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Death in the line of duty...

National Institute for Occupational Safety and Health NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program March 21, 2017

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

Executive Summary

On December 9, 2014, a 37-year-old female career fire fighter/EMT died after becoming lost and running out of air in a residential structure fire. The fire fighter/EMT was the third fire fighter on a hoseline crew attacking the fire when the fire overran their position. One fire fighter and the officer escaped, but the fire fighter/EMT was trapped and radioed a Mayday. However, before she could be located, her buddy breather hoseline burnt through and she lost her available air.

Side Alpha of the fire building (*NIOSH photo.*)

At 02:49 hours, two engines, two trucks, and a battalion chief were dispatched to a residential structure fire. Four minutes later, the first arriving engine, Engine 73, reported nothing showing but was informed by Dispatch that a resident might be trapped. The Engine 73 officer investigated and informed Command, who was on-scene, that they had a possible fire in the basement. The battalion chief investigated the first floor and noticed only light smoke. The battalion chief walked upstairs, found an elderly woman in the bedroom, and carried her outside. The Engine 73 officer and two fire fighters stretched a 1¾-inch hoseline into the kitchen and requested water. Engine 63 was in the rear of the structure and reported fire in the first-floor kitchen window. Engine 73 flowed water towards the basement door then advanced but the hoseline came up short at the door. Command upgraded the response to a full box. Command ordered Ladder 8 to ventilate the structure but Ladder 8 was still en route. Engine 63 made entry into the basement from the rear. Command made several attempts to contact the Engine 73 officer over the radio. Ladder 21 reported a negative primary search on the second floor. Command radioed Engine 73 to back out. At 03:02 hours, a Mayday was heard and believed to be from Engine 63. Command radioed the Engine 63 officer, then the Mayday was repeated by the Engine 73 fire fighter/EMT that she was trapped on the first floor. Over the next several minutes, the Engine 73 fire fighter/EMT called for help several times. The Engine 73 officer went inside to search for her. Engine 63 was advancing on the fire in the basement, and Ladder 21 was ventilating the roof and windows. Engine 51 and Engine 72 were fighting fire on the first floor and searched for the Engine 73 fire fighter/EMT. At 03:16 hours, Engine 72 found the Engine 73 fire fighter/EMT and brought her out. The Engine 73 fire fighter/EMT was transported to the hospital where she was pronounced dead.

Contributing Factors

- Fireground tactics

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- Unrestricted flow path of the fire due to uncontrolled ventilation
- Crew integrity
- Mayday training of fire fighters and officers
- Thermal degradation of SCBA
- Personal protective equipment not donned before entry
- Adequate resources not arriving in a timely manner
- Lack of rapid intervention team assignment and activation

Key Recommendations

- Fire departments should ensure that fire suppression is initiated on the floor level of the fire whenever possible.
- Fire departments should ensure that officers and fire fighters are trained in the latest fire behavior research affecting fireground tactics.
- Fire departments should ensure that crew integrity is maintained.
- Fire departments should ensure that all fire fighters and officers are trained in the use of hose nozzles and hoseline management skills.
- Fire departments should ensure that all fire fighters and officers are trained in Mayday techniques and communications.
- Fire departments should consider upgrading their SCBA and PASS to the latest edition of the NFPA standards to benefit from the increased thermal protection characteristics.
- Fire departments should ensure that rapid intervention teams are on-scene and activated before interior operations begin.
- Fire departments should ensure that adequate resources respond in a timely manner.
- Fire departments should ensure that personal protective equipment is donned prior to entering a structure.
- Fire departments should ensure that a stationary command post is established and the command team communicates effectively.

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Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

Introduction

On December 9, 2014, a 37-year-old female career fire fighter/EMT died after becoming separated from her crew and running out of air after her SCBA hoseline burned through. On December 9, 2014, the United States Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On December 12, 2014, a safety engineer and an occupational safety and health manager from the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) traveled to Pennsylvania to visit the site and meet with the city fire commissioner. On December 16–20, 2014, a NIOSH FFFIPP investigation team traveled to Pennsylvania to investigate this incident. The NIOSH investigators met with the fire commissioner and executive staff of the fire department, the fire marshal and his staff, the health and safety officer for the department, the International Association of Fire Fighters local union, the department's training academy staff, the city's Department of License and Inspection, and the fire department's communication center. The investigators reviewed the fire department's standard operating procedures; department and Commonwealth of Pennsylvania training records for the incident commander, the Engine 73 officer, and the Engine 73 fire fighter/EMT; and dispatch and tactical channel printouts plus audio radio transmissions. During the investigation, witness statements were reviewed and interviews were conducted with the fire fighters, fire officers, and incident commander involved in this incident. The NIOSH investigators inspected and photographed the personal protective clothing (turnout gear) and self-contained breathing apparatus (SCBA) worn by the fire fighter/EMT, which were under control of the fire marshal's office. On December 28–30, 2014, the investigators returned to complete interviewing the fire department personnel who were on the scene at the time of the incident.

Fire Department

The fire department involved in this incident has 63 fire stations with 2,000 uniformed members serving a population of approximately 1,526,000 within an area of approximately 134 square miles.

The fire department consists of four major divisions that include Emergency Medical Services, Operations, Technical Services, and Administrative Services. Each of these divisions has the responsibility for carrying out the various functions of fire-fighting and emergency medical services. A fire commissioner, who is appointed by the city's mayor, and four deputy commissioners manage the department. A Deputy Fire Commissioner of Operations commands the Fire Suppression and Special Operations Divisions, the Fire Academy, the Safety Office, and the Aviation Operations Division. The Fire Suppression Division has two division chiefs who are each responsible for overseeing the fire department operations for one half of the city. Division 1 consists of 5 battalions and 29 fire stations, while Division 2 has 6 battalions and 34 fire stations. A Deputy Fire Commissioner of Technical Services commands the Fire Communications, Fire Prevention, Fire Code, Fire Marshal, and Technical Support Divisions. A Deputy Fire Commissioner of Administrative Services commands the Fiscal,

Human Resources, Information Technology, Information Services, Computer Services, and Facilities Maintenance Divisions. A Deputy Commissioner of Emergency Medical Services commands the Emergency Medical Services Operations and the EMS Regional Office.

The fire department currently has 54 engine companies, 27 ladder companies, 1 heavy rescue company, 2 squad companies (pumpers plus a special operations unit), and 2 fire boats (plus 1 in reserve). The department operates specialty companies for technical rescue, hazardous materials incidents, and aircraft rescue fire fighting.

Twenty-two of the engine companies are designated as Pipeline (e.g., Pipeline 61), which means the pumpers carry 1,000 feet of 5-inch diameter hose. Four of the engine companies are designated as Squirt (e.g., Squirt 55), which have a 50-foot articulating boom. Two of the engine companies are designated as Foam (e.g., Foam 33) and carry Class B foam. Also, Foam Tender 1 operates with Foam 33. Two of the ladder companies are 85-foot Snorkels (Snorkel 2 and Snorkel 28) and have an articulating boom with a platform. Two of the ladder companies are Ladder Towers (Ladder Tower 6 and Ladder Tower 22). The remainder of the ladder companies are tractor-drawn aerials. Nearly 35 percent of the fire stations are comprised of both an engine and a ladder company, while the remainder are comprised of one or the other of these fire-fighting apparatus.

The staffing on an engine company is an officer and three fire fighters. The staffing on a truck company is an officer and four fire fighters. Each squad is staffed with an officer and four fire fighters. Rescue 1 is staffed with an officer and five fire fighters. Each division chief and battalion chief is assigned a staff assistant or chief's aide.

In addition to fire suppression, hazardous materials mitigation, and special operations response, the fire department operates an Emergency Medical Services (EMS) Division, which consists of 50 advanced life support medic units, and support staff including EMS field officers. Thirty of the medic units operate on a full-time basis, and 20 of the medic units operate on a part-time basis. The fire department operates an aircraft rescue fire-fighting station at the airport in the southern part of the city in Battalion 7.

Department members assigned to the Operations Division work a daily 12/12 shift (0800–2000 and 2000–0800) with four platoons or shifts (42-hour work week). All fire department apparatus are maintained by the city's fleet maintenance division. Annual testing (e.g., pumps and ladders), as recommended by National Fire Protection Association (NFPA) standards, is conducted by qualified vendors.

On August 2, 2010, the fire department implemented a "brownout" policy. It involved taking an engine or ladder company out of service temporarily and redistributing the staff. Every week, two engine companies close during the day shift and one engine company and one ladder close during the night shift. This policy was discontinued in December 2015. In February 2013, the fire department instituted a second policy—Firefighter Rotation Policy. This policy imposed involuntary transfers of senior fire fighters to other fire stations in order to ensure that all fire fighters have equal opportunity to work in

various assignments and acquire diverse skills. One aspect of the policy is it may impact effective fire-fighting teams and removes fire-fighting expertise from neighborhoods and the family culture. An important aspect of being a fire fighter is being able to work as a member of a team, and the skill of an officer is to develop that team. The subtext to every activity that fire fighters do is that they are doing it in coordination with others [Willing 2010]. This policy was discontinued after February 2016.

Training and Experience

The Commonwealth of Pennsylvania does not have prerequisite training or education requirements for an individual to become a fire fighter. The department participates with the Pennsylvania State Fire Academy in the Voluntary Participation and Certification Program, which was started in 2003 to provide national certification for department members through the National Board on Fire Service Professional Qualifications and the International Fire Service Accreditation Congress.

To become a member of the fire department, an individual must apply and successfully complete a civil service examination for fire fighters. Prospective candidates are selected from the established civil service list by highest test score. The process includes department interviews, a criminal investigation, and a background investigation. If selected for conditional appointment, a candidate must successfully pass a medical examination that complies with NFPA 1582 *Standard on Comprehensive Occupational Medical Program for Fire Departments.* Selected candidates are appointed as cadets or recruit fire fighters in an extensive 20-week academic, practical, and physical training program at the department's fire academy.

At the fire academy, recruit fire fighters are trained in fire-fighting operations as well as emergency medical services, for which they must obtain state certification as an emergency medical technician. Upon the successful completion of training, recruit fire fighters are assigned as probationary fire fighters and receive national certification as a NFPA 1001 *Standard for Fire Fighter Professional Qualifications,* Fire Fighter I and Fire Fighter II; Hazardous Material Awareness and Hazardous Materials Operations certification; NFPA 1035 *Standard on Fire and Life Safety Educator, Public Information Officer, Youth Firesetter Intervention Specialist and Youth Firesetter Program Manager Professional Qualification*; and as a state-certified emergency medical technician/basic (EMT/B)[NFPA 2013b; NFPA 2015]. A probationary fire fighter is assigned to the Operations Division on either an engine company or a ladder company. As an EMT/B, fire fighters are also assigned as needed to work on basic life support (BLS) and advance life support (ALS) medic units. During the probationary period, the probationary fire fighter is tested by the fire academy staff at 9 months (written and practical examinations) and 12 months (written examination). Recertification for an EMT/B and paramedics (EMT/P) is every 2 years, which requires 18 hours of continuing education for EMT/B and 24 hours for EMT/P.

Members assigned to the Operations Division are required to complete at least 1hour of training per shift. Also, fire officers and fire fighters are required to complete 170 hours of training annually.

