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Death in the line of duty... NIOSH National Institute for Occupational Safety and Health

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program July 30, 2020

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Executive Summary

The Lieutenant was killed in a V-shape collapse while fighting a row house fire. Arrow points to victim's SCBA and the approximate area where the victim was trapped.
(Cover Photo Courtesy Fire Department)

On January 6, 2018, a 42-year-old career Lieutenant (Engine-45 officer) was killed in a structural collapse while fighting a fire in an 1800's era row house. Firefighters arrived to find a two-story row house heavily involved in fire. Fire crews faced limited street access to the fire dwelling (snow covered narrow road and civilian parking), excessive clutter in the building, extreme cold, multiple inoperable fire hydrants and a frozen handline (nozzle). The first arriving crews operating only off tank water were able to locate and remove a civilian victim from the first floor and initially knock down the fire on the first floor. Interruptions in water supply hampered fire-fighting efforts and forced a change in strategy until a reliable supply was established.

Once the water supply was re-established, crews re-entered the structure to continue to extinguish the fire. Fire crews reported excessive debris scattered throughout the interior. Engine-45's officer and his tip man re-entered the structure after changing out their SCBA cylinders and joined several other members on the first floor including, Rescue-1's Search Firefighter, Squad-72's officer and Engine-50's Pak. There was a total of 5 firefighters on the first floor with 2 additional firefighters (Squad-72 Tip and Squad-72 Pak) in the vestibule area at the front door. Another crew of 3 firefighters from different companies stretched a line in and up the interior stairs on the Bravo wall to the second floor. One firefighter from this crew advanced onto the second floor, while the two other members remained on the stairs to advance hoseline. The firefighter on the second floor experienced a shift in the floor and without time to react, the second floor collapsed into the first floor. Squad-72's officer reported hearing a loud crack and went to the front door (side Alpha) and told Command to get everyone out.

Some members operating on the first floor were pushed forward (towards side Alpha interior) during the collapse except for the Engine-45 officer. Members of the crew on the second floor either rode the floor down and escaped out of side Charlie or escaped out of the side Alpha entry door. The victim was

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pinned down by the second-floor joists and was unable to escape. Rescue crews worked continuously for approximately 60 minutes in extremely dangerous conditions to extricate the lieutenant. He died of positional asphyxia with superheated gas and smoke inhalation (see cover Photo).

Contributing Factors

- *Extreme cold weather, water supply (6 inoperable hydrants).*
- *Inherent building characteristics and unique row house variation.*
- *Structural overloading, excessive clutter and deteriorated building conditions.*
- *Risk assessment that included a structural condition evaluation after strategy change (fire severity on primary building materials and extension within ceiling spaces).*

Key Recommendations

- *Fire Departments should consider increasing response capabilities during extreme weather.*
- *Fire Departments should consider defensive operations when a dependable, continuous water supply is lost or not available and the building's primary building materials may have been subject to severe fire conditions.*
- *Fire Departments should ensure that firefighters are trained to understand the influence of building age, use, design, modifications and construction on structural collapse, and consider defensive operations when hoarding/dilapidated conditions are evident or encountered.*
- *Fire Departments should perform a thorough risk assessment, including an evaluation of structural conditions, when switching from a defensive strategy back to an offensive strategy.*

Additionally, governing municipalities (federal, state, regional, and local) should:

- *Consider upgrading access to narrow roadways in 19th century neighborhoods or restrict parking so access is maintained for modern fire apparatus.*

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Introduction

On January 6, 2018, a 42-year-old Lieutenant was killed in a structural collapse while fighting a fire in an 1800's era row house.

On January 7, 2018, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On February 8, 2018, the Fire Department contacted the NIOSH Firefighter Fatality Investigation and Prevention Program and requested assistance with an independent investigation of the incident. A number of phone conversations were held to exchange information and arrange the on-site investigation. On March 9-14, 2018, a Safety and Occupational Health Specialist and a General Engineer with the NIOSH Firefighter Fatality Investigation and Prevention Program traveled to Pennsylvania to investigate this incident. The NIOSH investigators met with the Fire Commissioner and senior staff officers from the fire department, including the Deputy Chief of Health and Safety and members of the Health and Safety Office After Action Review Team. NIOSH investigators also met with the fire department's Deputy Chief of Training and representatives of the International Association of Firefighters (IAFF) Local 22. The NIOSH investigators met with and interviewed the career firefighters and officers involved in the incident.

The NIOSH investigators visited the incident scene, examined and photographed building materials, and also obtained wood joist samples from the fire department's Health and Safety office and brought them to the West Virginia University School of Wood Science for identification. Additionally, mortar samples were obtained and sent to NIST for identification analysis. NIOSH investigators worked with the department's Health and Safety Office After Action Review Team and a SCBA manufacturer's representative to obtain information from the victim's electronic data logger. NIOSH investigators also accompanied fire department Health and Safety office representatives to Intertek labs in New York state to perform a pneumatic evaluation on the victim's SCBA. NIOSH obtained and reviewed fire department breathing air compressor service records, department training requirements, standard-operating procedures, incident scene photographs and drawings, and victim training records and medical records. On March 27-28, 2018, the NIOSH investigators returned to Pennsylvania to conduct additional interviews.

Fire Department

The fire department involved in this incident has 63 fire stations. It provides emergency medical and fire suppression services to a population of approximately 1.6 million residents within an area of approximately 141 square miles. For fiscal year 2017, the department had a total of 2,573 budgeted positions, of which 2,447 were uniformed fire and EMS providers. In FY18, the positions grew to 2,806 with 2,681 being uniformed. For FY19 that number has further increased to 2,851 positions, with

2,707 uniformed. In FY 2017, the department responded to 314,722 incidents. Of these, 267,266 were EMS incidents and 47,456 were fire incidents, 2,506 of which were working structure fires.

This fire department has a fire commissioner, who is appointed by the city's mayor; a chief of staff; and deputy commissioners who manage the department. There is also a part-time medical director, a full-time communications director, and four assistant deputy commissioners.

Over the previous 5 years, the fire department has undergone many changes. At the time of this incident, there were four major operating sections: Operations; Logistics; Planning/Risk Reduction; and Finance/Administration. The deputy commissioner for Operations commands: Fire Suppression, EMS, Special Operations and the Aviation Operations Division. The deputy commissioner for Logistics commands: Health and Safety, Fire Academy (training), Fire Communications Center, Technical Support Unit (apparatus, equipment, warehouse, water and facilities) and Information Technology. The deputy commissioner for Planning/Risk Reduction commands: Fire Prevention, Fire Code, EMS Community Risk Reduction, Fire Marshal Units, Performance, Analytics and Management Information Systems. The deputy commissioner for Finance/Administration commands: Fiscal and Human Resources, Recruitment, Employee Assistance, Employee Relations, and Special Investigations.

At the time of the incident, the city was divided into two divisions. Division 1, which consisted of 5 battalions and 29 fire stations, and Division 2, which had 6 battalions and 34 fire stations. Since this incident, the department added a new division with an additional division chief and two additional battalion chiefs. A Division Chief is responsible for each division.

The department has 56 engine companies, 27 ladder companies, one heavy rescue company, two squad companies and two fire boats (plus one in reserve). The department operates specialty companies for technical rescue, hazardous materials incidents, and aircraft rescue & firefighting (ARFF). All non-specialized engine companies carry 1,000 feet of 5-inch diameter hose. Two engine companies are designated as squirts which have 54-foot articulating booms. Two are elevated water towers which have 50-foot booms. Three engine companies are designated as foam and carry class B foam. Also, Foam Tender 1 operates with Foam 33. Two ladder companies are 85-foot snorkels and have an articulating boom with a platform. Two ladder companies are ladder towers. The remainder of the ladder companies are tractor-drawn aerials.

The staffing on an engine company is an officer and three firefighters. The staffing on a ladder company is an officer and four firefighters. Each squad is staffed with an officer and four firefighters. Rescue-1 is staffed with an officer and five firefighters. Each Division Chief and Battalion Chief is assigned a staff assistant or chief's aide.

The fire department's EMS division consists of 60 medic units and supervisory staff, including EMS field officers. Fifty of the medic units operate on a full-time basis, and ten operate on a part-time basis.

The fire department operates an ARFF station at the international airport in the southern part of the city.

Department members assigned to the operations division work a daily 12/12 shift (0800–2000 and 2000–0800) with four platoons or shifts (on average a 42-hour work week).

Training and Experience

The Commonwealth of Pennsylvania does not have pre-requisite training or education requirements for an individual to become a firefighter. 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 firefighters. 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* [NFPA 2018a]. Selected candidates are appointed as cadets or recruit firefighters in an extensive 36-week academic, practical, and physical training program at the department's fire academy.

At the fire academy, recruit firefighters 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 firefighters are assigned as probationary firefighters and receive national certification as per NFPA 1001, *Standard for Firefighter Professional Qualifications* [NFPA 2013b], Firefighter I and Firefighter II; Hazardous Material Awareness and Hazardous Materials Operations certification; NFPA 1035, *Standard on Fire and Life Safety Educator, Public Information Officer, Youth Fire-setter Intervention Specialist and Youth Fire-setter Program Manager Professional Qualification* [NFPA 2010]; and as a state-certified emergency medical technician/basic (EMT/B).

A probationary firefighter is assigned to the Operations Division on either an engine company or a ladder company. As an EMT/B, firefighters 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 firefighter 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 1 hour of training per shift. Also, fire officers and firefighters are required to complete 170 hours of training annually.

Additionally, the department has a procedure that personnel are trained on for emergency situations. When any member is in distress, lost, trapped, or injured, they are trained to depress the emergency activation button on their portable radio and announce "Mayday" 3 times followed by their location, identification and problem. This emergency activation overrides all other radio traffic on that frequency and provides several seconds of undisturbed radio transmission by the member on the frequency (hands free). As noted in the equipment and personnel section, this department provides portable radios to all members.

Equipment and Personnel

Emergency calls are answered by the city's police dispatch center. If a 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 Logistics, who directs all staff and support functions for the fire department and reports to the fire 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 previously 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.

A Tactical Box Alarm is assigned for reports of fires in appliances, chimneys, and outside rubbish fires. If 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.

A Tactical Box Alarm dispatches:

- 2 Engines
- 2 Ladders
- 1 Battalion Chief

A Box Alarm is assigned for single family dwelling fires, fires in commercial or industrial buildings, factories, warehouses, educational buildings, or multiple-family dwellings fewer than seven stories in height, and dispatches:

- 4 Engines
- 2 Ladders
- 2 Battalion Chiefs
- 1 Advanced Life Support (ALS) medic unit

A High-rise Box Alarm is assigned for fires in buildings seven stories in height or higher, and dispatches:

- 4 Engines
- 3 Ladders (1 for lobby control)
- 2 Battalion Chiefs
- Rescue company (Rescue 1)
- 1 ALS medic unit

A Major Incident Response is assigned to large-scale events, and dispatches:

- 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 is assigned to a Box Alarm Assignment and advises the FCC that "all hands are working," the 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 company, 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.

The minimum staffing on an engine company is an officer and three firefighters. The minimum staffing on a ladder company is an officer and four firefighters. Each squad is staffed with an officer and four firefighters. Rescue 1 is staffed with an officer and five firefighters. Each Division Chief and Battalion Chief are assigned a staff assistant or chief's aide. They are designated by position on the apparatus, for example Engine-45 Officer, Engine-45 DPOP (Driver/Pump/Operator/Pump), Engine-45 Pak and Engine-45 Tip (Pak and Tip denote responsibilities for advancing hoselines [Pak] and responsibility for advancing and operating the nozzle [Tip]. These terms are used throughout the report to identify personnel by position.

All members are assigned portable radios and the radio is electronically linked to the riding position. In the event of an emergency button activation, the FCC is able to identify the member by position and relay that information to the incident commander.

At the time of the incident, the department had a Health and Safety Office comprised of the following:

1 Deputy Chief in charge of the Health and Safety office

1 Captain

4 Lieutenants.

Since this incident the department added a Battalion chief to the Health and Safety office. Additionally, the department has 4-field Deputy Chiefs that serve as operational Incident Safety officers. They work shifts and respond to "All Hands" notification or greater fires.

In this incident, the first alarm and special units (through Mayday response) and their reported times to the fire were:

First Alarm (Box)

Engine-45, dispatched at 0851:43, en-route 0852:48, on-scene 0854:32

Engine-13, dispatched at 0851:43, en-route 0852:51, on-scene 0858:55

Engine-34, dispatched at 0851:43, en-route 0853:52, on-scene 0859:24

Engine-59, dispatched at 0851:43, en-route 0852:27, available 0856:05 (replaced Engine 50)

Ladder-14, dispatched at 0851:43, en-route 0852:44, on-scene 0855:05

Ladder-12, dispatched at 0851:43, en-route 0852:34, on-scene 0855:42

Battalion-8, dispatched at 0851:43, en-route 0852:31, on-scene 0855:47

Battalion-3, dispatched at 0851:43, en-route 0852:27, on-scene 0854:27

Medic-25, dispatched at 0851:43, en-route 0853:56, on-scene (not reported, however they arrived and worked)

Engine-50, (additional) dispatched at 0854:09, en-route 0854:35, on-scene 0857

2 and 2 Response:

Ladder-3, dispatched at 0856:21, en-route 0859:15, on-scene 0904:19, assigned as RIT (on a 2 and 2 response, a ladder and a medic are automatically dispatched as RIT)

Medic-31, dispatched at 0856:21, en-route 0857:35, on-scene 0905:48 (assigned as RIT medic unit)

ES-9 (EMS Supervisor) dispatched at 0856:21, en-route 0858:14, on-scene 0906:34

Squad-72 (1^{st} response), dispatched at 0856:21, en-route 0858:19, response canceled and available 0902:24

Rescue-1, dispatched at 0902:06, en-route 0902:31, on-scene 0916:45

All Hands Response:

Squad-72, 2^{nd} dispatch at 0907:44, en-route 0908:40, on-scene (not reported, however they arrived and worked)

Deputy Chief-2, dispatched at 0907:44, en-route 0943:14, on-scene 1002:42

Incident Safety Officer, dispatched at 0907:56, en-route 0909:05, on-scene 0931:18

ES-1 (EMS Supervisor), dispatched at 0907:44, en-route at 0910:12, on-scene 0923:08

ES-3, (EMS Supervisor) dispatched at 0908:06, en-route at 0910:34, on-scene 0929:56

Fire Marshal-13, dispatched at 0914:09, en-route at 0914:09, on-scene at 0948:00

Fire Marshal-15, dispatched at 0900:22, en-route at 0900:22, on-scene at 0900:22 (reported)

Medic-36, dispatched at 0913:06, en-route at 0914:36, on-scene at 0920:36

Special Call:

Engine-59, dispatched at 0914:49, en-route 0915:27, on-scene at 0918:00

Engine-29, dispatched at 0914:48, en-route 0915:56, on-scene at 0918:30

Medic-34, dispatched at 0916:30, en-route 0917:02, on-scene at 0929:24

Medic-44, dispatched at 0916:30, en-route 0917:46, on-scene at 0930:02

Second Alarmers-10, dispatched at 0927:15, en-route 0927:15, on-scene at 0933:57

Mayday Response:

Engine-55, dispatched at 0936:22, en-route 0937:12, on-scene 0940:17

Engine-43, dispatched at 0937:02, en-route 0941:59, on-scene 1000:00

Ladder-8, dispatched at 0936:22, en-route 0940:33, on-scene 0950:01

Battalion-4 dispatched at 0936:22, en-route 0936:39, on-scene 0943:57

Medic-13, dispatched at 0936:22, en-route 0937:41, on-scene 0943:50

Medic-15, dispatched at 0936:22, en-route 0938:56, on-scene 0945:56

AU-1 (Air Unit-1), dispatched at 0937:02, en-route 0942:02, on-scene 1000:00

PN-10 (Fire Prevention), dispatched at 0949:09, en-route 0949:09, on-scene 1015:09

Car-1, (Fire Commissioner) dispatched at 0942:13, en-route 0942:13, on-scene 0947:44

Second Alarm Units

Engine-20, dispatched at 0952:09, en-route 0952:49, on-scene 0952:50

Engine-9, dispatched at 0952:09, en-route 0952:20, on-scene 1002:51

Engine-35, dispatched at 0952:09, en-route 0953:27, on-scene 0958:22

Engine-25, dispatched at 0952:09, en-route 0954:00, on-scene 1000:41

Engine-28, dispatched at 0952:09, en-route 0953:32, on-scene 1001:31

Ladder-10, dispatched at 0952:24, en-route 0952:5026, on-scene 0959:03

Ladder-18, dispatched at 0952:37, en-route 0954:41, on-scene 0958:42

Battalion-9 dispatched at 0952:09, en-route 0952:50, on-scene 1008:45

Battalion-11 dispatched at 0952:09, en-route 0955:00, on-scene 1010:00

Battalion-1 dispatched at 0952:09, en-route 0952:15, on-scene 1006:04

Battalion-10 dispatched at 0952:37, en-route 0952:42, on-scene 1002:37

Timeline

The following timeline is a summary of events that occurred as the incident evolved. Individual unit times are noted above, however unit arrival times and actions may also be noted in the timeline below. Not all incident events are included in this timeline. The times and actions were obtained by studying department reports, dispatch records, audio recordings, witness statements, and other available information. All times are approximate and rounded to the closest minute.

Incident Conditions	Time	Response & Fireground Operations
Box Alarm for dwelling fire, 4 Engines, 2 Ladders, 2 Battalion Chiefs and Medic unit dispatched.	0851	Engine-45, Engine-13, Engine-34, Engine-59, Ladder-14, Ladder-12, Battalion Chief-8, Battalion Chief-3 and Medic 25 respond Engine-50 added.
Dispatch advised report of people inside (dwelling).	0853	Dispatch updated possible address.
Engine-45 arrived on scene (victim's engine). Ladder-12, Battalion Chief-8 arrived.	0854-0855	Engine-45 officer gave initial arrival report, 2 story, 15' x 35' middle of the row dwelling, fire showing first floor. Bravo and Delta (exposures) same size and dimensions all occupied. 2N2 in service, (denotes 2 engines and 2 ladders will be working). The stretch from Engine-45 to front of dwelling was approximately 260 feet (15 row homes in).
Battalion Chief-8 established command.	0856	Command called Ladder-14 officer and advised that a report of a civilian inside.

Incident Conditions	Time	Response & Fireground Operations
Command called dispatch and provided the correct address, updated to heavy fire conditions first floor. Command told Engine-34 to bring 1 ¾" handline and check exposure Delta.	0856	Engine-34 officer acknowledged.
Engine-45 Pak called Engine-45 DPOP and told him to send water (to their 1 ¾" handline).	0856	Very narrow street didn't allow for heavy fire apparatus to access side A. The crew from Engine-45 hand stretched to the dwelling. Pump operator hand stretched to hydrant. **Hydrant possibly frozen.**
Command called Engine-13 for their arrival order. Command Called Engine-50 and told them to stretch 1 ¾" and back up Engine-45 going in the front door.	0857	Engine-13, advised of their arrival order, Engine-50 acknowledged.
Command aid called dispatch. Aid was in the vehicle and Battalion-8 (command) was outside and in front of the fire dwelling. *Note: Resident cars were parked on one side of the narrow snow-filled street.*	0858	Battalion-8 aid, radioed dispatch and advised 3N2 in-service (3 Engines, 2 Ladders working) for a middle of the row, occupied dwelling 15' x 35', heavy fire first floor, Exposures Bravo and Delta same dimensions.
Command radioed Ladder-12 officer and told him to search and ventilate exposure Bravo.	0858-0859	Ladder-12 officer acknowledged, then radioed command that they were in Bravo and that original dwelling had smoke on 1st and 2nd floors (rear).

Incident Conditions	Time	Response & Fireground Operations
Engine-45 officer radioed command with a broken transmission, (that they were bringing out a…) command was in visual with Engine-45 officer and acknowledged over the radio and told dispatch to send a medic unit immediately with stretcher to front of the fire dwelling.	0900	Civilian located on first floor and removed from fire building (Deceased).
Charlie division (Battalion Chief-3) radioed command to report he had fire in the breezeway and needed a line stretched.	0900	Command acknowledged.
Command called Ladder-14 officer. Command called Engine-45 officer and request a progress report on the interior. Command called Engine-45 officer and told him fire had extended to second floor and Engine-50 would be coming in behind him on first floor.	0901- 0902	Ladder-14 officer reported back that primary is on the way. Engine-45 officer radioed back but transmission unreadable.
Victim's data logger showed PASS/SCBA turned on (*note: the time information is from the internal clock on PASS device a different time source from other entries in the timeline*).	0902	(*Electronic data log work sheet provided in Appendix 1*)
Engine-45 DPOP radioed Engine-45 officer.	0903	Engine-45 DPOP advised that he had a new hydrant and that water is coming now.

Incident Conditions	Time	Response & Fireground Operations
Command called Engine-45 officer and advised of the fire conditions on second floor and he (Engine-45) had Engine-50 coming in behind him and needed them to make the second floor.	0905	Engine-45 officer acknowledged and told command of trouble making stairs due to the debris inside.
Command told division Charlie that he had Engine-13 stretching a line to him.	0905	
Engine-45 officer called Engine-45 DPOP. Engine-34 officer told Engine-34 DPOP to send water.	0906	Engine-50 DPOP told Engine-50 officer that he had a bad hydrant. Battalion Chief-8 aid gave progress report of "all hands in-service, heavy fire, first and second floors" and confirmed the incident address with dispatch.
FCC provided information to Battalion Chief-8 aide and command regarding information that someone in the building (exposure Delta) cannot get out of their property.	0907	Battalion Chief-8 aide acknowledged, and Command acknowledged and said that he would send someone in.
Command told all companies operating-exit the building they were going to switch to a defensive attack.	0907	**Command repeated this defensive command twice.**
All hands response dispatched: Deputy Chief-2, Incident Safety Officer, Emergency Service-1, and 3, Fire Marshal-13, and 15, Medic-36.	0907	Deputy Chief-2 responded at 0943 and arrived at 1002. Note: Deputy Chief-2 response and arrival were delayed due to a communication issue.

