Chiefs carry the “Tactical Command Sheet,” designed to assist the initial incident commander with accountability during the early stages of the incident prior to the set-up of the Command Board. It is an abbreviated and more portable version of the full command board.” The command board is set up upon the arrival of the deputy chief on a second alarm. At this incident, Car 4 arrived on scene with Engine 7. The incident command technician (ICT) parked the vehicle across the street from the fire building. Engine 33 was already on the scene and stretching a line in the front door. The ICT donned his turnout gear and SCBA and entered the building with Engine 7 and helped stretch Engine 7’s hoseline. Car 4 assumed command of the incident. As the ICT and Engine 7 entered the building, a violent change in fire conditions occurred. The conditions became untenable for the fire fighters from Engine 7. They moved out of the building to the landing of the front steps. Then the officer of Engine 33 called a Mayday.

The tactical worksheet is a vital resource because it helps the incident commander organize fireground operations. Also the tactical worksheet provides reminders, prompts, and a convenient workspace for tracking companies and apparatus. It allows the incident commander to slow down during an incident (although the worksheet can be used for fires big and small, as well as EMS incidents, to help develop proficiency) and record vital information that may help make future operational decisions. By documenting the assignments of division/group officers, and division/group resources, the incident commander creates a visual reference of the overall fireground organization and deployment [NFPA 2014a]. The tactical worksheet provides the necessary documentation when command of an incident is transferred. Upon arrival of C6 (deputy chief), the Car 6 ICT initiated the command board and Car 7 was assigned Accountability Officer (Resource Status).

Recommendation #6: Fire departments should implement a personnel accountability system to be used at all emergency incidents.

Discussion: The personnel accountability system was designed and is operated to ensure that fire fighters do not become lost or missing in the hazard zone. The system is designed to track fire fighters by location and function. An integral part of the accountability system is to make sure that the fire fighters who are assigned and operating in the hazard zone are accounted for, starting with the initial operations through the entire incident. Also, a process must be in place to periodically check to make sure that all members operating in the hazard zone are accounted for by this system.

A personnel accountability system is a system that readily identifies both the location and function of all members operating at an incident scene [NFPA 2013a; NFPA 2014a]. The philosophy of the personnel accountability system starts with the same principles of an incident management system— company unity and unity of command. Unity can be fulfilled initially and maintained throughout the incident by documenting the situation status and resource status on a tactical worksheet.

One of the most important functions of Command Safety is for the incident commander to initiate an accountability system that includes the functional and geographical assignments at the beginning of operations until the termination of the incident. It is very important for the first on-scene resource to initiate an accountability system. This initial system allows the passing or transfer of information to the next officer who assumes command upon his/her arrival [NFPA 2014a].

A functional personnel accountability system requires the following:
- Development and implementation of a departmental SOP.
- Necessary components and hardware.
- Training all members on the operation of the system.
- Strict enforcement during emergency incidents.

There are many different methods and tools for resource accountability. Some examples are:
- Tactical worksheets.
- Command boards.
- Apparatus riding lists.
- Company responding boards.
- Electronic bar-coding systems.
- Accountability tags or keys (e.g., PASSPORT System) [NFPA 2014a].

Resource accountability should be assigned to personnel who are responsible for maintaining the location and status of all assigned resources at an incident. As the incident escalates, resource status would be placed under the Planning Section. This function is separate from the role of the incident commander. The incident commander is responsible for the overall command and control of the incident. Due to the importance of responder safety, resource status should be assigned to a dedicated member as the size and complexity of the incident dictates. A number of positions could function in this role including an incident command technician, staff assistant, chief officer, or other defined member. As the incident escalates and tactical-level management components (e.g., divisions or groups) are assigned, the resource status officer (accountability officer) works with the division or group supervisors to maintain an on-going tracking and accountability of members [FIRESCOPE 2012]. A properly initiated and enforced personnel accountability system enhances fire fighter safety and survival. It is vital that resources can be identified and located in a timely manner.

An important aspect of a personnel accountability system is the personnel accountability report (PAR). A PAR is an organized on-scene roll call in which each supervisor reports the status of their crew when requested by the incident commander [NFPA 2014a]. The PAR should be conducted every 15–20 minutes or when benchmarks are met.

In order for the personnel accountability system to properly function, the process should include a standard operating procedure that defines each function's responsibility in making this process successful on the fireground. Also a training component—both classroom and practical—should occur to ensure this process operates properly during emergency incidents.

The department in this incident has a Standard Operating Procedure (SOP) #207 *Personnel Accountability System*, which states, "All District and Deputy Chiefs carry the "Tactical Command Sheet," designed to assist the initial incident commander with accountability during the early stages of the incident prior to the set-up of the Command Board. It is an abbreviated and more portable version of the full Command Board." The Command Board is set up upon the arrival of the deputy chief on a second alarm.

At this incident, Command called for a personnel accountability report at 1521 hours, which was 39 minutes into the incident and Box 1579 was operating at the eighth alarm. Car 7 was assigned as accountability officer. Due to the number of companies operating at the incident plus companies in staging, a personnel accountability report was not completed until after 1605 hours. The personnel accountability system should be initiated with the first arriving resource. The department provides each district chief with an incident command technician (ICT). The ICT can start the personnel accountability process upon arrival and maintain this process throughout the incident.

Recommendation #7: Fire departments should provide the incident commander with a Mayday tactical checklist in the event of a Mayday.

Discussion: When a Mayday is transmitted for whatever reason, the incident commander has a very narrow window of opportunity to locate the lost, trapped, or injured member(s).

The incident commander must restructure the strategy and Incident Action Plan (tactics) to include a priority rescue [NFPA 2014a].

Some departments have adopted the term LUNAR—location, unit assigned, name, assistance needed, and resources needed—to gain additional information in identifying a fire fighter who is in trouble and needs assistance. The incident commander, division/group supervisors, company officers, and fire fighters need to understand the seriousness of the situation. It is important to have the available resources on scene and to have a plan established prior to the Mayday [NFPA 2013d; NFPA 2014a].

A checklist is provided in **Appendix Three, Incident Commander's Tactical Worksheet for Mayday,** which can assist the incident commander in the necessary steps for clearing the Mayday as quickly and safely possible. This checklist serves as a guide and can be tailored to any fire department's Mayday procedures. The checklist format allows the incident commander to follow a structured worksheet. This process is too important to operate from memory and risk missing a vital step that could jeopardize the outcome of the rescue of a fire fighter who is missing, trapped, or injured.

At this incident, when the Mayday occurred, the incident commander quickly called for additional resources and conducted a personnel accountability report to determine if any companies were lost or missing. The intent of a Mayday worksheet, like the tactical worksheet, is to assist the incident commander during a very difficult and stressful time on the fireground.

Recommendation #8: Fire departments should ensure that the incident commander incorporates Command Safety into the incident management system.

Discussion: The purpose of Command Safety is to provide the incident commander with the necessary resources on how to use, follow, and incorporate safety into the incident management system at all incidents. Command Safety is used as part of the eight functions of command developed by Fire Chief Alan V. Brunacini (retired). Command Safety defines how the incident commander must use the regular, everyday command functions to complete the strategic-level safety responsibilities during incident operations. Using the command functions creates an effective way and a close connection between the safety officer and the incident command. The eight functions of command are:

- Assumption/confirmation/positioning
- Situation evaluation, which includes risk management
- Communications
- Deployment
- Strategy/incident action planning
- Organization
- Review/revision
- Transfer/continuation/termination [Brunacini 2002; Brunacini and Brunacini 2004]

A major objective of the incident management system is to create, support, and integrate an incident commander into this process. The incident commander will direct the geographical and functional needs of the entire incident on the task, tactical, and strategic level. Issues develop for the incident commander when these three standard levels are not in place, operating, and effectively connected. One of the most important components is to ensure the incident commander operates on the strategic level from the very beginning of the incident and stays on the strategic level as long as fire fighters are operating in an immediately dangerous-to-life-and-health (IDLH) environment [Brunacini 2002; Brunacini and Brunacini 2004].

The incident commander uses the incident management system as the basic foundation for managing the strategic-level safety function. Command Safety ensures the highest level of safety for fire department members operating at emergency incidents. The incident commander completes the operational and safety responsibility to the fire fighters by performing the eight command functions. These functions serve as a very practical performance foundation for how the incident commander completes the responsibility as the strategic-level incident manager and the overall incident safety manager [NFPA 2014a].

Following this incident, several Command Safety issues were addressed by the fire department as part of their recovery process. These issues included fireground communications personnel accountability, use of a tactical worksheet (which complements personnel accountability and crew integrity), and a continuous scene size-up and evaluation.

Recommendation #9: Fire departments should develop a training program for staff assistants or incident command technicians.

Discussion: The function of a staff aide (e.g., chief's aide, emergency incident technician, field incident technician, or staff assistant) is an essential component of the incident management system [Brunacini 2002]. Functions of the staff aide include maintaining the tactical worksheet; maintaining personnel accountability of all members operating at the incident (resource status and situation status); monitoring radio communications on the dispatch, command, and fireground channels; control information flow by computer, fax, or telephone; and accessing reference material and pre-incident plans [Ciarrocca and Harms 2011; Los Angeles Fire Department 2011; Phoenix Fire Department 2010]. NFPA 1561 *Standard on Emergency Services Incident Management System and Command Safety* states in Chapter 8, "Command Safety," that the staff aide is assigned to facilitate the tracking and accountability (resource status) of the assigned companies or crews [NFPA 2014a].

Some fire departments use fire fighters as staff aides and other fire departments use fire officers to serve as a staff aide for a command officer. Regardless of the rank of the staff aide, the staff aide has to be trained in the duties and responsibilities in order to proficiently function and meet the expectations of the incident commander. These job functions include:

- Size up of the incident Address of incident
  Type of incident
  Name of incident

Resources assigned and responding to the incident Life hazard
Additional resources needed
Exposure problems
Location of the command post

- Maintaining communications with the dispatch center or fire department communications center Dispatch channel
  Command channel
  Tactical channels
- Situation status (what is the incident doing) Are we making progress on this incident?
- Resource status (what are they doing)
  Personnel accountability system (e.g. PASSPORT System)—accountability board or tactical worksheet
  How, what, and where are companies operating? Who is in staging?
- Staging
  Staging area manager(s)
  Separate tactical channel
- Tactical worksheet
  Teletype printout can be used as initial *Incident Briefing* (ICS Form 201).
  Transfer information immediately upon arrival to the department's tactical worksheet and   document companies by assignment or location (personnel accountability system). Diagram the incident starting with Side Alpha.
  Document divisions and groups with assigned supervisor.
  Document response of other resources on scene (e.g., law enforcement, other fire departments).

As the incident expands, officers could be assigned as a division supervisor or group supervisor. The assigned officer will proceed to the division or group and evaluate and report conditions to the incident commander. If directed by the incident commander, the assigned officer will assume responsibility for directing resources and operations within their assigned area of responsibility. Division/group supervisors assigned to operate within the hazard zone must be with a second individual, which would be the staff aide. The staff aide can assist the division/group supervisor by maintaining accountability of the resources assigned that particular division/group. The division/group supervisor and the staff assistant will be required to be equipped with the appropriate protective clothing and equipment for their area of responsibility [Los Angeles Fire Department 2011].

At a structure fire, an incident command technician (ICT) is initially assigned to Side Charlie to report conditions to Command. The ICT then goes inside with the first-alarm companies. In order to ensure that personnel accountability is started during initial fireground operations, the ICT should assist the incident commander with the tactical worksheet as needed. Then the ICT starts the personnel accountability system process as defined by the department's SOP. At this incident, due to the immediate issues of life safety, the ICT assisted with the rescue of the building occupants.

Recommendation #10: Fire departments should integrate current fire behavior research findings developed by the National Institute of Standards and Technology (NIST) and Underwriter's Laboratories (UL) into operational procedures by developing standard operating procedures, conducting live fire training, and revising fireground tactics.

Discussion: The National Institute of Standards and Technology (NIST) and Underwriters Laboratories (UL) have conducted a series of live burn experiments designed to replicate conditions in modern homes and residential structures and to validate previous testing done in laboratory settings. The results of these experiments will enable fire fighters to better predict and react to effects of new materials and construction on fire. The fire research experiments were conducted in cooperation with the Fire Department of New York, Chicago Fire Department, Spartanburg, South Carolina Fire and Rescue, and other agencies. The live burn tests are aimed at quantifying emerging theories about how fires are different today, largely due to new building construction and the composition of home furnishings and products. In the past, these products were mainly composed of natural materials, such as wood and cotton, but now contain large quantities of petroleum-based products and synthetic materials that burn faster and hotter and generate large volumes of fuel-rich smoke. Where a fire in a room once took approximately 20 minutes to "flashover"—igniting all the contents—this can happen with today's furnishings in as little as 4 to 5 minutes [NIST and UL 2013; Madrzykowski and Kerber 2009].

In addition, modern living spaces tend to be more open, less compartmentalized, and better insulated than homes built years ago. As a result, interior residential fires can generate oxygen-depleted, fuelrich environment within minutes. This fire condition of hot, fuel-rich smoke is highly reactive to the introduction of oxygen. Introducing oxygen to this environment by opening a door or venting a window may result in a rapid transition to flashover. These same conditions can occur in commercial structures as seen in the Charleston, South Carolina, Sofa Super Store fire [NIOSH 2009].

The NIST and UL experiments evaluated individual and combinations of methods for strategically ventilating and isolating fires to prevent flashover—or at least delay it. In contrast, forcing a door open or breaking a window without knowledge of conditions inside could create a portal for air that can literally fan the flames by introducing oxygen into an oxygen-limited fire environment.

Fire suppression operations are frequently conducted from the interior of the structure as a means of introducing fire fighters into the building to locate occupants, reducing water damage, and limiting fire damage to structures. These operations must be coordinated with the ventilation operations. Previous research and examinations of line-of-duty deaths have shown that ventilation events occurring with fire fighters in the structure prior to suppression have led to tragic results [NIOSH 2009; NIOSH 2012, NFPA 2013]. One means of eliminating the possibilities of this occurrence would be a transitional attack in which water is directed into the structure from the exterior onto the known fire location in order to cool the fire gases and reduce the heat-release rate of the fire, prior to the fire fighters entering the building. The major concern with this type of operation is the potential harm that might occur to people trapped in the structure.

Based upon the NIST and UL research, NIOSH [2012] suggests the following fireground operations should be considered for implementation.

- **Size-Up.** Size-up must occur at every fire. Consideration must be given to the resources available and situational conditions, such as weather, fire location, size of the fire and building, and the construction features. Ensure a 360-degree size-up is conducted whenever possible. A tactical plan for each fire must be developed, communicated, and implemented.

- **Ventilation.** Fire departments should manage and control the openings to the structure to limit fire growth and spread and to control the flow path of inlet air and exiting fire gases during tactical operations. All ventilation must be coordinated with suppression activities. Uncontrolled ventilation allows additional oxygen into the structure that may result in a rapid increase in the fire development and increased risk to fire fighters due to increased heat-release rates.

- **Fire-fighting Operations.** Given the fuel-rich environment that the fire service operates in today, water should be applied to the fire as soon as possible. In many cases, water application through an exterior opening into a fire compartment may be the best first action. Fire departments should cool the interior spaces of a fire building with water from the safest location possible, prior to committing personnel into spaces with, or adjacent to, fully developed or ventilation-limited fire conditions.

- **Rapid Intervention.** Fire department rapid intervention procedures should be updated to ensure that during fire fighter Mayday incidents, water is put on the fire as soon as possible and ventilation openings are controlled.

The fire service has recently been introduced to (and many fire departments have adopted) the acronym *SLICE-RS* by the International Society of Fire Service Instructors, which has been specifically designed to help first-arriving company officers apply recent research on modern fuels and fire dynamics to their early strategic and tactical decisions on the fire ground.

- **S**ize up all scenes.
- **L**ocate the fire.
- **I**dentify and control the flow path.
- **C**ool the heated space from a safe location.
- **E**xtinguish the fire.
- **R**escue and **S**alvage (are actions of opportunity that must be considered not only at the initiation of operations, but throughout the incident) [Modern Fire Behavior, 2014].

Identifying and controlling the flow path is about knowing where the air comes from and where it’s headed. The importance of identifying and using flow path information cannot be underestimated and should find its way into every after-action review. The intent is to locate the fire, cool the heated space from a safe location, and ensure for the safety of the fire fighters. Once the fire is under control, the fire can be completely extinguished. The rescue and salvage operations are self-explanatory—if anything can be saved, save it. These two actions are always active, from initial scene size-up to extinguishment.

This information is presented to educate the fire service and to ensure that fire departments consider a change in fireground tactics based upon the current research presented by NIST and UL. Much of this research has been directed toward developing a better understanding of the characteristics of the modern fire. This modern research provides members of the fire service with the information and knowledge needed to modify essential fire-fighting tactics. While fire-fighting will never be without risk, this research represents a vital contribution to overall efforts to reduce risks and increase fire fighter effectiveness and to save lives of civilians and fire fighters.

Recommendation #11: Fire departments should ensure that fire fighters use structural fire-fighting protective hoods on all structure fires.

Discussion: NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program* states that members should be provided and use a protective ensemble that meets the requirements in NFPA 1971 *Standard on Protective Ensembles for Structural Firefighting and Proximity Firefighting* [NFPA 2013h]. Protective hoods are an integral part of the overall protective ensemble. They are included as an interface device to protect the areas of the fire fighter’s head, face, and neck that are not covered by the protective helmet, SCBA facepiece, and protective coat collar and collar closure. These hoods are typically constructed of knitted material with a face opening to fit around the SCBA facepiece and "bib" extensions of the material to remain tucked under the fire fighter's coat. NFPA 1971 states that protective hoods have a lower thermal insulation requirement than garments (a TPP rating of 20 for protective hoods, compared to the minimum 35 required for garments). Protective hoods still have to meet all of the flame and heat resistance requirements typically associated with garment materials. As a consequence, protective hoods are heavy, single-ply or double-ply materials using Nomex®, PBI®, P84®, Basofil®, Kevlar®, and FR rayon fibers. The lower TPP rating for the hoods is justified on the basis that as an interface device, other ensemble components (mainly the helmet ear covers, which are also required to have a minimum TPP rating of 20) work together to afford the needed thermal insulation [Stull and Stull 2014; NFPA 2013h].

Owing to their knit constructions, hoods are typically "one size fits all" but should be carefully selected to fit properly with the other equipment, primarily the SCBA facepiece. Because hoods are repeatedly stretched over the facepiece and the wearer's head, some hoods quickly lose their shape and can fail to properly protect the fire fighter [Stull and Stull 2014]. NFPA 1971 has attempted to address this requirement with a test for measuring the hood face opening size after repeated donning and doffing of the hood on a manikin head form [NFPA 2013h, 2014b].

Features for hoods are relatively simple. These usually consist of:

- The type of face opening (some hoods are designed to accommodate specific respirator facepieces).
- The length of the sides, front, and back (sometimes referred to as "bibs").

Some of the reluctance to using protective hoods has been due to resistance by some fire fighters to the idea of total encapsulation of the body. Many more traditional fire fighters claim that they use their ears as "early warning" sensors to detect excessive heat and know when to leave. Unfortunately, the sensitivity of ears to heat also makes them very vulnerable to high heat. Protective hoods have repeatedly demonstrated their effectiveness in covering those exposed portions of the face not covered by other elements of the ensemble [Stull and Stull 2014].

At this incident, protective hoods were not worn by the individual fire fighters. While the lack of protective hoods were not found to be a contributory cause to the fatalities as determined in this investigation, the fire service should consider using complete protective ensembles, including protective hoods, for structural fire-fighting.

Recommendation #12: Fire departments should ensure that all members engaged in emergency operations receive annual proficiency training and evaluation on fireground operations.

Discussion: In order to ensure for the proficiency and competency of fire department members, the fire department should conduct annual skills evaluation to verify minimum professional qualifications. This annual evaluation should address the qualifications specific to the member's assignment and job description. This process should be structured in a manner where skills are evaluated on a recurring cycle with the goal of preventing the degradation of skills and abilities and ensuring for the safety of members. Proficiency evaluation and training provides an opportunity to ensure that all fire officers and fire fighters are competent in the knowledge, skills, and abilities in fireground operations. NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program* requires a fire department to establish and maintain a training, education, and professional development program with the goal of preventing occupational deaths, injuries, and illnesses. This ensures members are trained and competencies are maintained in order to effectively, efficiently, and safely execute all responsibilities [NFPA 2013d].

This process is consistent with the organizational statement that establishes the existence of the fire department. The services the fire department is authorized and expected to perform, the organizational structure, and the job descriptions and functions of fire department members are essential in formulating a structured training program [NFPA 2013d]. The primary goal of all training, education and professional development programs is the reduction of occupational injuries, illnesses, and fatalities. As members progress through various job duties and responsibilities, the department should ensure the introduction of necessary knowledge, skills, and abilities to members who are new in their job titles as well as ongoing development of existing skills [NFPA 2015].

NFPA 1410 *Standard on Training for Emergency Scene Operations* defines basic evolutions that can be adapted to local conditions and serves as a method for the evaluation of minimum acceptable performance during initial fireground operations [NFPA 2015]. Proficiency training for fireground operations and emergency incidents should be conducted annually. This training should include, but not be limited to, scene size-up, situational awareness, use of the incident management system, personnel accountability system, strategy and tactics, search and rescue, hoseline operations, ladder operations, ventilation, thermal imaging cameras, fireground communications, use of rapid intervention teams, and Mayday operations.