The Engine 73 fire fighter/EMT successfully completed recruit school at the department's fire academy and was certified as a fire fighter and EMT/B in March 2004. Other training courses and certifications included 800 MHz Radio Refresher Training (2004), IS 700 Introduction to NIMS (2005), ICS 100 Basic ICS (2005), Arson Awareness (2005), Ethics Training (2006), SCBA CBRNE Training (2007), Cellar Fire Operations (2007), Con-Ed-1 Mayday training (2007), National Fire Incident Reporting System (2008), "Firezone" Computer Program (2008), Philadelphia Electric Company—Fireground Safety (2009), Communications Unit Training (2009), and various other worksite and department's fire academy courses.

The Engine 73 lieutenant successfully completed recruit school at the department's fire academy in 2006 and was promoted to lieutenant in 2013. His training courses and certifications include IS 700 Introduction to NIMS (2006), ICS 100 Basic ICS (2006), Ethics Training (2007), SCBA CBRNE Training (2007), Cellar Fire Operations (2007), Con-Ed-1 Mayday training (2007), National Fire Incident Reporting System (2008), "Firezone" Computer Program (2008), Philadelphia Electric Company—Fireground Safety (2007), Con Ed-2 Basic Fireground Ops (2010), and various other worksite and department's fire academy courses.

The battalion chief had over 31 years of experience. He successfully completed recruit school at the department's fire academy in 1984 and was promoted to lieutenant in 1994, to captain in 2005, and to battalion chief in 2012. His training courses and certifications include Emergency Medical Technician (1993), Building Construction/Collapse (1993), High Rise Building Fires (1993), Firefighting Strategy and Tactics (1994), Officer Development Program (1994), Refinery Firefighting (1994), Fundamental Factors-FG Commanders (1994), Safety and Survival on the Fireground (1995), Emergency Vehicle Ops (1996), Water Rescue (1997), Rapid Intervention Training (2001), 800 MHz Radio Training (2002), 800 MHz Radio Refresher Training (2004), IS 700 Introduction to NIMS (2005), NIMS Communication/Accountability (2006), ICS 100 Basic ICS (2005), ICS 300 H-465 Intermediate ICS for Expanding (2011), Ethics Training (2007), SCBA CBRNE Training (2007), Cellar Fire Operations (2006), Incident Safety Officer (2007), National Fire Incident Reporting System (2008), "Firezone" Computer Program (2008), Philadelphia Electric Company—Fireground Safety (2006), Communications Unit Training (2009), Con Ed—2 Basic Fireground Ops(2009),and various other worksite and department's fire academy courses.

Structure

The fire structure was a residential row house of ordinary construction built in 1925.The house was two stories plus a basement and had 1,314 square feet of living space. The house was 18 feet wide by 35 feet long and was located approximately in the middle of the row of dwellings of equal size. The exterior was brick with a stone entrance and it had a pitched roof covered with slate over the front entrance. The primary roof was flat. The front entrance (see Photo 1) to the house sat back 43 feet from the street and was accessed by six steps from the sidewalk to a 20-foot walkway that led to four additional steps to the front door. The main floor consisted of a living room, dining room, and kitchen (see Diagram 1). The second floor, which was accessed by stairs just off the right side of the front entry door, consisted of a master bedroom/bathroom and two additional bedrooms and a bathroom (see

Diagram 2).The basement could be accessed either by an interior door leading to stairs off the right side of the kitchen or an exterior door at the rear (see Photo 2) of the house via an alley. The basement had a recreation room with half bath in the front half of the house, utility area on the left rear, and a garage on the right rear area (see Diagram 3).The garage was accessed by a standard aluminum garage door and had no interior access to the utility or recreation area and was formed by concrete block walls. The garage area was used for storage.

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Photo 1. Front of row house.
(NIOSH photo.)

Photo 2. Rear of row house.
(NIOSH photo.)

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

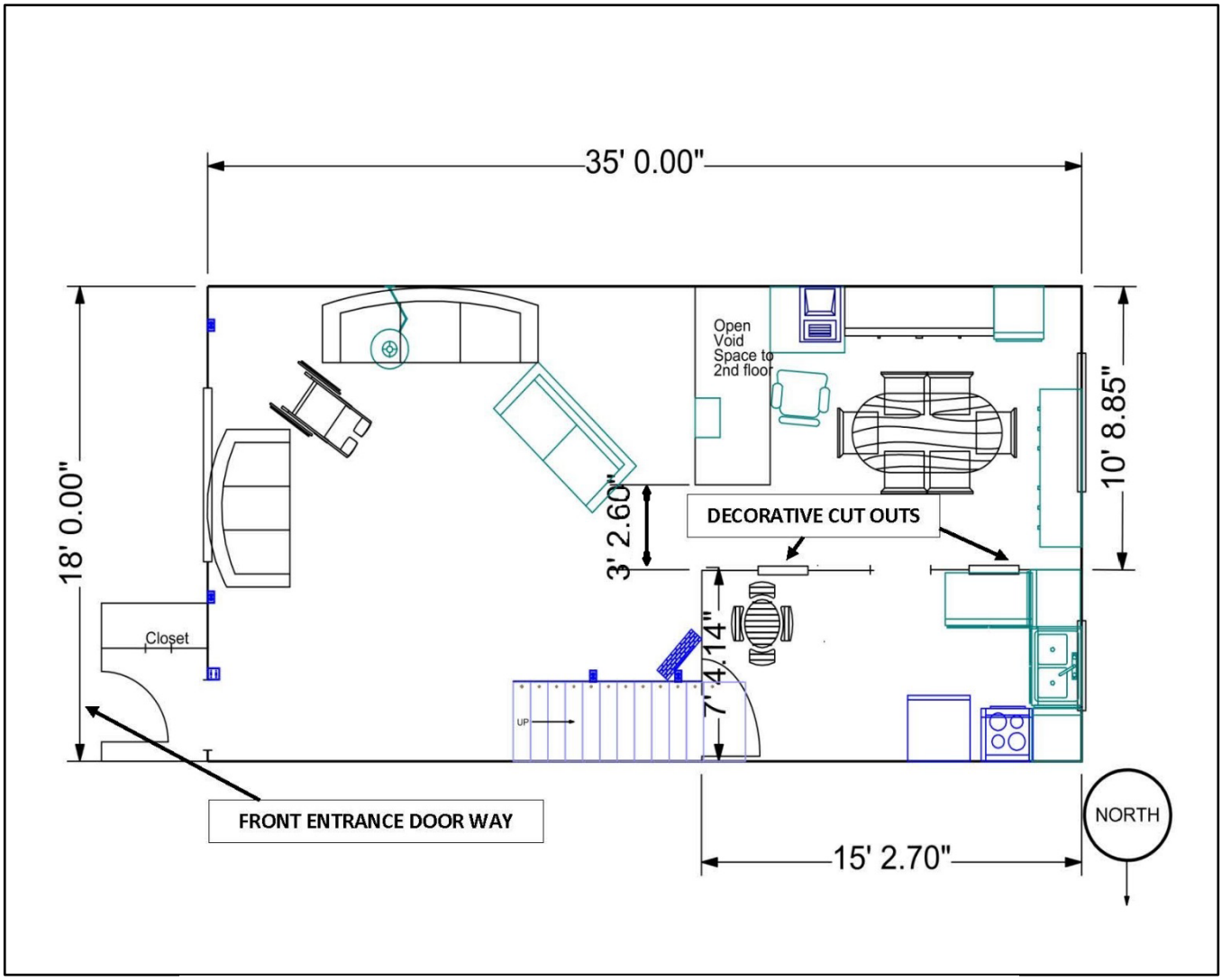

Diagram 1. First floor layout.
(Courtesy of the fire department.)

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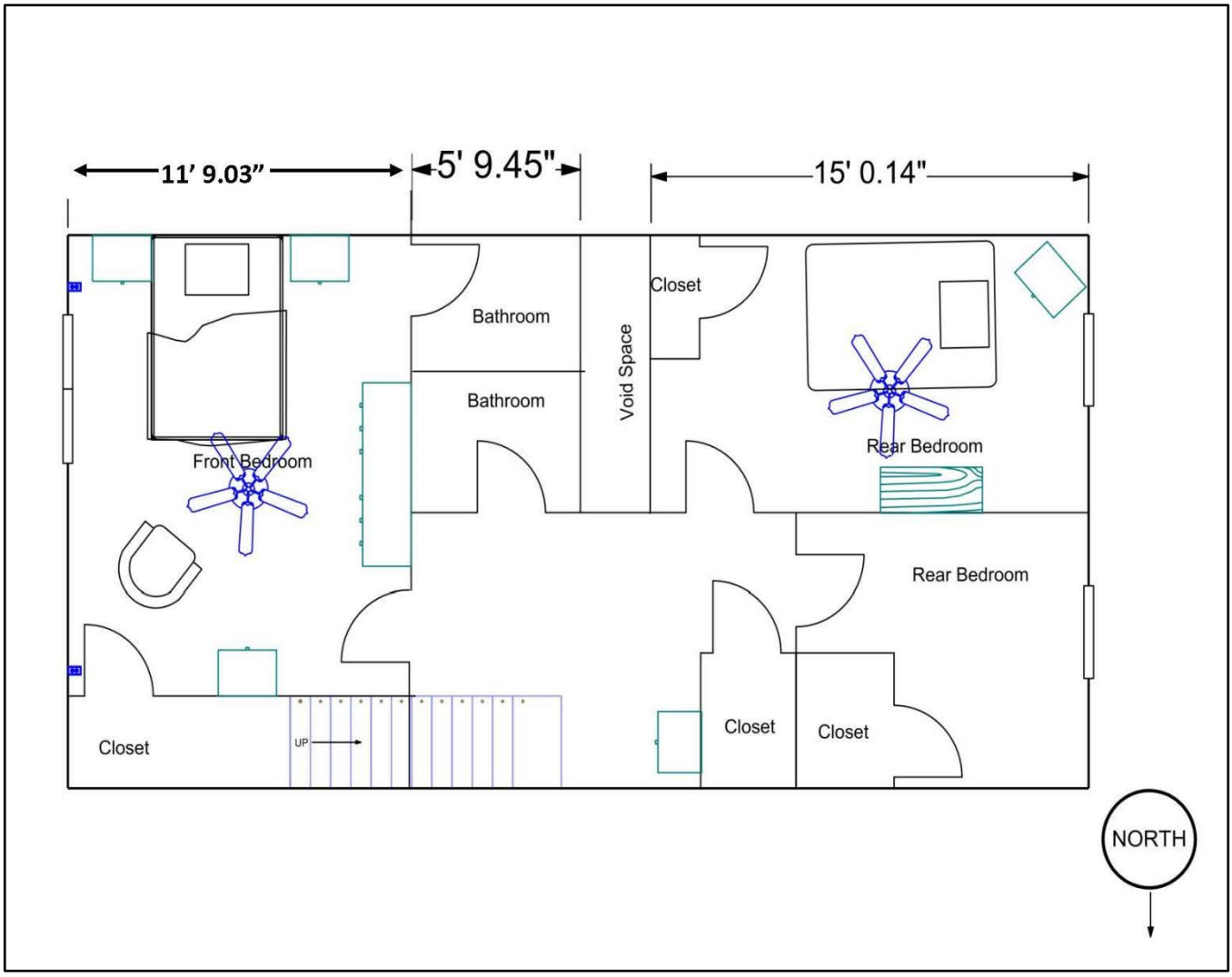

Diagram 2. Second floor layout.
(Courtesy of the fire department.)