Incident Conditions	Time	Response & Fireground Operations
Command called Division Charlie and told him that they were pulling everyone out of the building and to get a PAR, (Personnel Accountability Report) then they would regroup and go back inside.	0908	Division Charlie gives PAR for Ladder 12 and told Command he was still waiting for a hoseline to come to the rear.
Command called Engine-45 officer and told him to exit the building and bring his members outside and standby for a PAR and then gave the same message to Engine-50 officer.	0908	Battalion Chief-8 aide gave FCC a report of an exterior attack and that they were doing a PAR.
Victim's helmet camera shows that he is outside on side Alpha.	0908	
Command called Engine-34 officer and told him to make sure and back out your crew and standby for a PAR.	0909	Engine-50 DPOP radioed Engine-50 officer and told him they had a second bad hydrant.
Command called Engine-45 officer. Command called Engine-50 officer.	0909	Engine-45 officer confirmed he had a PAR outside the structure. Engine-50 officer responded that they were making their way out.
Command called Engine-13 officer then called Ladder-14 officer.	0910-0911	Engine-13 officer acknowledged PAR and Ladder-14 officer (told his members to do a face to face out front and acknowledged PAR.
Battalion Chief-8 aide told FCC that they were in an exterior attack and all members accounted for.	0911	**FCC acknowledged the Battalion Chief-8 aide and advised of elapsed time of 20 minutes, Battalion Chief-8 was not aware on the tac channel.**

Incident Conditions	Time	Response & Fireground Operations
Engine-45 officer's PASS data logger shows several sensing to pre-alarm entries.	0911-0916	These are likely lack of movement logs (the victim was recorded outside by his helmet cam at 0908) and reset by user and turned off at 0916.
Command called Division Charlie and asked for status. Command acknowledged Division Charlie and asked FCC to send utility company. Command requested 2 more engine companies special call.	0913	Division Charlie reported he was in the rear with Engine-13 and Ladder-12 still waiting on water and that fire was extending to exposure Delta and that he needed the electric utility company in an emergency response.
Operations change back to offensive Command called Division Charlie and told him that they had Engine-34 back on the first floor and that they were having water problems in the front as well.	0914	Division Charlie said they would help him (Command) out as soon as they could get water.
Special call for Engine-59, Engine-29 and Medics 34, 44 transmitted.	0914	Engine-59, Engine-29 both arrived 0918, Medics 34, 44 arrived 0929-0930.
Engine-50 officer called Engine-50 DPOP and told him that he needed water. Engine-13 officer called Engine-13 DPOP and told him to send water. Command told FCC to advise the first additional engine that arrived to assist Engine-50 DPOP to establish a water supply.	0915-0916	Engine-50 DPOP told him that he was working on getting a hydrant that works. He was working on his third hydrant (frozen). Engine-45 DPOP called another Engine and told him to send water (to Engine-45). Dispatch acknowledged and advised that Engine-59 and Engine-29 were the additional units dispatched.

Incident Conditions	Time	Response & Fireground Operations
Engine-13 Tip radioed that they were ready for water and leaving shortly. Battalion Chief-8 Aide advised dispatch that Engine-59 to assist Engine-50 DPOP with water supply-acknowledged.	0916	Command called division Charlie and told them that Engine-34 would be coming through exposure Delta with a charged hoseline and that he had Engine-45 operating in the front with a charged hoseline.
Engine-45 DPOP called Engine-45 officer and told him he had a good water supply. Engine-13 DPOP told his officer that he had water.	0917-0918	Engine-45 officer acknowledged. Engine-13 officer relayed to his tip man that water was coming.
Command asked Engine-50 officer what the fire conditions were on the first floor. Command asked division Charlie for a report. Command acknowledged and told him they had Engine-50 on the first floor.	0919-0920	Engine-50 officer told command that there was a lot of trash inside and then the radio transmission cut off. Division Charlie reported he had Engine-13 and Engine-34 and knocking down the fire impinging on exposure Delta.
FCC advised command that there was a female in distress in a nearby structure.	0924	Command acknowledged and asked emergency medical supervisor (ES-9) to check on it.
Engine-45 officer's Data logger shows the PASS unit being powered back on.	0925	
Command called Engine-50 officer for a report on how they are doing on the first floor. Command acknowledged.	0925	Engine-50 officer told command that Engine-45 had the hoseline and that he was on his way out to change his cylinder, he also said that Engine-45 had a positive water supply.

Incident Conditions	Time	Response & Fireground Operations
Command called Engine-45 officer for a progress report on first floor.	0925-0926	Engine-45 officer radioed back that they had their hoseline on the first floor, lots of debris inside the dwelling and they were going to make an attempt to reach the second floor.
Command called Division Charlie and told them to take a line from the rear to the first floor and back up E-45 while they went to second floor. Command acknowledged Division Charlie and then told Engine-50 officer that they were charging a line for him and they would be good to go (back up Engine-45). Command called Engine-45 officer and told him that Engine-50 had water and would be coming in behind him.	0927-0929	Division Charlie told command they couldn't because Engine-13 did not have water. Engine-34 had water (in the rear) but they were needed due to fire impinging on exposure Delta. Engine-45 officer acknowledged.
Command told Engine-45 officer to hold the first floor and that Engine-50 would be (unintelligible) the second.	0931	Safety Officer arrived 0931.
Engine-45 officer's Data logger showed the PASS indicating sensing to pre-alarm.	0926-0939	No reset indicated by PASS data logger from 0926.40 through 0939.02 (a total of 7 data log entries indicating sensing to pre-alarm with no further step up to full alarm motion until log entry at 0939).
Collapse Occurred Command orders all units to exit the building and that they were going defensive.	0933	Command told all units to stand by for a PAR.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Incident Conditions	Time	Response & Fireground Operations
Command called FCC and told them to sound the emergency evacuation signal. Engine-50 officer activated his emergency button (portable radio).	0934	FCC acknowledged, and told Command that they had an emergency activation signal coming from Engine-50 Pak (portable radio emergency button).
Mayday-Mayday-Mayday, Engine-50 officer, radioed he couldn't find Ladder-12 Pak and that they were on the second floor.	0934-0935	Command asked Engine-50 officer for his location, then Ladder-12 Pak radioed that he had made it out the rear. Division Charlie radioed Command that he had accountability for Engine-50 Pak.
Command called for all units to standby for a PAR. **Command called for Engine-45 officer.**	0936	FCC sounded emergency evacuation signal over the radio.
Command told all units to standby unless they had a priority. Command called Engine-45 officer twice. Command told dispatch that they were still looking for Engine-45 officer. Command called Engine-45 officer. Command called Engine-50 officer for PAR.	0937-0938 0939	No response from Engine-45 officer. No response from Engine-45 officer. Division Charlie told Command they had PAR in the rear with Engine-34 and Engine-13. Engine-50 acknowledged and said he had PAR.
Engine-45 officer's Data logger showed the PASS indicating pre-alarm to alarm. (see Appendix 1)	0939	**This data logger entry at 0939.14 to full alarm was by *motion not manual alarm.***

Incident Conditions	Time	Response & Fireground Operations
Last recorded entry from electronic data logger occurred at 0939.14.(see Appendix 1)	0939	Note: Engine-45 officer's SCBA had to be cut when he was extricated. The wires for the integrated PASS were also cut and there was considerable effort by the manufacturer and the Fire Department's Health and Safety office to remove/replace parts to read the data from the requested date.
Mayday response was dispatched.	0936	Engine-55, Engine-43, Ladder-8, Battalion Chief-4, Medics 13, 15.
Command radioed Ladder-14 officer for PAR. Command ordered Engine-55 and crew to front of the dwelling.	0940-0941	Ladder-14 officer confirmed PAR. Engine-55 acknowledged.
Car 1 dispatched (Fire Commissioner).	0942	Car 1 on scene 0947.
Command asked Division Charlie if he could place a line to the second floor from the rear.	0944	Division Charlie radioed, negative, they had a unstable kitchen floor and partial collapse and extension in the rear.
Squad-72 roof radioed command that they had a partial collapse in the rear and to pull anyone out if they were in there. **Command radioed FCC and advised that they had all companies out of the building, but they had one member unaccounted for, start the collapse unit and send a 2nd alarm.**	0947	Command acknowledged.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Incident Conditions	Time	Response & Fireground Operations
FCC tells Battalion-8 aid of the 2nd alarm chiefs. Battalion-8 aid acknowledged and updated that they were still in a defensive mode and that they had one member they were trying to remove from the building.	0952-0955	Second alarm units dispatched Battalion Chief-9, Battalion Chief-11, Battalion Chief-1, Engine-20, Engine-35, Engine-25, Engine-28 and responded. Additional units were Ladder-10, Ladder-18, Battalion Chief-10, Car-5.
RIT group radioed Command to tell him that they shut hoselines down inside and to request quiet on the fireground.	0955-0958	Command called all companies to shut their hoselines down and requested quiet on the fire scene.
Squad-72A officer reported during NIOSH interviews that he heard a PASS sounding.		Squad-72A officer reported that when they located Engine-45 officer and took his facepiece off, there was an air sound and the vibration alert was sounding from the victim's SCBA.
RIT group radioed command that they were going to fog out the first floor (use the hoseline to help ventilate).	0958	Command acknowledged.
Deputy Chief-2 arrived and asked for a progress report.	1002	Command told him that they had evacuated the building of all members and Engine-45 officer was not accounted for, but they had eyes on him and Rescue-1 and Squad-72 were trying to remove him.
Operations Division established.	1007	

Incident Conditions	Time	Response & Fireground Operations
Operations Division gave an update to Command.	1010-1011	RIT group supervisor reported that there had been an interior collapse and parts of the building were unstable and they were in the process of shoring and the rescue operation. Collapse unit arrived.
Command gave a progress report to FCC.	1022	Report - *Crews had shored up the collapse on the first floor and located the downed firefighter and that they were in the process of extricating him to the exterior of the building.*
Car-5 assumed command.	1027	
	1035	**Victim extricated, operations called command and advised that they extricated the firefighter (Engine-45 officer) and they were on their way out.**

Building Construction and History

Note: Much of the following building construction description and history for the fire structure is based on a NIOSH funded expert review and report provided by Chief Christopher J. Naum, SFPE (NY). His full review report of the incident is included in Appendix 2.

Additionally, the Fire department's Health and Safety Office After Action Review Team investigated this fatality and provided NIOSH with extensive information, including the fire department's history of fighting fires in highly congested urban areas such as this row house community. The fire department's Health and Safety Office After Action Review Team completed a comprehensive review and investigation of this incident and many of the findings, resources and references have been referenced and/or included in this report.

There was additional analysis needed for building material identification used during the period of construction. West Virginia University analyzed wood joist samples in their wood science laboratory and identified them as Eastern Hemlock.

Additionally, samples of the brick mortar were analyzed by the National Institute of Standards and Technology (NIST) and noted that they lacked Portland cement as an ingredient. Appendix 3 contains the findings by NIST.

The fire structure was a 2-story, approximately 1,038 square feet, single family, occupied residential row house of ordinary construction (Type III) masonry, brick and wood joist built between 1880 and 1888 (see Photo 1 and floor layout in Diagrams 1 through 5). It was located on a narrow street comprised of thirty-four attached row house buildings that spanned the city block. Similar row houses made up the exposures on all four sides. Side Charlie had a slight buffer area for utilities, but not enough room for access by fire department vehicles or equipment.

Photo 1. Side Alpha of incident dwelling, including view of exposures Bravo and Delta. (Photo Courtesy of Google Earth)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

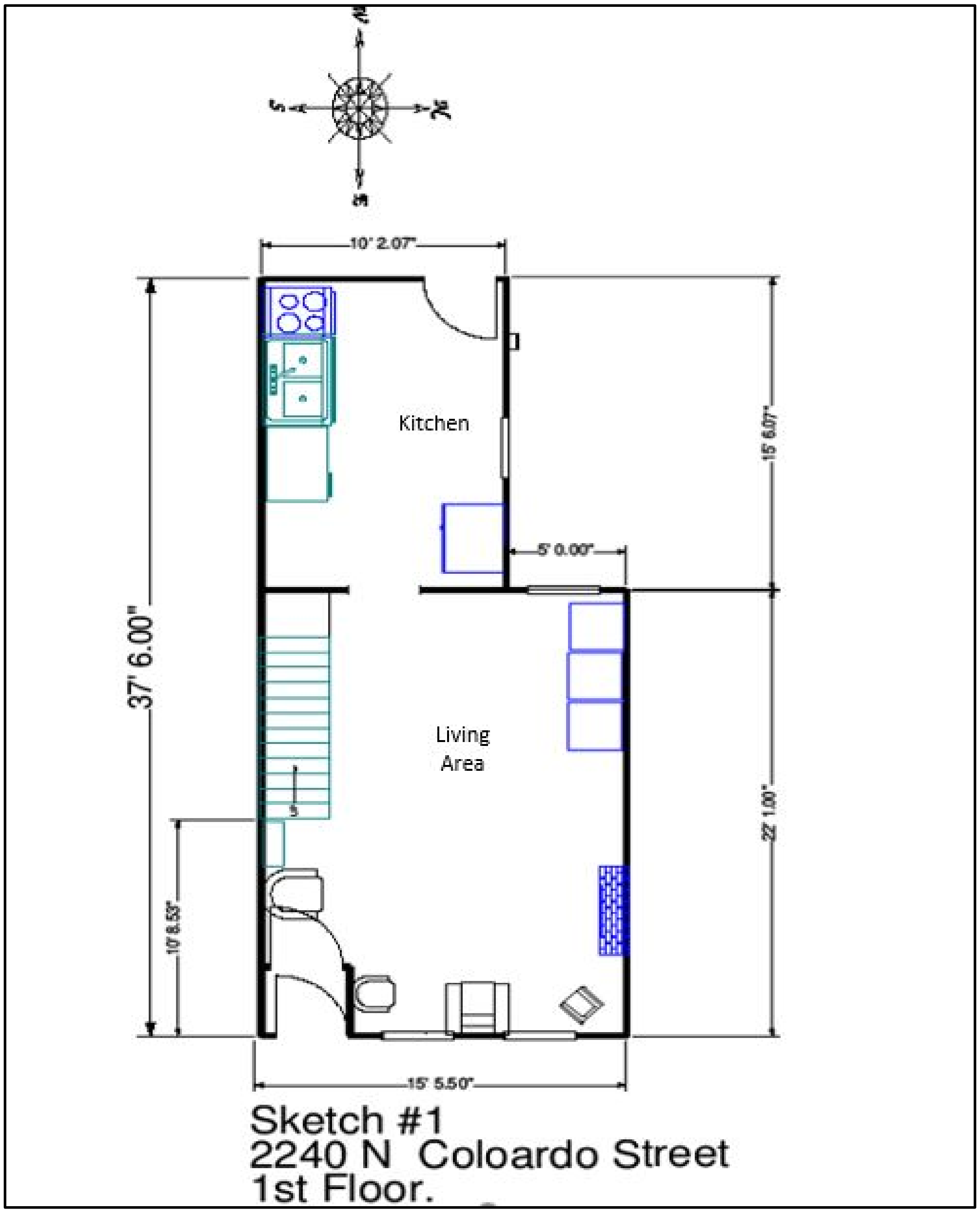

Diagram 1. Sketch of first floor layout.
Note: there was severe clutter conditions not depicted in this sketch.
(Diagram courtesy of fire department Health and Safety Office)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

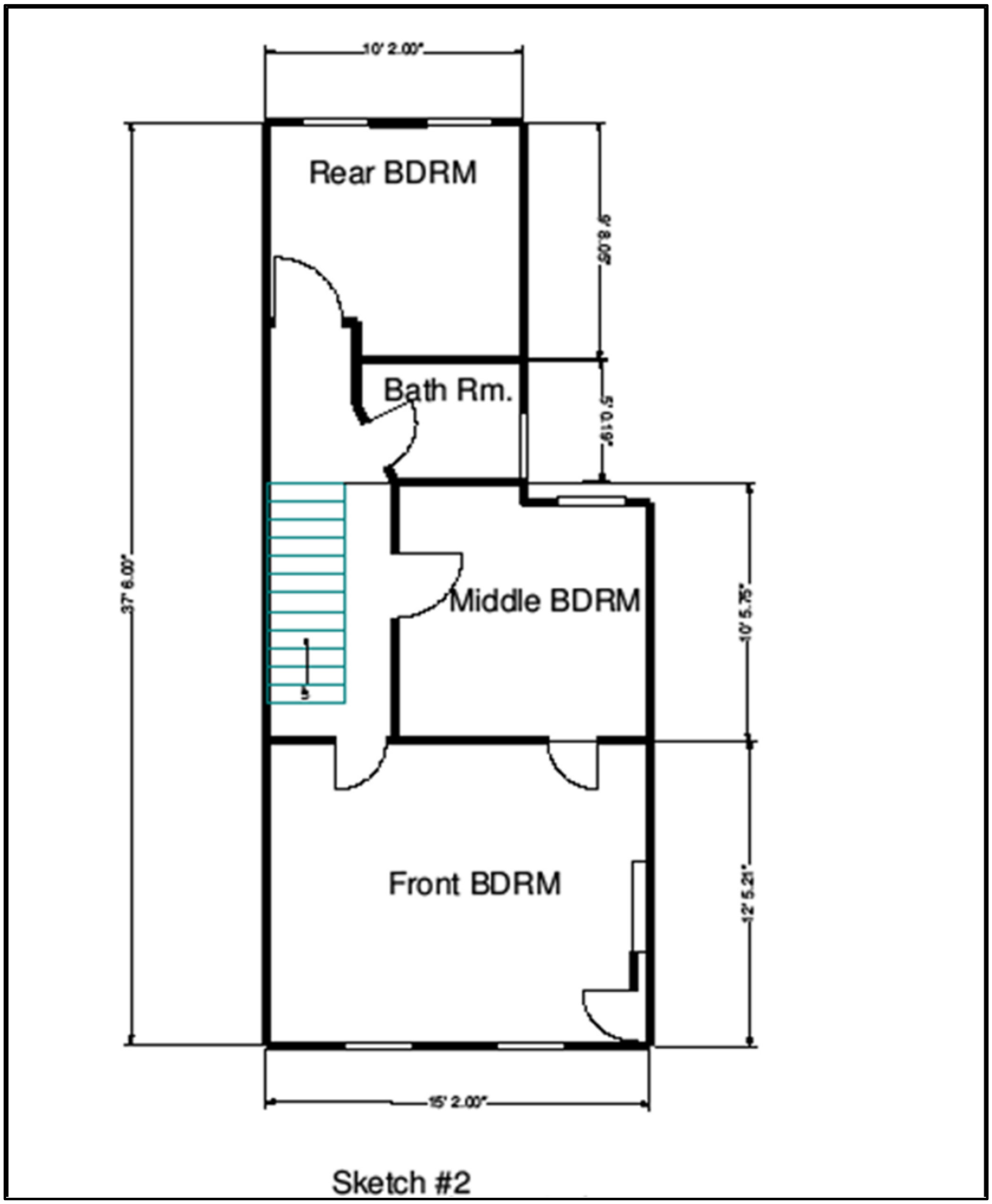

Diagram 2. Sketch of second floor layout.
Note: there was also severe clutter conditions not depicted in this sketch.
(Diagram courtesy of fire department Health and Safety Office)

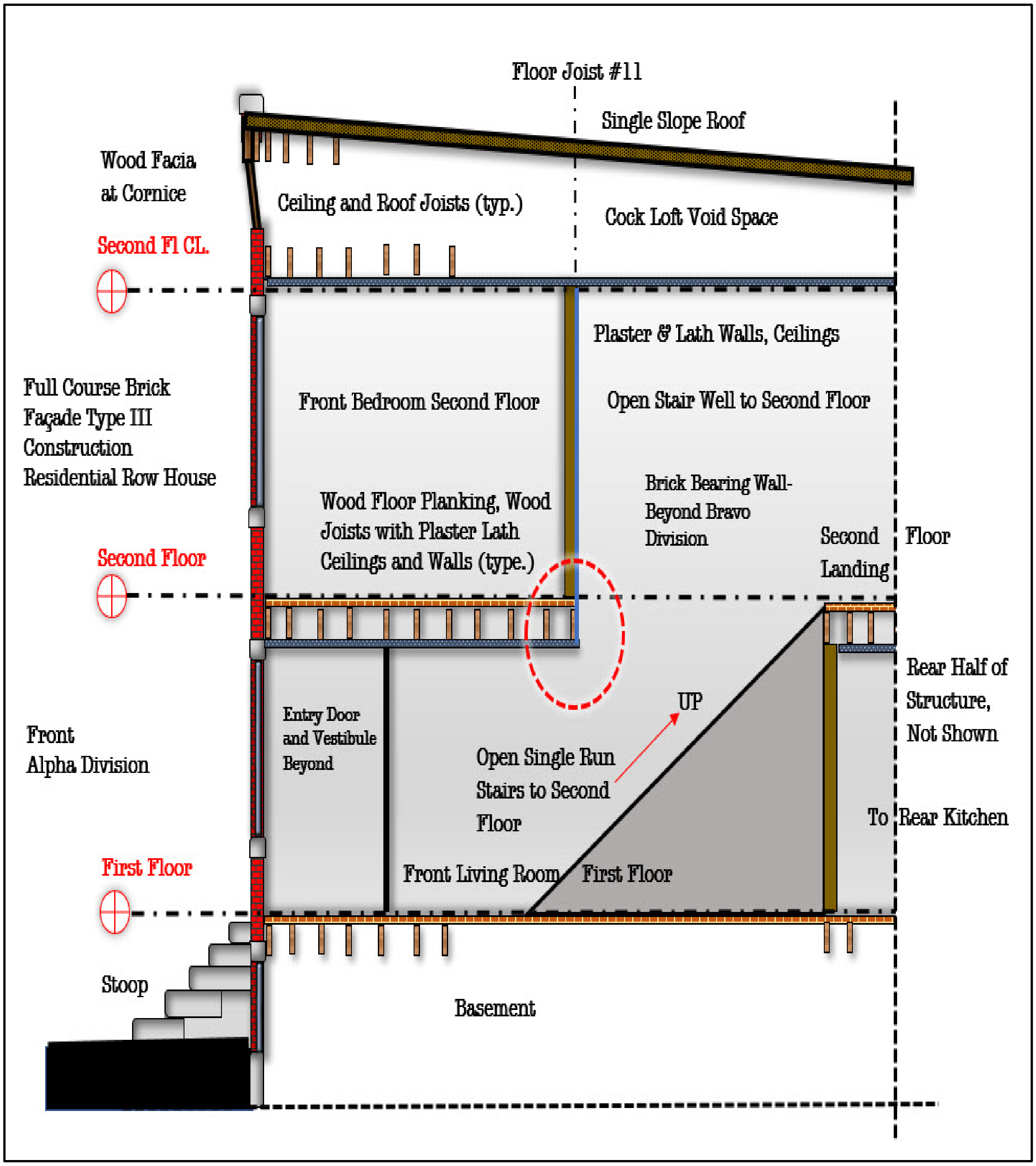

Diagram 3. Cross-Section of Row house. Red dotted circle indicates where second floor joists framed up to the stairwell opening
(Graphic Courtesy of Buildingsonfire.com | C.J. Naum)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