As part of the department's analysis process of this incident, the commissioner has initiated a "back to basics" training program for the department. This process involves a structured training program that consists of company-level training conducted at the fire academy. All companies will be required to participate in live-fire training evolutions annually at the fire academy. This training will be completed by each district on each shift. The training will be conducted by companies who are dispatched as part of a first-alarm assignment in their first-due area.

Recommendation #13: Fire departments should consider using large-volume SCBA cylinders for operations in medium- and high-risk occupancies.

Discussion: A typical 30-minute (1200-liter) SCBA cylinder may not provide an adequate quantity of breathing air for fire fighters working in multi-family, commercial, or high-rise occupancies. The 1200-liter cylinder will last an average fire fighter actively engaged in suppression activities about 15– 18 minutes [Gagliano et al. 2008]. NFPA 1852 *Standard on Selection, Care and Maintenance of Opencircuit Self-contained Breathing Apparatus,* A.5.1.5, states, "During extreme exertion, for example, actual service time can be reduced by 50 percent or more" [NFPA 2013f]. In addition to the degree of user exertion, other conditions that effect the SCBA service time include:

- Physical condition of the fire fighter.
- Emotional conditions, such as fear or excitement, which can increase the user's breathing rate.
- Degree of training or experience the user has had with such equipment.
- Amount of air in the cylinder at the beginning of use; the cylinder should be fully charged at the beginning of use.
- Facepiece fit.
- Use in a pressurized tunnel or caisson.
- Condition of the SCBA.
- The SCBA effective dead air space.

SCBAs that are certified by NIOSH include a rated service time based on laboratory tests required by NIOSH. The SCBA is tested using a specified breathing machine with a breathing rate of 40 liters/minute. NIOSH uses the 40 liters/minute rate because it represents a moderate work rate that an average user can sustain for a period of time. To attain a rated service time of 30 minutes, during this 40 liter/minute test, the typical SCBA cylinder has to contain 1200 liters or more of compressed breathable air. A 45-cubic-foot cylinder has a capacity of 1273.5 liters, based on 28.3 cubic feet. Because actual work performed by fire fighters often results in a ventilation rate that exceeds 40 liters/minute, these fire fighters frequently do not attain the rated service time of 30 minutes [NFPA 2013f].

Fire departments should ensure that fire fighters have enough air in their cylinder to complete the mission of their work assignment. A 30-minute (1200 liter) SCBA might be sufficient for fire fighters operating in a 3000-square-foot, single-family dwelling. For fire fighters operating in a multi-family, commercial, or high-rise occupancy, a 1200-liter cylinder might not be sufficient. Fire fighters must have enough air by volume to effectively provide a work period inside an IDLH atmosphere and still contain enough air volume to exit the IDLH with their reserve air intact. The primary benefit of an 1800-liter cylinder is the substantial increase in reserve air if an emergency occurs. The intent of the additional breathing air is to keep the same work period but also increase the amount of emergency reserve air.

In conjunction with the department's community risk assessment program, a risk assessment should include, but not be limited to:

- The expected hazards that can be encountered by fire fighters using SCBA.
- The type of duties to be performed, frequency of use, and the organization's experiences.
- The organization's geographic location and climatic conditions.

An assessment can identify various occupancies in a jurisdiction that require additional breathing air. The companies assigned to the areas or occupancies can be equipped with 1800-liter cylinders. Cylinders are made of significantly lighter materials and contain higher pressure, greater volume, and smaller profile. All SCBA manufacturers are now offering these cylinders. Some manufacturers are offering higher pressure (5500 psi) cylinders, which reduce the weight and increase the volume over existing cylinders. The most important part of the needs assessment is to identify the areas of the jurisdiction that need the increased air volumes and then provide the equipment and training to those companies that respond or could be called upon to respond to incidents in those areas. NFPA 1852 *Standard on Selection, Care and Maintenance of Open-circuit Self-contained Breathing Apparatus* provides fire departments with basic criteria for evaluation and selecting open-circuit SCBA [NFPA 2013f].

In this incident the fire department provided current edition, certified SCBA with 4500-psi composite 1200-liter (30-minute) cylinders to all fire fighters. Many fire fighters reported that end-of-service-time indicators (EOSTIs) were sounding inside the fire building in the IDLH atmospheres in less than 20 minutes. With a change to 1800-liter cylinders, this would allow a true 20-minute work period with emergency reserve air capacity.

Recommendation #14: Fire service research organizations, standards making organizations, equipment manufacturers, and fire departments should consider the effects of thermal degradation on fire attack hose.

Discussion: During this incident, the 1¾-inch attack hoseline used by Engine 33 was burned through during the initial fire-fighting operations. Engine 33 had stretched the hoseline down the stairs from the first floor to the basement. This placed the hoseline in the flow path of the fire and super-heated gases coming up the stairs. The 1¾-inch hoseline was burned completely in two. The 2½-inch hoseline that Engine 7 stretched to the first floor was severely damaged as well.

During the investigation of this incident, NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) investigators reviewed previous cases and identified several instances in which hoselines had been burned through during structural fire-fighting operations. Current hoseline standards do not address the thermal performance of attack hoselines, and technical information published by manufacturers does not include thermal performance data. Attack hose is defined by NFPA 1961 *Standard on Fire Hose* [NFPA 2013g] as "hose designed to be used by trained fire fighters and fire brigade members to combat fires beyond the incipient stage. Attack hose is designed to convey water to hoseline nozzles, distributor nozzles, master stream appliances, portable hydrants, manifolds, standpipe and sprinkler systems and pumps used by fire departments." The hoseline serves not only as a tool to help extinguish the fire but also provides a measure of safety to the hoseline crew. Attack hose can be used as a means to locate an escape route in the event of Mayday or other emergency.

In an effort to better understand the thermal performance of attack hose, NIOSH FFFIPP investigators contacted the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) for assistance. In response, the ATF Fire Research Laboratory began a series of tests to explore the impact of radiant heat on attack hose. The ATF Research Laboratory established heat flux values and developed full-scale tests to replicate fireground conditions. To date, the testing has included full-scale burns and bench testing using samples of new and used 1¾-inch attack hose of varying grades and construction. Tests are being conducted with hose samples dry and charged at both high and low heat flux levels. Hose similar to that used in this incident was incorporated in the test samples and continued testing will include samples of 2½-inch hose of varying styles and manufacturer. The results, including documentation of the test methods, will be made available to NFPA and the fire service at the completion of the test series.

The NFPA Technical Committee on Fire Hose has discussed two issues, but no final action has been taken yet. First is to develop a registry on reported hose failures. Second is to develop a safety alert about fire hose and thermal degradation.

It is hoped that this information will prompt further research, discussion, a review of fireground tactics by fire departments, and action on the part of fire service research organizations, equipment manufacturers, standard-making organizations, and fire departments.

Additionally, Recommendation #15: Code-setting organizations and municipalities should consider requiring the use of sprinkler systems in residential structures. Especially residential occupancies having high fuel loads, other unique life-safety hazards, and to establish retroactive requirements for the installation of fire sprinkler systems.

Discussion: This recommendation focuses on fire prevention and minimizing the impact of a fire if one does occur. The National Fire Protection Association (NFPA) *Fire Protection Handbook* states, "Throughout history there have been building regulations for preventing fire and restricting its spread. Over the years these regulations have evolved into the codes and standards developed by committees concerned with fire protection. The requirements contained in building codes are generally based upon the known properties of materials, the hazards presented by various occupancies, and the lessons learned from previous experiences, such as fire and natural disasters" [NFPA 2008]. Although municipalities have adopted specific codes and standards for the design and construction of buildings, structures erected prior to the enactment of these building codes may not be compliant.

Such new and improved codes can improve the safety of existing structures [NFPA 2008]. Sprinkler systems are one example of a safety feature that can be retrofitted into older structures. Sprinkler systems can reduce fire fighter and civilian fatalities since such systems can contain and may even extinguish fires prior to the arrival of the fire department.

Fire development beyond the incipient stage presents one of the greatest risks fire fighters are exposed to during fireground operations. This risk exposure to fire fighters can be dramatically reduced when fires are controlled or extinguished by automatic sprinkler systems.

NFPA statistics show that most fires large enough to activate a sprinkler system are controlled by just one or two sprinkler heads [NFPA 2008]. An automatic fire sprinkler system also reduces the exposure risk to fire fighters during all phases of fireground operation and allows the safe egress of building occupants before the fire department arrives on scene. Finally, by controlling fire development, the risks associated with the potential for structural collapse and during overhaul operations are greatly reduced, if not eliminated.

References

Brunacini AV [2002]. Fire command. Quincy, MA: National Fire Protection Association. Brunacini AV, Brunacini N [2004]. Command safety: the IC's role in protecting firefighters. Phoenix, AZ: Across the Street Publications.

Ciarrocca M, Harms T [2011]. Help on the scene. Fire Rescue Magazine *29*(2):40–48.

FDNY [2009a]. Firefighting procedures. Vol. 1. Book 2: Brownstone and rowframe building fires. New York, NY; Fire Department of New York.

FDNY [2009b]. Firefighting procedures. Vol. 1. Book 4: Taxpayer fires June 2009. New York, NY: Fire Department of New York.

FDNY [2011]. Communications manual. Chapter 4, Critical information dispatch system **(**CIDS). New York, NY: Fire Department of New York.

FDNY [2013a]. Wind impacted fires in fireproof multiple dwellings, Addendum 3. In: Firefighting procedures. Vol. 1. New York, NY: Fire Department of New York.

FDNY [2013b]. Training bulletin, search. New York, NY. Fire Department of New York, October.

Fire and Rescue Departments of Northern Virginia [2013]. Engine company operations. 2nd ed. Fairfax, VA: Northern Virginia Regional Commission, Fire and Rescue Departments of Northern Virginia.

Fire Protection Research Foundation [2013]. Fire fighter tactics under wind driven conditions, parts 1– 4, rev. Quincy, MA: National Fire Protection Association, Fire Protection Research Foundation, http://www.nfpa.org/research/fire-protection-research-foundation/projects-reports-and-proceedings/for-emergency-responders/fireground-operations/fire-fighting-tactics-under-wind-drivenconditions.

FIRESCOPE [1994]. Incident command system for fire department structure fire operations. Riverside, CA: FIRESCOPE, ICS-SF.

FIRESCOPE [2012]. Field operations guide. Riverside, CA: FIRESCOPE, ICS 420-1.

Gagliano M, Phillips C, Jose P, Bernocco S [2008]. Air management for the fire service. Tulsa, OK: Penn Well Corporation, Fire Engineering.

IAFF [2010]. Fire ground survival. Washington, DC: International Association of Fire Fighters. ISFSI [2013]. International Society of Fire Service Instructors position statement--fire dynamic research in tactical operations. Press release, October 30.

Los Angeles Fire Department [2011]. Los Angeles Fire Department command post training. Los Angeles, CA: Los Angeles Fire Department.

Madrzykowski D, Kerber S [2009]. Firefighting tactics under wind driven conditions: laboratory experiments. Gaithersburg, MD: National Institute of Standards and Technology, NIST TN 1618.

Modern Fire Behavior [2014]. SLICE–RS, (This text is also accessible at the following URL: http://modernfirebehavior.com/s-l-i-c-e-r-s/).

New York Landmarks Conservancy [2003]. The brownstone guide: maintenance & repair facts for historic property owners; New York, NY: New York Landmarks Conservancy. NFPA [1997]. NFPA 1582 *Standard on comprehensive occupational medical program for fire departments*. Quincy, MA: National Fire Protection Association.

NFPA [2008]. Fire protection handbook. 20th ed. Quincy, MA: National Fire Protection Association. NFPA [2013a]. Fire service deployment: assessing community vulnerability. 2nd ed. High-rise implementation guide. Quincy, MA: National Fire Protection Association.

NFPA [2013b]. NFPA 472, *Standard for competence of responders to hazardous materials/weapons of mass destruction incidents.* Quincy, MA: National Fire Protection Association.

NFPA [2013c]. NFPA 1001 *Standard on fire fighter professional qualifications*. Quincy, MA: National Fire Protection Association.

NFPA [2013d]. NFPA 1500 *Standard on fire department occupational safety and health program*. Quincy, MA: National Fire Protection Association.

NFPA [2013e]. NFPA 1710 Standard *for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments*. Quincy, MA. National Fire Protection Association.

NFPA [2013f]. NFPA 1852 *Standard on selection, care and maintenance of open-circuit selfcontained breathing apparatus for emergency services*. Quincy, MA. National Fire Protection Association.

NFPA [2013g]. NFPA 1961 *Standard on fire hose*. Quincy, MA: National Fire Protection Association. NFPA [2013h]. NFPA 1971 S*tandard on protective ensembles for structural fire-fighting and proximity firefighting*. Quincy, MA: National Fire Protection Association.

NFPA [2014a]. NFPA 1561 *Standard on emergency services incident management system and command safety*. Quincy, MA: National Fire Protection Association.

NFPA [2014b]. NFPA 1851 *Standard on selection, care, and maintenance of protective ensembles for structural fire-fighting and proximity firefighting*. Quincy, MA. National Fire Protection Association.

NFPA [2015]. NFPA 1410 Standard on training for emergency scene operations. Quincy, MA: National Fire Protection Association.

NIOSH [2009]. Nine career fire fighters die in rapid fire progression at commercial furniture showroom—South Carolina. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2007-18 http://www.cdc.gov/niosh/fire/pdfs/face200718.pdf. (This link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/pdfs/face200718.pdf)

NIOSH [2012]. Volunteer fire fighter caught in a rapid fire event during unprotected search, dies after facepiece lens melts—Maryland. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2011-02, http://www.cdc.gov/niosh/fire/pdfs/face201118.pdf. (This link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/pdfs/face201118.pdf)

NIOSH [2013]. Career captain sustains injuries at a 2½ story apartment fire then dies at hospital - Illinois. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2012-28 http://www.cdc.gov/niosh/fire/pdfs/face201228.pdf. (THis link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/pdfs/face201228.pdf)

NIOSH [2015]. Four career fire fighters killed and 16 fire fighters injured at commercial structure fire—Texas. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2013-16 TX, http://www.cdc.gov/niosh/fire/pdfs/face201316.pdf. (This link is also accessible at the following UR: https://www.cdc.gov/niosh/fire/pdfs/face201316.pdf)

NIST [2013a]. Report on high-rise fireground field experiments, fire fighter safety and deployment study. Gaithersburg, MD: National Institute of Standards and Technology.

NIST [2013b]. Wind driven fires. Gaithersburg, MD: National Institute of Standards and Technology, http://www.nist.gov/index.cfm.

NIST, UL [2013]. Studying fire behavior and fireground tactics. Presentation at the IAFF Redmond Symposium, Denver, CO, August 24.

Phoenix Fire Department [2010]. Command procedures. In: Phoenix regional standard operating procedures, management procedures, 201.01. Rev**.** Phoenix, AZ: Phoenix Fire Department.

Stull J, Stull G [2014]. How to select firefighter helmets and hoods. FireRecruit.com, April 5, https://www.firerecruit.com/articles/245718-How-to-select-firefighter-helmets-and-hoods. (This link is also accessible at the following URL: https://www.firerecruit.com/articles/245718-How-to-select-firefighter-helmets-and-hoods).

Township of Spring Fire Rescue [2013]. Initial fireground assessment standard operating procedure, section 3. Response to alarms, subsection 3.00.01. Township of Spring, PA: Township of Spring Fire & Rescue.

Weather Underground [2014]. Weather history for KBOS, Wednesday, March 26, 2014. Atlanta, GA: The Weather Channel Interactive, Inc., http://www.wunderground.com/history/airport/KBOS/2014/3/26/DailyHistory.html?req_city=Boston&req_state=MA&req_statename=Massachusetts&reqdb.zip=02101&reqdb.magic=1&reqdb.wmo=99999. (This link is also accessible at the following URL; https://www.wunderground.com/history/airport/KBOS/2014/3/26/DailyHistory.html?req_city=Boston&req_state=MA&req_statename=Massachusetts&reqdb.zip=02101&reqdb.magic=1&reqdb.wmo=99999).

Investigator Information

This incident was investigated by Murrey Loflin, Matt Bowyer, Steve Miles, and Stacy Wertman 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 authored by Murrey Loflin. Two subject matter experts who assisted with the investigation and provided the technical review were Deputy Chief Michael McPartland of the Fire Department of New York and Peter Van Dorpe, Chief at Algonquin-Lake in the Hills Fire Protection District and retired Director of Training for the Chicago Fire Department. Additionally, Adam St. John, Fire Protection Engineer with the Bureau of Alcohol, Tobacco, Firearms, and Explosives, Stephen Kerber, Director, UL Fire Fighter Safety Research Institute, and Dan Madrzykowski, fire protection engineer in the Firefighting Technology Group of the Fire Research Division (FRD) of the Engineering Laboratory (EL) at NIST served as a subject matter experts due to their expertise with modern fire behavior and wind-driven fires. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Additional Information

Modern Fire Behavior

This site is meant to serve as a clearinghouse of news and training information related to Modern Fire Behavior and Modern Building Construction Research, Tactics, and Practices along with actual street experiences.(This link is also accessible at the following URL: http://modernfirebehavior.com/).

National Institute for Standards and Technology and Underwriters Laboratories
These two agencies provide information including training videos showing the findings from NIST and UL research conducted in cooperation with the Fire Department of New York on Governor's Island in 2012.
http://www.firecompanies.com/modernfirebehavior/governorsislandonlinecourse/story.html.

Flashover TV sponsored by FireRescue.com includes a series of training presentations by NIST researcher Dan Madrzykowski. (This link is also accessible at the following URL: http://flashovertv.firerescue1.com/videos/1875870-nist-and-ul-research-on-fire-dynamic-case-studiespart-4/).

Information on completed fire-fighting research studies available at the National institute of Standards and Technology website at
http://www.nist.gov/el/fire_research/firetech/index.cfm.

The information on completed fire-fighting research studies available at the UL Firefighter Safety Research Institute website. (This link is also accessible that the following URL: www.ULfirefightersafety.com).

IAFC Rules of Engagement for Firefighter Survival

The International Association of Fire Chiefs (IAFC) is committed to reducing fire fighter fatalities and injuries. As part of that effort the nearly 1,000 member Safety, Health and Survival Section of the IAFC has developed DRAFT "*Rules of Engagement for Structural Firefighting*" to provide guidance to individual fire fighters, and incident commanders, regarding risk and safety issues when operating on the fireground. The intent is to provide a set of "model procedures" for structural fire-fighting to be made available by the IAFC to fire departments as a guide for their own standard operating procedure development. http://www.iafcsafety.org/downloads/Rules_of_Engagement.

IAFF Fire Ground Survival Program
The purpose of the International Association of Fire Fighters (IAFF) Fire Ground Survival Program is to ensure that training for Mayday prevention and Mayday operations are consistent between all fire fighters, company officers and chief officers. Fire fighters must be trained to perform potentially lifesaving actions if they become lost, disoriented, injured, low on air or trapped. Funded by the IAFF and assisted by a grant from the U.S. Department of Homeland Security through the Assistance to Firefighters (FIRE Act) grant program, this *comprehensive fire ground survival training program* applies the lessons learned from fire fighter fatality investigations conducted by the National Institute for Occupational Safety and Health (NIOSH) and has been developed by a committee of subject matter experts from the IAFF, the International Association of Fire Chiefs (IAFC) and NIOSH. (This link is also accessible at the following URL: http://www.iaff.org/HS/FGS/FGSIndex.htm).

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*
(2014 edition)

The primary focus of the revision to NFPA 1561 in the 2014 edition is develop requirements directly aimed at reducing and eliminating fireground injuries and fireground deaths of fire department members. The most apparent change addition to this edition has been the document title to include "Command Safety" and the creation of a new chapter, *Command Safety*. This chapter is intended to provide a foundation on how to incorporate the incident management system at all emergency incidents especially *Type V* and *Type IV* incidents.

The chapter on "Command Safety" clearly defines the requirements for the incident commander to meet including establishing a fixed Command Post, personnel accountability, the use of staff aides, rapid intervention crews, and the appointment of a safety officer and assistant safety officer(s)(as needed) plus the expectations and authority of the safety officer. There are annexes that cover *Functional Assignments for High-Rise Building Incidents*, *Development of Subordinate Officers or Implementing a More Efficient Management System*, *Incident Management for the Fire Service on Type 5 or Type 4 Incidents*, and *Structural Firefighting — Risk Assessment and Operational Expectation.*

NFPA 1561, *Standard on Emergency Services Incident Management System and Command Safety*
(2014 edition) can be purchased from the National Fire Protection Association. (This link is also accessible at the following URL; http://www.nfpa.org).

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). In addition, citations to Web sites 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 Web sites. All web addresses referenced in this report were accessible as of the publication date.

Appendix One

Status Investigation Report of Two Self-Contained Breathing Apparatus Submitted By: The NIOSH Division of Safety Research

NIOSH Task Number 19925
(***Note:*** *Full report is available upon request*)

Background

As part of the ***National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program***, the Technology Evaluation Branch agreed to examine and evaluate two SCBA identified as Scott Health and Safety model AirPak 4.5, 4500 psi, 30-minute, selfcontained breathing apparatus (SCBA).

This SCBA status investigation was assigned NIOSH Task Number 19925. The NIOSH Division of Safety Research (NIOSH/DSR) and fire department were advised that NIOSH would provide a written report of the inspections and any applicable test results.