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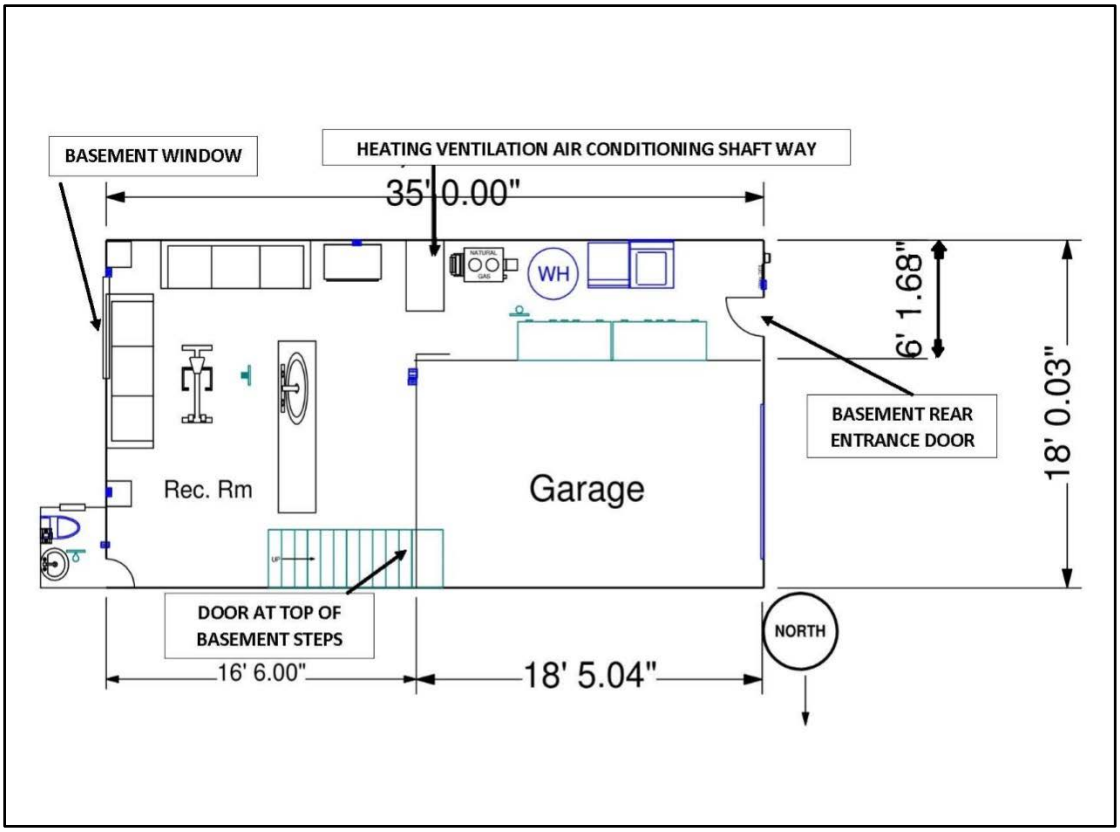

Diagram 3. Basement floor plan.
(Courtesy of the fire department.)

Equipment and Personnel

All 911 calls are answered by the city's police dispatch center. If the 911 call is for a fire or a medical emergency, the call is then routed to the fire department's Fire Communications Center (FCC). The FCC is operated by non-uniformed members of the fire department, consisting of a shift supervisor, four call takers, four dispatchers, and one relief person. The FCC is overseen by the Deputy Commissioner of Technical Services, who directs all technical services for the fire department and reports to the commissioner. In the event of a structure or building fire, the FCC assigns the appropriate number and type of fire companies to the incident. All incidents are assigned a box number based upon the location of street boxes that were used as a method of transmitting alarms to the FCC. The fire department communicated information from an incident to the FCC by a street box, which was done primarily before the radio system came into existence. All of the street boxes have been removed from service but their locations are maintained within the FCC computer system.

The FCC sends four assignment levels to reported or confirmed structure fires: Tactical Box Alarm, Box Alarm, High-rise Box Alarm, and Major Incident Response Assignment.

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Tactical Box Alarm is assigned to fires in a single-family dwelling. When multiple calls are received, people are reported trapped, severe weather conditions are in effect, or the first engine arrives on-scene with fire showing, the incident is upgraded to a Box Alarm Assignment. *Note: If a report of nothing showing is given by the first arriving engine, dispatch issues a reduce speed directive to other responding units.*

- 2 engines
- 2 ladders
- 1 battalion chief

Box Alarm is assigned for fires in commercial or industrial buildings, factories, warehouses, educational buildings, or multiple-family dwellings fewer than seven stories in height.

- 4 engines
- 2 ladders
- 2 battalion chiefs

High-rise Box Alarm is assigned for fires in buildings seven stories in height or higher.

- 4 engines
- 3 ladders (1 for lobby control)
- 2 battalion chiefs
- rescue company (Rescue 1)
- 1 medic unit

Major Incident Response is assigned to large-scale events.

- 5 engines
- 4 ladders
- deputy chief
- 3 battalion chiefs
- 2 rescue companies
- 1 squad
- 1 EMS command officer
- 3 ALS medic units
- 1 air unit

When the incident commander assigned to a Tactical Box Assignment advises FCC that "all hands are working," FCC will dispatch an additional ladder company to serve as the rapid intervention team (RIT), a squad company (either Squad 47 or Squad 72), the rescue company (Rescue 1, if they are not already assigned), and a medic unit. *Note: Squad 47 and Squad 72 are engine companies trained and equipped in technical rescue and hazardous materials mitigation.*

If the incident commander advises FCC that the alarm assignment needs to be filled out to a "full box," the deputy chief (Division 1 or Division 2) and EMS command officer are dispatched. If the fire is

large and of enough severity, the incident commander, either a battalion chief or deputy chief, will transmit additional alarms, starting with a second alarm going up to a ninth alarm to bring more companies and staffing to the scene above the existing Tactical Box Assignment, Box Alarm Assignment, High-rise Box Assignment or Major Incident Response Assignment.

Second Alarm Assignment

- 5 engines(1 for logistics)
- 2 ladders
- 4 battalion chiefs (first-due battalion chief is assigned as logistics officer with first-due engine on the 2nd Alarm; second- and third-due battalion chiefs are assigned to fire-fighting operations [e.g., Bravo Division, Delta Division]; fourth-due battalion chief is assigned as safety officer.)

Third Alarm Assignment

- 4 engines

Fourth Alarm Assignment

- 4 engines

Fifth Alarm to Ninth Alarm Assignments

- 4 engines per Alarm

Outside Fire/Local Alarm. Any configured fire response not requiring a box or tactical response. The closest engine company is sent. If a ladder company is available to respond from close by, it will also be added.

- 1 engine or 1 engine and 1 ladder

On December 9, 2014, the FCC transmitted a tactical box alarm for a residential structure fire. The initial unit dispatched was Engine 73, Engine 63, Ladder 8, Ladder 21, and Battalion 2. *Note: Ladder 29 would have normally been the first-due ladder but they were on a medical call.* 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 73	lieutenant, engine operator, and 2 fire fighters	0249 hrs	0253 hrs
Battalion Chief 2 (incident commander)	battalion chief and a battalion aide	0249 hrs	0254 hrs

Engine 63	lieutenant, engine operator, and 2 fire fighters	0249 hrs	0255 hrs
Ladder 8	captain, ladder operator, and 3 fire fighters	0249 hrs	0311 hrs
Ladder 21	captain, ladder operator, and 3 fire fighters	0249 hrs	0258 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.

- **0249 Hours**
  The FCC transmitted a tactical box alarm for a residential structure fire and dispatched Engine 73, Engine 63, Ladder 8, Ladder 21, and Battalion 2.

- **0253 Hours**
  Engine 73 arrived and the officer gave a report of nothing showing. Dispatch informed responding units to reduce speed and informed the Engine 73 officer of a reported trapped civilian in the living room. *Note: The fire department/dispatch should re-evaluate their policy to reduce speed for a person trapped which may require additional crews.*

- **0254 Hours**
  Battalion 2 arrived on-scene and took command. Engine 73 officer informed Command of a fire in the basement. Engine 73 officer exited the structure to retrieve his SCBA. Battalion 2 carried the occupant out of the residence.

- **0255 Hours**
  Engine 63 arrived on-scene and proceeded to the rear. Engine 73 officer and nozzle operator were in the kitchen with the hoseline, donning their facepieces.

- **0256 Hours**
  Battalion 2 informed Dispatch of size-up and gave assignments to the engine and ladder company. Dispatch had responding companies resume emergency speed. Engine 73 officer called for water.

- **0257 Hours**
  Engine 63 reported changing conditions in rear. Initially, nothing showing was changed to seeing a flash of fire through kitchen window to heavier smoke conditions. Engine 63 established a water supply in rear. Engine 73 officer flowed water toward basement door from kitchen area while the nozzle operator completed donning her SCBA.

- **0258 Hours**
  Ladder 21 arrived on-scene. Battalion 2 raised Dispatch to fill out the box requesting 2 engines, RIT, special operations company, and a battalion chief. Battalion 2 reported heavy fire in basement. The Ladder 21 Officer went to second floor for primary search in heavy smoke and started horizontal ventilation on the second floor. A Ladder 21 fire fighter then broke out the glass blocks in the 5-foot x 1.5-foot front basement window and threw ground ladders.

- **0259 Hours**
  The Engine 73 nozzle operator had trouble with her SCBA and exited the kitchen and brushed against the Engine 73 fire fighter/EMT who had been stretching hoseline near the dining room. The Engine 73 officer continued to flow water toward the basement stairs. Battalion 2 radioed Ladder 8, who were still en route. Command ordered Engine 63 to open up the rear.

- **0300 Hours**
  Engine 63 made entry into basement with heavy fire in recreation room area with a 1¾-inch hoseline off of a 3-inch supply line. Engine 73 officer still on hoseline, requested more line, could hear a fire fighter moving hoseline and he got a few more feet.

- **0302 Hours**
  Fire was seen venting out the basement window on Side A, and Command ordered Engine 73 out. Engine 73 officer stated that at that time a “fireball came up the stairs and knocked him down.” He followed the hoseline out of the building, assuming his fire fighters were already out. Engine 73 officer made it outside just prior to the fire fighter/EMT calling a Mayday. Ladder 21 officer on the second floor stated he felt extreme heat above and below him.

- **0303 Hours**
  Command sent Engine 73 officer and two Ladder 21 fire fighters to search for Engine 73 fire fighter/EMT. Engine 73 fire fighter/EMT transmitted two additional Maydays and activated her emergency button. Ladder 8 was delayed in traffic and still not on-scene. Ladder 29 originally had the RIT assignment; Dispatch changed the assignment and gave it to Ladder 8.

- **0304 Hours**
  Ladder 21 officer exited the structure, diving down the stairs to the outside landing without his helmet and light. Engine 73 officer and Ladder 21 fire fighters were still on first floor looking for the Engine 73 fire fighter/EMT. Ladder 21 fire fighters heard calls for help and were using a thermal imager to search. Battalion 9 arrived on-scene and took control of Side C. Engine 63

officer asked for more pressure on their 3-inch supply line and had not yet gotten effective water to the fire in the basement.