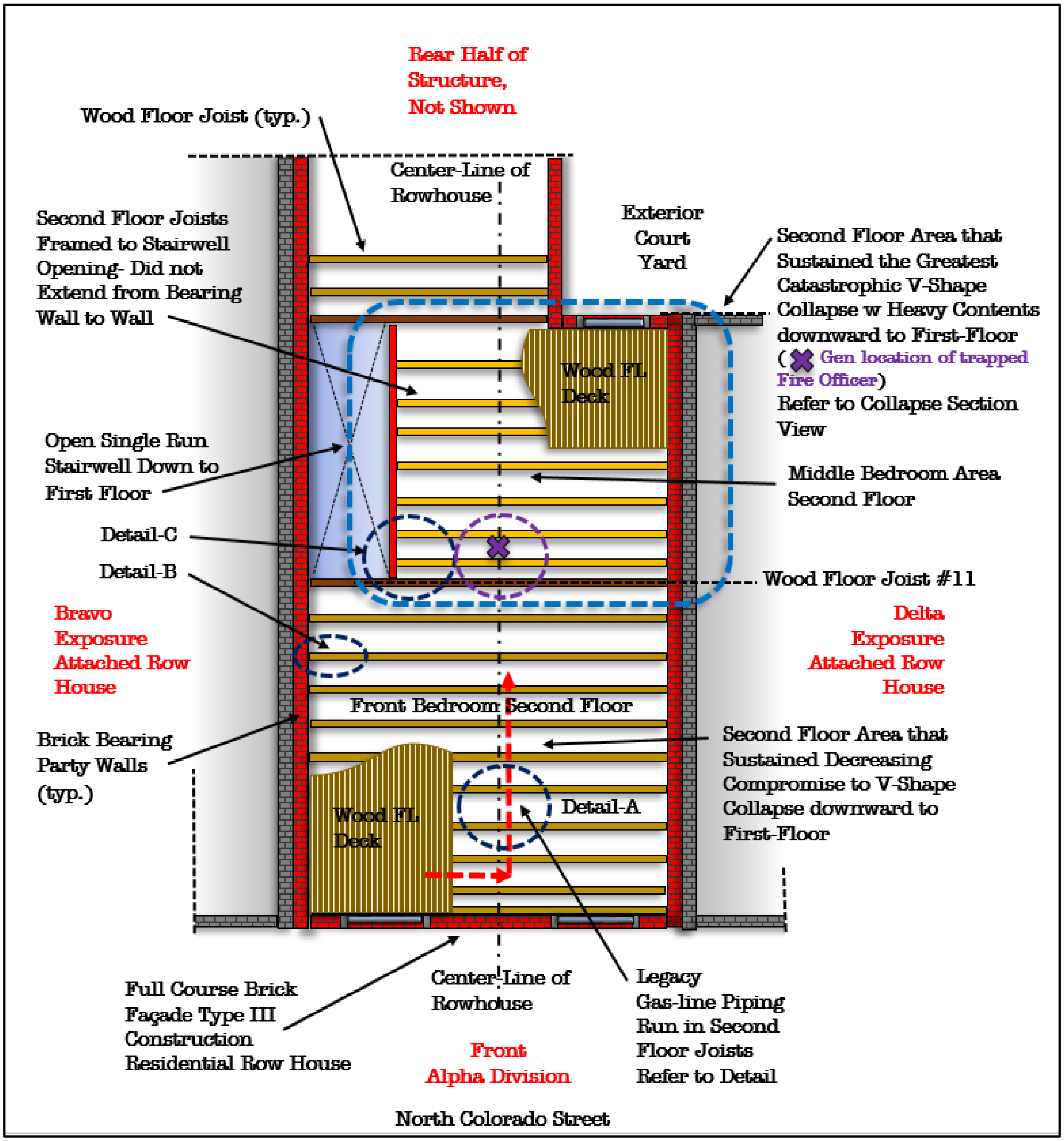

Diagram 4. Row house Floor Joist Plan-Second Floor. Detail A indicates gas piping run in joists. Detail B indicates second floor joists extend from bearing wall to bearing wall. Detail C indicates joists terminating at stairwell opening.
(Graphic Courtesy of Buildingsonfire.com | C.J. Naum)

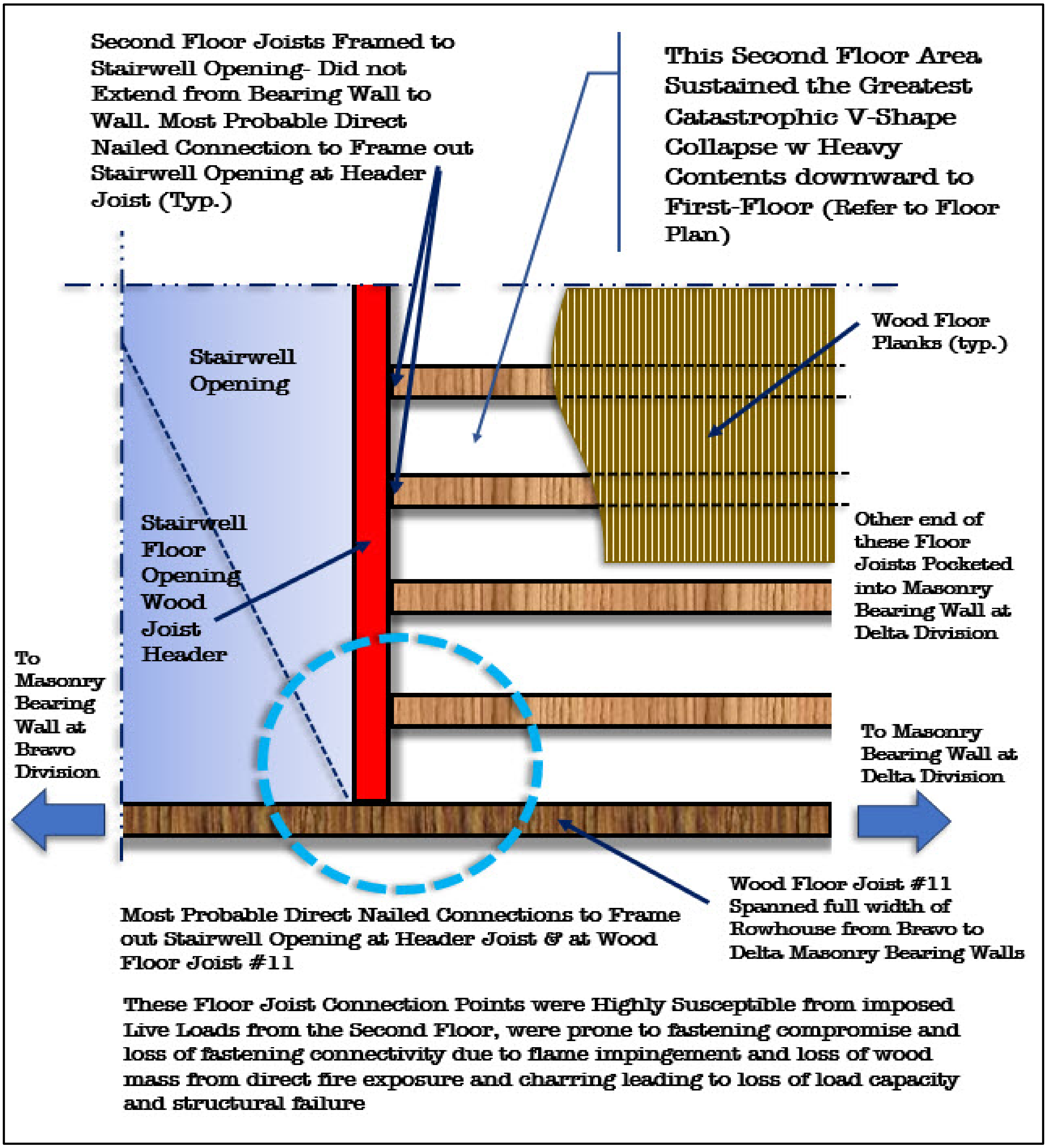

Diagram 5. Stairwell Opening Framing and Second Floor Joists.
(Graphic Courtesy of Buildingsonfire.com | C.J. Naum)

The building's style and design are commonly referred to as a row house or *Workingman's House* with defining characteristics that include:

- Two-floors of occupied space (approximately 519 square foot per floor) with a limited window basement below grade
- Masonry brick bearing-party walls with masonry front facades and narrow windows (a party wall is a wall that is shared by two occupancies)
- 3-inch x 7.5-inch wood floor joists as structural support pocketed into the masonry bearing walls (WVU wood science division identified the floor joist as Eastern Hemlock wood with a moisture content of 3.6%).
- Eastern Hemlock is moderately light weight, and moderately weak in strength, moderately weak in bending strength and moderately low in splitting resistance. Hemlock is similar to Spruce in appearance but is considered inferior and used almost exclusively as a cheap rough-framing timber [Naum 2014].
- A unique feature of this row house (as well as the exposure structures and likely in other surrounding row houses) was a 1-inch by 1-inch notch cut in the upper top portion of the wood joists to allow for a gas pipe when gas service was provided in the late 1800's. These notches are in every joist in a line from Side A inward approximately 20 feet (see exemplar from exposure in Photo 2).
- Plaster and lath over wood framing interiors.
- Single sloping timber rafter roof with wood deck and covering with a brick cornice on Side A.
- Masonry walls on Bravo and Delta Exposure (party walls), brick wall on Side A and wood frame backing on Side C.
- Access from street via a vestibule (Side Alpha).
- Single run stairway located adjacent to the left along the wall just after the vestibule.
- Flooring consisted of material over 3-inch x 1-inch planking.
- Indoor kitchen, plumbing and heating (this unit was equipped with gas lighting at one time and the gas feed pipe was run through a cut in the floor joists as seen in Photo 2).
- The row house was in a poorly maintained condition with structural deterioration and excessive clutter and heavy contents with hording like conditions.

- Narrow utility alley (no access for vehicles) on side Charlie with partial fencing and overgrown vegetation restricting access to a working area.

- The department reported that although the dwelling was occupied, (a deceased civilian was located and removed early in the fire), it may not have had an operable fixed heating system. The dwelling had roof and wall deterioration, and open areas directly exposed to the environment [Naum 2019].

- The department reported evidence that significant clutter conditions of materials by the occupant over time and a significant degree of clutter that was present and encountered by operating FD companies throughout the rooms and floors of the structure that imposed critical operational impediments and may have affected the structure during the early development stages of the fire within the room compartments [Naum 2019].

- Occupied row houses on either side (see Photo 1).

Photo 2. Exposure row house exemplar photo showing the floor joists cut to allow for gas pipe and the gas pipe drop for the light fixture. Electric light fixtures were attached to these pipes in later years.
(Photo courtesy of fire department Health and Safety Office)

Personal Protective Equipment

Engine-45's officer was wearing full personal protective equipment (PPE) including NFPA compliant coat, bunker pants, helmet, gloves, boots and a 2013 Edition, 5500 psi, 1800-liter, Self-Contained Breathing Apparatus (SCBA). The NIOSH Division of Safety Research sent the victim's SCBA to Intertek labs in New York for a Posi-check pneumatic flow performance test. The testing was witness by the Health and Safety Office personnel from the department. There were no issues found with the SCBA's pneumatic performance.

The victim's integrated personal alert safety system (PASS) device was examined and the electronic data logger was downloaded courtesy of a manufacturer's vendor due to significant damage to the PASS housing. A partial PASS electronic data log was collected, and a marked version is included in Appendix 1 of this report. This SCBA with integrated PASS did not have pneumatic data logging capability, just the electronic PASS data.

The PASS device electronic data log indicated the victim initially turned on the SCBA at 0902:34 (according to the PASS internal clock). The Engine-45 officer likely changed his cylinder out when the PASS device recorded a sensing to off at approximately 0916:40. This may have been during the time the strategy had changed from offensive to defensive. At approximately 0925:04, the Engine-45 officer's PASS data log indicated an *Off to Sensing* mode indicative of the SCBA being turned back on. The Engine-45 officer's data logger showed the PASS device indicating *sensing to pre-alarm* from 0926:40 to 0939:02 with a total of 7 data log entries with no reset. At 0939:14 (internal PASS clock) the Engine-45 officer's data logger indicated *pre-alarm to full alarm motion*. It is important to note that the alarm was motion and not manual, which indicates the alarm sounded due to a *lack of motion by the officer and not by him manually activating it.*

The last entry in the data logger was the final log of 0939:14 which showed the PASS going into full alarm by lack of motion (not manual). The victim's SCBA was cut off while he was being extricated which also cut the electronic wires for the PASS device. This may have damaged the internal electronics and made downloading the stored information difficult. It is also the likely reason for the missing electronic data logs that would have followed (i.e., alarm reset, alarm to off or low battery). The manufacturer provided considerable assistance to NIOSH investigators to obtain the information stored in the PASS device. This involved considerable and delicate technical work to gather basic information from the PASS device. The limited data that was able to be removed from the device appeared to be reliable.

The department's SCBA breathing-air compressor maintenance records were checked by NIOSH personnel. The SCBA in use by the department at the time of the incident were only one year old and there were no reported problems.

Although not considered a contributing factor in the line-of-duty-death in this incident, the investigation by the fire department's Health and Safety Office noted a need to update the training on SCBA filling of the newer high pressure (5500 psi) cylinders. This was also noted by NIOSH investigators when reviewing the initial on-air times for the first crews in and early end-of-service-time-indicator (EOSTI) activation. 5500 psi cylinders require a full charge to deliver the 1800 liters that provide a rated service time of 45 minutes. *Note: a rapid fill (sometimes referred to as a hot fill) will result in a loss of pressure after the cylinder cools. It is important to follow the manufacturer's instructions on the rate of fill to achieve the proper operating pressure. Some cylinders may require slower fill rates and/or the ability to top off after they have cooled down. Firefighters need to understand that a rapid fill may result in an 1800-liter, 5500 psi cylinder having only a partial fill to capacity after it has cooled down. To obtain the 45-minute rated capacity of 1800 liters, the cylinder needs to be slowly filled to an operating pressure of 5500 psi.*

The department's Health and Safety Office did a considerable amount of work to identify typical fill rates and how to reduce the "hot fill" air loss which can be significant in a small volume/high pressure cylinder. Their work is noted in Recommendation 13 in this report. Although the cylinder pressure and air usage was not considered a contributing factor in this fatality, NIOSH provided a recommendation on filling SCBA air cylinders as a best safety practice for the fire service. This can be useful to other departments who have upgraded to higher pressure 5500 psi SCBA and may not be aware of the need to alter fill procedures, upgrade breathing air compressors and/or increase the number of fill sites in the operations area to reduce out of service time.

Weather and Road Conditions

The weather was a primary contributing factor in this incident. Firefighters experienced significant interruptions in water supply with as many as 6 inoperable (possibly frozen) fire hydrants as well as a frozen nozzle tip and difficulties with personal protective equipment including SCBA (frozen head straps and a head net in a SCBA facepiece). They also faced extreme cold, snow and ice in the response roadways and a narrow street that had cars parked on one side of the street, making it impossible for heavy fire apparatus to access the front of the fire building. Crews had to hand stretch handlines 260 feet past 15 row houses from intersecting larger streets that could accommodate engines and ladders (see Photos 3 and 4).

At approximately 0854 hours on January 6, the weather in the immediate area (Airport) was reported to be 9 degrees Fahrenheit, with a dew point of -7 degrees Fahrenheit, and the relative humidity was 48%. Wind conditions were up to 20 miles per hour (mph) from the west, and within the hour having gusts from the WNW at 35 mph. [Weather Underground 2019].

Photo 3. Red pin and horizontal arrow point to incident structure, vertical white arrows indicate the narrow access to side A due to narrow roadway and on street parking and very limited access to the utility alley on side C.
(Photo courtesy of Google Earth)

Photo 4. 1800's era row homes with dense construction and narrow streets. Incident location noted with red pin and exposures noted.
(Courtesy of Google Earth. Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Investigation

On January 6, 2018, a 42-year-old Lieutenant (Engine-45 officer) was killed after becoming trapped in an interior structural collapse while fighting a fire in an 1800's era row house.

At approximately 0851 hours a box assignment was dispatched for a reported dwelling fire in a middle of the block row house in an older section of the city. Dispatched to the box assignment were Engine-45, Engine-13, Engine-34, Engine-59, Ladder-14, Ladder-12, Battalion Chief-8 and Battalion Chief-3 and Medic-25. Engine-50 was out on another assignment, but cleared and was added to the dispatch assignment. Firefighters arrived to find a two-story row house heavily involved in fire in the middle of the block. The narrow streets and resident parking prevented fire apparatus from accessing the front of the dwelling and there was no access to the rear of the dwelling except through an alleyway overgrown with vegatation.

En-route to the fire, firefighters had a report of possible victims trapped in the structure. Engine-45 was the first engine to arrive and parked on the main street. Engine-45's officer instructed his crew to stretch a 3-inch line connected with a gated wye to a 1 ¾ inch handline and for Engine-45 to find a hydrant to secure a water supply. The Engine-45 officer sized up the incident and gave his initial arrival report of a two story, 15 feet by 35 feet middle of the row dwelling with fire showing on the first floor (see Photos 5 and 6).

The Engine-45 crew (Pak and Tip[1]) hand stretched approximately 300 feet of 3-inch hoseline along with 150 feet of attack line to the middle of the block (15 row homes in) from Engine-45's location approximately two hundred and sixty feet down a snow and ice covered street to the front of the fire dwelling (see Photos 5 and 6).

[1] In this jurisdiction there are four firefighters assigned to an engine. An officer, Driver/Pump/Operator/Pump (DPOP), and the PAK firefighter and TIP Firefighter. The position of a PAK is to assist in hose advancement to the seat of the fire and the TIP firefighter is the nozzleman.

Photo 5. Fire conditions pre-arrival of fire department time: 08:55:20.
(Photo courtesy of fire department from resident video)

Photo 6. Initial fire department operations.
(Photo courtesy of fire department from video taken by area resident across the street)

Battalion Chief-8 (BC-8) arrived and assumed Command *Note: Battalion Chief-8 would become the incident commander. He was an experienced fire officer with 28 years of service in busy companies, with 4 years as a Battalion Chief. Prior to this incident, he had sent out a notice at the beginning of the shift warning of icing conditions, "slick streets" and the possibility of frozen hydrants.*

Battalion Chief-8 reported during interviews that he observed smoke at the roof top on arrival then heavy fire at the 1st floor windows. The Battalion Chief-8's aid was able to drive up the narrow street with his SUV. Battalion Chief-8 advised the Fire Communications Center (FCC) of heavy fire conditions on the first floor of the dwelling and placed 3 engines and 2 ladders in-service. Command then ordered Engine-34 to go to the Delta Exposure with a 1¾-inch hoseline and check for fire extension. Command told Engine-50 to stretch a 1¾-inch line via side Alpha and back up Engine-45.

Engine-45's Driver/Pump/Operator/Pump (DPOP) charged the 3-inch and 1¾-inch hoseline off the Engine-45 internal tank. The Engine-45 officer directed the Engine-45 Tip to flow water from the outside, but no water would come out. During interviews, the Engine-45 Tip stated that the nozzle was frozen. Engine-45's officer instructed the Engine-45 Tip to remove the stream straightener off the nozzle and this allowed water to flow. This did knock the fire down on the first floor (see Photo 6).

The initial 2 engines, 2 ladder trucks and Battalion Chief-8 began initial fire suppression and rescue efforts. The crews making entry found excessive clutter (hoarding conditions) that hampered their ability to enter and search. Battalion Chief-3 arrived and was assigned Division Charlie.

The Engine-45 Pak reported during interviews that after they stretched hoselines to the dwelling (Engine-45 officer, Engine-45 Pak and Engine-45 Tip), located a civilian behind the door and removed him to the street. The crew was still operating off internal tank water from Engine-45, and re-entered the structure and tried to locate the stairs to the second floor. Engine-45's Tip reported that they flowed water into the living room area until they ran out of water and exited the structure. Command ordered Ladder-12 to exposure Bravo to search for any other occupants and fire extension.

Ladder-14 reported they were conducting a primary search. Division Charlie advised Command that there was fire in the breezeway (area at the corner of side C and side D) and that they would need a hoseline stretched to side C. Command acknowledged and advised dispatch that the fire had extended to the 2nd floor and then radioed the Engine-45 officer with the same information. Command told the Engine-45 officer that Engine-50 would be coming in behind him on the 1st floor and for Engine-45 to go to the 2nd floor. The Engine-45 officer told Command that he was having difficulty getting to the stairs due to excessive clutter. Engine-50 entered the dwelling to back up Engine-45. Engine-45's DPOP radioed that he had a bad hydrant and was waiting for water while Engine-50 operated their hoseline.

An "All Hands" message was transmitted at 0907. This meant that 4 engines and 2 ladders were working (in-service) and the protocol was that a Deputy Chief, Incident Safety Officer, EMS Division Chief and Squad-72 were dispatched. All Hands units responded and arrived, except for Deputy Chief 2 who was delayed and didn't respond until 0943.

Interruptions in water supply hampered fire-fighting efforts and forced a change in strategy until a reliable supply was established. At approximately 0906, Engine-50's crew reported that they had lost water on their hoseline. At approximately 0908, Command ordered all units to exit the building and that they were switching to a defensive attack. Engine-45's crew exited and changed out SCBA cylinders. Engine-45 officer's helmet camera recorded his exit. Command told Charlie division of the strategy change and for Charlie division to report back with a Personnel Accountability Report (PAR) on their companies. Charlie division reported back with PAR complete on his companies.

Engine-50's DPOP then reported that he had a second bad hydrant, and approximately 1 minute later, Engine-34's officer reported to Engine-34 DPOP that he had lost water pressure on his hoseline. The last member to exit the structure was Engine-50's officer at approximately 0910. Command told FCC that they were in a defensive strategy and all members were accounted for at approximately 0911. FCC acknowledged and replied with a 20-minute elapsed time notification.

At approximately 0913, Charlie division notified Command of fire extension to exposure Delta and that he needed a water supply, and to contact the electric utility company to cut-off power to the structure due to the live wires arching. Command then contacted dispatch to call for 2 additional engine companies (Engine-59 and Engine-29). The Engine-13 crew stretched a hoseline from side Alpha to Charlie via the Delta exposure. Engine-45 reported that he had re-established a water supply and re-charged the 3-inch line that Engine-45 had stretched.

Once the water supply was re-established, crews re-entered the structure to continue to extinguish fire. At approximately 0916, Command radioed Charlie division and advised him that Engine-34 was coming to the rear with a charged hoseline and that Engine-45 was operating in the front of the dwelling with their hoseline. At approximately 0917, Engine-45's DPOP advised the Engine-45 officer that he had a good water supply. Engine-13's DPOP then radioed his crew that water was on its way.