The SCBA units, contained within cardboard boxes, were delivered to the NIOSH facility in Bruceton, Pennsylvania on November 6, 2014. After their arrival, the packages were taken to building 20 and stored under lock until the time of the evaluations.

SCBA Inspection

The packages were opened initially in the General Respirator Inspection Area (Building 20) on

November 14, 2014 and an initial visual inspection was conducted by Tom Pouchot, Certification Coordinator NPPTL. A reference SCBA was included by the fire department. On November 17, 2014, the SCBA data logger for Unit #2 was down loaded by personnel from Scott Health and Safety with NIOSH personnel present. The SCBAs were inspected extensively on November 14 and 17, 2014. The SCBA identified as the fire department SCBA, was labeled by NPPTL as SCBA Unit #1, and was inspected on November 14, 2014. The SCBA identified as fire department SCBA was labeled by NPPTL as SCBA Unit #2, and was inspected on November 17, 2014. A third SCBA was included as a reference unit and was labeled *Unit Reference*. The SCBA units involved in the incident were extensively examined, component by component, in the condition they were received to determine the conformance of the unit to the NIOSH-approved configuration. The units were identified as the Scott Health and Safety Company model AirPak 4.5, 30 minute, 4500 psi units, NIOSH approval numbers TC-13F-0076CBRN. The visual inspection process was documented photographically.

Also on November 17, 2014 Scott Health and Safety conducted a down-loading of the data logger for SCBA Unit #2. The SCBA Unit #1 data logger could not be down loaded due as the unit was extensively damage. Once all inspections were completed, the SCBA units were repackaged and placed back in Building 20 in a secured and locked room.

The condition of each major component of each of the SCBA's that were photographed with a digital camera.

It was judged that only Unit #2 could be safely pressurized and tested using a substitute cylinder and facepiece provided by the fire department. Unit #2 and the Unit Reference were tested on February 27, 2015.

SCBA Testing

The purpose of the testing was to determine the conformance of each SCBA to the approval performance requirements of Title 42, *Code of Federal Regulations,* Part 84 (42 CFR 84). Further testing was conducted to provide an indication of the conformance of each SCBA to the National Fire Protection Association (NFPA) Air Flow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service,* 1997 Edition.

NIOSH SCBA Certification Tests (in accordance with the performance requirements of 42 CFR 84):
Positive Pressure Test [§ 84.70(a)(2)(ii)]

1. Rated Service Time Test (duration) [§ 84.95]
2. Static Pressure Test [§ 84.91(d)]
3. Gas Flow Test [§ 84.93]
4. Exhalation Resistance Test [§ 84.91(c)]
5. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

National Fire Protection Association (NFPA) Tests (in accordance with NFPA 1981, 1997 Edition):

6. Air Flow Performance Test [Chapter 5, 5-1.1]

Unit #2 was the only unit in a condition to be tested along with the Unit Reference. These units were tested on February 27, 2015 using a substitute cylinder and facepiece.

Summary and Conclusions

Two SCBA units along with a reference SCBA unit were submitted to NIOSH by the NIOSH Division of Safety Research for the fire department for evaluation. The SCBA units were delivered to NIOSH on November 6, 2014 and initially inspected on November 14, 2014. The units were identified as a Scott Health and Safety model AirPak 4.5, 4500 psi, 30-minute, SCBA (NIOSH approval number TC-13F-0076CBRN). Scott Health and Safety performed a downloading of the Unit #2 data logger on November 17, 2014. The complete inspections of the SCBA units were conducted on November 14, 2014 for Unit #1 and on November 17, 2014 for Unit #2. The Unit #1 was extensively damaged while Unit #2 suffered only slight levels of heat damage, exhibited other signs of wear and tear and both units were covered generally with dirt and grime. The cylinder valve as received on Unit #2 was in the closed position. The cylinder gauge on Units #2 read 0 psig. The cylinder valve hand-wheel could be turned. No cylinder was included with Unit #1. The regulator and facepiece mating and sealing areas on the Unit #2 were relatively clean but for Unit #1 the facepiece and regulator were locked together due to the damage of both components. There was some dirt on the inside of the facepiece of Unit #2. Unit #1 facepiece was extensively damaged. Unit #2 had some scratches present on the lens. The lens on Unit #1 extensively damaged. Visibility through the facepiece lenses of Units #2 was fair as the lens had scratches and dirt present heat damage.

The facepiece head harness webbing on the Unit #2 was in fair condition with dirt present and some evidence of wear. Unit #1 facepiece head harness was missing. Only the PASS on the Unit #2 functioned. The NFPA approval label was only on present on Unit #2 and readable.

The air cylinder on the Unit #2 had a manufactured date of 10/2011. Under the applicable DOT exemption, the air cylinder is required to be hydro tested every 5 years. For the air cylinder on Unit #2, a retest date before the last day of 10/2016 is required. Therefore the cylinder was within the hydro certification when last used. The cylinder on Unit #2 was partially black. No air was remaining in the cylinder.

Replacement air cylinders with a current hydrostatic re-test qualification were supplied by the fire department. These cylinders were substituted for all Units #2 and Unit Reference tests. In addition, the facepieces were replaced by a facepiece supplied the fire department. No other maintenance or repair work was performed on the units at any time.

SCBA Unit #2 did meet the requirements of the NIOSH Positive Pressure Test, as the unit did maintain a positive pressure, minimum 0.1 inches of water, for the 30 minute minimum duration of the unit. Unit #2 **did meet** the requirements of all of the other NIOSH tests.

SCBA Unit Reference met the requirements of the NIOSH Positive Pressure Test, with a minimum pressure of 0.00 inches of water. The Unit Reference **did meet** the requirements of all of the other NIOSH tests.

In light of the information obtained during this investigation, NIOSH has proposed no further action on its part at this time. The SCBAs were returned to storage pending return to the fire department.

If Unit #2 is to be placed back in service, the SCBA must be repaired, tested, cleaned, damaged components replaced, and inspected by a qualified service technician, including such testing and other maintenance activities as prescribed by the schedule from the SCBA manufacturer. Typically a flow test is required on at least an annual basis.

Appendix Two

Personal Protective Equipment Evaluation
Examination of Fire Fighter Protective Ensemble Items

An examination was made of the selected personal protective equipment worn by the lieutenant and fire fighter from Engine 33, who sustained fatal injuries in a Brownstone on March 26, 2014. These items included the protective coat and protective pants worn by the lieutenant and fire fighter and the station/work uniform worn by the lieutenant.

The lieutenant and fire fighter from E33 entered the structure on the first floor and proceeded down the stairs with a 1¾ inch hose to the basement. Shortly after being in the basement, the fire conditions deteriorated significantly trapping both fire fighters in the basement. Following a Mayday from the lieutenant, radio communications indicated that there was no water to their hoseline. Approximately 30 minutes after entering the structure, a rapid intervention team was were able to remove the fire fighter from E33 from the basement. The lieutenant was not recovered until several hours later.

The protective coat and protective pants worn by fire fighter showed low to moderate thermal damage. Due to the extended time for which he was exposed to the thermal conditions, the protective capabilities of this clothing had been exceeded. In contrast, the protective coat, protective pants, and station/work uniform pants worn by the lieutenant exhibited extreme degradation with burn through of several areas of his turnout gear. The degradation extended to his station/work uniform pants as well.

It was the general conclusion that the protective clothing worn by both fire fighters were not contributory to their fatal injuries. This is given the severe fireground conditions that existed during their entrapment in the basement before they could be located and recovered. Both fire fighters were exposed to extended high heat conditions. The lieutenant had a much long exposure given the extreme conditions that prevented other fire fighters from entering the area where he was trapped.

Although not contributory to this incident, several general recommendations to department regarding personal protective equipment:

- transitioning all of its turnout gear to the current edition of NFPA 1971, *Protective Ensembles for Structural Firefighting and Proximity Firefighting*;
- provide structural fire-fighting protective hoods for all members;
- instruct all members in the proper wearing of these clothing items;
- retain the personal protective equipment for a period of at least two years or otherwise deemed necessary by the fire department.

Appendix Three
Incident Commander's Tactical Worksheet for Mayday

INCIDENT COMMANDER'S TACTICAL WORKSHEET FOR "MAYDAY"

- ☐ MAYDAY - MAYDAY - MAYDAY Message is Transmitted;
- ☐ Announce *EMERGENCY RADIO TRAFFIC* only;
- ☐ Acknowledge Company/Member transmitting the Mayday – Obtain LUNAR information:

LOCATION ______________________________

UNIT ______________________________

NAME ______________________________

ASSIGMENT AND AIR SUPPLY ______________________________

RESOURCES NEEDED ______________________________

- ☐ If no answer after two attempts conduct a PAR of all operating companies on the fire ground to isolate company/member;
- ☐ Deploy RIC to reported or last known location/assignment;
- ☐ Request an additional alarm;
- ☐ Request an additional TAC channel for fire operations TAC___
- ☐ Assure that companies not assigned to the rescue or near the rescue change to the new fire operations channel and conduct a PAR;
- ☐ Maintain fire-fighting positions. Withdraw only if necessary;
- ☐ Establish a Rescue Group with a Safety Officer;
- ☐ Review the Building Pre-Plan if available;
- ☐ Establish a Backup RIC to replace the deployed RIC;
- ☐ Establish a forward staging area for the Rescue Group and provide support with adequate staffing and equipment;
- ☐ Request additional EMS Resources/ALS Ambulances;
- ☐ Request Specialized Resources if needed – Technical Rescue;
- ☐ Conduct a PAR if an emergency evacuation is ordered (due to structural stability or fire conditions);
- ☐ Conduct a PAR after the rescue operation is completed;
- ☐ Announce the end of the Mayday;

Lieutenant and Fire Fighter Die and 13 Fire Fighters are injured in a Wind-driven Fire in Brownstone – Massachusetts.
This link is accessible at https://www.cdc.gov/niosh/fire/pdfs/face201409.pdf#page=77.

Handout 1-1 Group 4:

Career Fire Fighter Dies in Heavy Smoke on Second Floor of a Residential Structure — Texas

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation

Career Fire Fighter Dies in Heavy Smoke on Second Floor of a Residential Structure—Texas

Executive Summary

On July 9, 2014, a 46-year-old male career fire fighter died while conducting interior operations in a two-story residential structure fire. At 15:55 hours, Engine 104 with a crew of four was dispatched to a shed fire. The captain observed fire and black smoke coming from the right side and rear of the structure and called in a box alarm. The crew reported hearing ammunition going off while fire fighter 1 (FF1) and fire fighter 2 (FF2) pulled a 1¾-inch hoseline off the engine.
The captain and FF1 unsuccessfully attempted to force entry into the garage on the front right corner of the structure while FF2 tried knocking down the fire on the right side of the structure.

Two-story residential structure.

The captain and FF1 were able to make forcible entry at the front door.

The captain ordered the hoseline to the front door. After seeing only minimal smoke and no visible fire or civilians on the first floor, they proceeded to a narrow stairway to the second floor. The captain, FF2, and FF1 went to the top of the stairs and encountered several louvered doors and a scuttle hole to the attic. The captain opened the attic access but could only see dark, brown smoke. The captain used a thermal imager and opened doors, searching for civilians and fire. The captain used a pike pole to open the attic scuttle door and poked holes in the ceiling. The captain heard one of the fire fighters say he was getting hot, low on air, and, "Let's go get flashlights." The crew backed down the stairs. The captain then realized FF1 was missing. The captain radioed FF1 several times with no response, then he informed the incident commander of a missing fire fighter. The captain went back to the second floor and could hear a PASS alarm in the room on his left and notified command. His low-air alarm was going off so he had to back out. Engine 63 made entry through the rear double doors off the deck on the second floor and located FF1 just inside the double doors. Engine 63 encountered the rapid intervention crew and took him down a ladder off the rear deck to the yard. After receiving basic life support, he was transported to the hospital where he died from his injuries.

Contributing Factors

- *Crew integrity*
- *Air management*
- *Mayday procedures*
- *Fire-fighting experience*
- *Operational characteristics of the SCBA and other life safety devices*
- *Fireground communications*
- *Ventilation timing*
- *Hoseline deployment*
- *Construction features of the residence*
- *Munition hazards*

Key Recommendations

- *Fire departments should ensure that crew integrity is properly maintained by voice or radio contact when operating in an atmosphere that is immediately dangerous to life or health (IDLH).*
- *Fire departments should ensure that fire fighters and officers are properly trained in air management.*
- *Fire departments should ensure that fire fighters understand the operational characteristics of their SCBA and other life safety devices.*
- *Fire departments should ensure that fire fighters are properly trained in out-of-air SCBA emergencies and SCBA repetitive skills.*
- *Fire departments should ensure that fire fighters are properly trained in Mayday procedures and survival techniques.*
- *Fire departments should ensure fire fighters are sufficiently retrained when transitioning from the emergency medical service back to fire operations.*
- *Fire departments should ensure that accountability officers are proficient in fire fighter tracking/monitoring systems.*
- *Fire departments should ensure that fire fighters are trained in situational awareness, personal safety, and accountability.*

For further information, visit the program website at NOISH program or call toll free 1-800-CDC-INFO (1-800-232-4636). (this link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/)

Death in the line of duty...

NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

Career Fire Fighter Dies in Heavy Smoke on Second Floor of a of a Residential Structure—Texas

Introduction

On July 9, 2014, a 46-year-old male career fire fighter died while conducting interior operations in a

two-story residential fire. On July 10, 2014, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On July 14–18, 2014, a general engineer and an investigator from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Texas to investigate this incident. The NIOSH investigators met with members of the career fire department, an investigator with the Texas State Fire Marshal's Office, and the dispatch center. NIOSH investigators interviewed the incident commander and fire fighters who were on scene at the time of the incident. The NIOSH investigators visited the incident site and took photographs. The selfcontained breathing apparatus (SCBA) was shipped to the NIOSH National Personal Protective Technology Laboratory for evaluation.

Fire Department

The career fire department involved in this incident serves a city with a population of 2,239,000, which is the fourth largest city and the fourth largest fire department in the United States. The fire department is rated by the Insurance Services Office as a Class I fire department and is an internationally accredited department through the Commission on Fire Accreditation International.

The metropolitan population covering a 10-county-wide area is 6,200,000 residents. The city has a total area of 656 square miles that is comprised of 634 square miles of land and 22 square miles of water. The fire department provides aircraft rescue fire-fighting (ARFF) for two large commercial airports. The fire department provides automatic aid with one career fire department and one volunteer fire department, which are located in entities within the municipality. Also, the fire department is part of a regional mutual aid pact that covers transportation emergencies in the greater metropolitan area.

The fire department employs 3,907 personnel, of which 3,789 are uniformed members. The daily minimum staffing for the Emergency Response Division is 832 personnel. The Emergency Response Division operates on a 24/72 work schedule, which equates to a 47.6-

hour work-week, including a 24hour debit day, which is worked approximately once every 36 days.

The Emergency Response Division is divided into two divisions—north and south. A deputy chief staffs each division on each shift. The South Division (Shift Commander 37) contains 13 districts or battalions (District 21, 28, 59, 68, 78, 83, 20, 26, 46, 70, 71, 11 [Rescue], and 22 [Haz Mat]). The North Division (Shift Commander 15) contains 10 districts or battalions (District 4, 5, 6, 8, 19, 34, 45, 64, 102, and ARFF). District 54, which provides ARFF and emergency medical services, is under the direction of the aircraft rescue coordinator covering Fire Stations 54, 81, 92, and 99. District 22 is the department's hazardous materials unit staffed at Fire Station 22. District 11 is the department's rescue district, which has three rescue companies: Rescue 10, Heavy Rescue 11, and Rescue 42. Also, Safety 30 is housed with District 11.

The fire department operates a fire administration office, a fire marshal's office, a fire training academy, an arson division, a logistics center, a fire apparatus maintenance shop, and a fire operations division. The fire Emergency Response Division consists of 92 fire stations, staffing 87 engine companies, 37 ladder or truck companies (including 5 tower ladders), 56 basic life support ambulances with one EMT/B fire fighter and one engineer operator per unit, 34 medic units (advanced life support [ALS] with two paramedic/fire fighters per unit), 11 squads (non-transport ALS units staffed by two paramedics), 3 rescue companies (including one heavy rescue), and 3 shift safety officers. There are 23 districts or battalions in the city. The minimum staffing for each engine company, ladder company, and rescue company is an officer (senior captain or captain), an engineer operator, and two fire fighters. Each district is staffed with a district chief and an incident command technician.

The rescue companies (Rescue 10, Heavy Rescue 11, and Rescue 42) provide technical rescue services such as structural collapse, high- and low-angle rescue, trench rescue, and confined space rescue. The hazardous materials team consists of 10 members (two captains, three engineer operators, and five fire fighters) per shift and 3 operating response vehicles (HM22 Unit 1, HM22 Unit 2, and Foam Engine 22). The hazardous materials team is under the direction of a district chief (District 22) and assisted by a senior captain. In calendar year 2014, the fire department responded to 318,630 incidents (276,880 EMS and 41,750 Fire). The average response time for a fire incident was 5.8 minutes.
The Prevention Bureau is managed by an assistant chief and consists of 126 fire inspectors (1 assistant fire marshal, 7 chief inspectors, 16 senior inspectors, and 102 inspectors) and 7 civilian positions. The members of the Fire Marshal's Office are certified to NFPA 1031 *Standard for Professional Qualifications for Fire Inspector and Plan Examiner* [NFPA 2013b] through the local community college. Each inspector must receive 20 hours of continuing education units (CEU) annually.

The Prevention Bureau consists of the following divisions and teams:

- Schools Division, including Home Day Care Facilities (Inspections)
- High-Rise Team (Inspections)
- Plans Review Division Fire Alarm System

Sprinkler Systems through the Building Officials Office

- Liaison to the city's Building Officials Office New Construction
  Sprinkler Systems; Electrical; Plumbing; Building Construction
- Special Operations Team
  Providing fire and EMS services for festivals and special events
- Weekend and Night Inspections
  24-hour coverage
  Occupancy Load
  Complaints

The Public Education Division of the Prevention Bureau conducts life safety training in:

- Schools
- High-rise occupancies

The Fire and Arson Investigation Bureau is a law enforcement agency under the Prevention Division. The Arson Bureau responds in the event of incendiary fires, multiple-alarm fires, fire deaths, bombings, and criminal or terrorist activity associated with fires. In many cases, investigators work with Federal, state, and local agencies, such as the Bureau of Alcohol, Tobacco, Firearms, and Explosives; Federal Bureau of Investigation; and the city's police department. Other operations within the Fire and Arson Bureau are Crime Lab, Polygraphs, Photography, and the region's Arson Task Force.

Other divisions within the department include:

- Planning/Administration, which includes Office of Emergency Communication (Fire), Human Resources, Information Technology Liaison, and Planning.
- Finance, which includes Finance, Budget, Procurement, Fixed Assets, Internal Audit, Grant Accounting, Warehouse Operations and the Selection, Care, and Maintenance of SCBA.

The rank structure in the fire department is fire fighter, engineer operator, captain, senior captain, district chief, deputy chief, assistant chief, executive assistant chief, and fire chief.

Training and Experience

The fire department involved in this incident requires potential candidates for employment as a fire fighter to have a high school diploma or GED and 60 hours of college credit or 2 years of military service with an honorable discharge

Once selected as a candidate, the fire fighter trainee begins a 15-month probation period with the fire department. As a fire fighter trainee, the initial step is to attend the 9-month Recruit Training Program at the department's fire academy. The training consists of Texas Commission of Fire Protection Basic Fire Suppression Curriculum. The Texas basic curriculum includes 468 hours of training. The curriculum covers all of the National Fire Protection Association's (NFPA) qualifications for NFPA 1001 *Standard on Fire Fighter Professional Qualifications*, Fire Fighter I, Fire Fighter II, Hazardous Materials Awareness, and Hazardous Materials Operations [NFPA 2013a]. Also, the trainee meets the requirements of NIMS 100 *Introduction to ICS*; NIMS 200 *Basic ICS*; IS 700A *The*

National Incident Management System, An Introduction; and IS 800B *The National Response Framework, An Introduction*.

In addition to the fire fighter training, the fire fighter trainees receive emergency medical services *Emergency Medical Technician Basic* (EMT/B) certification, which is a 150-hour curriculum.

Upon completion of recruit school, the fire fighter trainee is assigned as follows:

Phase 1: 2 months with an engine company
Phase 2: 2 months with a truck company
Phase 3: 2 months with EMS

Upon completion of probation, the fire fighter trainee becomes a fire fighter.
The department requires that all Emergency Response Division fire fighters receive 2 hours of CEU training, 1 hour of risk management training, and 24 hours of in-service training per month. The fire department uses district training officers to assist with this in-service training as well as to ensure that probationary fire fighters are obtaining the proper training during their 6-month period in the Emergency Response Division. The Texas State Fire Commission requires 20 hours of CEUs per month and the Insurance Services Office requires 8 hours of CEUs plus eight multi-company drills per month.

The department conducts live fire training twice a year at the department’s fire academy. The live fire training is compliant with NFPA 1403 *Standard on Live Fire Training* [NFPA 2012]. Each live fire training evolution uses four engine companies, two ladder companies, one medic unit, and a district chief.

The department provides a certification program for all emergency operators, which is a tested position. The fire academy provides the training for the 56-hour certification program, which complies with NFPA 1002 *Standard for Apparatus Driver/Operator Professional Qualifications* [NFPA 2014].