- **0305 Hours**
  Engine 73 fire fighter/EMT attempted a transmission, but it was unintelligible.

- **0306 Hours**
  Engine 73 fire fighter/EMT transmitted her last Mayday message stating she couldn't breathe. The recreation area in the basement and kitchen on the first floor were heavily involved in fire and heavy smoke throughout the rest of the structure. Engine 63 crew advanced in the basement.

- **0308 Hours**
  The Engine 73 nozzle operator re-entered the structure with a new cylinder but encountered extreme heat at the stairs to the second floor.

- **0309 Hours**
  Engine 51 and Squad 72 were getting water on the first floor with additional hoselines. The Engine 73 officer and nozzle operator exited the structure. The outside crews mistook the nozzle operator for the Engine 73 fire fighter/EMT for nearly a minute before the mistake was realized. Engine 51 and Squad 72 continued to advance on the first floor after the misidentification was realized.

- **0310 Hours**
  Battalion 9 reported bulk of fire knocked down in basement.

- **0311 Hours**
  Ladder 8 arrived on-scene. Ladder 21 search crew had to exit due to low air, but Engine 73 officer was still searching.

- **0313 Hours**
  Fire fighters in basement searched for missing fire fighter.

- **0314 Hours**
  Bulk of fire knocked down on first floor.

- **0315 Hours**
  Ladder 29 fire fighter entered dining room through window from ground ladder. Squad 72 officer followed the Engine 73 hoseline, removed an office chair in the way, and found Engine 73 fire fighter/EMT slumped over against a buffet under the dining room window. Squad 72 reported bringing out the fire fighter/EMT. Squad 72, Ladder 29, and Ladder 8 carried the fire fighter/EMT out.

- **0316 Hours**
  Medic 16 performed CPR.

- **0333 Hours**
  Medic 16 transported the fire fighter/EMT to hospital where she was pronounced dead.

Personal Protective Equipment

The fire fighter/EMT was wearing a work station uniform, turnout coat and pants, hood, boots, helmet, self-contained breathing apparatus (SCBA) with an integrated personal alert safety system (PASS), and a portable radio.

At the time of the incident, the department was in the process of upgrading their SCBAs. The department had not placed the new SCBAs in service at the time of the fire and the fire fighter/EMT was using a SCBA with a 45-minute air cylinder conforming to the 2002 edition of NFPA 1981. However, the fire fighter/EMT had received, and was using, a new high-temperature facepiece conforming to the 2013 edition of NFPA1981. The SCBA was evaluated by the NIOSH National Personal Protective Technology Laboratory (NPPTL), along with three other fire department SCBAs belonging to initial attack crew members. A summary report is enclosed as Appendix I. The evaluation showed that the SCBA performed within specifications until the Emergency Breathing Support System (EBBS) hose (commonly referred to as a buddy breather hose) was compromised, apparently due to thermal degradation. The full NPPTL report is available upon request. Also, a special test was conducted by NPPTL to try to simulate the effect that a burned-through EBBS hose would have on the inhalation resistance and the duration of the air supply (see Appendix II).

The fire fighter/EMT's portable radio functioned well during the fire fight and Mayday. The emergency button functioned as designed and provided her with the correct priority functions under extreme fire conditions. The fire fighter/EMT's personal alert safety system (PASS) device was not heard and may have ceased to function intermittently from extreme heat exposure since it was a pre-2007 device [NFPA 2007].

Weather Conditions

At the time of the incident, the sky conditions were rain with 3-mile visibility. The temperature was 37 degrees F. Dew point was 33 degrees F. Relative humidity was 86%. Wind speed was 16.3 mph and wind direction was northeast. Since the wind speed was greater than 10 mph, it may have assisted in the rapid fire growth once a flow path via horizontal ventilation was provided to the main living area of the residence. Barometric pressure was 30.22 [Weather Underground 2014].

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

Investigation

On December 9, 2014, a 37-year-old female career fire fighter/EMT died in a residential structure fire after becoming separated from her crew and running out of air from a burned-through SCBA hoseline. At 02:49 hours, two engines, two trucks, and a battalion chief were dispatched to a residential structure fire. Approximately 4 minutes later, the first arriving engine, Engine 73, reported on the scene with nothing showing. Dispatch directed the en route companies to reduce speed due to report of nothing showing and informed the Engine 73 officer of a possible trapped resident. The officer from Engine 73 proceeded to the front door where he was met by the elderly female occupant of the home and she informed him of a fire in the basement. The officer instructed her to leave the home. The officer walked into the kitchen area where he encountered a light haze of smoke on the first floor. He encountered an open basement door and noticed "heavy, brown smoke" in the basement. At 0254 hours, Battalion 2 arrived on-scene and assumed command. The officer from Engine 73 radioed Command informing him that there was fire in the basement. Command then reported to Dispatch that he had a 15-foot by 35-foot middle of the row, occupied dwelling, with a fire in the basement and ordered Engine 73 and Ladder 21 to enter the structure. Dispatch ordered responding companies to resume emergency speed.

The officer from Engine 73 had entered the structure without his SCBA on, so he exited to put it on. He ordered the other three fire fighters from Engine 73 to stretch 200 feet of 1¾-inch hoseline into the first floor. Both female fire fighters, the nozzle operator (regularly assigned to Engine 73) and fire fighter/EMT (working overtime from Engine 63) had donned their SCBA en route except for their facepieces. The fire fighter/EMT had replaced a male fire fighter on Engine 73. *Note: This addition of a second female caused some confusion later during efforts to locate the fire fighter/EMT.* As the fire fighters from Engine 73 were beginning to stretch their hoseline, Command entered the structure. Command proceeded to the second floor where he encountered the occupant, who had not evacuated the structure like the Engine 73 officer ordered but had gone upstairs to get a change of clothes from the front bedroom. He noticed a layer of smoke near the ceiling and told the occupant to follow him to the front door, and he proceeded back down the stairs to the first floor. He realized that the occupant had not followed him so he returned to the second floor and she informed him she couldn't walk. He picked her up in his arms and carried her down the stairs to the front door and handed her to another fire fighter. Command noticed at the bottom of the stairs that the Engine 73 fire fighters had advanced their 1¾-inch hoseline through the front door and into the dining room.

At 02:55 hours, Engine 63 arrived on-scene and proceeded to the rear of the structure, via the rear alley (see Diagram 4). The Engine 73 officer and nozzle operator were donning their facepieces in the dining room while the fire fighter/EMT was flaking out the hoseline outside the front door. At 02:56 hours, the Engine 73 officer radioed the Engine 73 driver to give them water. Looking through a 2-foot by 2-foot decorative cutout in the wall between the dining room and kitchen, the officer could see fire beginning to vent from the top of the basement doorway. A minute later, the Engine 63 officer reported nothing showing in the rear but immediately changed that to seeing fire through the window in the first-floor kitchen area with smoke conditions getting heavier from the first-and second-floor windows.

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The Engine 63 crew returned to their apparatus and began to stretch a 3-inch supply line down the rear driveway, where they would connect it to a 1¾-inch hoseline.

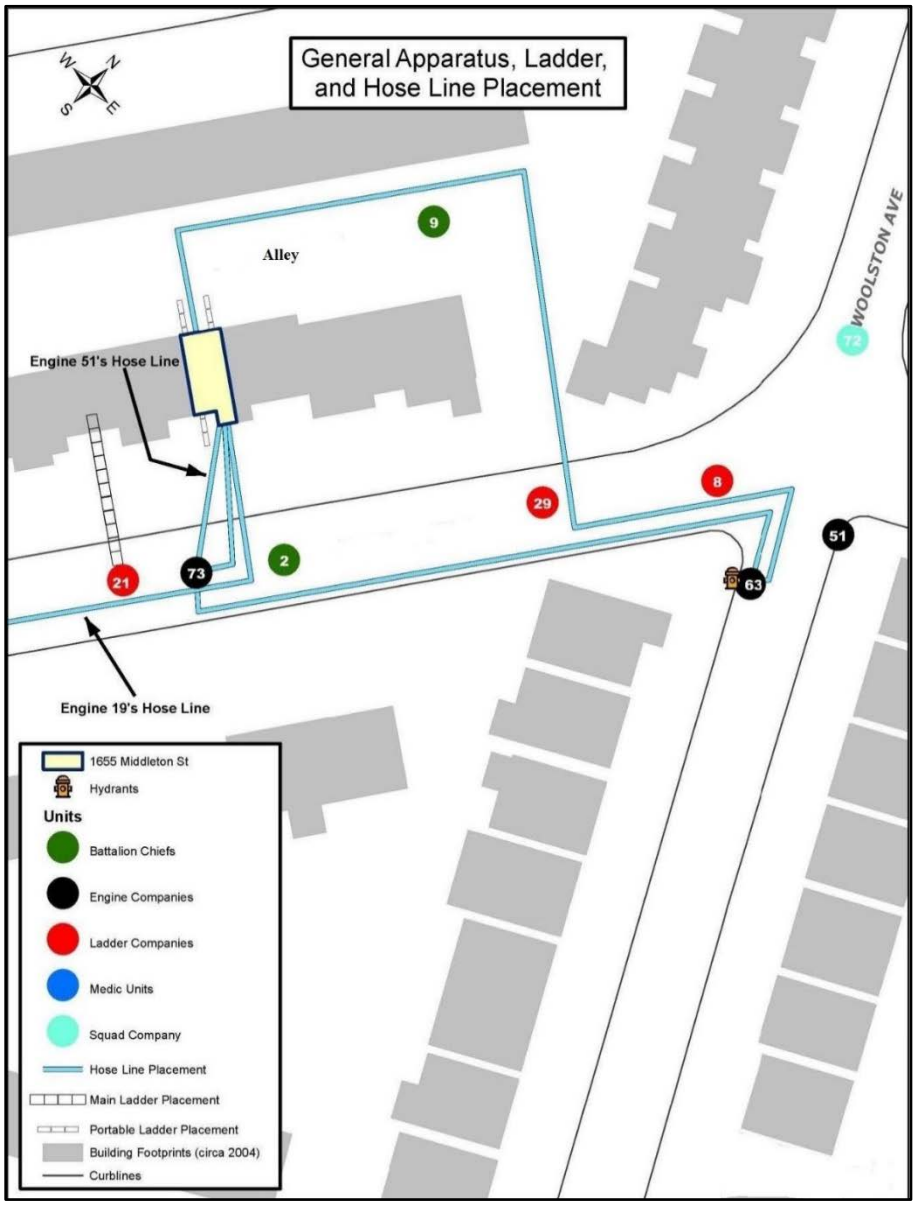

Diagram 4. Apparatus and hoseline placement.
(Courtesy of the fire department.)

The Engine 73 officer completed donning his SCBA facepiece, protective hood, and gloves and began to discharge water through the decorative cutout in the dining room wall through the kitchen and into the basement doorway. The nozzle operator was still in the process of donning her SCBA facepiece.

The nozzle operator, with facepiece donned, and the officer then advanced into the kitchen. They were approximately 3 or 4 feet from the basement doorway.