When Engine 45's PAK Firefighter returned to the front of the fire dwelling (he was previously told by Engine-45's officer to return to the apparatus to assist Engine-45's DPOP), Engine-45's officer gave him Engine-45's hoseline and instructed him to continue discharging water onto the first floor. The Engine-45 PAK said he still had air remaining in his SCBA cylinder and re-entered the dwelling just inside the front door. When the Engine-45's Tip firefighter returned to the front of the dwelling (he was previously instructed by the Engine-45's officer to return to the apparatus and bring back additional full SCBA cylinders), the Engine-45's Pak exited the dwelling to change his SCBA cylinder. While replacing his SCBA cylinder, Engine-45's officer gave Engine-45's nozzle to Engine-50's officer. The Engine-50 officer along with the Engine-45 Pak re-entered the structure from side Alpha and used Engine-45's hoseline to continue to knockdown the kitchen area. Division Charlie had Engine-34 and Engine-13 working from the rear with a hoseline flowing on the fire that was extending to the exposure.

The Engine-45 officer and Engine-45 Tip re-entered the structure from side Alpha where they joined 3 other members of Rescue-1 (search man), Squad-72's officer and Engine-50's Pak. The Engine-50 officer and Engine-45 Pak exited for new air cylinders. The Engine-45 officer now had the nozzle and with Engine-45 Tip, they continued to knock down fire. The Engine-45 officer called Command and told him they were trying to make it to the 2nd floor, however there was a lot of debris hampering their efforts. The Engine-45 Tip reported that they made it approximately one third the way up the stairs with the Engine-45 officer on the nozzle and they were flowing water on the 2nd floor.

The Engine-45 Pak and Ladder-12 Pak were outside of the structure on side Alpha. Engine-45's 3-inch line had water, so they used Engine-50's hoseline connected to Engine-45's gated wye and got a second line in operation from side Alpha. The Engine-50 officer was told by Command to take this second line to the 2nd floor. Command told the Engine-45 officer to hold the 1st floor and that Engine-50's crew was coming in and would make the 2nd floor. At this time, there were a total of 5 firefighters on the first floor (Engine-45 Officer, Engine-45 Tip, Engine-50 Pak, Squad-72 Officer, and Rescue-1 Search) with 2 additional firefighters (Squad-72 Tip man and Pak man) in the vestibule area at the front door.

The Engine-50 crew, which consisted of 3 firefighters (Ladder-12 Pak on the nozzle, backed up by the Engine-45 Pak, followed by the Engine-50's officer) entered the building and advanced up the stairs to the second floor. The Engine-50 officer reported that his SCBA head webbing and straps were frozen and that he was slightly delayed in entering the building. There were now two hoselines in operation inside the dwelling. Ladder-12 Pak reported that he made it to the 2nd floor and was in the hallway just off the top of the stair landing. He was flowing the nozzle towards the rear (side Charlie, 2nd floor), then turned and flowed water toward the other rooms in the direction of side Alpha (see Diagram 6).

The Engine-45 officer gave the nozzle to the Engine-45 Tip and they continued to flow water in the 1st floor living room area that kept flaring up. Visibility was reported as zero from different companies during interviews. The Rescue-1 Search firefighter was just inside the 1st floor area and reported that he told the Engine-45 Tip that there was an area of fire towards the front (1st floor) in the living room. The Engine-45 Tip and Engine-45 officer then made their way toward the front and started flowing water. The Engine-45 Pak reported that the collapse occurred approximately 30 seconds after he started hitting the fire in the front of the 1st floor living room (see Diagram 7). The Engine-45 Tip stated that a Rescue-1 member grabbed him and told him to get out.

The crew on the second floor reported that they experienced a shift in the floor and the Ladder-12 Pak yelled to the crew on the stairs that he felt the floor sag. During interviews, he reported the floor sagged approximately 2 inches. The Engine-50 officer ordered the Ladder-12 Pak man off the 2nd floor; however prior to getting back to the stairs, the 2nd floor collapsed into the first floor.

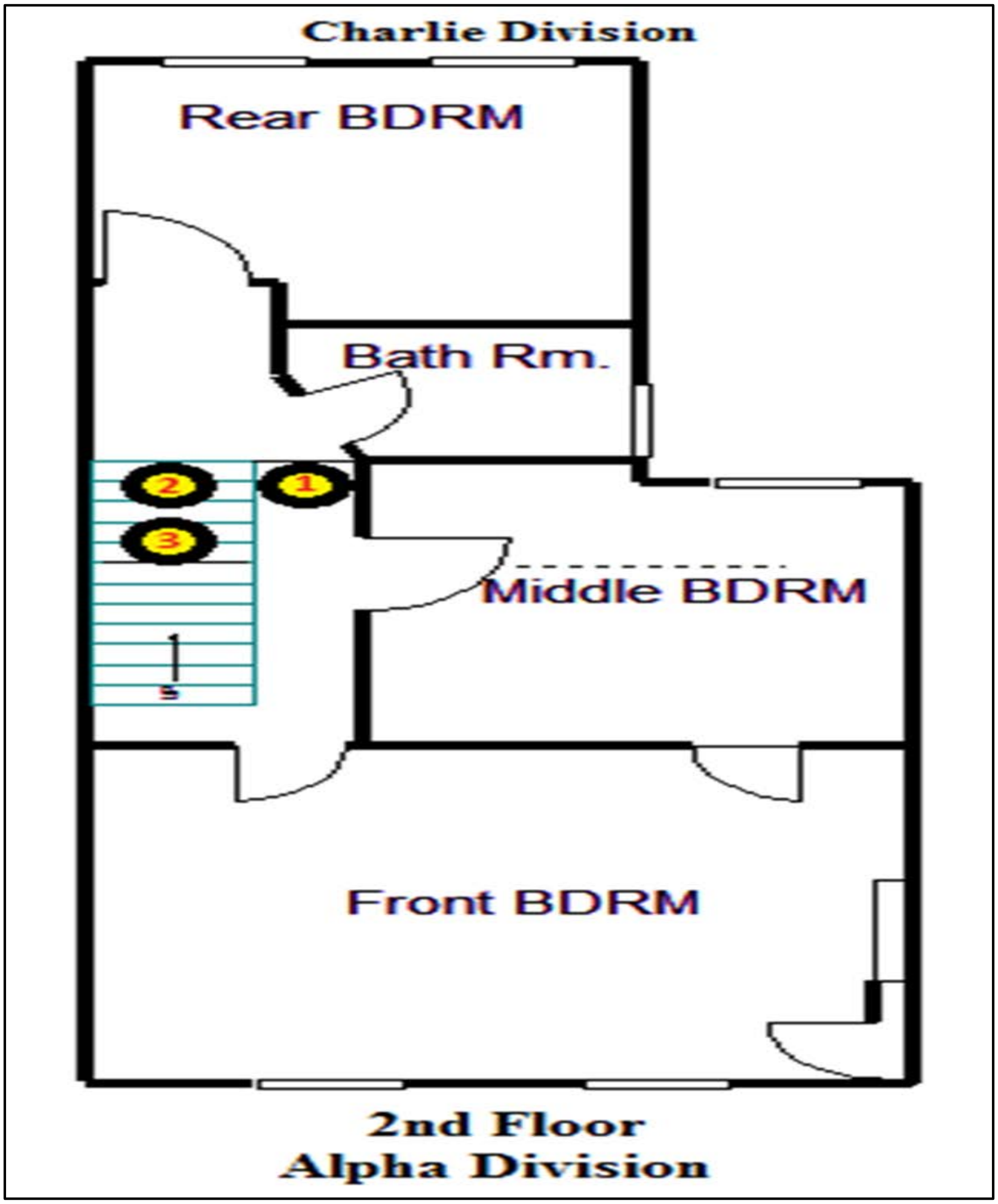

Diagram 6. Location of members on floor 2 at time of collapse. 1 = Ladder-12 Pak, 2 = Engine-45 Pak, 3 = Engine-50 Officer.
(Diagram courtesy of fire department Health and Safety Office, After Action Review Team)

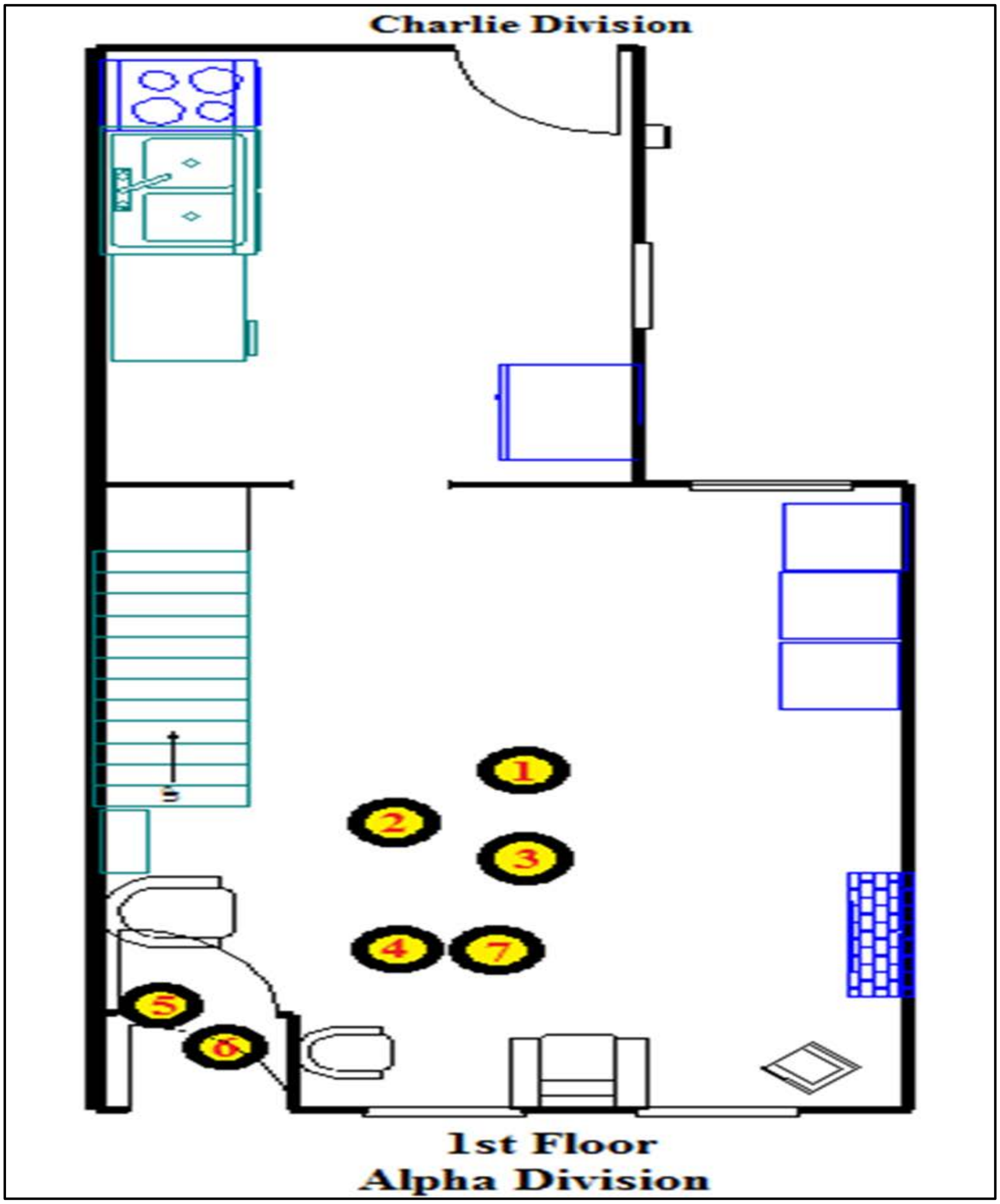

Diagram 7. Location of members on floor 1 at time of collapse. 1 = Engine-45 Officer (victim), 2 = Rescue-1 Search, 3 = Engine-45 Tip, 4 = Squad-72 Officer, 5 = Squad-72 Search, 6 = Squad-72 Pak, 7 = Engine-50 Pak.
(Diagram courtesy of fire department Health and Safety Office, After Action Review Team)

At the time of collapse the following members and companies were inside the structure:

- 2nd floor: Ladder-12 Pak, Engine-45 Pak, Engine-50 Officer
- 1st floor: Engine-45 Tip, Engine-45 Officer (victim), Rescue-1 Search, Squad-72 Officer, Squad-72 Pak, Squad-72 Tip, Engine-50 Pak

Squad-72's officer reported hearing a loud crack and went to the front door (side Alpha) and told Command to get everyone out. At approximately 0933 a V-shaped collapse occurred trapping several firefighters. Command ordered an evacuation of the building and a PAR and notified everyone that they were going defensive.

Two firefighters who were on the stairs leading to the second floor (Engine-45 Pak and Engine-50 officer) were trapped. Engine-50's officer activated the emergency button on his portable radio. FCC received this transmission and relayed the information back to Command. Command then had the dispatcher sound the emergency evacuation signal. The Engine-50 officer then transmitted a Mayday for Ladder-12's Pak (who had been above him on the 2nd floor). The transmission was successful, and he told Command the Mayday was for Ladder-12's Pak. The Engine-50 officer reported during interviews that he was unable to free himself but was able to assist the Engine-45 Pak and get him free from the entrapment. Rescue-1 Search was able to grab the legs of the Engine-45 Pak and free him and direct him to safety.

The Ladder-12 Pak reported during interviews that when the floor collapsed, he slid down to the first floor and was trapped in debris, and both of his legs were pinned. His SCBA facepiece became dislodged. He was able to place it back on his face and attempted to transmit a Mayday over the radio, but was not successful. The Engine-50 officer heard the Ladder12-Pak call the Mayday and transmitted a Mayday on his radio for Ladder-12's Pak. The Ladder-12 Pak reported during interviews that he was able to free one leg and then able to remove his foot from his other boot and self-extricate. He saw an area of light and made his way toward the light (which was side Charlie). He radioed that he had made it out of the structure and Charlie division called Command to let him know that Ladder-12 Pak was accounted for in the rear.

Rapid Intervention Team (RIT) Operation

A RIT group was established with Rescue-1, Squad-72 and other fire department members, including the collapse unit. The extensive rescue and extrication involved heavy shoring, cutting, jacking and stabilizing in hot, smoky conditions. The RIT group worked in these conditions while using SCBA until they could ventilate by fogging out (hydraulic ventilation) and using fans on side Charlie to remove smoke and provide air. Overhaul and extinguishing spot fires were still being performed throughout the RIT operation. At one point in the RIT operation, crews had to suspend water flow for the RIT group and keep an eye out for further collapse onto the RIT group. The rescue/removal operation took just over an hour. The incident safety officer controlled access (accountability) at the front doorway due to a threat of further collapse.

The victim (Engine-45 officer) was trapped by heavy second floor joists, building materials and debris (see Photo 7). Squad-72's officer reported that he heard a PASS device sounding and was able to locate the Engine-45 officer. They had to crawl through extensive debris and follow the Engine-45 hoseline in the contour of the collapse towards Delta wall (simultaneously, Engine-50 and other crew members searched the Bravo side wall). The Squad-72 officer reported that he heard a PASS device and crawled toward the noise. When they found the Engine-45 officer, he was heavily entrapped with his SCBA jammed in-between the floor joists and his leg pinned underneath debris. He was trapped between the two floor joists in a seated position facing the Delta side. Rescue-1's officer reported that they couldn't move him. Squad-72's officer reported that he removed the victim's face piece and air flow was heard along with the EOSTI (vibrating alert) on the victim's regulator, however the victim was not breathing. They silenced the victim's PASS device and turned off his cylinder. Squad-72 and Rescue-1 worked to free the officer using power cutting and spreading tools, hand tools, and shoring/cribbing, stabilizing, and jacking equipment.

The Engine-45 officer was eventually removed by the RIT group. Fire department paramedics began Advanced Life Support (ALS) measures which continued during transport. He was transported to a local trauma hospital and later pronounced dead. He died of positional asphyxia with superheated gas and smoke inhalation (see Diagram 8 and Photo 7).

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Photo 7. Arrow indicating victim's SCBA and approximate location where Engine-45's Lieutenant was located and extricated by Fire Department RIT crews.
(Photo courtesy of the Fire Department)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

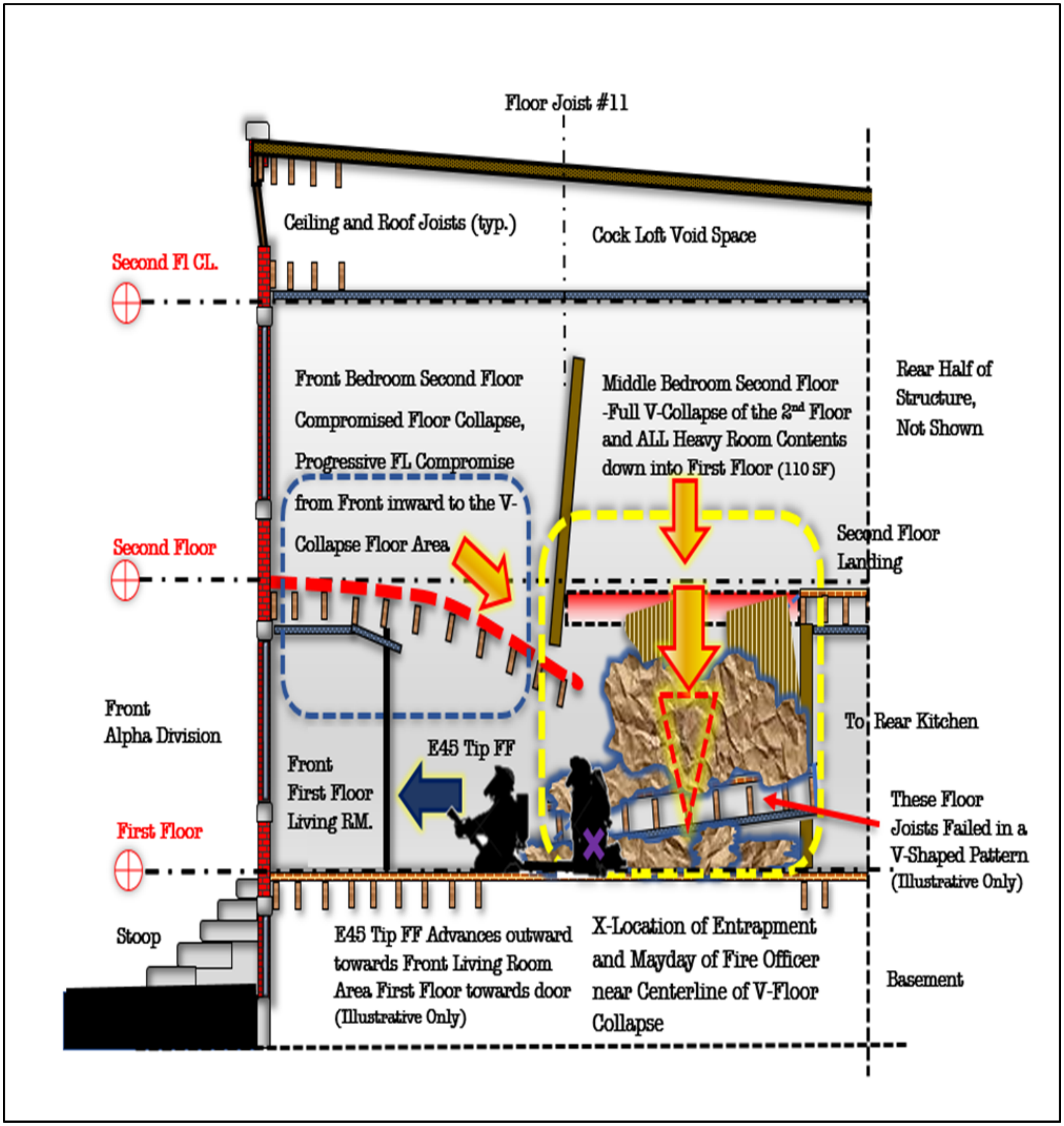

Diagram 8. Cross-Section of Second Floor Collapse.
(Graphic courtesy of Buildingsonfire.com C.J. Naum)

Fire Behavior

The origin and cause have not been released by the Fire Marshal at the time of this report.

Contributing Factors

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

- Extreme cold weather, water supply (6 inoperable hydrants).
- Inherent building characteristics and unique row house variation.
- Structural overloading, excessive clutter and deteriorated building conditions.
- Risk assessment that included a structural condition evaluation after strategy change (fire severity on primary building materials and extension within ceiling spaces).

Cause of Death

According to the Medical Examiner's Report, the medical examiner listed the victim's cause of death as Positional Asphyxia with Superheated Gas and Smoke Inhalation.

Recommendations

Recommendation #1: Fire Departments and Authorities Having Jurisdiction (AHJ's) should consider increasing emergency response capabilities during extreme weather.

Discussion: Fire departments can be challenged to perform seemingly standard life saving and fire suppression operations during periods of extreme weather, such as extreme cold, heat and/or severe flooding.

Fire departments and authorities having jurisdiction should consider pre-planning and pre-staging resources, assets and additional emergency personnel to best suit their local geographic and population density challenges during severe weather sitations. Severe weather can impact emergency response and block or restrict access to assets such as fire apparatus and emergency medical vehicles and law enforcement support to best perform the needed missions such as fire and rescue services.

Critical functions of emergency operations can be assisted by increasing resource and the response capabilities during severe weather operating periods. Additional personnel called back or held over are considerations for increasing staffing assets, however this should be pre-planned and then implemented in stages with forecasting and planning.

Firefighters were hampered with frozen nozzles, inoperable/frozen hydrants, frozen PPE and extreme freezing temperature conditions. They supplied handlines remotely by stretching supply and hand lines 260 feet to the front of the structure due to the turn of the century narrow streets and civilian parking that restricted access by modern fire apparatus. Recognizing problematic type hydrants and planning for additional maintenance can help to ensure operation during extreme weather conditions. For example, if problematic hydrants can't drain properly or leak past the valve seats, they should be identified and repaired or replaced. Additionally, if a certain tamper proof type of hydrant is identified as problematic during severe weather conditions, they should be planned for repair or replacement.

Recommendation #2: Fire Departments should consider defensive operations when a dependable, continuous water supply is lost or not available and the building's primary building materials may have been subject to severe fire conditions.

Discussion: As part of the initial size up and continuously throughout the incident, once the search and rescue of civilians has been completed, incident commanders should consider defensive fire operations when a continuous water supply is not available or is limited. Firefighters and officers need to communicate bench marks to the incident commander. It is also important to communicate when those benchmarks have not been or cannot be completed.

Benchmarks such as water on the fire (or lack of knock down), primary search complete, excessive clutter or hoarding limiting firefighter access, water supply established (or water supply difficulties), as well as scene access are important benchmarks that the incident commander uses along with many other factors (such as resource availability) to establish or change the strategy and tactics. When one or more of the bench marks are not accomplished or may be delayed, incident commanders should consider a defensive strategy and alter the tactics.

When the water supply is limited or insufficient for fireground operations, incident commanders should ensure this issue is factored into the strategy and incident action plan [NIOSH 2018]. Incident commanders should consider a defensive strategy whenever water supply is or becomes a factor. Adequate water supply during fire attack operations has a critical impact on fire control outcomes. Delayed or limited water supply and inadequate fire flow leads to delayed fire control, increased risk to firefighters, victims, and greater fire loss.