The department pays for the state certification process through the Texas State Fire Commission.

The fire department provides an officer development program for members, which is part of the department’s career path, plus the opportunity to acquire a college degree. This process uses curriculum from the National Fire Academy; local community colleges, colleges, and universities; and continuing education programs. The fire department uses the following designations for riding assignments on fire apparatus: officer is “A”; right jumpseat is “B”; left jumpseat is “C”; and the engineer operator is “D.”

Table 1. Training and Experience of Key Personnel

Fire Fighter	Training Courses	Years Experience
Fire Fighter	Basic Firefighting (Fire Fighter I, Fire Fighter II), Live Burn Firefighting, Driver Operator—Pumper, various firefighting procedures related to aircraft, and various other administrative and technical courses.	21
Captain	Basic Firefighting (Fire Fighter I, Fire Fighter II), Live Burn Firefighting, Managing Company Tactical Operations, Fire Behavior in Single Family Residence, Fire Model in Single Family Residence, Fire Chief Orientation, and various other administrative and technical courses.	25
District Chief 102 (Incident Commander)	Basic Firefighting (Fire Fighter I, Fire Fighter II), Live Burn Firefighting, and various other administrative and technical courses.	21

Note: All fire fighters must complete training equivalent to the NFPA 1001 Standard for Fire Fighter Professional Qualifications, Fire Fighter I and Fire Fighter II [NFPA 2013a].

Structure

The residential structure was built in 1963 and was wood frame construction on a slab foundation (see Photo 1). The two-story ranch had been remodeled in 2012 and consisted of 4,608 square feet of living space. The first floor consisted of a large living area, large kitchen, full bathroom, master bedroom with full bath, attached two-car garage, and an attached storage shed, which contained ammunition reloading equipment, ammunition components, and ammunition. The second floor had two bedrooms, a full bath, and a sewing room with French doors that led out onto a deck (see Diagrams 1 and 2). The first-floor exterior was covered with brick, and the second floor was oriented strand board covered with vinyl siding. In the rear of the structure, the first floor had a covered patio and the second floor had a large deck.

Photo 1. Residential structure Side Alpha.
(*NIOSH photo.*)

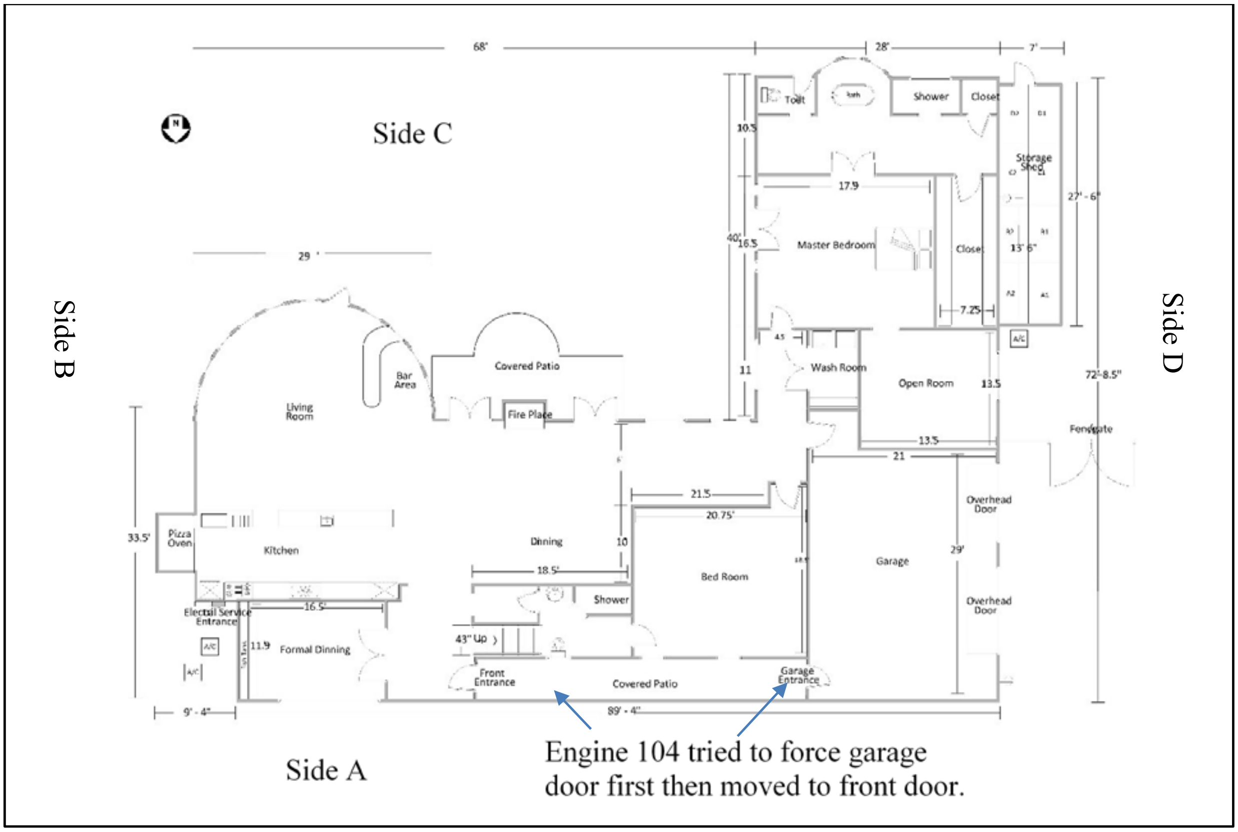


Diagram 1. First floor layout and general dimensions. Image shows Engine 104 tired to force garage door first then moved to the front door on Side A.
(*Courtesy of the Texas State Fire Marshal.*)
[A summary of a NIOSH fire fighter fatality investigation.](https://www.cdc.gov/niosh/fire/pdfs/face201415.pdf)
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#9

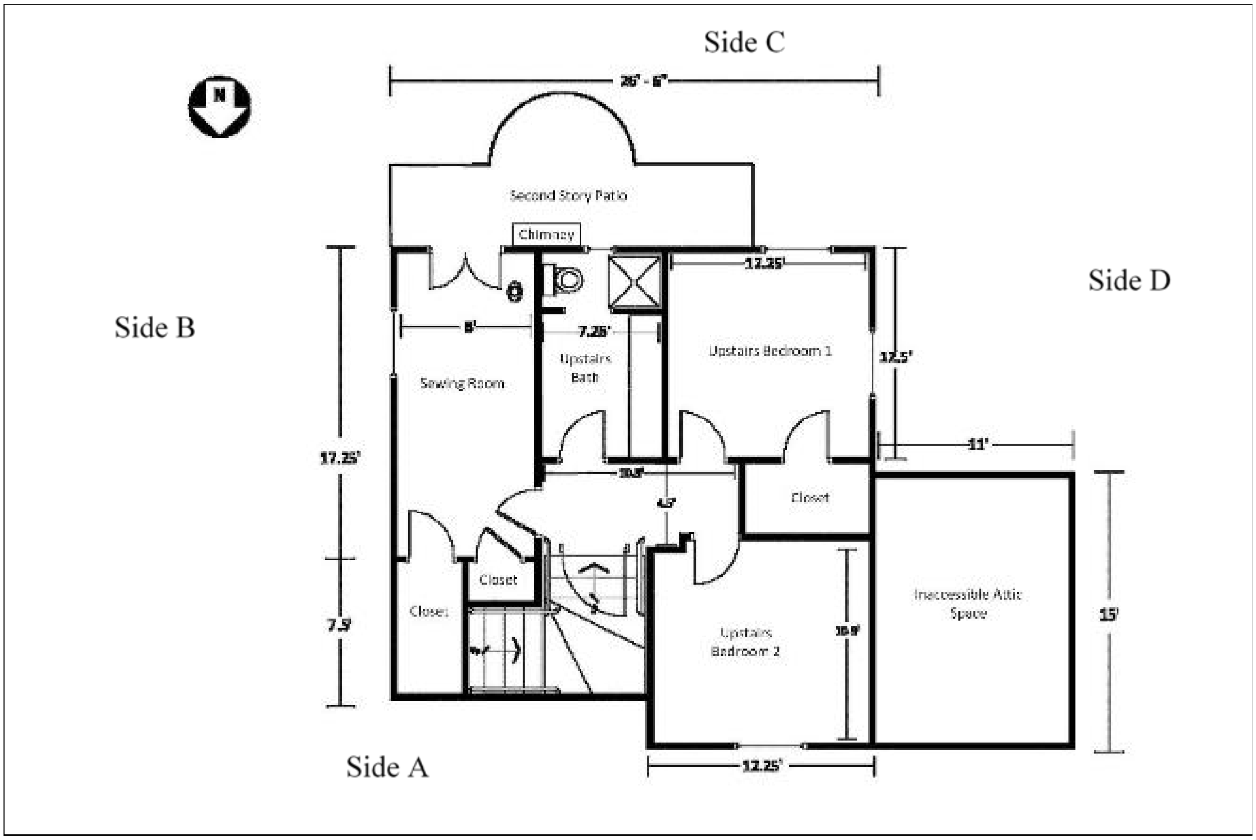


Diagram 2. Second floor layout and general dimensions.
(*Courtesy of the Texas State Fire Marshal.*)

A summary of a NIOSH fire fighter fatality investigation.
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#10

Equipment and Personnel

On July 9, 2014, the county dispatch center transmitted a still alarm for a shed fire. The initial unit dispatched was Engine 104 and upon arrival confirmed a working fire. This upgraded the alarm to a box alarm that dispatched two district chiefs, three engines, two ladders, a squad, and an ambulance. *Note: Engine 104's station was less than a mile from the structure fire.* The table below identifies the apparatus and staff dispatched on the first-alarm assignment, along with their approximate dispatch time and on-scene arrival times (rounded to the nearest minute).

Table. First-alarm Equipment and Personnel Dispatched

Resource Designation	Staffing	Dispatched (rounded to minute)	On-scene (rounded to minute)
Engine 104	captain, engine operator, and 2 fire fighters (victim)	1555 hrs	1600 hrs
District Chief 102 (incident commander)	district chief and an incident command technician	1559 hrs	1607 hrs
District Chief 64	district chief and an incident command technician	1559 hrs	1613 hrs
Engine 102	captain, engine operator, and 2 fire fighters	1559 hrs	1610 hrs
Engine 103	captain, engine operator, and 2 fire fighters	1559 hrs	1610 hrs
Engine 63	captain, engine operator, and 2 fire fighters	1559 hrs	1614 hrs
Ladder 102	senior captain, an acting engine operator, and 2 fire fighters	1559 hrs	1609 hrs
Ladder 101	senior captain, engine operator, and 2 fire fighters	1559 hrs	1612 hrs
Ambulance 56	engine operator/EMT and a fire fighter/EMT	1559 hrs	1612 hrs
Squad 64	engine operator/paramedic and a fire fighter/paramedic	1559 hrs	1612 hrs

Timeline

An approximate timeline summarizing the significant events of the incident is listed below. The times are approximate and were obtained by studying available dispatch records, photos, run sheets, witness statements, and fire department records. The times are rounded to the nearest minute. The timeline is not intended, nor should it be used, as a formal record of events.

- **1555 Hours**
  Engine 104 is dispatched on a still alarm to a shed fire.

- **1559 Hours**
  Engine 104 reports fire coming from a two-story and requests a box alarm. Dispatch upgrades to a box alarm, dispatching Districts 102 and 64; Engines 102, 103, and 63; Ladders 102 and 101; Ambulance 56; and Squad 64.

- **1600 Hours**
  Engine 104 corrects the address.

- **1601 Hours**
  District Chief 102 confirms he has a working fire. Dispatch assigns fireground channel. Engine 104 makes offense attack and reports ammunition going off.

- **1607 Hours**
  District 102 arrives on scene and assumes command. Incident command reports heavy smoke coming from two-story residence.

- **1608 Hours**
  Command assigns Ladder 101 to ventilate roof when they arrive on scene.

- **1609 Hours**
  Ladder 102 arrives on scene. Ladder 102 is assigned to ventilate roof, since Ladder 101 had not yet arrived.

- **1610 Hours**
  Engine 102 arrives on scene and is ordered to pull a second line and back up Engine 104. Engine 103 arrives on scene and is assigned the rapid intervention team (RIT).

- **1612 Hours**
  Ladder 101, Ambulance 56, and Squad 64 arrive on scene. Ladder 101 ordered to get a 1¾hoseline to D-side.

- **1613 Hours**
  Command requests Ladder 102’s engine operator to cut utilities, starting with the power. District Chief 64 arrives on scene. Command reports a 4-inch water supply is established and the accountability system is set up.

- **1614 Hours**
  Engine 63 arrives on scene.

- **1615 Hours**
  Command requests Dispatch call for the power company.

- **1617 Hours**
  Ladder 102 reports fire has broken through the roof on B-side. Command requests a status report from Engine 104.

- **1618 Hours**
  Engine 104's reply inaudible.

- **1621 Hours**
  Ladder 102 reports that the roof is vented.

- **1622 Hours**
  Engine 104 notifies Command they were coming out to change air cylinders.

- **1623 Hours**
  Engine 104 asks Command if Engine 104C (FF1) is in alarm? Accountability tried to contact FF1.

- **1625 Hours**
  District Chief 64 notifies Command that he is activating the RIT. Engine 104 captain tries to radio FF1.

- **1626 Hours**
  Engine 104 captain re-enters structure. He makes it to the top of the stairs, hears a PASS device going off in a room to the left, but is too low on air to investigate further. RIT is enroute to the second floor.

- **1628 Hours**
  District Chief 64 informs RIT to go to the top of the stairs to the room on the left. Ladder 102 is the secondary RIT.

- **1630 Hours**
  Engine 63 notifies Command that FF1 has been recovered and they had him on the secondfloor balcony, C-side. RIT requested hoseline C-side to protect from fire on roof.

- **1631 Hours**
  Medic unit called to C-side.

- **1632 Hours**

Crews lower Fire Fighter 1 down ladder, off the balcony to the ground. PARs are conducted.

- **1634 Hours**
  Medic unit starts CPR.

- **1635 Hours**
  Command calls for defensive operations.

- **1642 Hours**
  Ambulance 56 transports Fire Fighter 1 to the hospital. PARs are completed.

Personal Protective Equipment

The fire fighter was wearing a work station uniform, turnout coat and pants, gloves, hood, boots, helmet, self-contained breathing apparatus (SCBA) with an integrated personal alert safety system (PASS), and a portable radio.

The fire fighter's SCBA was evaluated by the NIOSH National Personal Protective Technology Laboratory and a summary report is enclosed as Appendix I. The evaluation showed no evidence that the performance of the SCBA, with the cylinder valve full open, was a contributing factor in the fatality. The full report is available upon request. A special test was conducted to try and simulate the effects of airflow to the facepiece when the cylinder valve is only partially opened (see Appendix II). It is believed that the fire fighter may have only partially opened his cylinder valve upon entry into the structure. This may have caused an air starvation effect that may have caused the fire fighter to lift his facepeice from his face to breathe.

Weather Conditions

According to data from the website Weather Underground, the sky conditions were overcast with 10mile visibility. The temperature was 92 degrees F. Dew point was 73 degrees F. Relative humidity was 54%. Wind speed was 11.5 mph and wind direction was south. Since the wind speed was greater than 10 mph, it may have contributed to the fire getting into the void spaces toward the main living area of the residence. Barometric pressure was 30.05 [NOAA 2015].

Investigation

On July 9, 2014, a 46-year-old male career fire fighter died while conducting interior operations in a two-story residential fire. At 15:55 hours, Engine 104, with a crew of four, was dispatched to a shed fire. Arriving on scene, the captain observed fire and black smoke coming from Side Delta and Side Charlie of the structure and called in a box alarm. The captain corrected the address for the dispatch center and advised them that ammunition was going off. District Chief 102 was en route and heard the captain's transmission and requested a confirmation of a working fire. The captain replied with a yes. The captain attempted to do a 360-degree size-up, but, due to a fence and ammunition going off, he was unable to complete it on Side Delta (see Photo 2 and Photo 3). Fire fighter 1 (FF1) and fire fighter 2 (FF2) had pulled a 1¾-inch hoseline off the engine. The captain met up with FF1 and attempted to force entry into the garage exterior man door on Side Alpha (see Diagram 1). FF1 was using a sledgehammer but was only able to open the door a foot while FF2 tried knocking down the fire on Side Delta of the structure. When FF1 was swinging the sledgehammer, his mask-mounted regulator (MMR) was swinging freely and hitting the SCBA donning switch. The captain informed FF1 that he was losing air. This occurred several times. It is believed that FF1 may have turned off his cylinder valve at that time. The Engine 104 pump operator engaged the pump then took 100 feet of 4-inch supply hose toward the hydrant on the Alpha/Bravo corner of the street.

Photo 2. Side Delta of fire structure where the area of origin of the fire occurred.

A summary of a NIOSH fire fighter fatality investigation.
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#16

Photo 3. A sample of ammunition and reloading supplies found on Side Delta. (*NIOSH photo.*)

A summary of a NIOSH fire fighter fatality investigation.
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#17

At 1607 hours, District Chief 102 and his incident command technician (ICT) arrived on scene. District Chief 102 gave a report to dispatch that heavy smoke was coming from a two-story residence and assumed incident command (IC). The IC sent his ICT to assist the Engine 104 pump operator with the supply hose to connect to the hydrant. The IC was approached by a civilian, who stated he had the owner on the phone and that no one was home but their three dogs. When Ladder 101 arrived, the IC directed them to ventilate the roof. After helping establish a water supply, the ICT and Engine 103's chauffer began to set up the accountability system. The Engine 104 captain and FF1 made a forcible entry at the Side Alpha front door.

At 1609 hours, Ladder 102 arrived on scene and was ordered to ventilate the roof since they were the first arriving truck company. The Engine 104 captain then went to Side Delta to have FF2 bring the hoseline to the Side Alpha front door. The captain noticed that some of the fire was knocked down but now fire was in the attic and smoke was coming out the eaves and ridge vent on Side Delta (see Photo 4). The captain and FF2 made entry at the front door and began to search the first floor.

Photo 4. Large void space over the garage at the Alpha/Delta corner connecting the L-shaped attic structure.
(*NIOSH photo.*)

A summary of a NIOSH fire fighter fatality investigation.
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#18

At 1610 hours, Engine 102 arrived on scene and was ordered to pull a second hoseline to back up Engine 104 (see Diagram 3**)**. Engine 103 arrived and was assigned as the RIT. The Engine 104 captain and FF1 had opened the interior man door to the garage and opened both garage doors and saw no smoke in the garage. After seeing only minimal smoke, no visible fire or civilians on the first floor, the Engine 104 captain and FF1 proceeded up a narrow stairway to the second floor where they met up with FF2, whom had tried to pull more hoseline to reach the top of the stairs. Engine 104 Captain requested a pike pole so, FF2 went and got it.

At 1612 hours, Ladder 101, Ambulance 56, and Squad 64 arrived on scene. The Engine 104 captain, FF2, and FF1 went up the stairs and encountered a louvered door at the top of stairs (see Photo 5). The captain opened it and saw a scuttle hole to the attic. The captain opened the attic access panel but could only see dark, brown smoke and used the thermal imager but did not see any fire.

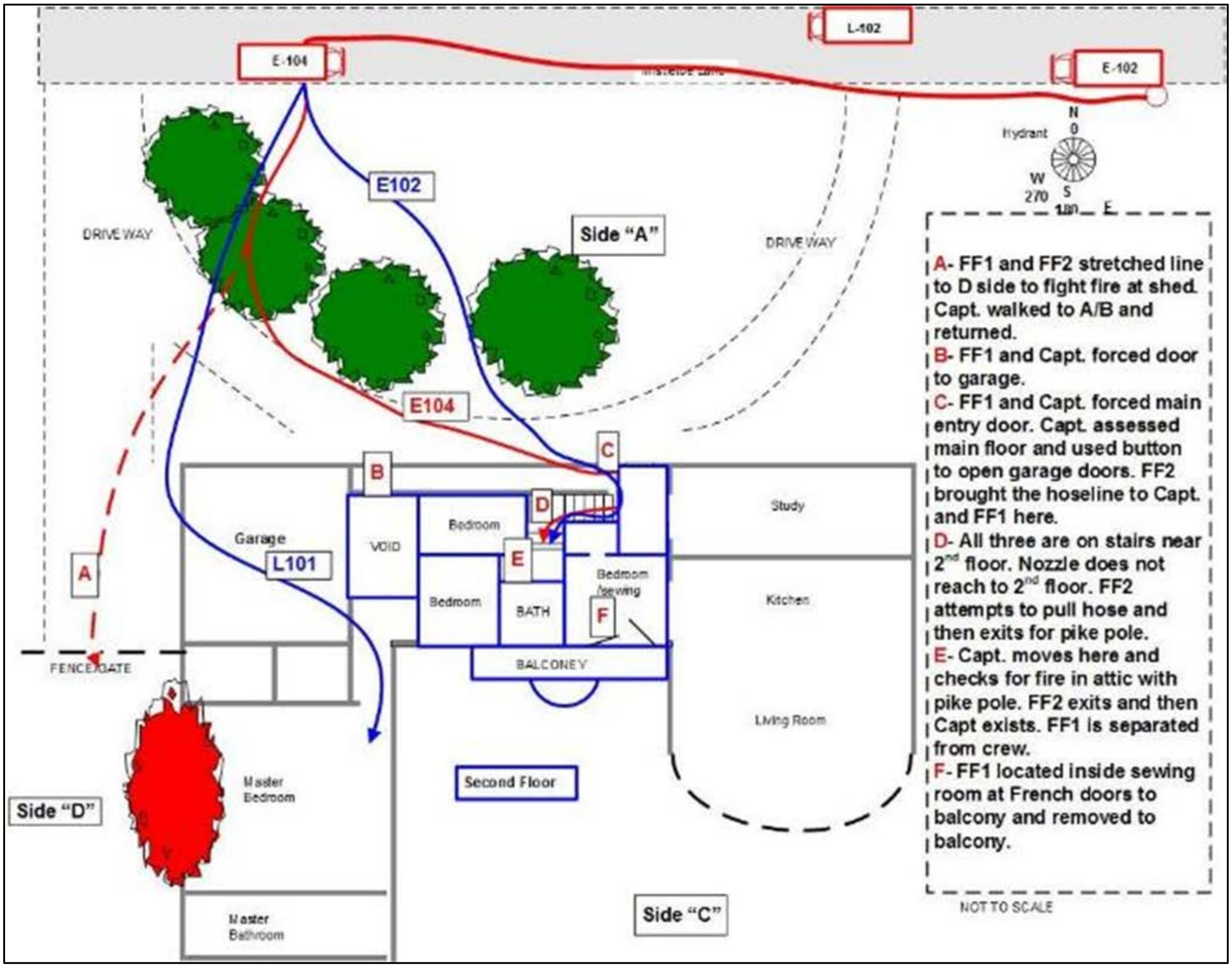


Diagram 3. Key apparatus and hoseline placement.
(Courtesy of the State Fire Marshal's Office.)