At 02:58 hours, Command radioed Dispatch to fill out a box. This would bring an additional two engine companies, a rapid intervention team ladder company, a special operations company, and a second battalion chief to the scene. Command reported heavy fire in the basement and stated he could see fire through the basement glass block window. Engine 63 fire fighters were stretching their hoseline down the rear driveway, and Ladder 21 had arrived on-scene. The Ladder 21 officer was assigned primary search and proceeded to the second floor. He had just vented the front bedroom windows when he saw the Ladder 21 fire fighter raising a 20-foot ground ladder to the second-floor front windows. The Ladder 21 fire fighter then broke out the glass blocks in the 5-foot x 1.5-foot front basement window. The Ladder 21 driver raised the main ladder to the roof. The Engine 63 officer radioed Command and reported he had light to medium smoke on the first and second floors in the rear.

The Engine 73 nozzle operator began to have difficulty with her SCBA and exited the kitchen. She followed the hoseline into the dining room and encountered the Engine 73 fire fighter/EMT on the hoseline next to the dining room by the kitchen (see Diagram 1). The Engine 73 officer began to operate the hoseline and was flowing water into the basement stairwell. The nozzle operator exited the structure without her helmet and proceeded to Engine 73 where the driver helped her exchange SCBA bottles.

At 02:59 hours, Command radioed the Ladder 8 officer who was still en route and attempted to radio the Engine 73 officer for a status report. The Engine 63 officer radioed Command that they were standing by in the rear of the structure, and Command ordered them to open up the rear.

At 03:00 hours, Dispatch filled out the balance of the box: Engine Company 51, Engine Company 19, Rapid Intervention Team (RIT) Ladder Company 29, Special Operations Company Squad 72, and Battalion Chief 9. Command radioed the Ladder 8 officer and ordered him to open up the structure, however Ladder 8 was still en route. A minute later, the Engine 63 crew forced the basement rear door. There was now heavy fire, floor to ceiling, in the recreation area with the rear basement door open, the front glass block window out, and the basement door at the top of the stairs open, allowing a flow path. The Engine 73 officer was calling for more hoseline, and it was being provided by someone who he assumed was the Engine 73 fire fighter/EMT. He was able to move to within about 2 feet of the basement door.

At 03:02 hours, Command radioed the Engine 73 officer several times with no response. Heavy fire was venting from the basement window with heavy smoke conditions on the first and second floors. Command then ordered Engine 73 to back out. The Engine 73 officer stated that he was “knocked down by a fireball” that had come up the basement stairs, and he immediately located the hoseline in heavy smoke and high heat and followed it out of the structure. He doesn’t recall running into anyone on or near the hoseline and assumed his crew was out. The Ladder 21 officer radioed Command that the primary search was negative. Engine 73 fire fighter/EMT radioed her first Mayday that she was

trapped on the first floor and hit her emergency button. Dispatch notified Command's aide of the emergency activation.

At 03:03 hours, Command ordered the Engine 73 officer and two fire fighters from Ladder 21 to search for the Engine 73 fire fighter/EMT. The Battalion 2 aide exited his vehicle and went directly to Command to verify he heard the Mayday. During the next minute, the fire fighter/EMT made four more transmissions with the next to the last one being unintelligible. *Note: No vibra-alert was heard during any of her radio transmissions, indicating that her SCBA still had air pressure in excess of her end of service time indicator limit.* The Engine 63 officer radioed the Engine 63 driver to send the water. Dispatch radioed the Ladder 29 officer and changed his assignment from the rapid intervention team (RIT) to the second-due ladder company and assigned Ladder 8, who was stuck in traffic, as the RIT. Command didn't know Ladder 8 was still not on-scene or that their assignment had been changed to RIT.

Within the next minute, the Ladder 21 officer on the second floor stated that he felt tremendous heat from above and below him, unlike anything he had ever experienced. He was forced to dive down the stairs to the first floor and crawl out the front door, losing his helmet and flashlight. He had noticed an orange glow in the dining room and heard someone yelling for help. The Battalion 2 aide again exited his vehicle to notify Command that Dispatch was still receiving an emergency activation from the Engine 73 fire fighter/EMT.

The Engine 73 officer and two Ladder 21 fire fighters were still searching for the Engine 73 fire fighter/EMT on the first floor. The Ladder 21 fire fighters had followed the hoseline toward the dining room. The one Ladder 21 fire fighter had a thermal imager but it did not provide a clear picture because of the high heat signatures throughout the dining room area and couldn't distinguish a body. They could hear the fire fighter/EMT yelling for help and were yelling back, trying to locate her. Near the dining room, they encountered an excessive amount of hoseline and continued the search while maintaining hand contact with the hoseline. Fire could still be seen coming out of the interior basement door and across the kitchen ceiling. Battalion 9 arrived on-scene and went to the rear and met up with the Engine 63 officer, who was needing more pressure in their 3-inch hoseline before entering the basement.

Engine 51 had arrived on-scene and the crew was bringing the 1¾-inch hoseline to the front of the structure. At 03:05 hours, Ladder 29 arrived on-scene and had to stop to allow the Engine 73 driver (who was helping Engine 73 nozzle operator change her bottle) to move out of the road, then proceeded to the rear. Dispatch notified the Battalion 2 aide that Ladder 8 was now the RIT and Ladder 29 would be second due. Again, the Engine 73 fire fighter/EMT keyed her radio, but the transmission was unintelligible.

At 03:06, the Engine 73 fire fighter/EMT made her last Mayday transmission: "Engine 73 can't breathe, I can't breathe. Engine 73 Pak." Command radioed the Engine 73 officer and asked him if he had any luck, in which, the reply was, "Negative, still searching." Ladder 8—the designated RIT—was not on-scene at this time and no other RIT was designated/or activated.

Fire conditions were floor-to-ceiling in the basement recreation room and venting from the front basement window. Fire extended into the cockloft and throughout kitchen from the basement door.

Battalion 9 informed Command that Engine 63 had an attack line ready to make entry if no one was in the basement. Command gave the okay and reported they were still searching the first floor for the fire fighter/EMT. Engine 63 advanced in and started putting water on the fire.

At approximately 03:07 hours, a member of the Ladder 21 search team's low-air alarm was going off and the team exited the structure. Command asked for a status from the Engine 73 officer on his search, and the reply was still negative. Fire now was extending into the living area on Sides A and B interior walls. At 03:08 hours, the Engine 73 nozzle operator had reentered the structure, got to the base of the second-floor stairwell and was stopped by extreme heat. The Battalion 2 aide radioed Command, asking if he was putting the RIT in service. Dispatch informed the Battalion 2 aide there was an emergency activation from the Squad 72 officer's radio and that he is still waiting on a report on Engine 73's fire fighter/EMT radio.

At 03:09 hours, Battalion 9 reported that Engine 63 was advancing on the fire. The Squad 72 officer and two fire fighters were in front, and Command ordered them to assist in putting out the fire. Smoke was starting to vent from the basement window since Engine 63 was getting water on it. With fire throughout the first floor, the Engine 73 officer was backing out and encountered the nozzle operator and exited the structure. The Engine 51 officer encountered the operator on her way out and, thinking she was the missing fire fighter since normally Engine 73 only has one female in their company, he announced, "We got her." She then spoke and the nearby Engine 73 officer realized she was not the missing fire fighter/EMT. The Battalion 2 aide approached her and told her to reset her radio from emergency alert status. The nozzle operator indicated to him that it was not her emergency button that was activated and that it was the other female fire fighter/EMT's, who was still missing. Command, newly assigned to Battalion 2, had not realized that another female fire fighter had been hired to work overtime and thought the missing female fire fighter had been found. This confusion caused the emergency button activation to be cleared. Once the misidentification was realized by Command, the Engine 51 and Squad 72 officers advanced on the first floor behind the hoseline of Engine 51. Fire was now venting from the first-floor front window and heavy fire was venting from the second-floor bathroom skylight.

At 03:10 hours, Battalion 9 reported that the bulk of the fire had been knocked down in the basement and that Ladder 29 was ventilating the rear. Ladder 29 had raised ground ladders to the kitchen, dining room, and the second-floor bedroom windows. Engine 19 had a 1¾-inch hose line protecting the Side B exposure.

At 03:11 hours, Ladder 8 arrived on-scene while Engine 51 and Squad 72 began making advances on the first-floor fire. The Squad 72 officer pulled on Engine 73's hoseline, but he stated that it felt like something was on it. At 03:12 hours, Battalion 2 aide ordered Medic 16 to the front of the structure. A minute later, Command radioed Battalion 9 to check the basement to make sure the fire fighter/EMT

was not down there. The fire was knocked down in the basement and was being extinguished on the first floor, but there was still heavy fire in the second-floor cockloft.

At approximately 03:14 hours, Ladder 8's crew entered the structure where first-floor conditions had significantly improved. At 03:15 hours, a Ladder 29 fire fighter entered the dining room through the dining room window via a ground ladder. The Squad 72 officer had followed the Engine 73 hoseline through the living room to the dining room entrance where he encountered an office-style chair lying on top of the hoseline. He moved the chair and followed the hoseline into the dining room where he saw the fire fighter/EMT sitting slumped over on her right side and leaning against a buffet table under the dining room windows. The 1¾-inch hoseline from Engine 73 was right beside her on her left side, and her left hand was next to the nozzle. The Ladder 29 fire fighter was standing to her right, not realizing he had gone over top of her when he entered through the window. The Squad 72 officer went over to fire fighter/EMT and realized that she was in trouble (see Diagram 5). The Squad 72 officer removed the fire fighter/EMT's regulator from her face mask and noticed that no air was escaping and the PASS was not activating. The Squad 72 officer radioed Command and reported that he had located fire fighter/EMT and they were bringing her out. Command acknowledged the message. The fire fighters from Squad 72, Ladder 29, and Ladder 8 were all involved in carrying the fire fighter/EMT from the structure. At approximately 03:16 hours, the fire fighter/EMT was placed on a Reeves stretcher from Medic 16 on the walkway between the structure and sidewalk steps. Her SCBA was removed and CPR was initiated, as she was moved to Medic 16. A paramedic from Medic 29 joined the paramedic from Medic 16 in the patient compartment and assisted. At 03:31 hours, the fire was declared under control by Command. At 03:33 hours, Medic 16 was en route to the hospital where she was pronounced dead.