Command is ultimately responsible for managing attack positions in either offensive or defensive locations. The key to effective attack positioning is WATER. Water not only extinguishes the fire, but water protects firefighters from the lethal products of combustion [MABAS 2015].

As an incident commander develops a strategy and incident action plan for an incident, the issue of water supply factors into this process. Incident commanders should have an acute awareness of the following water supply factors:

• What are the required fire flows for the incident

• What is the projected fire flows we can produce

• Do we have enough water to safely extinguish the fire

• Where is the water supply coming from

• Are the key tactical areas adequately supplied with water

• What units have/need a water supply

• How many handlines can the supplied pumper(s) charge and pump

• How many large-diameter openings can the supplied pumper(s) charge and pump

• Is there a need for pumped supply lines? [MABAS 2105]

If there is insufficient or an inadequate water supply or if the water supply is interrupted, incident commanders should make a decision to operate in a defensive strategy, especially if the fire has been burning for a considerable time prior to the arrival of the fire department.

In this incident the elapsed time from arrival to collapse was 37 minutes. The strategy was changed from offensive to defensive due to critical water supply interruptions, and back to offensive once a stable water supply was established. Hoarding conditions with heavy content, and likely added water weight, combined with age, weather-related deteriorated structural conditions, and prolonged fire exposure all contributed to the V-shaped collapse originating from the notch cut in the floor joists for the gas piping.

Firefighters were hampered with frozen nozzles, frozen hydrants, frozen PPE and extreme freezing temperature conditions. They supplied handlines remotely by stretching supply and handlines 260 feet to the front of the structure due to the turn of the century narrow streets and civilian parking that restricted access by modern fire apparatus. Despite these obstacles, the firefighters were still able to locate and remove a fire victim (who was deceased) utilizing internal fire engine tank water. The water supply was re-established and interrupted numerous times, however quick thinking and skilled DPOPs (driver/pump/operator/pump) members were successful in communicating the water supply issues to officers or their interior crews.

Recommendation #3: Fire departments should ensure that firefighters are trained to understand the influence of inherent building performance characteristics, unique row house variation (modifications and construction) on structural collapse and consider defensive operations when dilapidated/excessive clutter conditions are encountered.

Discussion: Firefighters are at significant risk for injury or death due to structural collapse during fire-fighting operations. Between the years 1979 and 2002 there were over 180 firefighter fatalities due to structural collapse, not including those firefighters lost in 2001 in the collapse of the World Trade Center Twin Towers. Structural collapse is an insidious problem within the fire fighting community. It often occurs without warning and may result in multiple fatalities. As part of a larger research program to help reduce firefighter injuries and fatalities, the U.S. Fire Administration (USFA) funded the National Institute of Standards and Technology (NIST) to determine if there were trends or patterns that could be detected in firefighter fatalities due to structural collapse [NIST 2003]. In 2020, NIOSH released a fact sheet with specific information on row house features and helpful firefighting tactics for consideration. [NIOSH 2020]

Fire departments should ensure that officers and firefighters are trained in legacy and modern building construction techniques to gain a better understanding of collapse potential. Structural collapse often results in firefighter injuries and fatalities. While structural collapse is a significant cause of injury and death to firefighters, the potential for a structural collapse is one of the most difficult circumstances to predict. The structure's age, use, design and modifications along with the construction all have a significant effect on the building's structural integrity. The extent, intensity, location of the fire and burn time are significant factors that command and all fire officers need to keep in mind.

In his report to NIOSH on this incident [Appendix 2], Chief Naum stressed the importance of understanding the specific row house building performance under fire conditions. Type III (ordinary construction) row houses have a recognizable predictability of expected building performance under fire conditions. This predictability is also based on inherent building anatomy, design, compartment fire dynamics in the building and the actions of fire fighting forces (intervention, time and effectiveness). They are prone to interior collapse and perimeter wall collapse within short operational periods based on influencing fireground factors such as fire severity, degraded building, component or structural conditions or heavy content that may have adverse effect on structural integrity or weight carrying capacity [Naum 2019].

In situations when suspected or actual degradation of the structure are observed, or excessive content clutter or observations indicate excessive live or dead loads may have an adverse effect on structural strength or stability, immediate actions need to take place to ensure fire fighting forces are able to communicate the risks to the incident commander and an effective strategy is selected.

When confronted with active fire conditions within a Type III row house, the size up considerations, in addition to life safety, should include building performance issues such as fire location and severity and length of burn time or duration, building age, occupancy (excessive clutter), structural condition(s), access, and availability of fire fighting resources to engage and stop the advancement of fire.

Inherent building characteristics and unique row house variations can contribute to the risk of collapse during a fire. In this incident, uniqueness and variances for this row house included material degradation and legacy notching of floor joists, as well as possible degraded load carrying capacity of the existing wood floor joists due to age, creep, the effects of loss of moisture content or cyclical exposure to environment elements [Naum 2019]. The inherent legacy notching of the existing wood floor joists (see Diagrams 9 and 10) was a primary contributor that created an existing floor system that was highly susceptible to being affected by a structural fire or affected by the addition of live or dead loads.

The 1-inch x 1-inch notch was cut into the upper top portion of the wood joist to accommodate the installation of a pipe run into the occupancy for gas service to the residence in the late 1800's. These cut notches and legacy gas pipe runs continued in each wood floor joist inward from the Alpha side wall area interior along a center-line approximately 20 ft. or more in length (see Diagram 11). There are additional details included in the expert analysis report attached in Appendix 2.

Many times, these factors are not known to first arriving companies and may not be able to be factored into the initial size up. Altered, dilapidated and or deteriorated structural building members should be reported to the incident commander as soon as possible so he/she can factor them into the size-up and risk assessment. Severe clutter conditions can add considerable weight that perhaps wasn't considered in the design of the original construction. Clutter conditions can also contribute to trapped water adding significant weight applied during a fire fighting operation. Additionally, severe clutter makes search and rescue operations very difficult. Just getting access to areas for a search can be challenging and very time consuming (as was experienced very early in this incident by the victim and other crews).

Fighting fire in a cluttered occupancy adds additional hazards to all areas of search, rescue and extinguishment. Occupants can be harder to locate, access in and around rooms and to stairways may be blocked, extreme overloading of structural members can occur as well as the possibility of clutter adding tremendous amount to a fuel load unexpected in a residential setting. Fire departments should ensure that their members are trained to recognize and report these conditions to the incident commander for consideration during size-up.

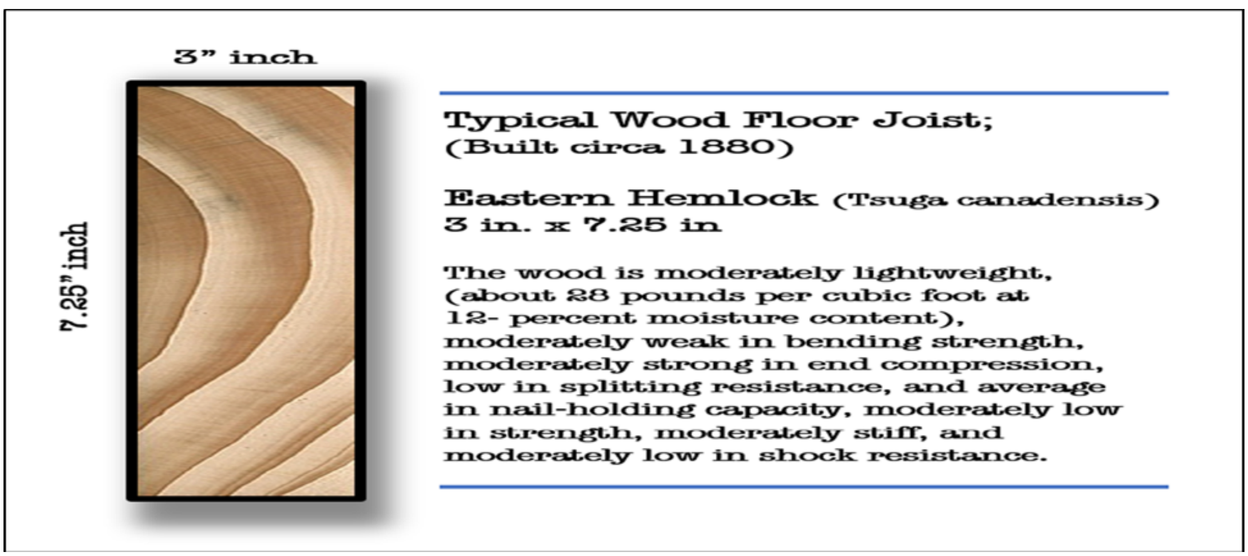

Diagram 9. Typical Wood Floor Joist. Uniqueness and variances for this row house included, possible degraded load carrying capacity of the existing wood floor joists due to age, creep, the effects of loss of moisture content or cyclical exposure to environment elements [Naum 2019]. (Graphic Courtesy of Buildingsonfire.com | C.J. Naum)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

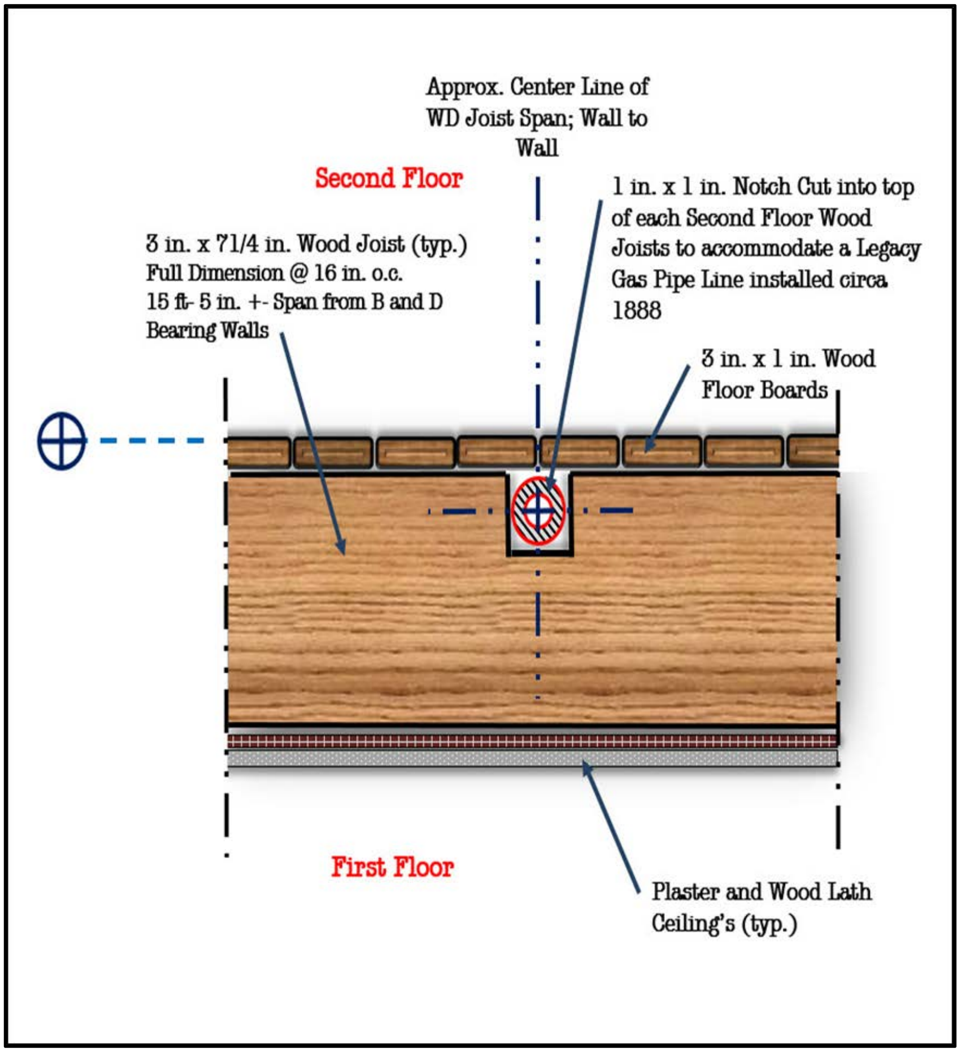

Diagram 10. Gas-line & Notch. The inherent legacy notching of the existing wood floor joists was a primary contributor to create an existing floor system that was highly susceptible and prone to be affected by an interior compartment or structural fire or affected by existing or in the addition of live or dead loads [Naum 2019].
(Graphic Courtesy of Buildingsonfire.com | C.J. Naum)

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

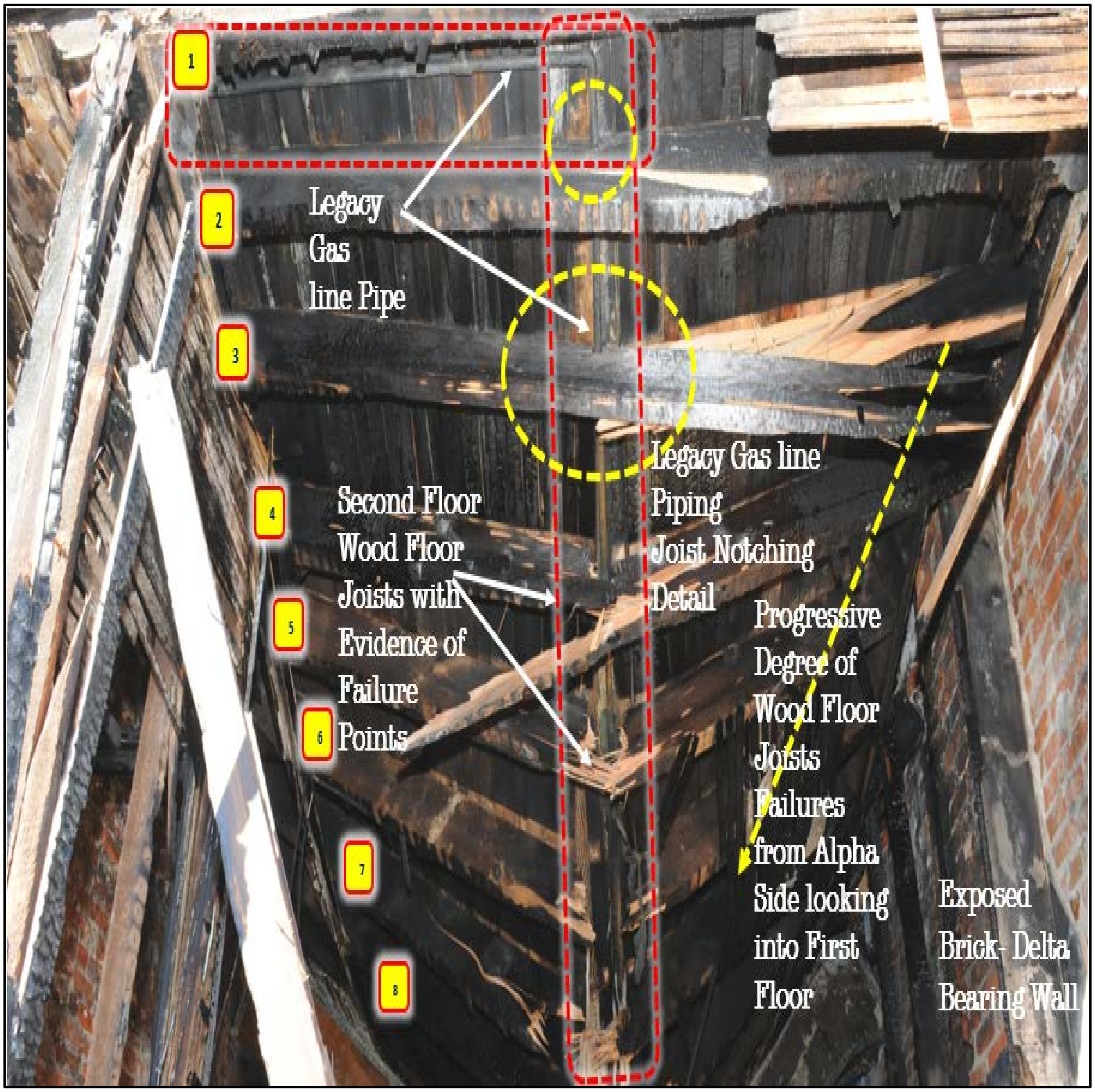

Diagram 11. Joists numbered from side Alpha toward side Charlie detailing the joist breaking points along the notched cut out for the gas pipe installation.
(Photo courtesy of fire department and analysis diagram courtesy of Buildingsonfire.com, C.J. Naum)

During initial size-up and ongoing fire-fighting operations, incident commanders need to consider many variables to determine the integrity of a burning structure. Understanding the influence of building design, condition, age and construction on structural collapse has a direct correlation to safe fire-fighting operations and firefighter survivability. In many cases, structural collapse results from damage to the structural system of the building caused by the fire or by fire-fighting operations [NIOSH 2013]. The longer a fire burns in a building, the more likely the building will collapse.

"The predictability of a building's performance and risk to structural collapse, compromise or failure should be foremost in the development and execution of incident action plans (IAP) with collapse precursors or indicators identified, monitored and managed by incident commanders, supervisors and operating companies." [Naum 2014, NIOSH 2016]

Based upon continuous risk assessments being conducted, coupled with pre-incident planning information, a collapse zone or exclusion zone should be established when factors indicate the potential for a building collapse. Fire departments should not rely solely on the amount of time a fire has been burning as a collapse indicator. An external load—such as a parapet wall, steeple, overhanging porch roof, awning, sign, or large electrical service connections—may cause a structural collapse. Additionally, excess water from fire fighting operations can add significant weight to upper floors, especially after switching from a defensive operation back to an offensive, or overhaul operation. Other factors to consider include:

• fuel loads (including excessive debris beyond the structure's design)

• fire behavior and building ventilation characteristics

• fire duration (burn time), size and location

• pre-existing structural damage/deterioration

• renovation/modifications to structure

• height and age of the building

• types of doors and windows

• engineered load systems/lightweight truss construction

• roof design and covering

• fire protection features such as sprinkler systems, standpipe systems, automatic fire alarm system [NIOSH 2014a].

Construction features, combined with fire factors, indicate the most probable type of structural failure [Klaene and Sanders 2007]. Given the fact that the incident commander is always working with incomplete and imperfect information, it is impossible to accurately predict the type of collapse and resultant collapse zone.

Whenever the incident strategy has changed (from offensive to defensive or even back to offensive for overhaul), a risk assessment needs to be performed. A collapse or exclusion zone should be established for any areas identified by the risk assessment. Many times, after a defensive fire is knocked down, the strategy is changed again so crews can overhaul or knock down remaining pockets of fire. If the strategy is changed back to offensive, significant attention must be given to the structural integrity and any areas identified as exclusion zones should be communicated to all operating companies prior to the entry of firefighters for overhaul.

A risk-versus-benefit analysis is essential in the risk assessment of the structure. The crucial question that any incident commander must ask is:

- What could I potentially save in relation to the risk being taken?
- Obviously, no building is worth a firefighter's life; therefore, imminent risk to a firefighter's life to save a building is unacceptable.
- When a defensive operation represents a reasonable risk, positions at the corners of the buildings are normally safer than those on the flat side of a wall.
- Consideration should also be given to using unstaffed ground monitors to reduce the risk of placing personnel in exposed positions.
- When total collapse is imminent, collapse zones represent exclusion zones that no one is permitted to enter or re-enter regardless of the level of protective clothing [Klaene and Sanders 2007].

In this incident, there was heavy fire involvement for a significant amount of time prior to the collapse. There was an extreme amount of clutter that added to the weight of the dilapidated dwelling along with likely additional water weight from defensive operations. This was further compounded by critical interruptions of water supply (frozen hydrants, and a frozen attack nozzle). Despite all of the difficulties, the initial arriving crews were able to locate and remove a civilian victim in very challenging removal conditions from the first floor of the 125-year-old dilapidated structure.

Water supply issues continued after the civilian victim removal. The strategy was changed from offensive to defensive and all interior crews removed, and exterior streams applied after 16 minutes due to water supply interruptions. After approximately 6 minutes, water supply was re-established. The collapse occurred approximately 19 minutes after the re-entry. Elapsed time from arrival to collapse was 37 minutes. Hoarding conditions with heavy content, and likely added water weight, combined with age, weather related deteriorated structural conditions, and prolonged fire exposure all contributed to the V-shaped collapse originating from the notch cut in the floor joists for the gas piping.

Recommendation #4: Fire departments should ensure that Incident Commanders establish a stationary/expandable command post, which includes the use of a tactical worksheet and effective fireground communications.

Discussion: When a Chief Officer (e.g., Battalion Chief, District Chief, Deputy Chief) arrives on scene, he/she should automatically assume a standard stationary, exterior, and remote command position and immediately assume "Command" and begin functioning as the Incident Commander. Command officers generally establish and continue command and control functions inside their vehicles or at the rear of the vehicle, which has a command board and/or a tactical worksheet. This stationary command post can allow for expansion of an effective command team if the incident expands beyond initial responding units.

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 firefighting efforts [NFPA 2014].

When establishing a command post, the Incident Commander should ensure the following:

- 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 tactical, command, and designated emergency traffic channels for that incident
- The location of the command post is communicated to the communications center
- The Incident Commander, or his/her 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 pick-up truck type vehicle. This method will provide the incident commander with an area that may be quieter 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].

A 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 better manage a large, multi-alarm incident. The worksheet can be used on large complex and small fires as well as EMS incidents, to help develop proficiency and to record vital information that may aid 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].

A 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 good understanding of the initial deployment of resources, the need for additional apparatus and equipment, and the status of units in the staging area.

Some 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 knocked down, fire under control
- Facilitates consistent, organized information
- Documents assignments and responsibility
- Expedites passing of command or support for the incident commander
- Provides resource status [NFPA 2014].

When a division or group is implemented, 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. The fire department should have procedures for the announcement of emergency conditions, using the term “emergency traffic” as a designation to clear radio traffic” [NFPA 2018]. Emergency traffic should be declared by the Incident Commander, tactical level management unit, or member who identifies a high-risk situation on the fireground (e.g. power lines down, signs of impending collapse) and should be used to alert members that the Incident Commander is ordering the evacuation of the building. The term “Mayday” should be reserved for only those situations where a firefighter or firefighters is/are in trouble or facing a life-threatening emergency.

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. Several members could function in this role including an incident command technician, chief officer, apparatus driver/operator, or other responder. There are several methods of accounting for resources including tactical worksheets, command boards, apparatus riding lists, company responder boards, a 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].

Recommendation #5: Fire departments should consider the capacity and capability of the dispatch process to ensure response accountability and prevention of a single source failure in the response matrix.