A summary of a NIOSH fire fighter fatality investigation.
https://www.cdc.gov/niosh/fire/pdfs/face201415.pdfpage=#19

Photo 5. Louvered door to sewing room at top of stairs to the left. Picture taken from inside the room. The top half of the louvered closest door (right) is broken out (see Possible scenarios, #2). (NIOSH photo.)

At 1613 hours, the IC ordered the Ladder 102 engine operator to cut the utilities, and a minute later Engine 63 arrived on scene. The IC radioed the Engine 104 captain for a status report but did not get a reply. District Chief 64 (DC64) and his ICT arrived on scene. The IC assigned DC64 to Side Alpha, and DC64's ICT assisted with accountability. The Engine 104 captain observed three other louvered doors in the hallway. He started on his left and opened each door, using the thermal imager to scan the room. He never saw any fire or civilians but he did notice that doors closed on their own after he moved back into the hallway.

At 1616 hours, Ladder 101 was ordered to take a 1¾-inch hoseline supplied by Engine 104 to Side Delta. A minute later, the Ladder 102 engine operator reported to Command that fire had broken through the roof on Side Bravo. The IC asked for a report from Engine 104. A minute later, the Engine 104 captain radioed Command but the message was inaudible. After the captain completed the bedroom search, he used a pike pole, opened holes in the ceiling, and heard a fire fighter say it's getting hot, he was low on air, and, "Let's go get flashlights." The Engine 104 captain pulled the ceiling as he worked toward the stairs and saw FF2 go down the stairs. As the captain and FF2 descended the stairs, FF2 asked where FF1 was. The captain had assumed FF1 had already gone down the stairs because he never saw FF1 go past him when he was on the second floor.

At 1621 hours, the captain radioed FF1 several times with no response. *Note: The captain had mistakenly called FF2's radio instead of FF1's.* Ladder 102 notified Command that the roof was vented on Side Charlie. The Engine 104 captain notified Command they were coming out for a bottle change. The captain saw DC64 at the front door and informed him that FF1 was missing. The Engine 104 captain radioed Command to see if FF1 was in alarm. Ladder 101 notified Command that they had a fire fighter they were sending out with a burn injury. Command notified Squad 64 to check on the burned fire fighter. The accountability officer noticed FF1 was in alarm and tried to radio FF1 for a verbal response but none came.

At 1624 hours, DC64 tried to radio FF1 with no response. Again, the accountability officer radioed FF1. The Engine 104 captain was low on air but went back up the stairs to search. FF2 went to change his bottle. At 1625 hours, DC64 notified Command that he was activating the RIT. A minute later, the Engine 104 captain heard a faint PASS device in the room to the left through a closed louvered door. The captain opened the door and could still hear the PASS but had to back out because his air was getting very low. He radioed Command about hearing the PASS and having to back out.

At 1628 hours, DC64 notified the RIT that FF1 would be in the second floor bedroom to the left. Minutes later, the Engine 63 made entry through the exterior Side Charlie double doors on the balcony to the room on the second floor (see Diagram 3, Notation F, and Photo 6). The Engine 63 engine operator notified Command they had FF1 on the balcony (see Photo 7). Engine 63 and the RIT took him down a ladder off the balcony to the yard.

Photo 6. The double glass panel doors of the sewing room that lead out to the second floor balcony. Note that the door handle on the right is a nonfunctioning handle and is bent down (see *Possible scenarios*, #3). FF1 was found on the floor at the base of the right panel door. (NIOSH photo.)

Photo 7. The second floor balcony where FF1 was brought out and lowered to the ground via a ground ladder. (NIOSH photo.)

At 1635 hours, Command called for defensive operations while personnel accountability reports (PAR) were in progress.

At 1642 hours, PARs were completed and Ambulance 56 transported FF1 to the hospital where he was pronounced dead.

Possible scenarios. (1) FF1 was found unconscious and unresponsive on the second floor with his facepiece partially dislodged and helmet off. It is not known why his helmet was off and his facepiece dislodged but one possibility is that the fire fighter attempted to remove his facepiece (shedding the helmet) and was exposed to products of combustion due to an SCBA or out-of-air emergency. The cylinder was later discovered to have approximately 500 psi of air remaining (see Appendix II). He may have become unconscious and collapsed on the floor. (2) In Photo 5, the top half of the louvered closest door is broken out. It is possible that FF1 thought this was the door on the left being the way out and tried to break through it, causing him to become trapped. (The entry door to the room was the same louvered style.) (3) In Photo 6, the right panel door has a nonoperating handle on it but it is bent down, possibly by FF1 trying to open the door just prior to him becoming unconscious.

Fire Behavior

According to the state fire marshal, the fire started in the storage shed that contained ammunition reloading equipment, ammunition components, and ammunition.

Indicators of significant fire behavior:
- Ammunition going off
- Smoke and fire on Side Delta upon arrival
- Heat and heavy black smoke in attic and void spaces
- Second-floor hallway attic access opened and ceiling pulled, causing heat and smoke to push down
- Heavy fire on Side Charlie, both first floor and attic
- Fire under control approximately 31 minutes after arrival

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 that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that led to the fatalities:
- Crew integrity
- Air management
- Mayday procedures
- Fire-fighting experience
- Operational characteristics of the SCBA and other life safety devices
- Fireground communications
- Ventilation timing
- Hoseline deployment
- Construction features of the residence
- Munition Hazards

Cause of Death

According to the county coroner’s report, the cause of death of the fire fighter was smoke inhalation.

The fire fighter had a carboxyhemoglobin of 22 percent.

Recommendations

Recommendation #1: Fire departments should ensure that crew integrity is properly maintained by voice or radio contact when operating in an atmosphere that is immediately dangerous to life and health (IDLH).

Discussion: When an engine company enters a structure, the members must remain in contact by visual (eye-to-eye), verbal (radio or face-to-face), or direct (touch) contact. NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*, 8.5.5, states, "Crew members operating in a hazardous area shall be in communication with each other through visual, audible, or physical means or safety guide rope, in order to coordinate their activities." Section 8.5.4 states, "Members operating in hazardous areas at emergency incidents shall operate in crews of two or more." Additionally, NFPA 1500 8.5.6 states, "Crew members shall be in proximity to each other to provide assistance in case of an emergency" [NFPA 2013d].

The International Association of Fire Chiefs, Safety, Health, and Survival Section has redefined the *Rules of Engagement for Structural Firefighting*. One of its objectives is to ensure that fire fighters always enter a burning building as a team of two or more members and no fire fighter is allowed to be alone at any time while entering, operating in, or exiting a building. A critical element for fire fighter survival is crew integrity. Crew integrity means fire fighters stay together as a team of two or more. They must enter a structure together and remain together at all times while in the interior, and all members come out together. Crew integrity starts with the company officer ensuring that all members of the company understand their riding assignment, have the proper personal protective equipment, and have the proper tools and equipment. Upon arrival at the incident, the company is given a task to perform by the incident commander. The company officer communicates to the members of the company what their assignment is and how they will accomplish their assignment. To ensure that crew integrity is maintained, all the members of a company should enter a hazardous environment together and leave together. If one member has to leave, the whole company leaves [IAFC 2009].

It is the responsibility of every fire fighter to stay connected with crew members at all times. All fire fighters should maintain the unity of command by operating at all times under the direction of the incident commander, division/group supervisor, or their company officer. The ultimate responsibility for crew integrity and ensuring no members get separated or lost rests with the company officer. While operating in a hazard zone, they should maintain constant contact with their assigned members by visual observation, voice, or touch. They should ensure they stay together as a company or crew. If any of these elements are not adhered to, crew integrity is lost and fire fighters are placed at great risk.

NFPA 1500, 8.4.4–8.4.6 states:

- The incident commander shall maintain an awareness of the location and function of all companies or crews at the scene of the incident.

•Officers assigned the responsibility for a specific tactical-level management component at an incident shall directly supervise and account for the companies and/or crews operating in their specific area of responsibility.

•Company officers shall maintain an ongoing awareness of the location and condition of all company members [NFPA 2013c].

If a fire fighter becomes separated and cannot immediately get reconnected with his/her crew, the fire fighter must attempt to communicate via portable radio with the company officer. If reconnection is not accomplished after three radio attempts or reconnection does not take place within 1 minute, a Mayday should be declared. If conditions are rapidly deteriorating, the Mayday should be declared immediately. As part of a Mayday declaration, the fire fighter should next activate the radio's emergency alert button (when provided), followed by manually turning on the PASS alarm. Similarly, if the company officer or the fire fighter's partner recognizes they have a separated member, they should immediately attempt to locate the member by using their radio or by voice. If contact is not established after three attempts or within 1 minute, a Mayday must be declared immediately [IAFC 2009].

In this incident, FF1 became separated in the smoky stairwell just prior to or after the captain thought the crew was leaving together. The captain and FF2 were near the front door when they realized FF1 was missing. The captain immediately returned to the second floor and reported hearing FF1's PASS but didn't have sufficient air to continue the search.

Recommendation #2: Fire departments should ensure that fire fighters and officers are properly trained in air management.

Discussion: Chief Bobby Halton, retired chief and editor in chief of Fire Engineering notes: "If you run out of air in a working fire today, you are in mortal danger. There is no good air at the floor anymore, no effective filtering methods, no matter what others may say to the contrary" [Gagliano et al. 2008]. The only protection for fire fighters in the toxic smoke environments in today's fires is the air that they carry on their backs. Like SCUBA divers, fire fighters must manage their air effectively and leave enough reserve air in case of unforeseen occurrences while inside a structure fire. Fire fighters must manage their air so that they leave the IDLH atmosphere before the low-air alarm activates. This leaves an adequate emergency reserve [air] and removes the noise of the low-air alarm from the fireground [NFPA 2013d].

Air management is a program that the fire service can use to ensure that fire fighters have enough breathing air to complete their primary mission and allow enough reserve air for the fire fighter to escape an unforeseen emergency. Fire departments and fire fighters need to recognize that the smoke in modern construction is an IDLH atmosphere and manage their air along with their work periods so the fire fighters exit the IDLH with their reserve air intact. NFPA 1404 *Standard for Fire Service Respiratory Protection Training* states that fire fighters shall exit from an IDLH atmosphere before the consumption of reserve air supply begins. A low-air alarm is notification that the individual is consuming the reserve air supply and that the activation of the reserve air alarm is an immediate action item for the individual and the fire-fighting team [NFPA 2013c].

Fire fighters and command officers need to monitor their air status and communicate it to crew members. Air management happens at the individual fire fighter level, the crew level, and the command level. Fire fighters need to ensure their air supply is adequate (full cylinder) at the start of each shift and need to monitor their air usage during an event. For example, when the 50% heads-up display (HUD) light flashes, fire fighters need to communicate that information to his/her crew members. Fire fighters need to understand principles of air management such as the need to exit the IDLH atmosphere before they go into their emergency reserve air and their end-of-service-time indicator (EOSTI) sounds. If they are not out of the IDLH atmosphere and go into their emergency reserve air, they need to immediately communicate their situation to their crew and command as this can now be considered an emergency. Fire fighters should not wait until their EOSTI sounds or they are out of air to communicate.

Fire-fighting crews need to communicate their air supply status among the crews so they can plan accordingly to notify command of the need to exit and still have their reserve or emergency air level available. One method is to have the first person on a crew who reaches their 50% air capacity notify the crew leader and he/she can then estimate the amount of work period left so they can leave the structure (or IDLH) before the person with the least amount of air goes into their emergency reserve air.
Command needs to understand air management at the command level. This means that someone at the command post is monitoring not only accountability of the crews, but how long they have been working (estimating air supply usage), checking on air status through PAR checks, and then rotating crews with enough time to ensure that crews exit the IDLH with their emergency reserve air intact.

Too often fire fighters may not pay attention to their air usage and remaining air until they get into their emergency reserve air (often referred to as the low-air alarm) and their EOSTI sounds or vibrates. This can be due to a number of reasons, including lack of familiarity with a new or different model SCBA (with an HUD) or a lack of training. Another reason may be the old culture of waiting to take an action based on when the low-air alarm sounds. Fire fighters in the past didn’t have HUDs and relied on the low-air alarm to warn them of their low-air status. It was very difficult if not impossible in some fire-fighting incidents to read the over-the-shoulder gauge. With the addition of HUDs, fire fighters now have the ability to know their approximate air supply status by reading the lights in their facepiece. The four lights in the facepiece start in the illuminated green position and then turn off as the air supply decreases. Once the SCBA air supply reaches approximately 50%, the light begins to flash. Some change color to yellow below 50% then change to red in the EOSTI mode. HUDS are designed to alert the fire fighter that they should be taking an action to ensure they have enough escape time to exit the building with their reserve air intact. Once the air supply reaches the EOSTI, the SCBA will provide another signal (bell, whistle, and/or vibration) that alerts the user that they are nearing the end of the usable air in the cylinder. On pre-2013 edition SCBAs, this level was approximately 25% (+/- 2), but on the 2013 edition and newer SCBAs this EOSTI level was increased to 33%.

In this incident, FF1 became separated from his crew and experienced a low-air emergency. His crew had already left their position due to low-air concerns of one of the members. FF1 was separated from his crew, became lost, and believed to have experienced an air starvation emergency on the second floor of the structure and was unable to escape. NIOSH investigators have identified a lack of air management training as a contributing factor on a number of LODD investigations. Fire departments need to ensure that training on air management occurs at all levels of the fireground command structure: command level, crew level and individual fire-fighter level [NIOSH 2011, 2012].

Recommendation #3: Fire departments should ensure that fire fighters understand the operational characteristics of their SCBA and other life safety devices.

Discussion: Fire fighters need to understand and be thoroughly familiar with the specific type of SCBA they are using. It is critically important when a department changes manufacturer or model that they provide extensive time and experience in training with the new model. Training shall comply with applicable governing standards and follow manufacturer's instructions and guidelines [NFPA 2013d]. If fire fighters have "muscle memory, repetitive skills training" based on the manufacturer's operational instructions, they would be more able to overcome an out-of-air emergency involving their SCBA. In the aviation industry, this skill building is sometimes referred to as cockpit time. Although a pilot may have extensive experience in one aircraft, he/she needs to have sufficient "cockpit time" in the plane that they are presently flying in order to overcome and control an unanticipated issue. In the same way, a fire fighter must have sufficient "cockpit time" with their SCBA because they operate in an IDLH environment and there is little time to react so the responses have to be learned and automatic. Although the principles of different SCBA manufacturers and models are the same, controls, visual and audio signals, and valves and their locations are different in all of them.

All SCBA come with a user's manual. Fire fighters need to take the time and read these manuals independent of the training they are given and then practice with repetitive skill building. Often manufacturers include safety precautions and recommended practices for operating the equipment. The user should read these precautions and understand what may happen if they are not followed.

In this incident, it is believed that the fire fighter may not have turned his SCBA main cylinder valve to full open as the manufacturer recommends, which may have caused an air starvation situation. The manufacturer provided a warning in the user's manual to always fully open the main cylinder valve for the unit to function properly.

With the main cylinder valve not fully open, the SCBA would provide sufficient breathing air at the higher beginning pressures but could cause a restricted air flow at the lower pressure (approaching EOSTI pressures and below). The fire fighter may have thought he had run out of air because the partially opened cylinder valve would not allow sufficient air pressure at the facepiece even though the cylinder still had operational air at the lower pressure. The fire fighter may have been struggling to breathe while his SCBA cylinder still had emergency air in the cylinder. This air starvation due to a partially opened cylinder valve can be recognized by a higher static pressure and wide fluctuation of the analog gauge upon inhalation. For example, the static pressure may read 800–1,000 psi, but during inhalation the gauge pressure fluctuates drastically down to zero or near zero. This may also effect the operation of some of the EOSTI devices or signals such as the Vibralert®.

Recommendation #4: Fire departments should ensure that fire fighters are properly trained in outof-air SCBA emergencies and SCBA repetitive skills.

Discussion: Repetitive skills training with SCBA is vital for fire fighters working inside an IDLH atmosphere. SCBA skills training is an ongoing process that should be performed regularly to ensure that fire fighters "know their SCBA." The benefits of repetitive skills training with SCBA are an increased comfort and competency level, decreased anxiety, lower air consumption, increased awareness of the user's air level (noticing and using the heads-up display [HUD]) and an automatic muscle memory response of the vital function controls, such as the don/doff buttons, main air valve, emergency bypass operating valve, and auxiliary air connections (i.e., rapid intervention crew/universal air connection and the buddy breather connection). Repetitive skills training can also provide the user with an increased ability to operate these functions and controls in a high-anxiety moment or an emergency. Many times these skills will be necessary with gloved hands, limited vision, and reduced ability to hear commands from others. Performed in conditions that are non-IDLH, repetitive skills training helps build the fire fighter's muscle memory so their hands will be able to activate the controls with gloves on and the operation will be a conditioned or second-nature response. Fire fighters have died in IDLH conditions because they did not react properly to an out-of-air emergency [NIOSH 2011, 2012].

The first step in overcoming an SCBA out-of-air emergency is familiarization with your specific SCBA and your breathing air requirements and usage. Fire fighters need to recognize that many SCBA out-of-air emergencies are caused by fire fighters not recognizing the remaining air supply relative to the mission and then another event occurs, such as becoming separated from their crew or hoseline and becoming lost. Other events that can challenge a fire fighter's ability to overcome an out-of-air emergency include facepiece becoming dislodged, hose entanglement, vomiting in a facepiece, and mechanical issues with the SCBA. A fire fighter's ability to overcome these events is directly related to their level of repetitive skills and muscle memory, which is only achieved through training and experience with their current SCBA.

If a fire fighter has limited experience in a particular SCBA (whether it is because they are a new fire fighter or an experienced fire fighter with a new SCBA model or manufacturer), they may be concentrating so much on their SCBA that they miss fire environment signs such as fire growth, smoke behavior, orientation of the room, actions of other crew members, and other conditions that require attention. This undue concentration on the SCBA may even be subtle, and when faced with a condition that needs a trained muscle memory response, such as activating the bypass or checking the cylinder wheel, they don't have the automatic response that is necessary to overcome the initial event. In these conditions, anxiety further complicates the steps necessary to overcome the situation. Many uncontrolled SCBA out-of-air emergencies can be overcome by repetitive skill muscle memory training.

In this incident, FF1 had tried to force an external door when his doff button accidentally activated, possibly releasing up to 400 liters per minute from his SCBA cylinder. According to his captain, this happened several times. This would have significantly reduced the volume of air in his cylinder. It is unknown if FF1 used his cylinder valve or the donning switch to stop the flow of air. Upon making entry into the structure, he may have only cracked the cylinder valve back on, and an air starvation issue may have occurred. During the NIOSH investigation, investigators were unable to ascertain who had secured FF1's SCBA after the incident and how many turns on the cylinder valve were required to turn it off. The cylinder was later discovered to have approximately 500 psi of air remaining. NIOSH investigators tried to discover why the remaining air would not have exited the dislodged facepiece after the incident and offered some possible scenarios in the following paragraphs.

Before the FF1 entered the IDLH atmosphere through the Side Alpha entrance door, he and his crew had been trying to force entry on a door on the Alpha/Delta corner. During that task, he repeatedly lost air through his disconnected MMR when it was inadvertently struck with the forcible entry tools. If he stopped the air loss by closing his cylinder valve, he would have had to turn his cylinder valve back on before he entered the main door on Side Alpha. If he only partially turned his cylinder valve on, he would have had sufficient air pressure during the initial fire fight and search operations; but he could have experienced "air starvation" once his cylinder pressure dropped close to his EOSTI pressure. If he was experiencing air starvation and pulled his facepiece away from his face, this could have dislodged his helmet and exposed him to products of combustion.