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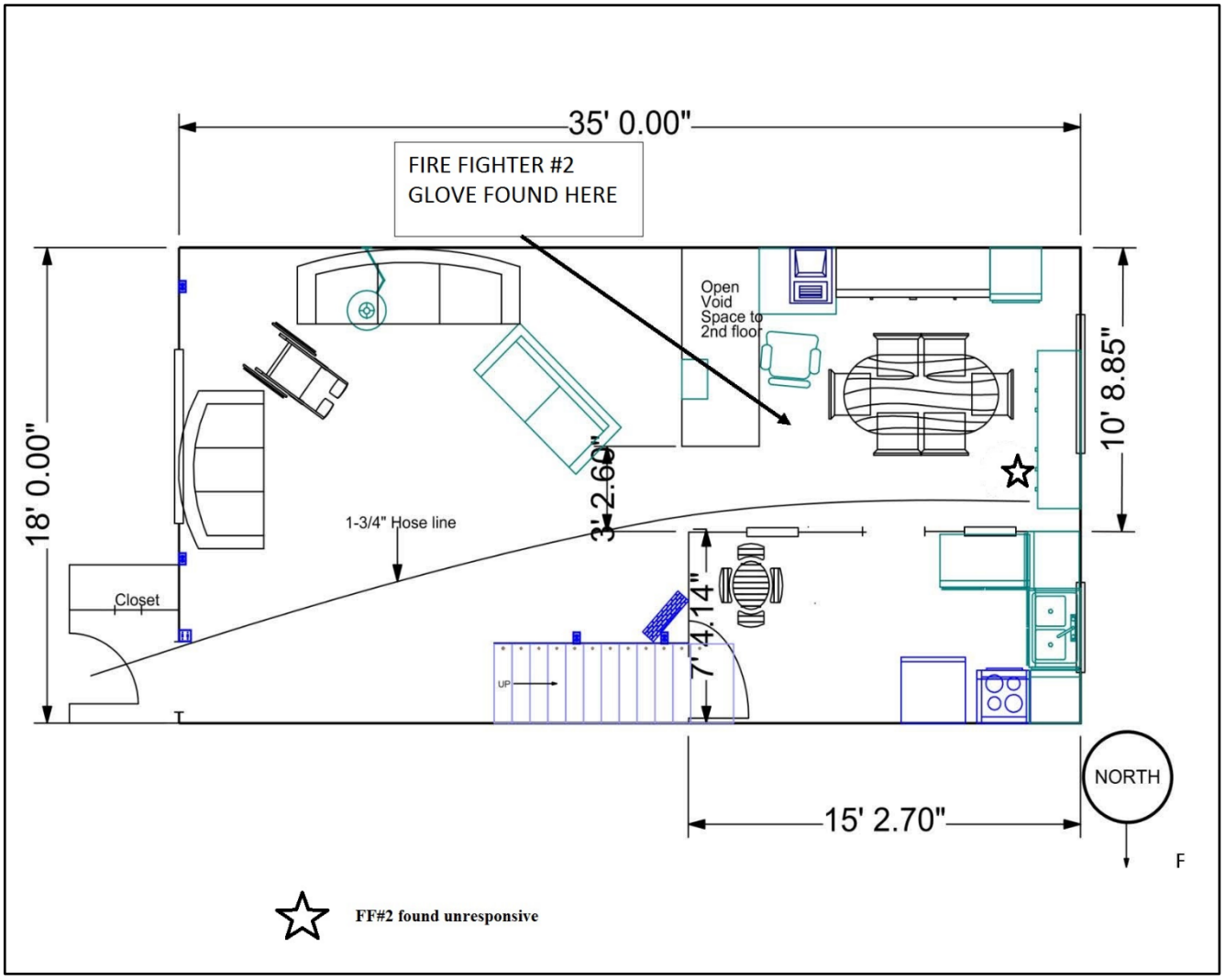

Diagram 5. Location of missing fire fighter.
(*Courtesy of fire department.*)

Fire Behavior

According to the city fire marshal's office, the cause of the fire was "undetermined." The origin of the fire was in the basement recreation room where combustible material was ignited by an undetermined source.

Indicators/contributors of fire behavior were:

- Initial light smoke on first floor and dark smoke in basement.
- Front door and interior basement door remain open, providing a low pressure vertical vent for the fire in the basement.

- Smoke conditions and heat increase in kitchen.
- Fire grows in recreation room area.
- Minimal water put on fire in basement stairwell.
- Horizontal ventilation on the second floor provided additional low pressure exhaust vents for the smoke flowing from the basement fire. The decreased pressure allowed the flowrate of smoke to increase.
- Crew ventilates front basement glass block window providing air for fire growth.
- Heavy fire venting from basement window and fire gases traveling up the basement stairs accelerate.
- High heat and heavy smoke on first floor.
- Second floor encounters high heat and smoke.
- Heavy fire venting out basement window.
- Extreme heat now on second floor.
- Heavy fire across kitchen ceiling.
- Fire extending into dining room and into cockloft.
- Heavy smoke throughout structure.
- Rear exterior basement door open providing air for fire growth.
- "Fireball came up the stairs"
- Fire now into living room and venting out second-floor bathroom skylight.
- Water knocking down fire in basement.
- Advancing hoselines on first floor.
- Minutes later, fire knocked down on first floor.
- Thirty-eight minutes after first arrival, fire is declared under control.

Contributing Factors

- Fireground tactics
- Unrestricted flow path of the fire due to uncontrolled ventilation
- Crew integrity
- Mayday training of fire fighters and officers
- Thermal degradation of SCBA
- Personal protective equipment not donned before entry
- Adequate resources not arriving in a timely manner
- Lack of rapid intervention team assignment and activation

Cause of Death

According to the medical examiner's report, the cause of death was suffocation. The autopsy examination revealed no evidence of smoke inhalation and the thermal burn injuries were not life-threatening.

Recommendations

Recommendation #1: Fire departments should ensure that fire suppression is initiated on the floor level of the fire whenever possible.

Discussion: Studies and fatality reports have shown that operating above or below the fire has risks and hazards. Although initial fire suppression should occur at the level of the fire, this may not be as easy as it sounds. Obstacles such as sloping terrain, fencing, and narrow alleys, may deter fire fighters from initiating their fire attack at the appropriate level of the structure. These obstacles may also prevent a proper 360-degree size-up. For fire fighters to avoid being caught in the fire flow path or working above the fire, time should be taken to determine what floor the fire is on and the safest way to attack it without introducing ventilation, causing fire growth [Alkonis et al. 2015; NIST 2014; NIST 2015].

An initial report of "nothing showing" or "light smoke" can be misleading once openings are made, such as opening a door. Crews must read the building and consider the possibility of ventilation-limited fire conditions. Modern construction and modern fuels combine to produce fires that can consume all available oxygen within the building and quickly become ventilation-limited [Alkonis et al. 2015; NIST 2014; NIST 2015].

Basement fires should not be considered routine [Alkonis et al. 2015; NIST 2014; NIST 2015]. Fuel loads and remodeling make basements a hazardous rich environment. If an exterior access door to a basement exists, the majority of the time it is on Side C. Exterior access to a basement should be used whenever possible and be the preferred option whenever preplanning for basement fires.

In this incident, the resident had been removed by the battalion chief. Engine 73 determined the fire was in the basement and used an interior door to the basement. This door had been left open, and once the basement windows were removed a flow path was created that trapped the Engine 73 fire fighter/EMT and drove the rest of the Engine 73 crew out of the structure. Closing doors can help to close off the exhaust vent and limit the flowpath of the fire. Ladder 21 had vented the Side A basement glass blocks without a charged hoseline present and prior to Engine 63 establishing effective water in the rear of the structure. An exterior entrance on Side C was accessed by Engine 63 afterward, who subsequently knocked down the bulk of the fire. For a ventilation limited fire, no ventilation should be conducted unless a charged hoseline is in place to flow water. The importance of coordinating ventilation and suppression tactics cannot be overstated.

Recommendation #2: Fire departments should ensure that officers and fire fighters are trained in the latest fire behavior research affecting fireground tactics.

Discussion: The fire behavior in this incident was similar to more than 15 flow path related line-of-duty deaths incidents that have been identified based on a review of NIOSH reports. [NIST 2015]

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 the effects of new materials and construction on structure fires. 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 new building construction and the composition of home furnishings and products impact the growth and development of fires in structures and how fire respond to fire fighter actions (legacy versus modern materials). 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—flash over can happen with today's furnishings in as little as 4 to 5 minutes [Madrzykowski and Kerber 2009; NIST and UL 2013].

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 an oxygen-depleted, fuel-rich 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 evidenced by 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 and/or without the ability to immediately apply effective water for suppression, will 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, reduce water damage, and limit fire damage. 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, 2012; NIST, UL 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 introducing fire fighters into the building and ventilation operations concurrently is that hose streams and/or fire flow paths that are introduced are a potential hazard to people trapped in the structure.

Based upon the NIST and UL research, NIOSH suggests the following fireground operations be considered for implementation.

• **Size-Up.** Size-up should 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

building's 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, which 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.

Many fire departments have adopted the acronym SLICE-RS, developed 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 fireground.

- **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 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.

In this incident, several circumstances occurred, such as a fuel-rich environment in the basement, an open door at the top of the kitchen/basement stairs (high pressure), and ventilation of glass block windows at the basement level (low pressure) before water was applied to the basement fire.

Recommendation #3: Fire departments should ensure that crew integrity is maintained.

Discussion: When an engine company enters a structure, the members should 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 2013c].

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 should be declared immediately [IAFC 2009].

In this incident, the Engine 73 fire fighter/EMT became separated in the heavy smoke and heat coming from the basement. The lieutenant and nozzle operator exited the structure believing the fire fighter/EMT had exited with them, then they realized the fire fighter/EMT was missing. The lieutenant returned to the first floor to search but the smoke and heat hampered the search. The fire fighter/EMT called several Maydays but no RIT was present on the fireground.

Recommendation #4: Fire departments should ensure that all fire fighters and officers are trained in the use of hose nozzles and hoseline management skills.

Discussion: Successful fire suppression and fire fighter safety depends upon discharging a sufficient quantity of water to remove the heat being generated and provide safety for the interior attack crews. When advancing a hoseline into a fire structure, air should be bled from the line once it is charged, and before entering the structure [IFSTA 2013]. Fire fighters should continually train in establishing a water supply, proper hose deployment, and advancing and operating hoselines to ensure successful interior attacks. When and why to use a certain hose nozzle spray pattern or hose nozzle motion is important to understand, as different spray pattern or nozzle movements can change the amount of air being entrained with the line. For example, exterior fire attacks should be made with straight streams or solid streams that initially are bounced off of the ceiling of the fire compartment to produce a broken stream. The streams should not be rotated or used to block the opening, as this will entrain additional air and potentially change the direction of the flow [NIST 2016].

In this incident the initial attack crew's hoseline came up short of reaching the interior basement door.

Recommendation #5: Fire departments should ensure that all fire fighters and officers are trained in Mayday techniques and communications.

Discussion: Fire departments should ensure that all fire fighters and officers receive Mayday training on a regular basis. It is essential to train fire fighters to 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 [Jakubowski and Morton 2001].

The most important element that fire fighters need to know is when to declare a Mayday. Recognizing that they are in, or about to be in, a life-threatening situation is the first step in improving the fire fighter's chances to survive a Mayday event. Many fire departments don't have a simple procedure for how a fire fighter communicates he/she is in trouble, a critical situation where communications must be clear [Jakubowski and Morton 2001]. A Mayday declaration is such an infrequent event in any fire fighter's career that they need to frequently train on recognizing the need to declare the Mayday, how to declare the Mayday, and what steps to take to improve their chances for survival.

Fire fighters should 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 message reduces the chance for a successful rescue. Knowledge and skill training on preventing a Mayday situation or how to call a Mayday should be mastered before a fire fighter engages in fireground activities or other immediately dangerous to life and health (IDLH) environments [IAFF 2010; Sendelbach 2004]. Fire fighter training programs should include training on such topics as air management; familiarity with a self-contained breathing apparatus (SCBA), a radio, and personal protective equipment (PPE); crew integrity; reading smoke, fire dynamics, and fire behavior; entanglement hazards; and 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 the danger 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 then annually [IAFF 2010; Sendelbach 2004]. Fire fighters need to also understand that their PPE 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.

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 [Clark 2005; Grossman and Christensen 2008]. 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.

Fire fighters 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 meet the standards for Mayday competency set by the authority having jurisdiction throughout their active duty service. Presently, there are no national Mayday standards for fire fighters to be trained to 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 [Clark 2005, 2008; IAFF 2010; USFA 2006].