Planning, accounting for, and assigning assets/resources is important at all stages of incident command or incident management development and begins with the communications center or dispatch agency. When assets and/or resources are delayed by factors including traffic, weather and or road conditions, being involved in a crash, assigned to other incidents or failure to arrive to an incident, dispatch should have a system to account for those units and replace or modify the notification as necessary [NIOSH 2017].

In a recent NIOSH investigation that occurred in MD, a fire department safety officer was unaccounted for and units cleared the scene without knowing he was still in an exposure building after a fire and died from smoke inhalation. The safety officer was a single person emergency response vehicle. It was not realized he was unaccounted for until the following morning when his vehicle was spotted outside of the original fire building. To prevent this, fire communications centers, chief officers and supervisors and EMS supervisors, as well as dispatchers, should have a system to recognize when a unit or a resource doesn’t answer a call to respond and anytime a unit never clears the scene. This can be accomplished in many ways at all accountability levels (task, tactical and strategic) through electronic accountability systems that also have a back up system when other systems are not successful [NIOSH 2015].

In this incident, the initial incident commander was the Engine-45 officer for just over 1 minute. Battalion Chief 8 arrived at the same time as Engine-45 and maintained Command for approximately one hour and 10 minutes. The Deputy Chief dispatched to this incident had a delayed response due to a breakdown in the notification system by radio. The Deputy Chief didn't arrive until 55 minutes after being dispatched. Delayed arrival of command staff may interrupt the building of an effective command staff in large or complex incidents.

Battalion Chief-8's aide stayed in the SUV while Battalion Chief-8 stood in the snow- and ice-covered street in command in the sub-freezing conditions until well after the collapse when he was relieved by Deputy Chief 2. After the arrival of Car-5, the incident command was expanded to add an operations division (Deputy Chief 2).

Recommendation #6: Fire departments should ensure that fire officers and firefighters are trained-in and practice situational awareness, and personal safety.

The book Essentials of Fire Fighting and Fire Department Operations [IFSTA 2008] defines situational awareness as an awareness of the immediate surroundings. On the fireground, every firefighter should be constantly alert for changing and unsafe conditions. Even though a safety officer may be designated for an incident, it is the obligation of all personnel to remain alert to their immediate surroundings. They should maintain their situational awareness and be alert for unsafe conditions. This applies not only to the conditions found within a burning structure, but to the exterior fireground as well [Clark 2008]. In virtually every case, structural collapse results from damage to the structural system of the building caused by the fire or by fire-fighting operations [NIOSH 2013]. The longer a fire burns in a building, the more likely the building will collapse.

One of the most critical aspects of coordination between crews is maintaining situational awareness. The opposite of situational awareness is tunnel vision where the firefighters become so focused on fire fighting or other operational assignments that they fail to sense changes in their environment. Firefighters can maintain their situational awareness by looking up, down, and around as well as listening for new or unusual sounds and feeling vibrations or movement. Firefighters and officers should communicate any changes in their environment to other members as well as to the incident commander.

The International Association of Fire Chiefs (IAFC), Safety, Health and Survival section developed the "Rules of Engagement for Structural Fire Fighting." The rules of engagement have been developed to assist both the firefighter and the incident commander as well as command team officers in risk assessment and "Go" or "No-Go" decisions. The fireground creates a significant risk to firefighters and it is the responsibility of the incident commander and command organization officers to minimize firefighter exposure to unsafe conditions and stop unsafe practices [IAFC 2013].

The rules of engagement can assist the incident commander, company officers, and firefighters who are at the highest level of risk in assessing their situational awareness. One principle applied in the rules of engagement is that firefighters and the company officers are the members most exposed to the risk for injury or death and will be the first to identify unsafe conditions and practices. The rules integrate the firefighter into the risk assessment/decision making process. These members should be the ultimate decision makers as to whether it's safe to proceed with assigned objectives. Where it is not safe to proceed the rules allow a process for that decision to be made while still maintaining command unity and discipline [IAFC 2013].

The Firefighter's Rules of Engagement for Firefighter Survival:

• Size-up your tactical area of operation. This causes the company officer and firefighters to pause for a moment, look over their area of operation, and evaluate their individual risk exposure to determine a safe approach for completing their tactical objectives

• Determine the occupant survival profile. Occupant survival should be considered as part of the individual firefighter's risk assessment and action plan development

• Do not risk your life for lives or property that cannot be saved. This includes fire-fighting operations that may harm firefighters when fire conditions prevent occupant survival and significant or total destruction of the building is inevitable

• Extend limited risk to protect savable property. Risk exposure should be limited to a reasonable, cautious, and conservative level when trying to save a building

• Extend vigilant and measured risk to protect and rescue savable lives. Search and rescue operations should be managed in a calculated, controlled, and safe manner while remaining alert to changing conditions during high-risk primary search and rescue operations where lives can be saved

• Go in together, stay together, and come out together. Two or more firefighters should operate as a team. Maintain continuous awareness of your air supply, situation, location in the building, and fire conditions. Situational awareness is knowing where they are in the building and what is happening around them and elsewhere that can affect their risk and safety

• Constantly monitor fireground communications for critical radio reports

• You are required to report unsafe conditions or practices that can harm you. Stop, evaluate, decide. This prevents firefighter exposure to unsafe conditions or practices that can harm them, allows any member to raise an alert about a safety concern without penalty, and mandates the supervisor address the question to ensure safe operations

• You are required to abandon your position and retreat before deteriorating conditions can harm you. Firefighters must remain aware and exit early to a safe area when they are exposed to deteriorating conditions, unacceptable risk, and a life-threatening situation

• Declare a Mayday as soon as you think you are in danger. This ensures the firefighter is comfortable with declaring a Mayday as soon as they think they are in trouble [IAFC 2013].

The Incident Commander's Rules of Engagement for Firefighter Safety:

• Rapidly conduct or obtain a 360-degree situational size-up of the incident. Determine the safest approach to tactical operations as part of the risk assessment plan and action development plan before firefighters are placed at substantial risk

• Determine the occupant survival profile. Consider fire conditions in relation to the potential for occupant survival of a rescue event before committing to a high-risk search-and-rescue operation

• Conduct an initial risk assessment and implement a safe action plan. This rule causes an incident commander to develop a safe action plan by conducting a size-up, assessing the survival profile, and completing a risk assessment before firefighters are placed in high-risk positions on the fireground

• If you do not have the resources to safely support and protect firefighters, seriously consider a defensive strategy. This rule prevents the commitment of firefighters to high-risk tactical objectives that cannot be accomplished safely due to inadequate resources on the scene

• Do not risk firefighter lives for lives or property that cannot be saved. Seriously consider a defensive strategy. This rule prevents the commitment of firefighters to high-risk fire-fighting operations that may harm them when fire conditions prevent occupant survival and significant or total destruction of the building is inevitable

• Extend limited risk to protect savable property. The incident commander should limit risk exposure to a reasonable, cautious, and conservative level when trying to save a building that is believed, following a thorough size-up, to be savable

• Extend vigilant and measured risk to protect and rescue savable lives. The incident commander should manage search and rescue and supporting fire-fighting operations in a highly calculated, controlled, and cautious manner while remaining alert to changing conditions during high-risk search-and-rescue operations where lives can be saved

• Maintain frequent two-way communications and keep interior crews informed of changing conditions. The incident commander should obtain frequent progress reports, keeping all interior crews informed of changing fire conditions observed from the exterior that may affect crew safety

• Obtain frequent progress reports and revise the action plan. Frequent progress reports enable the incident commander to continually assess fire conditions and any risk to firefighters and to regularly adjust and revise the action plan to maintain safe operations

• Ensure accountability of every firefighter’s location and status. The incident commander and command organizational officers must maintain a constant and accurate accountability of the locations and status of all firefighters within a small geographic area of accuracy within the hazard zone and an awareness of who is presently in or out of the building

• If after completion of the primary search, little or no progress towards fire control has been achieved, seriously consider a defensive strategy

• Always have a rapid intervention team in place at all working fires.

Recommendation #7: Fire Departments should consider increased staffing and/or capacity of specialized rescue companies in dense urban areas or in targeted areas to assist in highly technical rescue capabilities and prevent a single source failure in response.

Discussion: A number of resources, such as the International Association of Firefighters, the National Fire Protection Association, and the 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 firefighter intervention in a risk event occurs in a timely and coordinated manner to limit risk escalation and negative outcomes. Additionally, specialized resource staffing and deployment are an important consideration in dense urban areas and/or in jurisdictions with specialized target hazards.

In basic firefighting, interdependent and coordinated tasks of all deployed fire-fighting personnel are required to meet standard fire fighting strategy and tactics (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) perhaps allowing a risk escalation to occur. The specialized rescue companies should have their staffing and assets identified and available for timely deployment to assist on incidents such as building collapse, technical rescue-high angle rescue, trench rescue, confined space rescue, water rescue and SCUBA operations as well as hazardous materials teams.

Departments should understand and plan to maintain these capabilities in the event of a single asset source failure, e.g., a deployment delay due to inadequate number and location of assets, a response delay due to traffic congestions and long response routes, frequency of need for specialized assets and a delay due to over burden.

In the case of building collapse, specialized heavy rescue assets (staffing and equipment) are likely to be needed quickly without waiting for a developed response from mutual aid or members being notified and responding from remote locations. In dense urban or targeted areas, pre-planning a likely response is key.

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 2013, NIOSH 2014b]. NFPA 1710 recommends that the minimum staffing level for an engine company to perform effective and efficient fire suppression tasks is four firefighters. However, NFPA 1710 also recommends that large jurisdictions with tactical hazards, high hazard occupancies, high incident frequencies, or other pertinent factors, should staff companies with a minimum of five or six on-duty members [NFPA 2013].

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 firefighters

• 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 2013, NIOSH 2014b].

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]. Additionally, fire departments and AHJ’s should plan for specialized resource equipment needs, staffing and deployment such as heavy rescue companies as they are an important consideration in dense urban areas and/or in jurisdictions with specialized target hazards.

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 2013, NIOSH 2014b]. 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 expectations 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 response force and heavy rescue capabilities. 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, or a single source specialty company is delayed it is more likely that insufficient resources have been deployed or planned for which may be associated with negative outcomes. Fire service leaders should consider several other factors when preparing standards of response coverage. These considerations should include an assessment of the probability or likelihood that an event will occur [NFPA 2013a, NIOSH 2014b] and the effect on operations when a single source failure may occur (asset response).

Urban fire departments should staff companies commensurate with the tactical hazards, high-hazard occupancies, high incident frequencies, geographic restrictions, and other pertinent factors that 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 firefighters. FDNY engine companies are staffed with one officer and four firefighters. The Chicago Fire Department staffs rescue companies with one officer and five firefighters. Also, Chicago Fire Department ladder companies and engine companies are staffed with one officer and four firefighters [NIST 2013a, NIST 2013b].

Recommendation #8: Fire departments should ensure that fire officers and firefighters are trained-in and practice accountability.

Discussion: Although there is no evidence that this recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. A fire department should develop its own system and standardize it for all incidents. All fire officers and firefighters operating at an incident should maintain accountability, situational awareness and conduct a continuous risk assessment throughout the incident, reporting unsafe or changing conditions to the incident commander. Firefighters need to understand the importance of and practice accountability, situational awareness and personal safety on the fireground. The fireground dangers and hazards can and do change as the incident becomes larger and the event duration increases.

Accountability on a fireground means identifying and tracking all personnel working at the incident. Accountability on the fireground can be maintained by several methods: a passport system, a system using individual tags assigned to each firefighter, a riding list provided by the company officer, a SCBA tag system, or an incident command board [IFSTA 2008, NFPA 2014].

Some SCBA and personal alert safety system (PASS) devices incorporated into SCBA have the ability to communicate automatically with a command/control module at the incident command post, establishing an automatic accountability system. NFPA 1500 Chapter 8, Section 8.4, and NFPA 1561, Chapter 4, Section 4.5, contain guidelines for the development of an accountability system for fireground and other emergency operations [NFPA 2014, 2018].

As the incident escalates, additional staffing and resources will be needed, adding to the burden of tracking personnel accountability. A tactical worksheet should be established at this point with an assigned accountability officer or chief's aide. In large incidents, this can also be used at the division level, with resources assigned to that division being assigned and tracked at the division level.

Accountability begins at the individual and task level with the company level officer. Accountability also occurs at the tactical level and this accountability is typically at the division level. Finally, overall accountability is established and maintained at the command level. This can be performed by the incident commander or designated to a member of the command team once the incident escalates and more companies are involved. One of the best training methods for incident scene accountability is repetitive skill training at the task, tactical and command levels (much like repetitive skill training for SCBA). The skills for effective incident scene accountability can be enhanced with frequent use. Frequent use of accountability on incidents such as "smells and bells", fire alarms and smaller incidents prepare and get all firefighters and officers in the habit of the accountability portion of incident command.

As stated above, ultimately overall accountability is the responsibility of the incident commander. However, this responsibility can be delayed or overlooked by task saturation at the command level. Building the command team with additional responding chief officers can help to ensure that the important functions of accountability and safety are covered.

Positive accountability is established by the fire arriving units and then transferred to an arriving battalion level chief. Some departments use a riding list or a passport system on the apparatus that is later collected and transferred to command. There are new electronic accountability systems that identify firefighters and officers electronically and the information is coordinated by an accountability officer for the incident commander. When a member is found to be in alarm, a signal goes to the accountability officer and the member or company is checked on. Command can also evacuate individual members or companies from areas or even a full evacuation can be sent via the accountability system. Once the incident escalates the company officers report accountability to the tactical level (e.g., Side Charlie or vent group) and then to incident command or strategic level. The incident commander then relies on his/her division officers to maintain accountability in those divisions. There are many systems available to fire departments to increase their effectiveness in personnel accountability. The most important aspect of any accountability system is training in the use of their system and then frequent repetition to ensure all fire officers and firefighters are comfortable and competent with their system.

An important aspect of a personnel accountability system is the personnel accountability report (PAR). A PAR is an organized on-scene roll call in which each supervisor reports the status of their crew when requested by the incident commander [NFPA 2018]. The use of a personnel accountability system is recommended by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2018] and NFPA 1561, Standard on Emergency Services Incident Management System and Command Safety [NFPA 2014]. A functional personnel accountability system requires the following:

• Development of a departmental SOP

• Training all personnel

• Strict enforcement during emergency incidents

The control of the personnel accountability system should be assigned to an individual responsible for maintaining the location and status of all assigned resources (resource status) at an incident. This is a separate role from the duties of the incident commander. The incident commander is responsible for overall command and control of the incident. Due to the importance of responder safety, this function would be assigned to a personnel accountability officer or resource status officer. This function can be staffed by the chief's aide, staff assistant, field incident technician, chief officer, or other responder familiar with the department's accountability system [NFPA 2014].

Recommendation #9: Fire departments should have a deployment strategy for rapid intervention crews/teams (RIC/RIT) which includes the initial dispatch and all working incidents. This strategy should incorporate all critical components of an appropriate response of structural collapse rescue capabilities and address strategic as well as tactical needs for RIC/RIT and escalation to heavy rescue.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Fire departments need to have a strategy for deployment of traditional rapid intervention teams and the critical components of response in an escalation to heavy rescue assets for structural collapse and other complex incidents.

Beginning with considerations for a standard structural fire incident, there is a narrow window of survivability for a firefighter who is out of air or trapped. On the task level, individual firefighters or company officers should not delay reporting to Command if they become lost, trapped, or are otherwise in need of assistance. Company officers or firefighters must not delay reporting to Command that they cannot account for members of their crew. Command officers must always assume that the missing firefighter is lost in the building until they can be located.

At all fireground operations, a rapid intervention team (RIT) or crew (RIC) should be designated and available to respond during all fireground operations. [NFPA 2018, IFSTA 2008, NFPA 2014] The rapid intervention team should report to the Incident Commander and be available within the incident's staging area. The size and complexity of an incident will ultimately determine the number of rapid intervention crews needed.

NFPA 1500, *Standard on Fire Department Occupational Safety, Health, and Wellness Program*, Chapter 8.8, *Rapid Intervention for Rescue of Members*, provides detailed guidelines for the deployment of rapid interview crews at emergency incidents. Chapter 8.8.1 states "The fire department shall provide personnel for the rescue of members operating at emergency incidents." Paragraph 8.8.1.1 of NFPA 1500 states, "Personnel assigned to perform the function of the initial rapid intervention crew (IRIC) or the rapid intervention crew (RIC) shall be trained on the requirements of NFPA 1407, *Standard for Training Fire Service Rapid Intervention Crews*."

On a tactical level, the rapid intervention mission can be separated into two categories. The first category is defined as the **Standby Mode** or preparation for Rapid Intervention as a precautionary measure (most frequent mode). The second category is the **Deployment Mode** or immediate rescue upon arrival at, or during the incident.

- *STANDBY MODE or preparation for rapid intervention* – In this category of rapid intervention the resources assigned as a RIC have time to gather equipment, perform reconnaissance, and liaison with the Command Post. Company Commanders need to stay vigilant and be prepared to initiate a rescue mission at a moment's notice. The same intervention configuration should apply in either rescue mission. The difference is in how much time you and your company will have to prepare for this most important mission. In this category of rapid intervention, the resources assigned as RIC should monitor the following radio channels:
    - Dispatch Channel
    - Command Channel
    - Incident Tactical Channel(s)

- *DEPLOYMENT MODE or* immediate rescue – Companies dispatched or assigned rapid intervention may find themselves involved in the immediate rescue of members upon arrival on scene of an incident. For this reason, the following RIC operations shall be followed and/or considered:
    - In the event of a Mayday, the RIC or rescue group will operate on the tactical channel that the lost, missing, or trapped firefighter(s) were assigned.

As the incident expands in size or complexity, which includes an incident commander's requests for additional resources beyond a fire department's initial attack assignment, the following should be considered [NFPA 2018]. The initial rapid intervention crew is most likely a single resource (e.g. engine, truck, or heavy rescue) recommended to be comprised of four personnel but with a minimum of three personnel.

An example could be the fourth due (to arrive) engine is designated as the initial rapid intervention crew. Also, the initial rapid intervention crew can be on-scene members designated and dedicated as a RIC. RIC is assigned from the resources that make up the initial alarm assignment to achieve the RIC capability. The trigger for the creation of the initial rapid intervention crew capability is an incident dispatch potentially requiring operation within an immediately dangerous to life and health (IDLH) atmosphere.

When an incident is declared a "working fire", the rapid intervention crew process is upgraded to at least one engine company and truck company or one heavy rescue company. These units are in addition to the units assigned to the initial box alarm and should be given priority in the dispatch sequence of any additional alarms. Once a working structure fire is confirmed by units on scene, this level shall be requested by the initial IC or the first due command officer to augment the initial rapid intervention crew.

The rapid intervention team should be comprised of RIT trained, well-rested firefighters, and be positioned and ready to respond when a firefighter(s) is down or in trouble [NFPA 2018].

NFPA 1500, Chapter 8.8, Rapid Intervention for Rescue of Members, provides detailed guidelines for the deployment of rescue teams at emergency incidents. Chapter 8.8.1 states "The fire department shall provide personnel for the rescue of members operating at emergency incidents." During the initial stages of an incident, the rescue crew members may be engaged in support operations outside the structure. Once the incident expands in size or complexity and the IC requests additional resources, the rescue crew must be dedicated to stand-by in case rescue operations are needed [NFPA 2018].

The rapid intervention team function should be incorporated into the department's incident management system and the personnel accountability system (PAR) [NFPA 2018]. Critical fireground operations and staffing needs should be continuously evaluated. Resource assignments should be made with the goal of having the RIT function in place at all times.

When the Incident Commander needs additional resources, the consideration of deploying the rapid intervention team for an operational assignment without additional resources on scene to function as RIT should be carefully assessed [NFPA 2018]. The following restrictions regarding the use of RIT should be considered by the Incident Commander during fireground operations:

• The RIT should not be used for fire-fighting operations. The RIT is dedicated to assist, and if necessary, rescue members who become trapped, distressed or involved in other serious life-threatening situations

• When the Incident Commander orders the RIT to work, the Incident Commander shall immediately assign another on-scene company to stand by as the RIT. If no units are available, the Incident Commander must assign at least two members to act as a rapid intervention team while waiting for additional resources to serve as a RIT to arrive. An engine company may be designated as the RIT pending arrival of an additional ladder company or rescue company. This ensures compliance with OSHA's "Two In/Two Out" rule under 29 CFR 1910.134, *Respiratory Protection* [OSHA 1998]

• The RIT should not be used to provide relief for operating companies until the fire/incident has been declared "Under Control" by the "Command"

• If assigned by a superior officer to other than RIT duties, the RIT unit officer should remind such officer of RIT designation [Toledo Fire Department 2012, Township of Spring Fire Rescue 2014].

On a strategic and tactical level, fire departments should consider a defined response plan for the dispatch of an additional company (engine, truck, squad, or heavy rescue company) to respond to an incident and standby as the rapid intervention team.

Based upon the complexity, magnitude, configuration of the structure, or geographical layout of the incident, the Incident Commander may deploy additional rapid intervention teams by location or function. [NFPA 2014] Fire departments should also ensure members are trained on a standard operating procedure for Rapid Intervention Team (RIT) operations including the RIT bag, tools, rescue equipment and how and where to get specialized equipment and personnel for collapse incidents. Additionally, RIT crews on all incidents should train to identify means of providing breathing air to trapped members.

Upon arrival or upon appointment, the RIT officer should confer with the Incident Commander. The RIT officer should establish an area to stage the rapid intervention team and the necessary RIT equipment. The RIT equipment should include:

• A tool staging tarp
• Rescue SCBA (RIT Pack)
• Forcible entry tools such as a Halligan bar or other pry tool
• Stokes basket
• 150’ long rope for search and rescue
• Wire cutters
• Saws
• Thermal Imaging Camera
• Emergency strobe lights
• Rebar cutter
• Life Saving Rope/Life Belt
• Elevator keys for buildings with elevators [Toledo Fire Department 2012, Township of Spring Fire Rescue 2014, FDNY 2011]

It is important to stage all necessary RIT equipment in an expedient manner. The RIT officer, accompanied by one member of the RIT, should perform an incident scene survey while the remaining RIT members assemble the RIT equipment. If the size of the structure negates a 360-degree survey of the building, this should be relayed to the Incident Commander as soon as possible. This should be a benchmark for “Command” to designate another RIT in order to effectively cover all sides of the building.

During this survey, the RIT officer and members should look for ways in and out of the structure, window configuration, fire escapes and construction features. The RIT officer should note the feasibility for placement of ground ladders for rescue or escape purposes. The RIT officer shall be responsible for setting up and securing a suitable secondary egress for interior crews. This may include laddering multiple sides of the structure. Once the RIT has determined the need for an egress ladder the window opening shall be cleaned of glass. This should only be done after conferring with “Command” that the removal of the window will not affect fire-fighting operations. Once approved by “Command”, the egress ladder should be placed at the window. The location of the egress ladder(s) should be announced over the radio by the RIT Officer.