After the event, the fire department performed a number of manual evolutions to try and simulate an air starvation condition. They were successful in causing difficulty on inhalation at the low end of the cylinder pressure/SCBA use period by a number of users. This was done by only partially opening the cylinder valve on the SCBA. The units operated without restriction at the beginning upper air pressures, but experienced an increase in breathing resistance once the users got below their EOSTI pressures when they felt the need to remove their facepieces due to air starvation. The cylinders still had a reported 400–500 psi remaining when this starvation occurred.

NIOSH investigators tried to replicate the scenario of air starvation in the lab with the assistance of the National Personal Protective Technology Laboratory (see Appendix II for the actual tests). These replications demonstrated that there is a correlation between air flow and how far the cylinder valve is opened. Limiting the air flow to the system by not opening the valve completely, creates a reduced positive pressure to the facepiece and causes higher resistance to obtaining a breath. Both of these situations were demonstrated in these tests, and both could result in a perceived out-of-air emergency situation. **It is important to note that all SCBA manufactures have instructions in their user's manual that clearly state that users need to fully open the SCBA cylinder valve for proper operation**. It is important for fire fighters to understand that although a partially open SCBA cylinder will operate (and the fire fighter may not realize any difficulty breathing), he/she may experience air starvation when the cylinder pressure is reduced during use. The system is only designed to provide consistent breathing air with the cylinder valve fully open.

Recommendation #5: Fire departments should ensure that fire fighters are properly trained in Mayday procedures and survival techniques.

Discussion: It is essential to train fire fighters to recognize when they are in trouble and know how to call for help. Fire fighters must recognize when they are in trouble, know how to call for help, and understand how incident commanders and others must react to a responder in trouble [NFPA 2013c; Jakubowski and Morton 2001].

One of the most difficult situations a fire fighter can face is when they realize they need to declare a Mayday. The word “Mayday” is designated to identify when a member is in a life-threatening situation and in need of immediate assistance [NFPA 2013d]. Recognizing that they are or about to be in a lifethreatening situation is the first step in improving the fire fighters’ chances to survive a Mayday event. Many fire departments don’t have a simple procedure for what to say when a fire fighter gets into trouble—a critical situation where communications must be clear [NIOSH 2011]. A Mayday declaration is such an infrequent event in any fire fighter’s career that they need to frequently train to recognize the need when to declare the Mayday and what steps to take to improve their survival chances.

Fire fighters must understand that when they are faced with a life-threatening emergency, there is a very narrow window of survivability, and any delay in egress and/or transmission of a Mayday reduces the chance for a successful rescue. Knowledge and skills training on preventing a Mayday situation and how to call a Mayday should be mastered before a fire fighter engages in fireground activities or IDLH environments [IAFF 2010; Sendelbach 2003]. Fire fighter training programs should include training on such topics as air management and emergency communications; familiarity with SCBA, a radio, and personal protective equipment; crew integrity; reading smoke, fire dynamics, and fire behavior; entanglement hazards; building construction; and signs of pending structural collapse. If fire fighters find themselves in a questionable position (dangerous or not), they must be able to recognize this and know the procedures for when and how a Mayday should be called. A fire fighter's knowledge, skill, and ability to declare a Mayday must be at the mastery level of performance. This performance level should be maintained throughout their career through training offered more frequently then annually [IAFF 2010; Sendelbach 2003]. Fire fighters need to also understand that their personal protective equipment and SCBA do not provide unlimited protection. Fire fighters should be trained to stay low when advancing into a fire as extreme temperature differences may occur between the ceiling and floor. When confronted with an emergency situation, the best action to take may be immediate egress from the building or to a place of safe refuge (e.g., behind a closed door in an uninvolved compartment, in a staging area on a lower floor) and manually activate the PASS device. A charged hoseline should always be available for a tactical withdrawal while continuing water application or as a lifeline to be followed to egress the building. Conditions can become untenable in a matter of seconds.

Calling a Mayday is a complicated behavior that includes the affective, cognitive, and psychomotor domains of learning and performance [Grossman and Christensen 2008; Clark 2005]. Any delay in calling a Mayday reduces the chance of survival and increases the risk to other fire fighters trying to rescue the downed fire fighter.

Firefighters should be 100% confident in their competency to declare a Mayday for themselves. Fire departments should ensure that any personnel who may enter an IDLH environment meets the Mayday competency standards of the authority having jurisdiction throughout their active duty service. Presently, there are no national Mayday standards for firefighters and most states do not have Mayday standards. A rapid intervention team (RIT) will typically not be activated until a Mayday is declared. Any delay in calling the Mayday reduces the window of survivability and also increases the risk to the RIT [IAFF 2010; Clark 2005, 2008; USFA 2006].

There are no rules on when a fire fighter must call a Mayday, and Mayday training is not included in the job performance requirements in NFPA 1001 [NFPA 2013a]. It is up to each authority having jurisdiction to develop rules and performance standards for a fire fighter to call a Mayday. The National Fire Academy Mayday courses present specific Mayday parameters or rules for when a fire fighter must call a Mayday. The courses may help fire departments in developing and teaching Mayday procedures for fire fighters.
The National Fire Academy has two courses addressing the fire fighter Mayday Doctrine. Q133 Firefighter Safety: Calling the Mayday is a 2-hour program covering the cognitive and affective learning domain of the fire fighter Mayday Doctrine. H134 Calling the Mayday: Hands-on Training is an 8-hour course that covers the psychomotor learning domain of the fire fighter Mayday Doctrine. These courses are based on the military methodology used to develop and teach fighter pilots ejection doctrine. A training CD is available to fire departments free of charge from the U.S. Fire Administration Publications office [Clark 2005; USFA 2006].

The IAFF Fireground Survival program is another resource fire departments can use and was developed to ensure that training for Mayday prevention and Mayday operations are consistent among all fire fighters, company officers, and chief officers [IAFF 2010].
Any Mayday communication must contain the location of the fire fighter in as much detail as possible and, at a minimum, should include the division (floor) and quadrant. It is imperative that firefighters know their location when in IDLH environments at all times to effectively give their location in the event of a Mayday. Once in distress, fire fighters must immediately declare a Mayday. The following example uses LUNAR (Location, Unit, Name, Assignment/Air, Resources needed) as a prompt: "Mayday, Mayday, Mayday, Division 1 Quadrant C, Engine 71, Smith, search/out of air/vomited, can't find exit." When in trouble, a fire fighter's first action must be to declare the Mayday as accurately as possible. Once the incident commander and RIT know the fire fighter's location, the fire fighter can then try to fix the problem, such as clearing the nose cup, while the RIT is en route for rescue [USFA 2006].

A fire fighter who is breathing carbon monoxide (CO) quickly loses cognitive ability to communicate correctly and can unknowingly move away from an exit, other fire fighters, or safety before becoming unconscious. Without the accurate location of a downed fire fighter, the speed at which the RIT can find them is diminished, and the window of survivability closes quickly because of lack of oxygen and high CO concentrations in an IDLH environment [Clark 2005, 2008].

Fire fighters also need to understand the psychological and physiological effects of the extreme level of stress encountered when they become lost, disoriented, injured, or trapped or run low on air during rapid fire progression. Most fire training curricula do not include discussion of the psychological and physiological effects of extreme stress, such as encountered in an imminently life-threatening situation, nor do they address key survival skills necessary for effective response. Understanding the psychology and physiology involved is an essential step in developing appropriate responses to life-threatening situations. Reaction to the extreme stress of a life-threatening situation, such as being trapped, can result in sensory distortions and decreased cognitive processing capability [Grossman and Christensen 2008].

Fire fighters should never hesitate to declare a Mayday. There is a very narrow window of survivability in a burning, highly toxic building. Any delay declaring a Mayday reduces the chance for a successful rescue [Clark 2005]. In the book *Stress and Performance in Diving*, the author notes: "**We know that under conditions of stress, particularly when rapid problem-solving is crucial, overlearning responses is essential. The properly trained individual should have learned coping behavior so well that responses become virtually automatic requiring less stop and think performance**" [Bachrach and Egstrom 1987].

The word Mayday is easily recognizable and is an action word that can start the process of a rescue. The use of other words to declare an emergency situation should be discouraged because they may not be recognizable as an immediate action word that will start a rescue process. During this incident, the fireground radio traffic was busy and many different communications were taking place. A Mayday message transmitted over the radio may have gotten the attention of command officers and other fire fighters much earlier in the event when a rescue attempt might have had a better chance of locating the fire fighter. In this incident, FF1 had a radio but never called a Mayday or activated his emergency button.

Recommendation #6: Fire departments should ensure fire fighters are sufficiently retrained when transitioning from the emergency medical service back to fire operations.

Discussion: In order to ensure for the proficiency and competency of fire department members, the fire department should conduct refresher or annual skills evaluations to verify minimum professional qualifications. This refresher/annual evaluation should address the qualifications specific to the member’s assignment and job description. This process should be structured in a manner that skills are evaluated on a recurring cycle with the goal of preventing skills and abilities degradation and ensuring for the safety of members. Proficiency evaluation and training provides an opportunity to ensure that all fire officers and fire fighters are competent in the knowledge, skills, and abilities in fireground operations.

NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program* requires a fire department to establish and maintain a training, education, and professional development program with the goal of preventing occupational deaths, injuries, and illnesses. This ensures members are trained and competencies are maintained in order to effectively, efficiently, and safely execute all responsibilities [NFPA 2013d]. This process is consistent with the organizational statement that establishes the existence of the fire department, the services the fire department is authorized and expected to perform, the organizational structure, and the job descriptions and functions of fire department members [NFPA 2013d].

The primary goal of all training, education, and professional development programs is the reduction of occupational injuries, illnesses, and fatalities. As members progress through various job duties and responsibilities, the department should ensure the introduction of necessary knowledge, skills, and abilities to members who are new in their job titles as well as ongoing development of existing skills [NFPA 2013d].

NFPA 1410 *Standard on Training for Emergency Scene Operations* defines basic evolutions that can be adapted to local conditions and serves as a method for the evaluation of minimum acceptable performance during initial fireground operations [NFPA 2010]. Proficiency training for fireground operations and emergency incidents should be conducted annually. This training should include, but not be limited to, scene size-up, situational awareness, use of the incident management system, personnel accountability system, crew integrity, strategy and tactics, search and rescue, hoseline operations, ladder operations, ventilation, thermal imaging cameras, fireground communications, use of rapid intervention teams, and Mayday operations.

In this incident, the fire fighter had spent most of his career as an EMT riding an ambulance and detailed to the airport. He recently returned to being a fire fighter without any refresher training or structure fire experience.

Recommendation #7: Fire departments should ensure that accountability officers are proficient in fire fighter tracking/monitoring systems.

Discussion: With the development of new technological systems that can track, monitor, and communicate with every fire fighter on scene, it is necessary that accountability officers be proficient at understanding and operating the equipment. In addition, the fire department's protocols and procedures should reflect the capabilities of the tracking system, and the accountability officers should be trained on and follow these procedures [NFPA 2013d].

In this incident, several failed attempts were made to contact the fire fighter who's PASS was alarming before it was determined that the fire fighter was missing.

Recommendation #8: Fire departments should ensure that fire fighters are trained in situational awareness, personal safety, and accountability.

Discussion: All fire fighters operating at an incident should maintain situational awareness and conduct a continuous risk assessment throughout the incident, reporting unsafe or changing conditions to the incident commander. Fire fighters need to understand the importance of situational awareness and personal safety on the fireground. The fireground dangers and hazards can and do change as the incident becomes larger and the event duration increases.

The book *Essentials of Firefighting and Fire Department Operations* [IFSTA 2008] defines situational awareness as an awareness of the immediate surroundings. On the fireground, every fire fighter should be constantly alert for changing and unsafe conditions. Even though a safety officer may be designated for an incident, it is the obligation of all personnel to remain alert to their immediate surroundings. They must maintain their situational awareness and be alert for unsafe conditions. This applies not only to the conditions found within a burning structure, but to the exterior fireground as well [Clark 2008]. **In virtually every case, structural collapse results from damage to the structural system of the building caused by the fire or by fire-fighting operations. The longer a fire burns in a building, the more likely that the building will collapse [IFSTA 2008]**.

One of the most critical aspects of coordination between crews is maintaining situational awareness. The opposite of situational awareness is tunnel vision where the fire fighters become so focused on firefighting or other operational assignments that they fail to sense changes in their environment. Fire fighters can maintain their situational awareness by looking up, down, and around themselves, as well as listening for new or unusual sounds and feeling vibrations or movement. Fire fighters and officers should communicate any changes in their environment to other members as well as to the incident commander.
The International Association of Fire Chiefs (IAFC), Safety, Health and Survival section developed the “Rules of Engagement for Structural Firefighting.” The rules of engagement have been developed to assist both the fire fighter and the incident commander as well as command team officers in risk assessment and “Go” or “No-Go” decisions. The fireground creates a significant risk to fire fighters, and it is the responsibility of the incident commander and command organization officers to minimize fire fighter exposure to unsafe conditions and stop unsafe practices [IAFF 2010].

The rules of engagement can assist the incident commander, company officers, and fire fighters who are at the highest level of risk in assessing their situational awareness. One principle applied in the rules of engagement is that fire fighters and the company officers are the members most exposed to the risk for injury or death and will be the first to identify unsafe conditions and practices. The rules integrate the fire fighter into the risk assessment/decision-making process. These members should be the ultimate decision makers as to whether it’s safe to proceed with assigned objectives. Where it is not safe to proceed, the rules allow a process for that decision to be made while still maintaining command unity and discipline.

Rules of Engagement for Fire Fighter Survival

- Size up your tactical area of operation. This causes the company officer and fire fighters to pause for a moment, look over their area of operation, and evaluate their individual risk exposure to determine a safe approach for completing their tactical objectives.
- Determine the occupant survival profile. Occupant survival should be considered as part of the individual fire fighter's risk assessment and action plan development.
- Do not risk your life for lives or property that cannot be saved. When fire conditions prevent occupant survival and significant or total destruction of the building is inevitable, do not engage in fire-fighter operations that may harm you.
- Extend limited risk to protect savable property. Risk exposure should be limited to a reasonable, cautious, and conservative level when trying to save a building.
- Extend vigilant and measured risk to protect and rescue savable lives. Search and rescue operations should be managed in a calculated, controlled, and safe manner while remaining alert to changing conditions during high-risk primary search and rescue operations where lives can be saved.
- Go in together, stay together, and come out together. Two or more fire fighters should operate as a team.
- Maintain continuous awareness of your air supply, situation, location in the building, and fire conditions. Situational awareness means knowing where you are in the building and what is happening around you and elsewhere that can affect your risk and safety.
- Constantly monitor fireground communications for critical radio reports.
- You are required to report unsafe conditions or practices. Stop, evaluate, and decide. This allows any member to raise an alert about a safety concern without penalty, and the supervisor should address the question to ensure safe operations.
- You are required to abandon your position and retreat before deteriorating conditions can harm you. Be aware and exit early to a safe area when you are exposed to deteriorating conditions, unacceptable risk, and a life-threatening situation.
- Declare a Mayday as soon as you think you are in danger. Officers should ensure that fire fighters are comfortable with declaring a Mayday as soon as they think they are in trouble. [IAFF 2010]

The Incident Commander's Rules of Engagement for Fire Fighter Safety

- Rapidly conduct or obtain a 360-degree situational size-up of the incident. Determine the safest approach to tactical operations as part of the risk assessment plan and action development plan before fire fighters are placed at substantial risk.

- Determine the occupant survival profile. Consider fire conditions in relation to the potential for occupant survival of a rescue event before committing to a high-risk search and rescue operation and ongoing risk assessment.
- Conduct an initial risk assessment and implement a safe action plan. This rule causes an incident commander to develop a safe action plan by conducting a size-up, assessing the survival profile, and completing a risk assessment before fire fighters are placed in high-risk positions on the fireground.
- If you do not have the resources to safely support and protect fire fighters, seriously consider a defensive strategy. This rule prevents the commitment of fire fighters to high-risk tactical objectives that cannot be accomplished safely due to inadequate resources on the scene.
- Do not risk fire fighter lives for lives or property that cannot be saved. Instead, seriously consider a defensive strategy. This rule prevents the commitment of fire fighters to high-risk fire-fighting operations that may harm them when fire conditions prevent occupant survival and significant or total destruction of the building is inevitable.
- Extend limited risk to protect savable property. The incident commander should limit risk exposure to a reasonable, cautious, and conservative level when trying to save a building that is believed, following a thorough size-up, to be savable.
- Extend vigilant and measured risk to protect and rescue savable lives. The incident commander should manage search and rescue and supporting fire-fighting operations in a highly calculated, controlled, and cautious manner while remaining alert to changing conditions during high-risk search and rescue operations where lives can be saved.
- Maintain frequent two-way communications and keep interior crews informed of changing conditions. The incident commander should obtain frequent progress reports, keeping all interior crews informed of changing fire conditions observed from the exterior that may affect crew safety.
- Obtain frequent progress reports and revise the action plan. Frequent progress reports enable the incident commander to continually assess fire conditions and any risk to fire fighters and to regularly adjust and revise the action plan to maintain safe operations.
- Ensure accountability of every fire fighter, their location, and status. The incident commander and command organizational officers should maintain a constant and accurate accountability of the locations and status of all fire fighters within a small geographic area of accuracy, within the hazard zone, and be aware of who is presently in or out of the building.
- If after completion of the primary search, little or no progress toward fire control has been achieved, seriously consider a defensive strategy.
- Always have a rapid intervention team in place at all working fires.

Always have fire fighter rehab services in place at all working fires. This allows fire fighters who endured strenuous physical activities at a working fire to be rehabilitated and medically evaluated for continued duty and before being released from the scene [IAFF 2010].

Recommendation #9: Fire departments should ensure all fireground ventilation is coordinated with fire-fighting operations.

Discussion: Fire departments should manage and control the openings to the structure to limit fire growth and spread and to control the flow path of inlet air and fire gases during tactical operations. All ventilation must be coordinated with suppression activities. Uncontrolled ventilation allows additional oxygen into the structure, which may result in a rapid increase in the fire development and increased risk to fire fighters due to increased heat release rates within the flow path. Underwriters Laboratories (UL) released a report on the *Impact of Ventilation on Fire Behavior in Legacy and Residential Construction*. This report addressed the impact of multiple ventilation locations and the possibility of creating fuel-limited fires. The research indicated it was not possible to create fuel-limited fires with multiple ventilation openings. The report stated, *"It is more likely that the fire will respond faster because the already open ventilation location is allowing the fire to maintain a higher temperature than if everything was closed"* [UL 2010].

The flow path of a fire is how a fire moves through the structure as determined by incoming and outgoing vents for air, since air allows fire to sustain or grow [UL 2010]. Identifying and controlling the flow path is about knowing where the air comes from and where it's headed, and its importance cannot be underestimated. The identification of flow path is an item that should find its way into every after-action review. While trying to locate the fire, it is important to cool the heated space from a safe location while ensuring the safety of the fire fighters. Once the fire is under control, the fire can be completely extinguished. The rescue and salvage operations are self-explanatory—if anything can be saved, save it. These two actions are always active, right from sizing up to extinguishing [ISFSI 2013].

The UL research was conducted on one-story and two-story houses. The data collected from this research project provides valuable insight on the impact of ventilation on fire behavior in both legacy and contemporary residential construction [UL 2010]. Based upon the UL research, the following tactical operations should be considered during fireground operations:

- **Stages of fire development**: The stages of fire development change when a fire becomes ventilation-limited. It is common with today's fire environment to have a decay period prior to flashover, which emphasizes the importance of ventilation.
- **Forcing the front door is ventilation**: Forcing entry has to be thought of as ventilation as well. While forcing entry is necessary to fight the fire, it also adds another vent that feeds air to the fire, and the clock is ticking before either the fire gets extinguished or it grows until an untenable condition exists, jeopardizing the safety of everyone in the structure.

- **Flow paths:** Every new ventilation opening provides a new flow path for the fire. This could create very dangerous conditions when there is a ventilation-limited fire.
- **No smoke showing:** A common event during the UL experiments was that once the fire became ventilation-limited, the smoke being forced out of the gaps of the houses is greatly diminished or stopped altogether. No smoke showing during size-up should increase awareness of the potential conditions inside.
- **Coordination:** If you add air to the fire and don't apply water in the appropriate time frame, the fire gets larger and safety decreases. Examining the times to untenability gives the best-case scenario of how coordinated the attack needs to be.
- **Smoke tunneling and rapid air movement through the front door:** Once the front door is opened, attention should be given to the flow through the front door. A rapid inrush of air or tunneling effect could indicate a ventilation-limited fire.
- **Vent Enter Search (VES):** During a VES operation, primary importance should be given to closing the door to the room. This eliminates the impact of the open vent and increases tenability for potential occupants and firefighters while the smoke ventilates from the now isolated room [ISFSI 2013].

At this incident, the attic access panel was opened prior to the roof being vented, which enabled the hot gases and heavy smoke to enter the second floor from the attic space.

Recommendation #10: Fire departments should ensure hoselines are deployed, staffed, and appropriately utilized to protect interior operating crews.

Discussion: Although the primary purpose of the initial attack hoseline is for fire suppression, it also protects the interior fire suppression crews if they become overrun with fire, need to cool down the area, and need to protect a fire fighter's egress point(s). A hoseline should be of sufficient length to advance the crew in their search for the fire and/or occupants.