There are no national standards on when a fire fighter must call a Mayday, and Mayday training is not included in the job performance requirements in NFPA 1001, Fire Fighter 1 or 2, standards [NFPA 2013b]. 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]. Also, the International Association of Fire Fighters (IAFF) Fireground Survival program is another resource fire departments can use and was developed to ensure that training for Mayday prevention and Mayday operations is 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 fire fighters know their location at all times when in IDLH environments to effectively be able to 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 [USFA 2006]. Once the incident commander and RIT know the fire fighter's location, the fire fighter can then try to follow a hoseline or manually activate their PASS, while the RIT is en route for rescue. Command should communicate to the fire fighter that help is coming and remind them to activate their PASS and/or get on the hoseline.

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 run low on air or become lost, disoriented, injured, or trapped during rapid fire progression. Most fire training curricula do not include discussion of the psychological and physiological effects of extreme stress 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 that while all training is important,

> We know that under conditions of stress, particularly when rapid problem-solving is crucial, over-learning 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 these are not as 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. The Mayday message transmitted over the radio may have gotten the attention of command officers and other fire fighters, however the response seemed delayed.

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 2014].

In addition to a stationary command post, effective communication can assist the incident commander to formulate a rescue plan. In many instances, an already established RIT can be put into action and managed by the incident commander. The incident commander may take the direction role or pass it to another officer at the command post. However, in most cases the responsibilities may be divided and a division commander may establish and direct a rescue group. The fire-fighting units need to be coordinated and those resources not directly involved in the rescue or fire fighting may be moved to a different channel.

Many things need to be coordinated once a Mayday has occurred. If incident commanders are trying to perform all of these functions in the front yard (by themselves), they can be quickly over tasked and may overlook critical needs. A command team that is properly set up can provide direction, assign responsibilities, and have the advantage of clear communications.

A properly set up command organization has the advantage of being able to quickly expand to meet the needs of the incident response. Conversely, if the command is mobile, much time may be lost in recognizing the significant event and developing a plan and assigning resources to overcome the event. Fire officers need to understand that while they may be comfortable commanding from the front yard, they may not understand the reasoning for establishing a stationary command post. Just because they have commanded many fires from the front yard and committed accountability and tactics to memory, when a significant event occurs, those actions committed to memory may be challenged. An incident

action plan and command of an emergency incident scene is best performed by a command team at a stationary command post with functions written down. In the rare event such as a Mayday, a worksheet may help to trigger response functions. We have included an example of a Mayday checklist in Appendix III.

This ability to command emergency incidents is learned not only through didactic training but skill development with hands-on training. Fire officers need to resist the temptation to command from the front yard even on minor incidents. Command skill can be built by establishing command on smaller incidents. This can benefit the experienced incident commander, however, it is a critical skill building process for newer officers or those "acting" in the roles. Everyone on the fireground benefits from repetition, including the command officers. While many officers can effectively command from the front yard or hallway, when a significant event such as a building collapse or Mayday occurs, a properly set up command structure is much more able to adapt and expand as needed.

Incident commanders, division/group supervisors, company officers, and fire fighters need to understand the seriousness of a Mayday situation. It is important to have the available resources on-scene and to have a plan established prior to the Mayday [NFPA 2013c, 2014]. A worksheet can assist the incident commander in the necessary steps for clearing the Mayday as quickly and safely as possible. This worksheet serves as a guide and can be tailored to any fire department's Mayday procedures. The worksheet 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 Engine 73 fire fighter could not be accounted for, the incident commander sent the Engine 73 officer back into the structure to bring her out. Once a Mayday was heard, a RIT had not been established. Four minutes prior to the Mayday occurring, the incident commander quickly called for additional resources. 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. The fire fighter radioed several Maydays and activated her emergency button. Although fire fighters attempted to account for her location, they were not able to establish verbal communication with her. Such communication may have allowed for an earlier accounting of her location and perhaps allowed Command to advise her on the status of the rescue efforts and actions she could take to facilitate it, such as find the hoseline and follow it, activate your PASS, remain calm and try to tell us where you are, reassure her, and other things to try and make her rescue more likely. Mayday training is more than how to call a Mayday; it is also how to respond to one.

Recommendation #6: Fire departments should consider upgrading their SCBA and PASS to the latest edition of the NFPA standards to benefit from the increased thermal protection characteristics.

Discussion: During this incident, the Engine 73 fire fighter/EMT's facepiece survived the thermal insult. However, the hose of the Emergency Breathing Support System (buddy breather) did not.

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

NFPA 1981 *Standard on Open-circuit Self-contained Breathing Apparatus for the Fire Service* underwent a significant change in the 2013 edition that increased the heat and flame testing of the SCBA and the facepiece. One of the collateral advantages of these new heat and flame tests was that other components of the SCBA were improved to withstand the new testing requirements [NFPA 2013e].

At the time of the incident, the department was in the process of upgrading their SCBAs. The department had not placed the new SCBAs in service at the time of the fire, and the fire fighter was using an SCBA conforming to the 2002 edition of NFPA 1981. However, the fire fighter had received and was using a new facepiece conforming to the 2013 edition of the NFPA 1981 standard. During this incident, the fire fighter's 2013 edition facepiece did not suffer thermal degradation, but the 2002 edition SCBA buddy breather hose did. It appears that the conditions encountered exceeded the capabilities of the 2002 edition buddy breather hose since it suffered a catastrophic thermal degradation resulting in a very large and quick air loss. It is unknown if the conditions encountered would have exceeded the 2013 edition heat and flame tests. However, since the fire fighter was wearing a 2013 edition SCBA facepiece that did not suffer thermal degradation, the NIOSH investigation team believes that fire departments should consider upgrading SCBA to the new 2013 edition to take advantage of all of the upgrades including the new heat and flame tests [NFPA 2013f].

Another benefit is the enhanced heat and flame testing that is performed on the PASS device. In 2007, NFPA 1982 *Standard on Personal Alert Safety Systems* required major upgrades for heat, moisture, and sound levels for PASS devices [NFPA 2007]. NIST evaluated the thermal characteristics of all the manufactured PASS devices and developed a standard test protocol.

In this incident, no one heard the Engine 73 fire fighter/EMT's PASS device although they were right next to her and even the crews that removed her said her PASS device was not sounding. The integrated PASS device was an older model (2002 or even 1997) and had not been upgraded to the 2007 edition, which contained the much more stringent requirements [NFPA 2007].

These updates included a more rigorous water-immersion test that requires all electronic devices to function properly and remain watertight following six cycles of heat at 350 degrees F for 15 minutes and water submersion to 1.5 meters deep. Previously, PASS devices had to undergo temperature stress tests from -4 degrees F to 160 degrees F; then, after being conditioned to a nominal 113 degrees F, they had to remain watertight after water immersion for 2 hours at a 1-meter depth. This requirement will help to ensure that electronics are more likely to function properly in the field after repeated exposure to heat and water.

A challenging 3-hour tumble test was added to PASS devices to ensure that electronic circuitry can endure long-term rough handling and transportation. The test consists of a 4-foot-diameter "squirrel cage" that rotates and tumbles its contents. Circuitry modifications will likely be required to most products on the market to better protect them from impact and vibration.

A new muffle test was added to PASS devices. In this test, the device must emit 95 dBA of sound at 3 meters while the wearer is positioned in each of five orientations (face down, supine right and left, and fetal right and left). The test helps to protect against the accidental muffling of a PASS device in various orientations.

A high-temperature performance of PASS devices was raised from 200 degrees F for 15 minutes to 500 degrees F for 5 minutes, after which the PASS must emit 95 dBA of sound at 3 meters.

Data-logging (time stamping the power on, pre-alarm, alarm, and reset functions) is be a new requirement for all PASS devices in the 2013 edition [NFPA 2013f].

Recommendation #7: Fire departments should ensure that rapid intervention teams are on-scene and activated before interior operations begin.

Discussion: At all fireground operations, a rapid intervention team (RIT) should be designated and available to respond before interior attack operations begin [NFPA 2013c; NIOSH 2011].The team should report to the officer in command and remain in a designated ready position until an intervention is required to rescue a fire fighter(s) or civilians. The RIT should have all tools necessary to complete the task (e.g., a search rope, first-aid kit, Haligan bar and flat-head axe combo, a resuscitator, and extra SCBA cylinders and/or transfill hoses). The RIT's only assignment should be to prepare for a rapid deployment to complete any emergency search or rescue when ordered by the incident commander. The RIT allows the suppression crews the opportunity to regroup and take a roll call instead of performing rescue operations. A RIT should preplan a rescue operation by finding out fire structure information (e.g., construction materials, layout, and entry/egress routes) and crew locations and assignments and by monitoring radio traffic. When the RIT enters to perform a search and rescue, they should have full cylinders on their SCBAs and be physically prepared. When a RIT is used in an emergency situation, an additional RIT should be put into place in case an additional emergency situation arises [NIOSH 2011].

In this incident, the rapid intervention crews were changed by the dispatch. The late arrival of one of the crews prohibited the crew to be in standby and caused confusion as to which crew was available. When the fire fighter was determined to be missing, there was no RIT established.

Recommendation #8: Fire departments should ensure that adequate resources respond in a timely manner.

Discussion: Interdependent and coordinated tasks of all deployed fire-fighting personnel are required to meet the incident action plan. 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 (NIST), 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 2013d]. 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 Underwriters Laboratory 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 2013d].

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 2013d]. 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 the safety of fire fighters and civilians, 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, Ladder 29, which is normally first due, was on a medical call. Dispatch then made Ladder 8 first due truck. Ladder 8 took 21 minutes to arrive on-scene, primarily because the crew was not familiar with the streets in the area. This affected the RIT assignment and the presence of RIT on the fireground.

Recommendation #9: Fire departments should ensure that personal protective equipment is donned prior to entering a structure.

Discussion: A fire fighter's responsibility is to maintain physical and mental readiness to handle situations that often are inherently dangerous. A fire fighter's situational awareness and applying the training they received leads to a successful outcome. Ultimately, safety is the fire fighter's responsibility, and properly wearing their PPE on the fireground is critical to their safety. "Not properly protected" means not wearing gloves, not using the helmet strap, and not donning their hood because they want to use their ears to sense heat. It also means not ensuring the lining of their coat and pants are properly in place and secured, not having their collar up and deployed with their helmet ear covers down, not completely closing their gear so there's no exposed skin, and finally, not wearing and using their SCBA [NFPA 2013c].

There are several reasons why fire fighters don't wear their gear. The reasons can be traced back to lack of training, lack of policy and procedures, lack of enforcement by fire officers, lack of example by fire officers, and over confidence [Grilliot 2007]. A recent study suggests peer-pressure at the peer and

organizational levels appear to be essential considerations fire fighters undertake when choosing whether or not to engage in safety behavior [Maglio et al. 2016].

In this incident, fire fighters entered the structure without their full ensemble of PPE and SCBA.

Recommendation #10: Fire departments should ensure that a stationary command post is established and the command team communicates effectively.