The RIT Officer should then radio “Command” that a 360-degree survey is complete, and the RIT is ready to engage, if necessary. Once the incident scene survey has been completed and the RIT’s equipment is in place, the entire RIT should be in an area immediately accessible to the building in order for rapid deployment plus maintaining radio contact with the Incident Commander. The RIT officer shall brief all members of the RIT as to the results of his/her incident scene survey. RIT members should take turns periodically doing 360-degree surveys throughout the incident for changing conditions and updating the team. The RIT should operate as one unit unless multiple RITs are required due to size, complexity or engagement of a RIT.

In the event of a complex incident such as a major collapse, large geographic area, multiple floor high-rise incidents or shipping, rail or tunnel incident, additional crews may be added to or in support of the initial team as necessary. When more than one company is added as part of the rapid intervention team, a rescue group should be formed with a rescue group supervisor [Toledo Fire Department 2012]. Another consideration for “Command” is to request the response of an advanced life support (ALS) engine company or truck company as a component of the RIT Group. The members of the ALS company should be trained to operate in an Immediately Dangerous to Life or Health (IDLH) atmosphere, and function as part of the RIT, and provide advanced life support to affected firefighters [FDNY 2011].

The RIT officer and RIT members should coordinate with the Incident Commander to formulate rescue plan contingencies and continue to monitor the radio and fire ground conditions. RIT protection is not a passive assignment. This is a process of ongoing information gathering and diligent scene monitoring until the unit is released by the Incident Commander. The RIT is a critical component for firefighter safety [NIOSH 2014b].

On the strategic level, Authorities Having Jurisdiction (AHJ’s) and fire departments should plan-ahead for considerations for major Heavy Rescue or collapse needs. An important part of the strategic assessment for structural collapse and heavy rescue considerations is identifying pre-planned assets for heavy rescue and structural collapse companies or resources. They should be identified and formally brought into the response matrix whether they be internal or outside mutual aid for larger collapse operations.

In some localities, there may not be enough assets or resources to staff heavy rescue and/or collapse units and the specifically trained personnel who perform these missions. Identifying the assets ahead of time with a formal mutual aid agreement or participation on regional response teams can help localities and their departments respond sooner rather than later. However, the AHJ and fire department need to consider a possible delay in on-scene capabilities when the assets are not available or able to respond early in an incident, or be adequately staffed when a major collapse has occurred.

Recommendation #10: Fire departments and municipalities should consider upgrading access to narrow roadways in 19th century neighborhoods or restrict parking so access is maintained for modern fire apparatus.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Modern fire apparatus should have access to buildings to effectively save lives and fight fire. This includes access for hoselines and ladder trucks as well as access for ground ladders in the narrow alleyways. It is important that fire departments and communities pre-plan operations and remove or alter parking on narrow streets to allow for heavy fire apparatus to access the buildings.

Restricting parking on one or both sides of the street, special access routes, specialized equipment and operations training are some remedies for existing clusters of buildings (such as these row homes). Additionally, the local fire marshal's office and administration should work with planners to identify and address fire department access for high density, multi-family areas.

In this incident, the neighborhood was established (buildings, roads and alleyways) between 1884 and 1888. This construction era would have preceded motorized fire apparatus and on street parking. The fire department was very experienced in fighting row house fires and were aware of the challenges presented by limited access. The fire department had a policy of keeping the heavy apparatus on the main streets and crews were trained to stretch hoselines to the dwellings with long hose drags.

The first arriving officer (victim), sized up the fire structure and identified the fire structure in his arrival report as a two story, 15' x 35', middle of the row, dwelling with fire showing from the first floor and then gave the size and dimensions of the two exposures in his size up. Engine crews had to stretch handlines 260 feet (15 row houses in) to get to side Alpha of the fire dwelling. There were no fire hydrants on the dwelling street (only at the main cross streets).

Ladder trucks were not able to access the dwelling with the aerial and had to hand carry ground ladders to the dwelling and exposures. Additionally, all equipment such as spare SCBA cylinders, hand tools, saws, shoring equipment, and extrication equipment had to be carried longer distances due to the very narrow streets and resident parking.

Recommendation #11: Fire departments should consider identifying and pre-planning emergency operations in target areas that present access problems or are known to have poorly maintained or abandoned/dilapidated structures.

Discussion: Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Fire departments, municipalities and local authorities having jurisdiction should consider developing strategies for the identification, prevention of and the remediation of vacant/abandoned structures and for hoarding prevention and have programs in place to address fire and emergency response in those target areas. Fire departments don't typically pre-plan residential structures, however groups of target hazards (such as row houses, town homes with limited access or unique multifamily garden apartments) can be identified and emergency response (including access) can be pre-planned. Additionally, AHJ's should consider programs to identify and plan for structures that are experiencing severe clutter or are in dilapidated conditions.

Poorly maintained, dilapidated and excessive clutter can have a substantial effect on the expected building performance under fire conditions. Many firefighters and officers may think that the expected building performance for a contents fire in an older row house can be compared or gauged by past fire experience in these type occupancies. In fact, experience in fighting fire in specific occupancies can provide great assistance to the firefighters in sizing up and preparing to fight a fire. However, firefighters and officers need to use knowledge gained in target hazard identification such as open roofs, excessive clutter, hoarding conditions, dilapidated structural conditions in their training to size up each fire building on its on merits and adjust the strategy accordingly.

There can be many challenges for fire departments and emergency response agencies in areas such as older neighborhoods with very narrow streets and limited access, densely populated areas, and areas that contain neglected/poorly maintained, abandoned/derelict, or vacant structures. Many of these challenges can be identified and planned for by addressing the problem through targeted hazard identification and/or pre-planning. Targeted hazard identification can be specific to one or more properties such as a closed down or abandoned factory, or a grouping of target occupancies such as vacant commercial buildings on a waterfront. A targeted hazard identification program can then allow a department to pre-plan a response that is likely to occur. Assets and resources, such as specific apparatus, additional manpower, specific emergency vehicle routing, and closing or re-routing traffic patterns to allow for emergency vehicle access are all factors in a pre-planned emergency response to a targeted hazard.

Additionally, a targeted hazard program can be a formal program of cooperation between other city agencies and the fire department. For example, when a fire inspector, police unit, or EMS unit observes a severely deteriorating living and/or building condition while performing their mission, a cooperative program that notifies social services as well as agencies like the building officials office and fire department that may be able to provide assistance or direction. Additionally, social service agencies may be able to notify other agencies (such as fire departments) that have a need to know of structurally deficient conditions such as a hoarding condition in combination with neglected structural conditions. Utility companies can also be a part of the program and provide information in cases where they observe dangerous living conditions while servicing electric, gas or water customers. This kind of a program ideally should be overseen in the AHJ's building department in close cooperation with the local fire inspections/fire marshal's office.

In this incident, the first arriving fire units performed a very difficult offensive rescue operation and firefight with severely limited water supply in extreme weather conditions to rescue a trapped civilian.

The civilian was pronounced dead after they removed him from the fire building. There was reported to be extensive clutter and hoarding conditions which added to an excessive strain on the dilapidated structure. It is unknown if the excessive clutter contributed to the civilian's inability to escape, however the excessive clutter contributed to the conditions that resulted in the Lieutenant being trapped and killed after a collapse occurred later in the fire.

Fire fighting suppression efforts also added weight from water used to extinguish the fire as well as firefighters and equipment. The excessive clutter could have easily slowed or prevented water runoff from the 2nd floor. Additionally, the structure itself was severely neglected with openings in the roof that allowed extensive degradation of the structure.

The department in this incident recognized the access issues with the narrow streets and had a planned response that kept heavy apparatus out on the main highways. This however resulted in long stretches of hose (which also means that additional equipment and ladders must be carried in) and a very limited access to side Charlie.

Recommendation #12: Fire Departments, water and utility department and authorities having jurisdiction should consider increased fire hydrant maintenance programs and identify and replace "problematic" type fire hydrants.

Discussion: Fire departments can be challenged to perform at even smaller residential structure fires when the domestic water supply is not available due to frozen or out of service fire hydrants. Most cities that experience cold temperatures utilize underground fire mains with dry barrel hydrants designed to keep the barrel and the valves of the hydrant dry. When the stem is operated a valve down below the street opens and fills the barrel, and then exits the steamer and/or 2 ½" threaded caps. When the hydrant is shut down, there is a drain system in place that drains the remaining water in the barrel, keeping the barrel dry for the next use.

Fire hydrants need maintenance and one important part of the maintenance is ensuring the hydrant drains after use. It is also recommended that hydrants that show a history of operational issues due to weather are identified and replaced when they are shown to be less effective or dependable.

In this incident, a number of the inoperable hydrants were identified to be of a similar type. In fact, five of the first six fire hydrants would not operate for engine crews. They were accessed only to find they would not supply water due to being frozen or broken. It was reported during interviews that one specific type of hydrant was problematic on this incident due to the tamper proof mechanism becoming frozen. Initial crews relied on apparatus tank water for an extended period of time including the removal of the civilian fire victim.

Fire departments, water/utility departments and AHJ's should ensure that fire hydrants are checked and maintained annually.

Recommendation #13: Fire departments should ensure that SCBA are stored fully charged to obtain full use and capacity as well as sufficient emergency reserve air, and cylinder pressure is checked during daily equipment checks.

Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of best safety practice for the fire service. Many new SCBA cylinders have a larger capacity in liters than older SCBA that is achieved by higher cylinder pressures. As an example, a department may have new 1800-liter SCBA 5500 psi, 45 minute rated vs. older 1800-liter SCBA 4500 psi, 30 minute rated. Some departments may have up upgraded to higher pressure SCBA cylinders with the same capacity (1800 liters for example) but the cylinder size is now smaller.

For example, changing from an 1800 liter at 4500 psi to an 1800 liter at 5500 psi can result in a smaller profile size of the cylinder. The cylinder size may be smaller than the older cylinders, however the amount of breathing air in liters is achieved by an increase from 4500 psi to 5500 psi. The user will only get the 1800 liters when the SCBA is properly filled (at the fill rate specified by the manufacturer) to capacity or 5500 psi (after cooling).

There was also a change in the EOSTI (End-Of-Service-Time-Indicator) setting that came with the 2013 edition SCBA, and that was the increase from 25% +/- 2%, which means the EOSTI could have activated anywhere between 27 and 23% in the past to 33%. The new standard has the EOSTI minimum activation at 33% so the EOSTI will sound sooner. This was changed to provide firefighters more emergency reserve air by sounding the EOSTI sooner in the use period [NFPA 2013c].

The normal breathing rate (non-working) for many firefighters, and the rate at which the SCBA receive their NIOSH certification rating, is 40 liters per minute. However, firefighters frequently will use more than 40 liters per minute and in some cases upwards of 100 liters per minute when performing heavy fire work. The user’s breathing rate has the most significant effect on the service time of an SCBA; however if departments have recently switched over from 1800 liter, 30 minute, 4500 psi cylinders to 5500 psi, 1800 liter cylinders, they should understand the limitations of older compressors and fill sites that may have been set up to fill the smaller and/or and lower pressure cylinders. Fully charging the 5500 psi cylinders can take longer periods, especially with older compressors that were designed to primarily fill 4500 psi cylinders.

Like SCUBA diving with compressed air, using SCBA in the fire service is a critical component of firefighter PPE in order to work in IDLH environments. Individual air management and repetitive skills training with SCBA can improve a firefighters individual and company level air management and usage. Understanding the capacity ratings and how they are arrived [at] is important to understanding what the SCBA can do for the user. Additionally, understanding the capabilities and limitations of the SCBA is essential for the firefighter get the most out of his/her SCBA.

In this incident, the Engine-45 officer’s SCBA vibrating EOSTI was heard sounding during a radio transmission after only approximately 10 minutes on the scene.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Chart 1 is an exemplar chart provided by the department's Health and Safety office team. It depicts a heavy usage of an SCBA and the beneficial effect of having a full cylinder to start the job. This chart uses 100 liters per minute as an example. Most firefighters would start off using well below that rate, however as the work demands climb, so does the rate of usage and rates approaching 80-100 liters per minute are easily attained and common in fire fighting.

In this incident, the fire department's Health and Safety office was clearly proactive and provided this information to the field units since the new higher-pressure cylinders were new to the department. This chart very clearly illustrates the relationship between the cylinders beginning pressure and service time.

It is critically important to completely fill SCBA cylinders to the manufacturer's recommended pressure. It is also important to note that there is a correlation in the rate of fill to heat produced and ultimately the ending fill pressure. High pressure cylinders, such as those rated at 5500 psi, require slower fill rates and higher compressor capacity to completely fill to a cooled down working pressure.

Fire departments should strictly follow SCBA and compressor manufacturers filling rates and ensure only trained operators perform the fills. Hot filling or rapid filling a cylinder during routine (non-emergent) filling should be discouraged due to a resulting lower pressure after cooling (if not topped off). Care must be taken not to over pressurize (routinely quickly filling with excessive pressures to allow for a cool down working pressure). Instead, SCBA cylinders should be filled at the recommended rate which may take longer filling periods with older breathing air compressors and cascade systems.

In this incident, Engine-45's officer and Engine-45 Tip firefighter both had their SCBA's EOSTI sounding approximately 10 minutes after arrival. It is suspected that their SCBA (5500 psi, 1800 liter) may not have been completely topped off to 5500 psi. No one interviewed recalling any large air loss of any of the members during the initial operations. This department had recently upgraded their SCBA to a 2013 edition SCBA with the same capacity of 1800 liters, but smaller cylinders (profile size) at a higher pressure (5500 psi). The EOSTI was also changed in the 2013 edition from 23-27% of 4500 psi (1800 liter) to 33% of the cylinder pressure. So, if a group of 5500 psi 1800-liter cylinders were filled with older breathing air compressors and cascade systems that were adjusted up from 4500 to 5500, it could take longer to fill multiple cylinders to the full mark of 5500 psi cold pressure.

One of the most important components of properly filling SCBA is understanding of and training in the manufacturer's instructions.

Fire departments should consider the breathing air compressor assets whenever they upgrade or consider changes to their SCBA as part of their overall respiratory protection program.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

PFD Health and Safety Office Bulletin

SCBA AIR USAGE

The SCBA cylinders used by the PFD are to be filled to 5500 psi (which equates to 1800 L of air). The chart below shows the relationship between cylinder pressure (the psi reading on the pressure gauge), cylinder volume (the amount of air in the cylinder), and cylinder usage time.

			When breathing 100 Liters per minute (an estimated breathing rate while firefighting)	
Cylinder pressure (pounds/sq. in.)	% of cylinder full	Cylinder volume (Liters)	Estimated time until out of air	Estimated time until vibra-alert
5500 psi	100%	1800 L		
5445 psi	99%	1782 L	18 minutes	12 minutes
5390 psi	98%	1764 L		
5335 psi	97%	1746 L		
5280 psi	96%	1728 L		
5225 psi	95%	1710 L	17 minutes	11 minutes
5170 psi	94%	1692 L		
5115 psi	93%	1674 L		
5060 psi	92%	1656 L		
5005 psi	91%	1638 L		
4950 psi	90%	1620 L		
4895 psi	89%	1602 L	16 minutes	10 minutes
4840 psi	88%	1584 L		
4785 psi	87%	1566 L		
4730 psi	86%	1548 L		
4675 psi	85%	1530 L		
4620 psi	84%	1512 L	15 minutes	9 minutes
4565 psi	83%	1494 L		
4510 psi	82%	1476 L		
4455 psi	81%	1458 L		
4400 psi	80%	1440 L		
4345 psi	79%	1422 L		
4290 psi	78%	1404 L	14 minutes	8 minutes
4235 psi	77%	1386 L		
4180 psi	76%	1368 L		
4125 psi	75%	1350 L		
4070 psi	74%	1332 L		
4015 psi	73%	1314 L		
3960 psi	72%	1296 L	13 minutes	7 minutes
3905 psi	71%	1278 L		
3850 psi	70%	1260 L		
2750 psi	50%	900 L	9 minutes	3 minutes
1815 psi	33%	594 L	6 minutes	N/A
1375 psi	25%	450 L	5 minutes	N/A

December, 2018

Chart 1. SCBA Air Usage chart developed and used by the fire department health and safety office. Figures have not been validated and are for demonstrative purpose. They reflect this department's ambient conditions, equipment, experience and calculations.
(Exemplar chart provided to NIOSH courtesy of the fire department's Health and Safety Office After Action Review Team)

References

Weather Underground [2019]. Weather history for Philadelphia, January 6, 2018 https://www.wunderground.com/history/daily/KPHL/date/2018-1-6?req_city=Philadelphia%20International&req_state=PA&req_statename=Pennsylvania&reqdb.zip=19113&reqdb.magic=6&reqdb.wmo=99999. Date accessed: November 25, 2019.

Clark BA [2008]. Leadership on the line: firefighter Mayday doctrine—where are we now? Firehouse, September 23, http://www.firehouse.com/podcast/10459336/leadership-on-the-line-firefighter-mayday-doctrine-where-are-we-now. Date accessed: May 2020.

FDNY [2011]. Fire Fighter Assist and Search Team, Managing Members in Distress, Chapter 2. November 2011. Fire Department of New York, New York, NY.

Harms, T. [2010]. Using tactical worksheets, tactical worksheets help maintain control at the scene. FireRescue Magazine. April 2010. https://www.firerescuemagazine.com/articles/print/volume-5/issue-4/news/using-tactical-worksheets.html. Date accessed: December 2019.

Klaene B, Sanders R, NFPA [2007]. Structural firefighting strategy and tactics. 2nd ed. Sudbury, MA: Jones & Bartlett Learning.

IFSTA [2008]. Essentials of fire fighting, 5th ed. Stillwater, OK: Fire Protection Publications, International Fire Service Training Association.

IAFC [2013]. Rules of engagement for structural firefighting. Fairfax VA: International Association of Fire Chiefs, Safety, Health and Survival Section http://iafcsafety.org/rules-of-engagement/ Date accessed: January 2020.

Los Angeles Fire Department [2011]. Los Angeles Fire Department Command Post Training. 2011 ed. Los Angeles, CA: Los Angeles Fire Department.

MABAS [2015]. MABAS Division 201, operations manual. Mishawaka, IN: Mutual Aid Box Alarm System.

Naum C [2014]. Building construction analysis and insights report. Prepared for NIOSH Fire Fighter Fatality Investigation and Prevention Team, November 8, 2014.

Naum C [2019]. INSIGHTS ON BUILDING PERFORMANCE DURING FIRE OPERATIONS; Residential Row House Fire & Collapse, Expert report, June 2019.

NFPA. [2010]: NFPA 1035, Standard for professional qualifications for fire and life safety educator, public information officer, and juvenile firesetter intervention. 2010 ed. Quincy, MA: National Fire Protection Association.

NFPA [2018a]. NFPA 1582, Standard on comprehensive occupational medical program for fire departments. Quincy, MA. National Fire Protection Association.

NFPA [2013]. NFPA 1710, Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments. Quincy, MA. National Fire Protection Association.

NFPA [2013a]. Fire service deployment: assessing community vulnerability. 2nd ed. High-rise implementation guide. Quincy, MA: National Fire Protection Association.

NFPA. [2013b]: NFPA 1001, Standard for fire fighter professional qualifications. 2013 ed. Quincy, MA: National Fire Protection Association.

NFPA [2013c]. NFPA 1981, Standard on open-circuit self-contained breathing apparatus (SCBA) for Emergency Services. 2013 ed. Quincy, MA: National Fire Protection Association.

NFPA [2014]. NFPA 1561, Standard on emergency services incident management system. 2014 ed. Quincy, MA: National Fire Protection Association.

NFPA [2017]. NFPA 1142, Standard on water supplies for suburban and rural fire fighting. Quincy, MA: National Fire Protection Association.

NFPA [2018]. NFPA 1500, Standard on a fire department occupational safety and health program. 2018 ed. Quincy, MA: National Fire Protection Association.

NIOSH [2013]. Career lieutenant and fire fighter killed and two fire fighters injured by wall collapse at a large commercial structure fire—Pennsylvania. By Miles S.T., Merinar T, Loflin M., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2012-13, http://www.cdc.gov/niosh/fire/reports/face201213.html.

NIOSH [2014]. NIOSH workplace solution: preventing deaths and injuries to fire fighters by establishing collapse zones at structural fires. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

NIOSH [2014a]. Career Captain Dies Conducting Roof Operations at a Commercial Structure Fire – Pennsylvania. By Bowyer M, Loflin M., Morgantown, WV: U.S. Department of Health and Human

Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2013-07. https://www.cdc.gov/niosh/fire/reports/face201307.html .

NIOSH [2014b]. Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire--Pennsylvania. By Bowyer M, Miles S.T., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2014-25, https://www.cdc.gov/niosh/fire/pdfs/face201425.pdf

NIOSH [2015]. Shift Safety Officer Falls through Hole in Floor into Basement of Vacant Row House and Dies from Smoke Inhalation – Maryland. By Merinar T., Loflin M. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2014-24, https://www.cdc.gov/niosh/fire/pdfs/face201424.pdf

NIOSH [2016]. Career Probationary Fire Fighter Runs Out of Air and Dies in Commercial Structure Fire—Michigan. By Miles S.T., Tarley, J., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2013-14 https://www.cdc.gov/niosh/fire/pdfs/face201314.pdf .

NIOSH [2017]. Career Fire Fighter Killed and Volunteer Fire Fighter Seriously Wounded When Shot during a Civilian Welfare Check—Maryland. By Miles S.T., Merinar T., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2016-06, https://www.cdc.gov/niosh/fire/pdfs/face201606.pdf

NIOSH [2018]. Volunteer Assistant Chief Killed and One Fire Fighter Injured by Roof Collapse in a Commercial Storage Building—Indiana By Miles S.T., Loflin M., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, F2014-18, https://www.cdc.gov/niosh/fire/pdfs/face201418.pdf

NIOSH [2020]. NIOSH Fact Sheet: Row House Firefighting Tactics. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/docs/2020-117/pdfs/2020-117.pdf?id=10.26616/NIOSHPUB2020117

NIST [2013a]. Report on high-rise fireground field experiments, fire fighter safety and deployment study. Gaithersburg, MD: By Jason D. Averill, Lori Moore-Merrell, Raymond T. Ranellone Jr., Craig G. Weinschenk, Nicole Taylor, Randy Goldstein, Robert Santos, Doug Wissoker, Kathy Notarianni, Kathryn M. Butler. National Institute of Standards and Technology. https://www.nist.gov/publications/report-high-rise-fireground-field-experiments (date accessed January 2020)

NIST [2013b]. Wind driven fires. Gaithersburg, MD: By Madrzykowski, D., Kerber, S. National Institute of Standards and Technology, https://www.nist.gov/publications/fire-fighting-tactics-under-wind-driven-conditions-laboratory-experiments (date accessed January 2020)

NIST [2003]. Trends in Firefighter Fatalities Due to Structural Collapse, 1979-2002, Gaithersburg, MD: By Brassell, L D, Evans D D. National Institute of Standards and Technology, https://www.nist.gov/publications/trends-firefighter-fatalities-due-structural-collapse-1979-2002 (updated 2009, date accessed January 2020).