When initial attack hoselines are deployed and charged to an area and a hoseline is needed elsewhere, another hoseline should be taken off the engine to address the need.
During this incident, the initial attack line was deployed to Side Delta of the structure where the fire was visible. Prior to making entry on Side Alpha, the officer called for the hoseline to follow his crew in search for occupants. Upon going up the stairwell to the second floor, the hoseline came up short at the top of the stairs. This prompted FF2 to go down the stairs to try and pull more hose.

References

Bachrach A, Egstrom G [1987]. Stress and performance in diving. San Pedro, CA: Best Publishing. Clark BA [2005]. 500 Maydays called in rookie school. Firehouse, http://www.firehouse.com/article/10498807/500-maydays-called-in-rookie-school. (This link is also accessible at the following URL: http://www.firehouse.com/article/10498807/firefighter-mayday-training-500-maydays-called-in-rookie-school)
Clark BA [2008]. Leadership on the line: firefighter Mayday doctrine—where are we now? Firehouse.com, podcast, http://www.firehouse.com/podcast/10459336/leadership-on-the-linefirefighter-mayday-doctrine-where-are-we-now. (This link is also accessible at the following URL: http://www.firehouse.com/podcast/10459336/leadership-on-the-line-firefighter-mayday-doctrine-where-are-we-now).

Gagliano M, Phillips C, Jose P, Bernocco S [2008]. Air management for the fire service. Tulsa, OK: Penn Well Corporation, Fire Engineering.

Grossman D, Christensen L [2008]. On combat: the psychology and physiology of deadly conflict in war and peace. 3rd ed. Millstadt, IL: Warrior Science Publications.

IAFC [2009]. Rules of engagement for structural firefighting, increasing firefighter survival. Fairfax, VA: International Association of Fire Chiefs, Safety, Health, and Survival Section.

IAFF [2010]. IAFF Fireground Survival Program. Washington, DC: International Association of Fire Fighters, http://www.iaff.org/HS/FGS/FGSIndex.htm. (This link is also accessible at the following URL: http://www.iaff.org/index.asp)

IFSTA [2008]. Essentials of firefighting. 5th ed. Stillwater, OK: Fire Protection Publications, International Fire Service Training Association.

ISFSI [2013]. International Society of Fire Service Instructors position statement: fire dynamic research in tactical operations. Press release, October. Centerville, VA.

Jakubowski G, Morton M [2001]. Rapid intervention teams. Stillwater, OK: Fire Protection Publications: Oklahoma State University.

NFPA [2010]: NFPA 1410 Standard on training for emergency scene operations. Quincy, MA: National Fire Protection Association.

NFPA [2012]. NFPA 1403 Standard on live fire training evolutions. Quincy, MA: National Fire Protection Association.

NFPA [2013a]. NFPA 1001 Standard for fire fighter professional qualifications. Quincy, MA: National Fire Protection Association.

NFPA [2013b]. NFPA 1031 Standard for Professional Qualifications for Fire Inspector and Plan Examiner. Quincy, MA: National Fire Protection Association.

NFPA [2013c]. NFPA 1404 Standard for fire service respiratory protection training. Quincy, MA: National Fire Protection Association.

NFPA [2013d]. NFPA 1500 Standard on a fire department occupational safety and health program. Quincy, MA: National Fire Protection Association.

NIOSH [2011]. Career fire fighter dies while conducting a search in a residential house fire–Kansas. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2010-13, https://www.cdc.gov/niosh/fire/reports/face201013.html. (This link is also accessible at the following URL: http://www.cdc.gov/niosh/fire/reports/face201013.html).

NIOSH [2012]. A career captain dies and 9 fire fighters injured in a multistory medical building fire— North Carolina. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2011-18, http://www.cdc.gov/niosh/fire/reports/face201118.html. (This link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/reports/face201118.html).

NOAA [2015]. Climate data online search. Washington, DC: Department of Commerce, National Oceanic and Atmospheric Administration, http://www.ncdc.noaa.gov/cdo-web/results. (This link is also accessible at the following URL: https://www.ncdc.noaa.gov/cdo-web/search;jsessionid=0C9343FA7DA851FEE821EE6F93D85B72).

Sendelbach TE [2003]. Managing the fireground Mayday. Firehouse, May, http://www.firehouse.com/article/10541890/managing-the-fireground-mayday. (This link is also accessible at the following URl: http://www.firehouse.com/article/10541890/managing-the-fireground-mayday).

UL [2010]. Impact of ventilation on fire behavior in legacy and residential construction. Northbrook, IL: Underwriters Laboratories.

USFA [2006]. Firefighter safety: calling the Mayday (Q133). Calling the Mayday: hands on training (H134). Emmitsburg, MD: U.S. Department of Homeland Security, U.S. Fire Administration, National Fire Academy.

Investigator Information

This incident was investigated by Matt E. Bowyer, General Engineer, and Stephen Miles, Investigator, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field
Investigations Branch, Division of Safety Research, NIOSH, located in Morgantown, West Virginia.
An expert technical review was provided by Daniel Rossos, Chief (Retired), Portland Fire and Rescue. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). 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.

Appendix I

Self-Contained Breathing Apparatus

National Personal Protective Technology Laboratory
Technology Evaluation Branch

Disclaimer

Investigator Information

The SCBA inspection and this report were written by Thomas D. Pouchot, General Engineer, Technology Evaluation Branch, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, located in Bruceton, Pennsylvania.
The purpose of Respirator Status Investigations is to determine the conformance of each respirator to the NIOSH approval requirements found in Title 42, *Code of Federal Regulations*, Part 84. A number of performance tests are selected from the complete list of Part 84 requirements and each respirator is tested in its "**as received**" condition to determine its conformance to those performance requirements. Each respirator is also inspected to determine its conformance to the quality assurance documentation on file at NIOSH.

In order to gain additional information about its overall performance, each respirator may also be subjected to other recognized test parameters, such as National Fire Protection Association (NFPA) consensus standards. While the test results give an indication of the respirator's conformance to the NFPA approval requirements, NIOSH does not actively correlate the test results from its NFPA test equipment with those of certification organizations which list NFPA-compliant products. Thus, the NFPA test results are provided for information purposes only. Selected tests are conducted only after it has been determined that each respirator is in a condition that is safe to be pressurized, handled, and tested.

Respirators whose condition has deteriorated to the point where the health and safety of NIOSH personnel and/or property is at risk will not be tested.

STATUS Investigation REPORT OF ONE
Self-Contained Breathing Apparatus

Submitted By the
NIOSH Division of Safety
Research NIOSH Task Number
19738

The National Institute for Occupational Safety and Health (NIOSH) has concluded its investigation conducted under NIOSH Task Number TN-19738. This investigation consisted of the inspection of a Scott Health and Safety AirPak 4.5, 45 minute, 4500 psig, Self Contained Breathing Apparatus (SCBA). The SCBA unit in question was contained inside an individual cardboard shipping box and was delivered to the NIOSH facility in Bruceton, Pennsylvania, on July 22, 2014. The package was taken to the NPPTL, Technology Evaluation Branch (TEB) Respirator Equipment Storage Area (building 20) and stored under lock until the time of the examination and evaluation.

SCBA Inspection:

An initial general inspection of the SCBA unit was conducted on July 22, 2014. The unit was identified as the Scott Health and Safety AirPak 4.5 model. In addition, Scott Health and Safety performed a down loading of the data logger present on the SCBA with NIOSH personnel present on August 27, 2014

A complete visual inspection of the SCBA unit was conducted on August 19, 2014. The unit was examined, component by component in the condition received, to determine conformance to the NIOSH-approved configuration. The visual inspection process was photographed.

The complete SCBA inspection is summarized in Appendix I of the enclosed Status Investigation Report. The condition of each major component was photographed with a digital camera. Images of the SCBA unit are contained in the Appendix III of the report.

The SCBA unit in question, Unit #1, exhibited some signs of wear and tear; and the unit was covered lightly with general dirt and grime. The cylinder valve as received on the unit was in the closed position. The cylinder gauge could be read and indicated approximately 500 psig remaining. The cylinder valve hand-wheel could be turned.

The regulator and facepiece mating and sealing area on the Unit #1 facepiece was relatively clean. The unit had only slight scratches on the lens. Visibility through the facepiece lens of Unit #1 was good as the lens condition was good. The facepiece head harness webbing on the Unit #1 was in fair to good condition with only a slight amount of dirt. The PASS on the Unit #1 functioned. The NFPA SCBA approval label on Unit #1 was present and readable.

Personal Alert Safety System (PASS) Device

The Personal Alert Safety System (PASS) device on Units #1 was operable and functional. The PASS device was activated and appeared to function normally. However, the unit was not tested against the specific performance requirements of NFPA 1982, *Standard on Personal Alert Safety Systems, (PASS),* 2007 Edition. Because NIOSH does not certify PASS devices, no further evaluation was performed.

SCBA Compressed Air Cylinder Contents

During the inspection, it was noted that the compressed air cylinder of the unit contained some air pressure, approximately 500 PSIG. An air sample was collected for analysis. The results of that analysis are contained in Appendix II.

SCBA Testing

The purpose of the testing was to determine the SCBA conformance to the approval performance requirements of Title 42, *Code of Federal Regulations,* Part 84 (42 CFR 84). Further testing was conducted to provide an indication of the SCBA conformance to the National Fire Protection Association (NFPA) Air Flow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service,* 1997 Edition.

NIOSH SCBA Certification Tests (in accordance with the performance requirements of 42 CFR 84):

1. Positive Pressure Test [§ 84.70(a)(2)(ii)]
2. Rated Service Time Test (duration) [§ 84.95]
3. Static Pressure Test [§ 84.91(d)]
4. Gas Flow Test [§ 84.93]
5. Exhalation Resistance Test [§ 84.91(c)]
6. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

National Fire Protection Association (NFPA) Tests (in accordance with NFPA 1981, 1997 (Edition):

1. Air Flow Performance Test [Chapter 5, 5-1.1]

The testing of the unit was conducted on October 3, 2014. SCBA Unit #1 passed all the testing.

Appendix II of the Status Investigation Report contains complete NIOSH and NFPA test reports for the SCBA Unit #1. Tables One and Two summarize the NIOSH and NFPA test results.

Summary and Conclusions

One SCBA unit was submitted to NIOSH by the NIOSH Division of Safety Research for the Texas Fire Department for evaluation on July 22, 2014. The SCBA was initially inspected on July 22, 2014. The unit was identified as a Scott Health and Safety AirPak 4.5, 45 minute, 4500 psig SCBA (NIOSH approval number, TC-13F-212CBRN). In addition on August 27, 2014, the SCBA data logger for SCBA Unit #1 was downloaded by personnel from Scott Health and Safety with NIOSH personnel present. An in-depth inspection of the SCBA was conducted on August 19, 2014. The unit was in mostly fair to good condition. The unit suffered very slight amount of damage but exhibited other signs of wear and tear and the unit was slightly covered with general dirt. The cylinder valve as received on Unit #1 was in the closed position. The cylinder gauge could be read. The cylinder valve hand-wheel could be turned. The regulator and facepiece mating and sealing areas on Unit #1 were relatively clean. The unit had only slight scratches on the lens. Visibility through the facepiece lens of Unit #1 was good as the lens condition was good. The NFPA approval label on Unit #1 was present and readable.

The air cylinder on the Unit #1 had a manufactured date of 03/08. Under the applicable DOT exemption, the air cylinder is required to be hydro tested every 5 years. For the air cylinder on Unit #1, a retest date before the last day of 03/13 is required. The retest label was readable on Unit #1 with a retest date of 4/13, therefore the cylinder was within the hydro certification when last used. The cylinder on Unit #1 was in fair to good condition with only minor surface scratches present on the outer coating.

The integrated PASS unit on Unit #1 was activated and appeared to function normally.

Approximately 500 psig of air remained in the cylinders and an air sample was taken and analyzed.

The SCBA Unit #1 was tested on October 3, 2014. Unit #1 did meet all the requirements as tested.

After the inspection and testing of the SCBA unit, the respirator was placed back into storage pending the final disposition from the Texas Fire Department.

If this SCBA unit is to be placed back into service, then the units should be cleaned thoroughly and any damaged components replaced and tested by a qualified SCBA technician.

From the information obtained during this investigation, NIOSH proposes no further action on its part at this time. The investigation under task number TN-19738 will be considered closed.

Appendix II

ADDENDUM

TN-19738

Air Starvation Test

Discussion:

The Fire Department requested NIOSH to conduct testing to determine what affects a partially closed cylinder valve may have on the air flow of a SCBA. The Fire Department conducted similar test with their fire fighters wearing a Scott Health and Safety Self Contained Breathing Apparatus (SCBA), and breathing normally throughout the duration of the 45-minute cylinder to determine if the turns of the cylinder valve regulated the air flow to the user.

The testing was done using a mechanical breathing machine and anthropometric head that are used in the certification and testing of SCBA in the NIOSH lab in Morgantown, WV. A mechanical pressure gauge was inserted inline in between the cylinder and the first stage regulator (reference Photos 1 and 2.) The cylinder valve was opened to different partial revolutions. Two and one half turns of the hand wheel opened the cylinder valve completely. The breathing machine was also set at different rates in liters/minute (LPM).

Observations/Summary of Air Starvation Tests

Test #1, ½ turn on cylinder valve, 40 LPM.
Face piece pressure .4 inches of water-positive
The test ran 47 minutes and 18 seconds before the pressure in the facepiece went negative and the pressure gauge read empty. During this test, there was not a significant drop in pressure to record.

Test #2, ¼ turn on cylinder valve, 40 LPM.
Face piece pressure .4 inches of water positive
At 2200 psi dropped to .35 inches of water-positive
At 1950 psi dropped to .3 inches of water-positive
At 1100 psi dropped to .25 inches of water-positive
At 1100 the VibrAlert came on and the positive pressure increased to .4 inches of water-positive A noticeable 200 – 300 psi swing in the needle on the gauge was witnessed.

The test ran 45 minutes before the pressure in the facepiece went negative and the pressure gauge read empty.

Test #3, ¼ turn on cylinder valve, 75 LPM.
Face piece pressure .25 inches of water positive
A 200 psi swing in the needle on gage at 4500 psi.

3000 psi - .15 inches of water-positive
2250 psi - .10 inches of water-positive
1350 psi - .05 inches of water-positive
1100 psi vibe alert and 300 psi swing in the needle
600 psi - .00 inches of water-but remainded positive
500 psi – 400 to 500 psi swing in the needle

Test #4, 1/8 turn on cylinder valve, 40 LPM.
Face piece pressure .4 inches of water positive
800 psi swing in the needle (Photo 3)
3800 psi - .35 inches of water-positive
3500 psi - .3 inches of water-positive (Approximately 2 minutes)
3300 psi - .25 inches of water-positive
2800 psi - .19 inches of water-positive (Approximately 10 minutes)
1200 psi - .15 inches of water-positive (Approximately 21 minutes)
1000 psi - .1 inches of water-positive (Approximately 25 minutes)
800 psi- VibrAlert in/out
500 psi - .2 inches of water-positive

At this time during test #4, the cylinder valve was turned completely open. The pressure climbed to 1000 psi and remained steady. The VibrAlert stayed on.

Conclusions

The tests represented that there is a correlation between air flow and how far the cylinder valve is opened. Limiting the air flow to the system, by not opening the valve completely, creates a reduced positive pressure to the facepiece and a higher resistance to obtain a breath by the wearer. Both of these situations were demonstrated in these tests and both could result in a perceived out-of-air emergency situation.

Handout 1-1 Group 5:

Fire Fighter Suffers Fatal Heart Attack at Commercial Fire — New Jersey

2015 05

Death in the line of duty...

NIOSH

Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation July 1, 2015

Fire Fighter Suffers Fatal Heart Attack at Commercial Fire – New Jersey

Executive Summary

On June 8, 2014, a 54-year-old male volunteer firefighter (FF) responded to the scene of a commercial fire and performed interior fire suppression activities. The FF was part of an engine crew that advanced a charged 2.5-inch hoseline into the building. The FF served as the doorman to ensure the hoseline did not get caught on the door. After his second building entry, the FF exited the structure and then collapsed on the curb in the front of the building. On-scene emergency medical service (EMS) personnel immediately initiated cardiopulmonary resuscitation (CPR) and placed the FF in an on-scene ambulance for transport to the emergency department (ED). Despite resuscitation efforts on scene, during transport, and in the ED, the FF died. The death certificate and autopsy report, both completed by the Assistant Medical Examiner, listed the cause of death as "atherosclerotic cardiovascular disease," with physical exertion and smoke inhalation as contributory factors. The autopsy found severely blocked coronary arteries and evidence of an acute heart attack. Based on the FF's undiagnosed coronary heart disease (CHD), NIOSH investigators concluded that the physical exertion associated with fire suppression activities at this fire triggered the FF's heart attack and subsequent sudden cardiac death.

Key Recommendations

- *Provide preplacement and annual medical evaluations to all fire fighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments*
- *Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582*
- *Phase in a mandatory comprehensive wellness and fitness program for fire fighters.*

For further information, visit the program website or call toll free 1-800-CDC-INFO (1-800-232-4636) (This link is also accessible at the following URL: www.cdc.gov/niosh/fire)

2015 05

Death in the line of duty... NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

July 1, 2015

Fire Fighter Suffers Fatal Heart Attack at Commercial Fire – New Jersey

Introduction

On June 8, 2014, a 54 year-old male volunteer FF suffered a fatal heart attack while operating at the scene of a commercial fire. NIOSH was notified of this fatality on June 10, 2014, by the U.S. Fire Administration. A contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) contacted the fire department (FD) on March 26, 2015, to schedule the investigation, which took place on April 27, 2015.

During the investigation, the NIOSH investigator interviewed the following people:

- Chief of the FD
- Captain of the FD who was working with the FF
- EMS Chief who provided initial care

The NIOSH investigator reviewed the following documents in preparing this report:

- FD fire report
- FD standard operating guidelines
- FD dispatch records
- Police Department investigative report
- EMS (Ambulance) pre-hospital care report
- Hospital ED medical records
- Death certificate
- Medical examiner's (autopsy) report
- Medical records from preplacement medical screening

Investigation

On June 8, 2014, at 1756 hours the FD received an alarm for a structure fire in a commercial building. The structure was a single-story building (approximately 70 × 70 feet) with terracotta/concrete block foundation and walls. The flat roof was constructed of steel I-beams and steel column supports and covered with tin. The building housed a fabrication company that repaired hydraulic equipment and made custom metal fittings. The weather conditions were clear and sunny with an air temperature of approximately 70°Fahrenheit and relative humidity of 75% [Weather Channel 2015].

The first units arrived on scene at 1800 hours reporting heavy smoke conditions. Dispatch deployed three engines, a truck, a brush truck, chief car, and several support vehicles. Initial fire attack efforts were hampered because the fire was located in the back of the building and the rear door (steel) to the building was covered with a steel bar and there were no windows in the rear of the building from which to attack the fire.

The FF was part of a four-person engine crew that was the third engine on scene arriving at 1805 hours. The FF and his crew were assigned to advance a 2.5-inch attack line into the building. Dressed in full personal protective equipment, the engine company made entry through the front door, but were inside for only about 5 minutes before exiting due to an inoperable thermal imaging camera.

The Chief of the FD arrived on scene at 1818 hours. After being briefed on ongoing operations including the difficulty gaining access to the back of the building, he assigned the FF's engine crew to reenter the front of the building and progress toward the rear of the building. After approximately 5 minutes, the FF and the entire engine crew were again forced to exit the building, this time due to rapidly deteriorating fire conditions and intense heat. The Chief checked on each engine crew member and then assigned the entire engine crew to rehabilitation (set up across the street). Nearly simultaneously, the Chief received a radio transmission that the roof was no longer safe for firefighting operations; he ordered all personnel to evacuate the building and activated the evacuation horn.

At approximately 1829 hours, with the Chief still standing in front of him, the FF sat down on the curb in front of the building and slumped onto his self-contained breathing apparatus (SCBA). Nearby fire fighters immediately rushed to the FF and carried him approximately 30 feet to the EMS personnel in the rehabilitation area. The FF was placed on a stretcher and his bunker gear was removed. He was quickly loaded into the ambulance which departed for the ED. Initial assessment inside the ambulance revealed that the FF had no pulse, was not breathing, and was unresponsive. CPR was begun, an oral airway was secured with oxygen supplied by a non-rebreather bag. An external automated defibrillator was attached to the FF and three shocks were administered; the last shock at 1838 hours without a change in his heart rhythm or clinical condition.

The FF was admitted to the ED at 1842 hours in asystole and CPR in progress. The FF was intubated with an endotracheal tube, and a central line catheter was inserted. The FF was given cardiac medications through this central line, including epinephrine, atropine, sodium bicarbonate, and lidocaine, but he never regained a viable heart rhythm. Two attempts to defibrillate the FF were made at 1914 and 1916 hours without any change in his cardiac rhythm. At 1917 hours the FF was pronounced dead by the ED physician and resuscitation efforts were discontinued.

Medical Findings

The death certificate and autopsy, both completed by the Assistant Medical Examiner, listed the cause of death as "atherosclerotic cardiovascular disease" with physical exertion and smoke inhalation as contributory factors. Pertinent autopsy findings included "severely occlusive calcified atherosclerosis" in all three main coronary arteries, and evidence of an acute heart attack (myocardial infarction) based on segmental thrombosis of the left main coronary artery and appearance of the myocardium. The FF also had an enlarged heart (cardiomegaly), and left ventricular hypertrophy (LVH). His carboxyhemoglobin level was 7.2%, suggesting minor to moderate exposure to carbon monoxide during this incident. See Appendix A for more detailed autopsy information.