Discussion: NFPA 1561 *Standard on Emergency Services Incident Management System and Command Safety*§5.3.1 states, "The incident commander shall have overall authority for management of the incident." The incident commander must establish and maintain a command post outside of the structure in order to assign companies, delegate functions, and continually evaluate the risk versus gain of continued fire-fighting efforts [NFPA 2014]. Fire departments should train their command officers to establish a stationary command post and effectively communicate with the command team members. Some command officers may be able to effectively command a fireground from the front yard when everything is going well. However, that comfort level can be quickly challenged when faced with unexpected fireground conditions such as a collapse, fire growth, or as in this case a Mayday that had no RIT response.

When critical communications occur, it is very easy to miss those communications with all of the fireground noise and confusion that occurs on many firegrounds. If those areas need a command-level officer, they should be staffed with a division-level officer, leaving the overall command officer with his/her team in an area outside of the immediate "hot zone." It is a critical function of Command to allow for clear communications with his/her divisions, dispatch center, and other agencies.

In the rare instances of a Mayday transmission, it is imperative that those communications are communicated to the incident commander. If the incident commander is mobile and a Mayday transmission is made by radio on a different channel, the incident commander may miss the transmission and a delay in taking action will occur.

When a chief officer (e.g., battalion chief, district chief) arrives on-scene, the first steps are to assume command, announce the name of the incident (e.g., Main Street Command), and establish a stationary, exterior, and remote command position. Once command is established and an initial size-up has been done, the incident commander should continue command and control functions inside or at the rear of the vehicle, which should have a command board [Ciarrocca and Harms 2011].

In establishing a command post, the incident commander shall ensure the following (NFPA 1561, Chapter 8—Command Safety):

- The command post is located in or tied to a vehicle to establish presence and visibility.
- The command post includes radio capability to monitor and communicate with assigned dispatch, tactical command, and other designated emergency traffic channels for that incident.
- The location of the command post is communicated to the communications center.
- The incident commander, or designee, is always present at the command post.

- The command post should be located in the incident cold zone [NFPA 2014].

In order to effectively command an incident, incident commanders must be in the most advantageous position possible. The best position is a fixed, visible, and accessible location at the command post. This can be accomplished by utilizing the incident commander's staff vehicle, a designated command vehicle, or fire apparatus. An acceptable alternative is utilizing the rear area of a sport utility vehicle or van-style vehicle. This method will provide the incident commander with an area that is quiet and free of distractions from which to command an incident. It is also vital for the incident commander to be able to hear all radio transmissions, especially from those operating on-scene. The best way to accomplish this is through the use of a radio communication headset. This will enable the incident commander to be in the best position possible to hear critical radio transmissions. The incident command post also should be visible and recognizable. This can be accomplished by displaying a colored light, flag, banner, or other symbol to mark the location. Where special command post vehicles are used, such vehicles are usually marked with distinctive identification to make the command post recognizable [NFPA 2014].

The tactical worksheet is a critical piece of equipment because it helps the incident commander organize tasks by providing reminders, prompts, and a convenient workspace for tracking companies and apparatus. It allows them to slow down during what could be a large, multi-alarm incident. The worksheet can be used for fires big and small, as well as EMS incidents, to help develop proficiency and to record vital information that may help them 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 [Los Angeles Fire Department 2011].

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 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 responsibility.
- Expedites passing of command or support for the incident commander.
- Provides resource status [NFPA 2014].

Fire departments should have a communications standard operating procedure (SOP) coupled with an effective training program. These procedures include the use of clear text (specifically, no 10 codes, or

other terms that may be unfamiliar to other responders), a separate radio channel for Dispatch, and a separate tactical channel to be used during the incident. When a tactical-level management unit is implemented (division or group), a fire department should provide a dispatch channel, a command channel, and a tactical channel. A fire department should provide the necessary number of radio channels with multiple tactical channels, depending on the type of incident and the complexity of the incident.

Another element that is essential to the success of the personnel accountability system is effective fireground or incident scene communications. The function of resource accountability should be assigned to a member, such as a chief's aide, who is responsible for maintaining the location and status of all assigned resources at an incident. This 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, this function should be assigned to an accountability officer or resource status officer. A number of members could function in this role including a staff assistant, chief officer, apparatus driver/operator, or other responder. There are many means of accounting for resources. Components can include tactical worksheets, command boards, apparatus riding lists, company responder boards, passport system, and electronic bar-coding systems, depending on whether equipment or personnel are being tracked. These components can be used in conjunction with one another to facilitate the tracking of responders by both location and function. The components of any resource accountability system should be modular and expand with the size and complexity of the incident [NFPA 2014].

Managing all these systems can quickly become overwhelming and create task saturation for the incident commander. A staff assistant or chief's aide is another essential element of this process. Verbal communication between the incident commander and chief's aide is more efficient when they are both at the stationary command post.

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Investigator Information

This incident was investigated by Matt E. Bowyer, General Engineer; Stephen T. Miles, Investigator; and Paul H. Moore, Chief, Fatality Investigations Team, 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 Peter Van Dorpe, Chief (ret.), Chicago Fire Department and current Chief, Algonquin-Lake in the Hills Fire Protection District and Dan Madrzykowski, P.E., M.S.F.P.E., Underwriters Laboratory's Firefighter Safety Research Institute. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Additional Resources

The Houston fire department has an officer development program that incorporates a state of the art incident command program complete with a multimillion dollar simulator building. Information on the program is available here:

Tony Reed
Regional Training Program Director
Houston Fire Department
Val Jahnke Training Facility
8030 Braniff St, Houston, TX, 77061
clifford.reed@houstontx.gov
Phone: (713) 859-4284

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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.

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

Status Investigation Report of Four
Self-Contained Breathing Apparatus
Submitted by the
NIOSH Division of Safety Research for the Fire Department

NIOSH Task Number 20003
February 9, 2015

Investigator Information

The SCBA performance tests were conducted by Mike Commodore, Engineering Technician, Jay Tarley, Physical Scientist and Jay Parker, Acting Laboratory Manager. The SCBA inspections were performed and this report was written by Jay Tarley, Physical Scientist. The investigators are part of the Policy and Standards Development Branch, National Personal Protective Technology Laboratory, National Institute for Occupational Safety and Health, located in Bruceton, Pennsylvania.

Background

As part of the ***National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program***, the National Personal Protective Technology Laboratory (NPPTL) agreed to examine and evaluate four SCBA units identified as Scott Health and Safety model AirPak 4.5, 4500 psi, 45-minute, self-contained breathing apparatus (SCBA).

This SCBA status investigation was assigned NIOSH Task Number 20003.The NIOSH Division of Safety Research (NIOSH/DSR) and the Fire Department were advised that NIOSH NPPTL would provide a written report of the inspections and any applicable test results.

SCBA Unit #4, contained within a plastic shipping container, was hand delivered to the NIOSH facility in Morgantown, WV on December 15, 2014.This unit was taken to the lower floor of lab room 1513 for secured storage. The SCBA Units #1 through #3, contained in cardboard shipping boxes were delivered to the NIOSH facility in Bruceton, PA on December 19, 2014.Unit #4 was then transported to Pittsburgh for inspection. The inspection was conducted on all the units on January 7, 2015 and they were taken to building 20 and stored under lock until the time of the evaluations on January 9, 2015.

SCBA Inspection

The units were removed from their packaging in the Communications Classroom, Room 116 (Building 40) and inspected on January 7, 2015 by Tom Pouchot, General Engineer, and Jay Tarley, Physical Scientist, NPPTL. The four SCBAs were identified as the Philadelphia Fire Department SCBA Unit #1 through Unit #4.These SCBA units were extensively examined, component by component, in the condition received to determine the conformance of each unit to the NIOSH-approved configuration.

The units were identified as the Scott Health and Safety Company model AirPak 4.5, 45 minute, 4500 psi units, NIOSH approval numbers TC-13F-212CBRN.The visual inspection process was documented photographically. Once all the inspections were completed the SCBA units were repackaged and placed back in Building 20 under lock.

The complete SCBA inspections are summarized in **Appendix I** of the full report. The condition of each major component of the SCBAs that were photographed with a digital camera is contained in **Appendix III** of the full report.

The cylinder from the victim's SCBA, Unit #4, was judged that it could not be safely pressurized and tested in the condition received. The fire department supplied 2 new air cylinders and one additional new facepiece and NIOSH supplied two additional cylinders for the evaluation. On January 9, 2015 all four units were tested with three representatives from the Fire Department and a representative from NIOSH/DSR present.

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*, 2013 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, 2013 Edition):

7. Air Flow Performance Test [Chapter 5, 5-1.1]

Appendix II contains the complete NIOSH test report for the SCBA units.

Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania

Summary and Conclusions

Four SCBA units were submitted to NIOSH/NPPTL by the NIOSH/DSR for the Fire Department for evaluation. The SCBA units were delivered to NIOSH in two separate shipments on December 15th and 19th, 2014 and extensively inspected on January 7, 2015.The four units were identified as a Scott Health and Safety model AirPak 4.5, 4500 psi, 45-minute, SCBA (NIOSH approval number, TC-13F-212CBRN).The unit worn by the victim, Unit #4, suffered heat damage and was covered by soot. The utility hose was burnt through making the unit not testable. A plug was sent to NIOSH by the manufacturer so that the testing could be completed on Unit #4.The overall conditions of the other three units were fair to good and exhibited normal signs of wear and tear. The additional units were slightly covered with general soot and dirt. The cylinder valve, as received, on Unit #4 was in the open position. The cylinder gauge showed no pressure. The cylinder valve hand-wheel could be turned on Unit #4.The regulator and facepiece mating and sealing area on Unit #4 were extremely sooty. Unit #4 had minimal scratches on the lenses and visibility through the facepiece lens was good. The facepiece head harness webbing on Unit #4 was in fair condition but was sooty. The NFPA approval label on all the units was present and readable after some dirt and soot was wiped away. The personal alert safety system (PASS) on all the units functioned.

The air cylinder on Unit #4 had a manufactured date of 01/01.Under the applicable DOT exemption, the air cylinder is required to be hydro tested every 5 years. For the air cylinder on Unit #4, a retest date before the last day of 01/06 is required. The retest label appeared to have been burnt off of the cylinder; therefore, it was determined that it was not safe to pressurize. The cylinder on Unit #4 was covered with a heavy layer of soot and received extensive heat damage. There was no air remaining in the cylinder. The SCBA Unit #4 was tested after the manufacture supplied the plug for the port for the utility hose. No other maintenance or repair work was performed on any of the units at any time. No cylinders were provided with Unit #1 through Unit #3.Two additional cylinders and one facepiece were supplied by the Fire Department so that the testing could be completed in a timely fashion on all four SCBAs.

All four units passed the NIOSH tests and the NFPA air flow test.

In light of the information obtained during this investigation, NIOSH has proposed no further action on its part at this time. The SCBA units were returned to the Fire Department on January 21, 2015 and February 10, 2015.

If these units are to be placed back in service, the SCBAs must be repaired, tested, cleaned and any 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 II

Severed Accessory Hose Test
August 18, 2015

Summary and Conclusions

The Fire Department requested NIOSH conduct testing to determine what effects a severed accessory hose would have on the inhalation resistance and the duration of the air supply. The tests conducted demonstrated that the units provided positive pressure to the facepiece even when the accessory hose was cut completely through; however, the duration decreased significantly. It was also determined that when the accessory hose was cut that air could be drawn back through the severed accessory hose to the user. This may have not been perceived as an out-of-air emergency situation to the user, especially since the Vibra-Alert did not function with the rapid loss of air.

Appendix III

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;