The FF was 74 inches tall and weighed about 233 pounds, giving him a body mass index of 29.9 kilograms per meter squared [CDC 2015]. The FF had not received a medical evaluation from the FD and little is known about his medical history. According to his wife, the FF had no history of cardiovascular disease**,** did not see a physician regularly, and took no medications**.** He was a nonsmoker. The FF worked as a driver for a shipping company, and reportedly had biannual medical evaluations to maintain his commercial driver's license. These records were not available to NIOSH at the time of this report.

Fire Department

The FD consists of 63 volunteers operating four stations serving approximately 6,500 people over 2 square miles. In 2014, the department responded to over 100 emergency calls.

Membership and Training

The FD requires new fire fighter applicants to be 18 years of age. Applicants must complete a form and be investigated by an "investigation committee" at the company level. If the investigation committee provides a positive recommendation, the potential member is presented to the entire company for a vote. If members vote to accept a potential member, a police department background check is performed. If the background check is acceptable, the potential member becomes a member and completes a state application form to be registered as a firefighter. Once registered with the State, the firefighter is enrolled in a County Fire Academy and required to complete a 192-hour state firefighter course (if he/she does not join the department with this credential).

Preplacement Medical Evaluation

The FD requires candidates to complete a respiratory medical evaluation questionnaire [29 CFR 1910.134]. If there are any positive responses, the candidate is referred to a Borough physician for evaluation. The FF joined this FD approximately 8 years earlier and completed the questionnaire at that time. In his responses, the FF answered no to all questions regarding cardiovascular or heart symptoms and the use of cardiovascular medications. Based on his responses, he did not receive a physician evaluation.

Periodic Medical Evaluations/Return to Work Medical Evaluations

The FD does not require annual medical evaluations for members. However the FD makes members aware of a state-wide program that provides free medical evaluations to all firefighters in New Jersey (Appendix 2). Firefighters who have had a serious injury or illness that requires hospitalization are required to be cleared for return to work by their primary care physician (PCP).

Fitness/Wellness Programs

The FD has no fitness equipment or program and offers no wellness program.

Discussion

Sudden Cardiac Death

The most common risk factor for cardiac arrest and sudden cardiac death is CHD, defined as the buildup of atherosclerotic plaque in the coronary arteries [AHA 2012]. Risk factors for CHD include three non-modifiable factors (age older than 45, male gender, and family history of CHD) and six modifiable factors (smoking, hypertension, high blood cholesterol, obesity, physical inactivity, and diabetes mellitus) [National Cholesterol Education Program 2002; AHA 2015]. According to the FF's wife, the FF had no known cardiovascular health issues, did not have a PCP, and took no medications. On the FD's self-administered medical questionnaire completed when he joined the department in 2007, he had no symptoms of cardiovascular disease and was taking no medications.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Most heart attacks occur when a vulnerable plaque ruptures, causing a blood clot to form and occlude a coronary artery. This sudden blockage is primarily due to blood clots (thrombosis) forming on top of atherosclerotic plaques [Libby 2013].

Establishing a recent (acute) heart attack requires one or more of the following: characteristic electrocardiogram changes, elevated cardiac enzymes, or coronary artery thrombus. At autopsy, the FF had evidence of a thrombus in his left main coronary artery confirming an acute heart attack.

Cardiomegaly/Left Ventricular Hypertrophy

The autopsy revealed that the FF had cardiomegaly and LVH. Both conditions independently increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the left ventricle is relatively common among individuals with long-term hypertension, a heart valve problem, or chronic CHD and ischemia to the heart muscle [Siegel 1997]. The FF had severe CHD at autopsy.

Carbon Monoxide, Carboxyhemoglobin Levels, and Cardiac Effects.

Carbon monoxide (CO) is a component of fire smoke. When inhaled, CO crosses the alveolar (lung) membrane gaining access to the body's blood stream. In blood, the CO can dissolve in the serum and displace oxygen on the hemoglobin molecule forming carboxyhemoglobin (COHb). CO disrupts the delivery of, and the intercellular use of, oxygen leading to hypoxia (inadequate oxygen supply) [Alonso et al. 2003; Roderique et al. 2015]. The brain and the heart are the organs most vulnerable to hypoxia, thus, the symptoms and signs associated with CO poisoning include headache, dizziness, weakness, nausea, confusion, fast heart rate, and shortness of breath [Ernst and Zibrak 1998]. During this incident, the FF did not express any of these symptoms. COHb levels in the blood are used to assess CO exposure and CO poisoning. COHb levels in nonsmokers are typically 1-3%, while cigarette smokers have levels that range from 4-8% [Castelden and Cole 1975]. The FF had a COHb of 7.3%, suggesting some CO exposure during his response at this incident. While COHb levels of 6% can increase the frequency of ventricular arrhythmias among patients with ischemic heart disease [Sheps et al. 1990], it is unclear whether CO has an acute effect on plaque rupture (e.g., an acute heart attack) [Zevin et al. 2001]. In summary, the FF was exposed to carbon monoxide at some point during this incident causing an elevation of his COHb level. It is unclear what role, if any, this exposure had in triggering his heart attack and sudden cardiac death.

Physiological Stress of Firefighting

Firefighting is widely acknowledged to be physically demanding. Firefighting activities require fire fighters to work at near maximal heart rates for long periods. An increase in heart rate typically occurs in response to the initial alarm and persists throughout the course of fire suppression activities [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Smith et al. 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulating properties of the personal protective clothing [Smith et al. 1995]. Recent evidence also indicates the firefighting results in increased clotting potential which persists for 2 hours after firefighting activities [Smith et al. 2014]. Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and/or sudden cardiac death [Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job, in the preceding 12 hours, increases the risk for a sudden cardiac event [Kales et al. 2003; Hales et al. 2007; Kales et al. 2007]

In summary, the FF had been performing firefighting activity in full PPE at a commercial fire for about 24 minutes. NIOSH investigators conclude that the strenuous work associated with firefighting duties triggered the FF’s fatal heart attack.

Occupational Medical Standards for Structural Fire Fighters

To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the National Fire Protection Association (NFPA) developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2013]. This voluntary industry standard provides (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria. The FD only requires a self-administered medical questionnaire for candidate and does not require any medical evaluations for incumbents. If the FD had a comprehensive medical evaluation in place, perhaps the FF’s cardiac condition could have been identified, evaluated, and treated prior to this incident.

Recommendations

Recommendation #1: Provide preplacement and annual medical evaluations to all firefighters in accordance with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Discussion: Guidance regarding the content of these medical evaluations can be found in NFPA 1582 [NFPA 2013]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. To ensure improved health and safety of candidates and members, and to ensure continuity of medical evaluations, it is recommended the FD comply with this recommendation, particularly the section addressing CHD. However, the FD is not legally required to follow the NFPA standard. Applying this recommendation involves economic repercussions and may be particularly difficult for smaller fire departments to implement.

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians or their employer. If the FD had a FD physician reviewing medical records from other employers (i.e., the FF's commercial driver's license exam), perhaps this FF's CHD could have been identified, evaluated, and treated. Another option is having the annual medical evaluations (vital signs, height, weight, visual acuity, and electrocardiogram) completed by paramedics and emergency medical technicians from the local ambulance service. This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed).
The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, city, or State. In the State of New Jersey a medical evaluation program titled "A Gift from Captain Buscio" was initiated by Captain's Buscio's widow. It provides free medical evaluations to New Jersey fire fighters (Appendix 2). Sharing the financial responsibility for these evaluations between fire fighters, the FD, the city, the State, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

Recommendation #2: Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Discussion: According to NFPA 1582, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty [NFPA 2013]. The physician should review job descriptions and essential job tasks required for all FD positions to understand the physiological and psychological demands of firefighting and the environmental conditions under which fire fighters perform, as well as the personal protective equipment they must wear during various types of emergency operations. In addition, this physician should oversee all fitness for duty recommendations provided by PCPs and have the final authority for all medical fitness for duty decisions. To ensure the FD physician or other PCP is familiar with NFPA 1582, the NIOSH investigators recommend the FD provide a copy of NFPA 1582 or a link to the NFPA website where a copy could be purchased or viewed on-line at no charge.

Recommendation #3: Phase in a mandatory comprehensive wellness and fitness program to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Discussion: Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor

Management Wellness/Fitness Initiative, the National Volunteer Fire Council Health and Wellness Guide, and in Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CHD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl et al. 2013]. The department should implement a wellness and fitness program to help ensure that their members are physically prepared for the strenuous work of firefighting.

References

AHA [2015]. Understand your risk of heart attack. American Heart Association.

[http://www.heart.org/HEARTORG/Conditions/HeartAttack/UnderstandYourRiskofHeartAttack/Unde rstand-Your-Risk-of-Heart-Attack_UCM_002040_Article.jsp]. Date accessed: May 2015.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med *343*(19):1355–1361.

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*:296-320.

Alonso JR, Cardellach F, Lopez S, Casademont J, Miro O [2003]. Carbon monoxide specifically inhibits cytochrome c oxidase of human mitochondrial respiratory chain. Pharmacol Toxicol *93*(3):142-146.

Barnard RJ, Duncan HW [1975]. Heart rate and ECG responses of firefighters. J Occup Med *17*(4): 247-250.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. Health and fitness programming for fire fighters: does it produce results? Med Sci Sports Exerc *38*(5):S454.

Castelden CM, Cole PV [1975]. Carboxyhaemoglobin levels of smokers and non-smokers working in the City of London. Brit J Ind Med *32*;115-119.

CDC [2015]. Assessing your weight. Centers for Disease Control and Prevention.

[http://www.cdc.gov/healthyweight/assessing/index.html]. Date accessed: May 2015.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register

Davies MJ [1992]. Anatomic features in victims of sudden coronary death. Coronary artery pathology. Circulation *85*[Suppl I]:I-19–24.

Dempsey WL, Stevens SR, Snell CR [2002]. Changes in physical performance and medical measures following a mandatory firefighter wellness program. Med Sci Sports Exerc *34*(5):S258.
Ernst A, Zibrak JD [1998]. Carbon monoxide poisoning. N Engl J Med *339*(22):1603–1608.

Hales T, Jackson S, Baldwin T [2007]. NIOSH Alert: Preventing Fire Fighter Fatalities Due to Heart

Attacks and Other Sudden Cardiovascular Events. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health Publication No. 2007-133.
[http://www.cdc.gov/niosh/docs/2007-133/]. Date Accessed: May 2015.

IAFF, IAFC [2008]. The fire service joint labor management wellness/fitness initiative. 3rd ed.

Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Fire fighters and on-duty deaths from coronary heart disease: a case control study. Environ Health *2*(1):14.

Kales SN, Soteriades ES, Christophi CA, Chirstiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. New Engl J Med *356*(12):1207-1215.

Kuehl KS, Elliot DL, Goldberg L, Moe EL, Perrier E, Smith J [2013]. Economic benefit of the PHLAME wellness programme on firefighter injury. Occup Med *63*(3):203-209.

Lemon PWR, Hermiston RT [1977]. The human energy cost of firefighting. J Occup Med *19*(8):558-565

Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP [1990]. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med *323*(24):1706–1707.

Libby P [2008]. The pathogenesis, prevention, and treatment of atherosclerosis. In: Fauci AS,

Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison’s principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1501–1509.

Libby P [2013]. Mechanisms of acute coronary syndromes and their implications for therapy. N Engl J Med *368*(21):2004-4013.

Manning JE, Griggs TR [1983]. Heart rates in fire fighters using light and heavy breathing equipment: Similar near-maximal exertion in response to multiple work load conditions. J Occup Med. *25*(3): 215218.

Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Engl J Med *329*(23):1677-1683.

NFPA [2008]. Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association. NFPA 1583.

NFPA [2013]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

National Cholesterol Education Program [2002]. Third Report of the National Cholesterol education

Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult treatment Panel III). NIH Publication No. 02-5215. National Institutes of Health, National Heart, Lung, and Blood Institute. Washington: Government Printing Office.

Roderique JD, Josef CS, Feldman MJ, Spiess BD [2015]. A modern literature review of carbon monoxide poisoning theories, therapies, and potential targets for therapy advancement. Toxicology *334*:45-51.

Schneider EL [2010]. Firefighter fitness: a health and wellness guide. New York: Nova Science Publishers.

Shah PK [1997]. Plaque disruption and coronary thrombosis: new insight into pathogenesis and prevention. Clin Cardiol *20*(11 Suppl2):II-38–44.

Sheps DS, Herbst MC, Hinderliter AL, Adams KF, Ekelund LG, O'Neil JJ, Goldstein GM, Bromberg PA, Dalton JL, Balienger MN, Davis SM, Koch GG [1990]. Production of arrhythmias by elevated carboxyhemoglobin in patients with coronary artery disease. Annals of Intern Med *113*;343-351.

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven, pp. 55–57.

Smith DL, Horn GP, Petruzzello SJ, Fahey G, Woods J, Fernhall B [2014]. Clotting and fibrinolytic changes after firefighting activities. Med Sci Sports Exerc *46*(3):448-454.

Smith DL, Horn GP, Petruzzello SJ, Freund G, Woods J, Cook M, Goldstein E, Fernhall B [2014]. Effect of Obesity on Acute Hemostatic Responses to Live-Fire Training Drills. Am J Cardiol *114*:1768-1771.

Smith DL, Manning TS, Petruzzello SJ [2001]. Effect of strenuous live-drills on cardiovascular and psychological responses of recruit fire fighters. Ergonomics *44*(3): 244-254.

Smith DL, Petruzzello SJ, Kramer JM, Warner SE, Bone BG, Misner JE [1995]. Selected physiological and psychobiological responses of physical activity in different configurations of firefighting gear. Ergonomics *38*(10): 2065-2077.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*(12):1148-1155.

Tofler GH, Muller JE, Stone PH, Forman S, Solomon RE, Knatterud GL, Braunwald E [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Study Group. J Am Coll Cardiol *20*(5):1049-1055.

USFA [2004]. Health and Wellness Guide for the Volunteer Fire and Emergency Services.

Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration. Publication No. FA-321.

Weather Channel [2015]. Historical Weather. (This link is also accessible at the following URL: http://www.wunderground.com/history).

Willich SN, Lewis M, Lowel H, Arntz HR, Schubert F, Schroder R [1993]. Physical exertion as a trigger of acute myocardial infarction. N Engl J Med *329*(23):1684-1690.

Womack JW, Humbarger CD, Green JS, Crouse SF [2005]. Coronary artery disease risk factors in firefighters: effectiveness of a one-year voluntary health and wellness program. Med Sci Sports Exerc *37*(5):S385.

Zevin S, Saunders S, Gourlay SG, Jacob III P, Benowitz NL [2001]. Cardiovascular effects of carbon monoxide and cigarette smoking. J Am Coll Cardiol *38*(6):1633-1638.

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Denise L. Smith, Ph.D, led the investigation and coauthored the report. Dr. Smith is professor of Health and Exercise Sciences, and Director of the First Responder Health and Safety Laboratory at Skidmore College. She is a member of the NFPA Technical Committee on Occupational Safety and Health. Dr. Smith was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component during this investigation. Thomas Hales, MD, MPH, provided medical consultation and coauthored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Disclaimer

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). In addition, citations to Web sites 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 Web sites.

Appendix One

Autopsy Findings

- Heart size and structure o Heart weight = 560 grams (expected weight 403 grams; lower 95% confidence limit 305 grams and upper 95% confidence limit 531 grams for a male weighing 234 pounds [the FF weighed 233 pounds]) [Silver and Silver 2001] o Left ventricular hypertrophy noted
- Coronary arteries o Severely occlusive calcified trivascular atherosclerosis o Segmental thrombosis of left main stem confirming an acute myocardial infarction (MI) o Myocardium changes of the postero-lateral wall of left ventricle suggesting an acute MI o 80-90% lumen occlusion of all major arteries
- No evidence of valvular disease
- No evidence for a pulmonary embolus
- Mild atherosclerosis of aorta ▪ Negative drug screen
- Carboxyhemoglobin (COHb) = 7.2%, suggesting the FF was exposed to carbon monoxide during this incident [Castelden and Cole, 1975; Sheps et al. 1990].

References

Castelden CM, Cole PV [1975]. Carboxyhaemoglobin levels of smokers and non-smokers working in the City of London. Brit J Ind Med *32*;115-119.

Colucci WS, Braunwald E [1997]. Pathophysiology of heart failure. In: Braunwald, ed. Heart disease. 5th ed. Philadelphia, PA: W.B. Saunders Company, p. 401.

Sheps DS, Herbst MC, Hinderliter AL, Adams KF, Ekelund LG, O'Neil JJ, Goldstein GM, Bromberg PA, Dalton JL, Balienger MN, Davis SM, Koch GG [1990]. Production of arrhythmias by elevated carboxyhemoglobin in patients with coronary artery disease. Annals of Intern Med *113*;343-351.

Silver MM, Silver MD [2001]. Examination of the heart and of cardiovascular specimens in surgical

pathology. In: Silver MD, Gotlieb AI, Schoen FJ, eds. Cardiovascular pathology. 3rd ed. Philadelphia,

PA: Churchill Livingstone, pp. 8–9.

Appendix Two:

A brochure describing free medical evaluations for fire fighters from the State of New Jersey.

A Message from Donna Buscio

Dear Friends,

My late husband Captain Dominick Buscio was a dedicated fire captain of the Jersey City Fire Department. Dom was a wonderful husband, father, brother and son to his family, and a true friend to all who knew him. At the age of 39, his life was unexpectedly taken when he suffered a heart attack during our ski vacation. Dom was the picture of health. In fact, the results of a complete physical he had only 19 months before his death were normal, except for the presence of a moderately high cholesterol level. Since he was found to be healthy at that time, he decided not to return for his annual physical the following year. While many people his age make the decision not to seek regular checkups, in his case, it resulted in an inconceivable loss to all of us.

I am sharing our experience with others because I have found that my husband's death was not a rarity. Heart attacks are the largest single killer of firefighters. For that very reason, I created the program "A Gift from Captain Buscio," which began in Jersey City and now spans across the State of New Jersey to offer strictly confidential, comprehensive medical evaluations with no out-of-pocket cost to all firefighters and officers. These annual examinations are provided by the medical director, Manmohan Patel, M.D., and other board-certified cardiologists and pulmonologists who have generously offered firefighters medical care that is specific to their profession.

My intention is not to instill anxiety. On the contrary, it's to provide an opportunity for peace of mind. I'm quite certain that this program would have had Dom's full support, given the current limited opportunities for firefighters to obtain physicals.

For me, this program, which was founded in Dom's memory, is an attempt to keep your occupational risk limited to fighting fires.

This brochure provides you with details on the program and how you may benefit from it. If you have any questions or concerns regarding information other then the Web site, please contact me at dbuscio@aol.com.

Sincerely

Donna Buscio

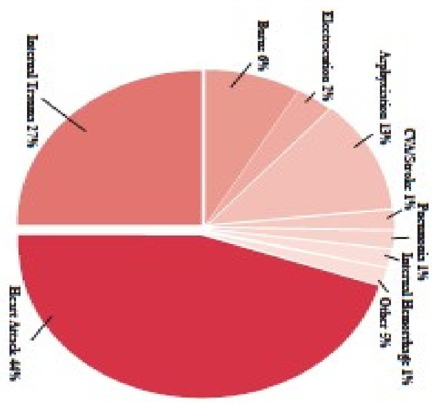
Statistics Tell the Story

When it comes to the relationship between firefighters and heart attacks, the statistics speak for themselves:

- Despite fluctuations, the trend in the proportion of firefighter fatalities from heart attacks has remained constant since 1984.
- More than one-half of all fatal heart attacks strike firefighters while on the scene of a fire or non-fire emergency.

Firefighter victims may not have had a previous medical history of heart disease. For this reason getting a comprehensive medical evaluation that is specific to your profession is not just for peace of mind. It is absolutely necessary.

Fatalities by nature of Fatal Injury (2002)



For additional details on this statistical data, visit the United States Fire Administration at the Federal Emergency Management Agency's Web site, www.usfa.fema.gov.

How 'A Gift from Captain Buscio' Works

All fire departments whose firefighters and officers are participating in the program throughout the State of New Jersey have the opportunity to receive confidential comprehensive medical evaluations with no out-of-pocket expense. These annual examinations are provided by the medical director Manmohan Patel, M.D., and other board-certified cardiologists and pulmonologists who have generously offered firefighters medical care that is specific to their profession.

Board certified in internal medicine, pulmonary medicine, critical care, emergency medicine and geriatric medicine, Dr. Patel is also a member of the New Jersey Board of Medical Examiners. He offers 20 years of experience working in these disciplines and has provided this annual service in the past, with great success, to railroad workers of New Jersey, and currently to the Jersey City Fire Department.

This comprehensive examination may also include any other testing deemed necessary, including pulmonary function testing, stress testing and laboratory work. Upon completion of the physical, each firefighter/officer will be provided with a full medical report to present to his or her family physician.

All visits will be scheduled by appointment, and the medical staff will direct you on what will be needed for the initial visit, such as bringing a listing of all medications that you currently may be taking. In addition, fasting the previous night is required for blood work, which is part of the evaluation.

To schedule an appointment call 201-216-3055.

A summary of a NIOSH fire fighter fatality investigation (This link is also accessible at the following URL: https://www.cdc.gov/niosh/fire/pdfs/face201505.pdf).