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

Toledo Fire Department [2012]. Rapid Intervention Team (RIT) Standard Operating Procedure C82. November 2012. Toledo Fire Department, Toledo, OH.

Township of Spring Fire Rescue [2014]. Rapid Intervention Team Interim Procedure 2014-003.

Investigator Information

This incident was investigated by Stephen T. Miles, Investigator/Safety and Occupational Health Specialist, and Matt Bowyer, Investigator/General Engineer with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, West Virginia. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division. Some text provided by expert reviewers was incorporated into the final report.

An independent identification and analysis of a wood floor joist sample was performed by Dr. DeVallance, Division of Wood Science, West Virginia University, Morgantown, WV. Assistance with a structural mortar sample analysis was performed by Mr. Paul Stutzman, Inorganic Materials Group, Materials and Structural Systems Division, Engineering Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899-8615. Additionally, the United States Department of Justice, Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), provided extensive information that was utilized in the timeline with information taken from police body cameras, civilian cell phone video and other sources.

NIOSH funded an evaluation of the victim's SCBA for pneumatic performance by Intertek Labs, 3933 Cortland NY. The victim's PASS device was evaluated with the assistance of the manufacturer.

An expert technical review was provided by Chief Christopher J. Naum, SFPE (NY) (Command Institute). Chief Naum provided information on building construction, historical data and structural collapse hazards. His full report is included in Appendix 2. Additionally, much of the building construction description and history for the fire structure is based on a review and material provided by Chief Naum. Some identifiers in this report have been removed by NIOSH.

Additionally, the Fire Department's Health and Safety Office put together an after-action review team consisting of a Deputy Chief, 2 Captains and a Lieutenant assigned to investigate this fatality. The Fire Department's Health and Safety Office after-action review team completed a lengthy and comprehensive incident review and many of the findings, resources and references have been included in this report. The Fire Department's Health and Safety Office after-action review team provided NIOSH with extensive information, including the fire departments history of fighting fires in highly congested urban areas such as this row house community. The Fire Department's Health and Safety Office after-action report identified contributing factors and developed changes based on lessons learned from this incident.

Additional information on row house firefighting considerations and tactics can be found at DHHS (NIOSH) Publication Number 2020-18 https://www.cdc.gov/niosh/docs/2020-118/default.html.

Disclaimer

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Appendix 1, Engine 45 Officer's Electronic PASS Data Log Record

		Off to Sensing	Sensing to off	Pre-Alarm to Alarm	MANUAL ALARM	Alarm Reset		Sensing to Pre-Alarm	
Time	Date	Off To Sen	Sensing To	PreAlarm 1	Manual Al	Alarm Res	Low Batter	Sensing To	Clock Rese
11:38:42	#########	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
10:41:00	#########	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
13:45:54	#########	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
13:45:46	#########	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE
13:45:42	#########	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
9:39:14	1/6/2018	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE
9:39:02	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:37:04	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:36:02	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:35:36	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:35:06	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:32:02	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:26:40	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:25:04	1/6/2018	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
9:16:40	1/6/2018	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
9:16:20	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:13:22	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:11:42	1/6/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
9:02:34	1/6/2018	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
18:52:26	1/5/2018	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
18:49:50	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:48:50	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:48:26	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:47:58	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:47:12	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:43:48	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:43:24	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:41:28	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:40:32	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:38:36	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:38:14	1/5/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
18:34:18	1/5/2018	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
16:55:18	1/4/2018	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
16:54:40	1/4/2018	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7:11:32	1/2/2018	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7:11:00	1/2/2018	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
7:10:26	1/2/2018	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7:10:14	1/2/2018	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7:10:12	1/2/2018	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE
7:10:08	1/2/2018	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
15:18:48	#########	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
15:18:36	#########	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
15:17:28	#########	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE
15:17:04	#########	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
7:20:50	#########	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
7:20:38	#########	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE

Victim's Partial Electronic Data Log. The PASS device sustained significant damage; however, the manufacturer provided assistance in obtaining this data.
(Data log information markings and highlighting by NIOSH Investigator - NIOSH worksheet provided with permission by the department)

Appendix 2

Special Expert Building Construction Report

Prepared by:

Christopher J. Naum, SFPE, CUSA

Fire Protection Analysis & Fire Management Consultant

Technical Advisor & Subject Matter Expert

Syracuse, New York USA

INSIGHTS ON BUILDING PERFORMANCE DURING FIRE OPERATIONS;

Residential Row House Fire & Collapse

January 6, 2018
ANALYSIS REPORT

NIOSH F2018-03

This Analysis Report was provided to NIOSH Firefighter Investigation and Prevention Program Investigative Team in support of the Technical Review and SME Support provided for Report F2018-03, which is based on the Final Executive Report of the comprehensive findings and insights issued to the Philadelphia Fire Department Health & Safety Office

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

INSIGHTS ON BUILDING PERFORMANCE DURING FIRE OPERATIONS;

Residential Row House Fire & Collapse

January 6, 2018

ANALYSIS REPORT

NIOSH F2018-03

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

I. Scope

The purpose of this report was to provide insights on Building Performance during fire suppression operations derived from the inherent and as-found building conditions, occupancy risk and incident fire suppression operations conducted at the residential row house fire that occurred on January 6, 2018 that resulted in the Line-of-Duty Death (LODD) of a Lieutenant, Fire Department.

Technical support was requested by the Fire Department's Health and Safety Office to support and supplement the scope and objectives of the Fire Department's After-Action Report for incident lessons, learning and insights.

The insights, observations, assessment and opinions expressed directly or indirectly by this report are based on a review of general information, documents and visual media provided by designated and authorized representatives from the Fire Department and are postulated, formulated and articulated based on generally accepted fire protection engineering, fire and emergency services, fire incident management & operations and occupational safety & health principles, practices and methodologies.

This report and its observations shall not be construed to be a result of an in-depth technical analysis of the events or conditions leading to or resulting from the Fire Department as referenced in this report. A review of media and documents provided by the Fire Department were used in the preparation of this report. The author assumes no liability for opinions expressed.

II. Executive Summary

The structure fire, occurring on January 6, 2018 at the residential property consisted of a single-family residential occupancy row house was a structure fire that the Fire Department encounters with both regularity, consistency in building and fire performance and conditions that have led to the development of proficiencies, skills sets and protocols for the incident management and tactical mitigation of these incidents and the protection of life for the affected occupants that reside in these occupancies.

The row house building type is synonymous and defined in the history of the City as is the Fire Department's response, control and mitigation of fire incidents in these building and occupancy types. This single-family residential occupancy row house sustained a fire within the structure that communicated throughout the building, (causal factors of which are under investigation), culminating in a catastrophic second floor collapse of that area, which resulted in the line of duty death on-scene of Lieutenant and other subsequent firefighter personnel injuries. The originating fire within this occupied structure resulted in the fatality of the single row house occupant.

It is suggested and highly probable the second-floor collapse was triggered by;

- Overloading and excessive stress and loss of load transfer or carrying capacity of the existing structural wood floor joist assembly on the Second Floor from existing hoarding, heavy loads and clutter; The center bedroom area's floor area appears to have had significant live loading added based on occupant hording, heavy loads and clutter that placed additional stress and load transfer as fire extension or exposure from the first-floor fire resulting in probable building component and assembly compromise, deterioration and failure that lead to the V-shaped collapse along a vulnerable inherent condition.

- the ensuing compromising floor conditions lead to interior V-shaped floor collapse and the progressive succession of compromise of the floor diaphragm commencing from second floor bedroom inwards towards the second-floor center bedroom area.
- This resulted in a compromising floor condition at the front second floor bedroom, progressing towards the full collapse of the most susceptible second floor area within the center part of the second-floor resulting in a V-shaped collapse configuration bring both structural floor joists, flooring, partition and hoarding condition, heavy contents from the rooms above downward into the V-shaped collapse and onto the first floor.
- The central area of the second floor had a series of shorter floor joists that terminated at a framing joist that in turn framed the stairwell opening and did not extend to or were pocketed into the masonry bearing wall (Bravo Division)
- Wood floor joist #11 progressing from the front of the building inward was the last floor joist to full span from each bearing wall.
- The predominate compromising conditions that followed the legacy notch lines in the wood joists from building front- inward exhibited signs of load stress, failure and compromise; exhibited by the splitting and cracking of the wood joists. The line of structural compromise and failure followed the existing gas line and joist notching coincided with an apparent structurally weak area and aligned with the axis of the subsequent V-shaped collapse (versus a more common single-sided lean-to collapse of the floor diagram and assembly.
- Fire severity (unquantifiable) and extension within the interior ceiling spaces; within the joist channels or possible direct impinged from room and contents fire conditions in the absence of some of the existing plaster and lath ceiling may have had a contributing effect on the wood joists due to fire exposure to increase susceptibility of floor joist compromise with diminishing load carrying capacity due to loss of wood mass (material charring and burn) coupled with the inherent characteristics of the aged wood.
- It is postulated and suggested that the addition of water introduced from the application of exterior hose streams into the upper interior from the street on the Alpha Division during a brief defensive tactical time period may have added additional live load (weight) that fall-out rates (non-evaporation) of water from the hose streams, would have soaked or saturated into porous or other soak-prone clutter and hoarding materials, thus increasing overall live loads that further exasperated floor structural stability, increased floor deflection and loss of load transfer and load carrying capacity that precipitated the compromise and resulting catastrophic collapse.

- The existing wood joist notches, creating a vulnerable condition on multiple adjacent floor joists, excessive hording and heavy clutter adding significant live load to an aged existing floor assembly and a varying degree of fire within the interior compartment and structural void space area suggest an apparent and highly probable series of conditions that aligned in such an manner at this row house fire that provided the sequence of events and mechanism of collapse that had adverse consequences to operating companies within the structure.

Uniqueness and Variances for this Row house and Fire

- The inherent legacy notching of the exiting wood floor joists was a primary contributor to create an existing floor system that was highly susceptible and prone to be affected by an interior compartment or structural fire or affected by existing or in the addition of live or dead loads.
- Existing Hoarding, Heavy Contents and Clutter introduced to the rooms by the occupant significantly contributed towards the potential for floor instability and compromise.
- Deterioration and exposure of the interior rooms and occupancy to environmental exposure and elements and their suggested impacts on the building structural components, materials and systems may have had a contributing effect on structural stability and integrity of building components. Possible degraded load carrying capacity of the existing wood floor joists due to age, creep, the effects of loss of moisture content or cyclical exposure to environment elements**.**
- The small size of the row house structure, when impacted by unstable or compromising structural stressors may not have the resiliency or resistance to recover from those conditions or allow for load transfers and still maintain its structural stability and integrity.

The alignment of seven separate conditions correlated in this row house occupancy to create a variance an irregularity that made this incident and fire operation unique that contributed to the collapse conditions and outcome;

- The Existing Hoarding, Heavy Contents and Clutter
- The presence of the legacy notch lines in the wood joists from created an existing condition that made each of the floor joists highly susceptible and prone to the effects of fire, heat & failure.
- Inherent building support systems (Wood joist) degrade or affected material conditions & postulated diminished structural integrity
- Floor joist framing at the stairwell and floor area above that creates a susceptible and prone interior condition (to fire) that is inherent in all row houses of this layout type, floor plan and configuration (Workingman's Row House)
- The suggested impact of water introduced during fire suppression affecting hoarding and clutter conditions
- The location and extent of fire
- The transitional tactics from Offensive to Defensive to Offensive may not have considered structural integrity of critical internal building systems or components that may have been subject to varying degradation, damage or compromise and the compounded effects of imposed loads on the building from hoarding, heavy content and clutter.

The significance of interior compartment hoarding conditions, elapsed time of fire suppression operations and the varying degrees of fire involvement within the structure alone would highly suggest that the elevating risk probability for a structural compromise or collapse could be highly expected and possibly imminent.

Whenever operations transition for Offensive-interior to Defensive-exterior and then back to Offensive-interior; The overall building risk profile and assessment must be made by Incident Command and a determination made on probable building integrity and operational benefits expected by placing companies back into a structure and compartments that have been subject to increased fire exposure and degradation, impacted by the introduction of large or small caliber hose streams during defensive operations and the potential effect of the water introduction, absorption, steam conversion and fall-out rate and run-off or containment in rooms, floors, voids or materials.

III. Building Construction and Occupancy Profile

Overview

The fire incident occurred within a densely populated neighborhood common to urban matrix of the City. The residential property consisted of a single-family residential occupancy row house that was located on a narrow street comprised of thirty-four (34) attached row house buildings that spanned the city block from a cross-street to the north street and a cross-street to the south. Similar row houses were present across the street from the residence and were found to the rear of the structure (Charlie Division- geographic West) along the adjacent city street and block, separated by a slight backyard buffer zone.

The residential row house was built between 1880 and 1888 [1] under the adopted building and construction standards in effect at that time. The structures were of Type III- masonry brick and wood joist construction [2] in accordance with recognized standards in that era and consistent with NFPA 220 Standard [3].

The single-family residential occupancy row house sustained a fire within the structure that communicated throughout the building, (causal factors of which are under investigation), culminating in a catastrophic second floor collapse of that area, which resulted in a firefighter fatality and other subsequent personnel injuries. The originating fire within the occupied structure resulted in the fatality of the row house occupant.

Progressive fire extension and further structural collapse and compromise occurred throughout the interior occupancy of the building during fire suppression operations. There was some damage to the adjoining residential properties on both the Bravo Divisions (Geographic South) and the Delta Divisions (Geographic North). The single-family residential occupancy row house was the 15th unit inward along North Colorado Street from the intersection of West Dauphin Street.

The row house was found to have evidence of physical, material and maintenance neglect and progressive physical building and structure deterioration. The building did not have an operable fixed heating system[1], had roofing and perimeter wall deterioration and had direct open areas to the environment with direct exposure and susceptibility to seasonal environmental cycles and conditions.

There was evidence that significant hoarding conditions of materials and a significant degree of clutter was present throughout the rooms and floors of the structure that imposed critical operations impediments and highly suggest; affected the structure during the early development stages of the fire within the room compartments and within concealed and exposed area of the building structural components, systems, assemblies and materials. These hoarding, heavy content and clutter conditions also had significant contributions towards building compromise, collapse and concurrent and subsequent Fire Department fire suppression operations, mitigation efforts and resulting fire service personnel extrication and rescue effort resulting from the structural floor collapse. [1, 17]

Appendix Photo 1. Street Photo: Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum Map Courtesy of Bing Maps | Photo Courtesy of Google Earth

Layout and General Features

The residential property consisted of a single-family residential occupancy row house. The row house style structure or commonly referred to as the row house, is typically a one to four-story residential house occupying a narrow street frontage and attached to adjacent houses on both sides. It evolved early in the city's history. [4]

Lining the city's straight, gridiron streets, the row house defines the vernacular architecture of the city. Row houses were built to fit all levels of taste and budgets, from single-room bandbox plans to grand town houses. The row house was easy to build on narrow lots and affordable to buy, and its pervasiveness resulted in Philadelphia becoming the "City of Homes" by the end of the nineteenth century.

The row house became synonymous with the city and was the model for affordable housing throughout the Mid-Atlantic and New England states and cities in the late 1800's and well into the early 20th Century.

From the city's founding, the row house has served as an easy solution to housing the city's residents. Streets, alleys, and courts were lined with relatively homogenous structures of predictable form and design. By the nineteenth century, the term "Philadelphia row" not only became synonymous with the landscape of the city, but it also became a term used elsewhere to describe orderly rows of regularized houses. [4, 5, 6]

The single-family residential property consisted of a two-story building located on a footprint of approximate 1,038 square feet. The building's style and design are commonly referred to as a Workingman's House [4] with defining characteristics that included;

- Masonry Brick bearing-party walls with masonry front facades
- Adjoining occupied buildings (row houses) on either side of the occupancy
- Wood Floor joists structural supports
- Plaster and lath over wood framing interiors
- Narrow Windows
- Single sloping roofs with modest ornate wood or brick cornice
- Front stoop (steps) accessing from street side,
- Entry vestibule,
- Two-floors of occupied space,
- Single run stairway,
- A basement with limited window(s)
- Indoor kitchen, plumbing, service and heating
- Small rear yards with partial court-yard area (adjoining to adjacent property)

These row houses can be found throughout the neighborhoods and sections of the city consisting of 1,000 – 1,600 sq. ft. on two-story homes. [4, 5, 6]

This row house style, configuration and layout was highly predictable in terms of expected performance under fire conditions and in typical fireground incident operations. These types of buildings and occupancies have consistently provided the Fire Department (FD) with extensive in-depth experience and operational insights from hundreds of thousands emergency incident responses, row house building firefighting and fire incident management, tactical deployment and incident mitigation over the past 138 years. These buildings and occupancies have been fundamental in firefighting principles, practices and tactical methodologies in these residential occupancy types and occupancy risks.

Building Construction and Occupancy

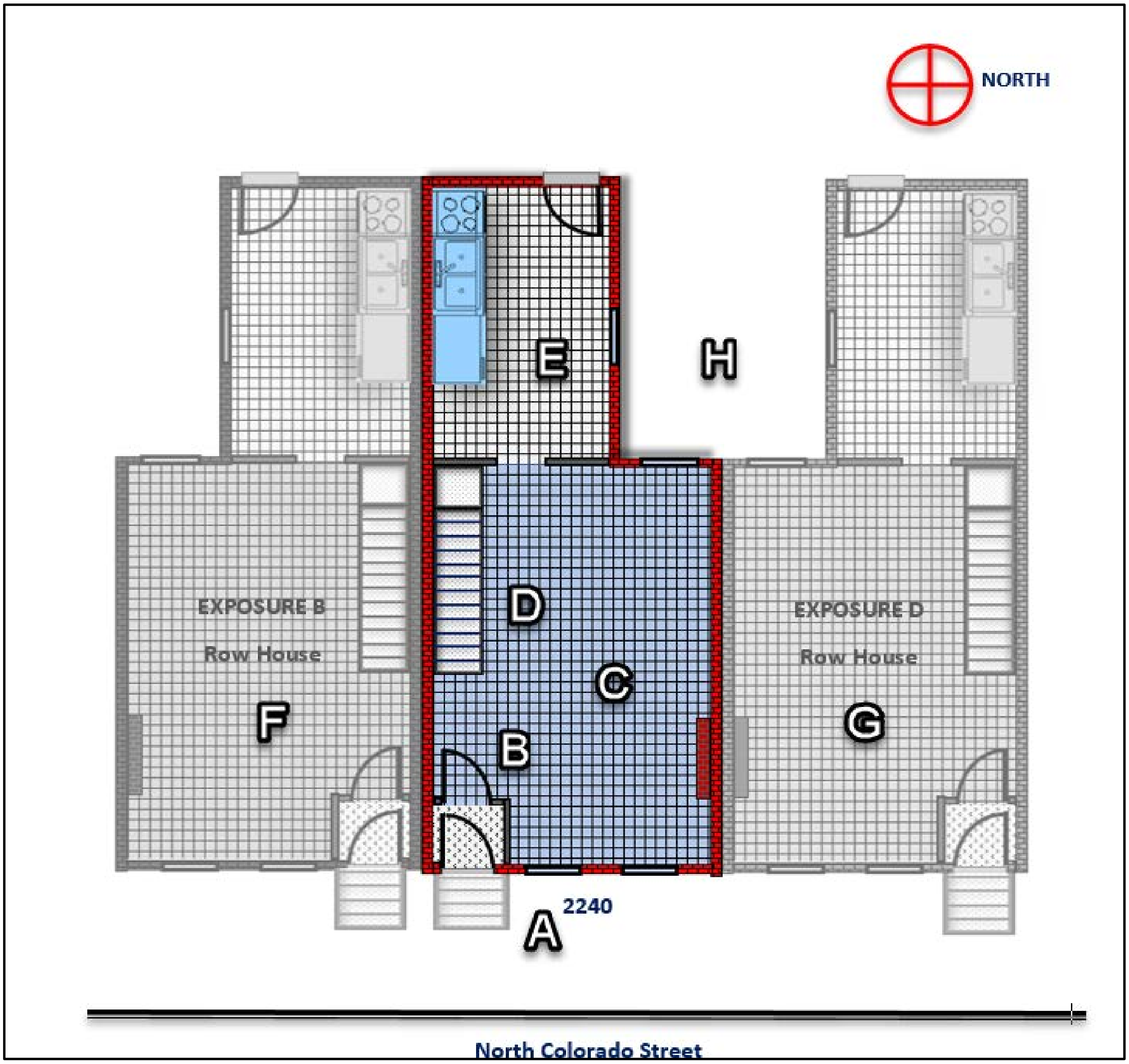
The building was a masonry constructed residential occupancy built in between 1880 - 1888.[1] Constructed of Type III, ordinary construction, was two-stories in height and had a basement. The building had masonry party bearing walls located perpendicularly to the main street running east-west on the Bravo (South) and Delta (North) divisions, with in-fill non-bearing masonry walls on the west and east building face (Alpha and Charlie divisions respectively). Sited on a city block, the building was accessible on two of the four sides and had attached exposure structures of single use occupancy on the Bravo division and a building exposure across the alley on the Delta division.

The residential property consisted of a single-family residential occupancy row house that was located on a narrow street (North Colorado Street) comprised of thirty-four (34) attached row house buildings that spanned the city block from a cross-street to the north (West Dauphin Street) and a cross-street to the south (West Susquehanna Ave.).

Similar row houses were present across the street from the residence and were found to the rear of the structure (Charlie Division- geographic West) along the adjacent city street and block, separated by a slight backyard buffer zone. Type III, ordinary construction [2, 3] (also referred to as “Brick and Joist” construction) generally refers to a construction system that incorporates masonry perimeter wall construction with both fully supporting masonry bearing and non-bearing wall characteristics, fully dimensioned timber wood construction for structural supporting floor joists, roof rafters and assemblies and dimensioned wood framing for interior partitions. Interior wood framing is commonly present for wall and room partitions and compartmentation with plaster and lath construction for finish treatments.

There was evidence that significant hoarding conditions of materials by the occupant over time and a significant degree of clutter that was present and encountered by operating FD companies throughout the rooms and floors of the structure that imposed critical operations impediments and highly suggest; affected the structure during the early development stages of the fire within the room compartments and within concealed and exposed area of the building structural components, systems, assemblies and materials. [1, 17]

These hoarding, heavy content and clutter conditions had significant influence and contributions towards subsequent building compromise, collapse and subsequent Fire Department fire suppression operations, mitigation efforts and resulting fire service personnel extrication and rescue effort resulting from the structural floor collapse.

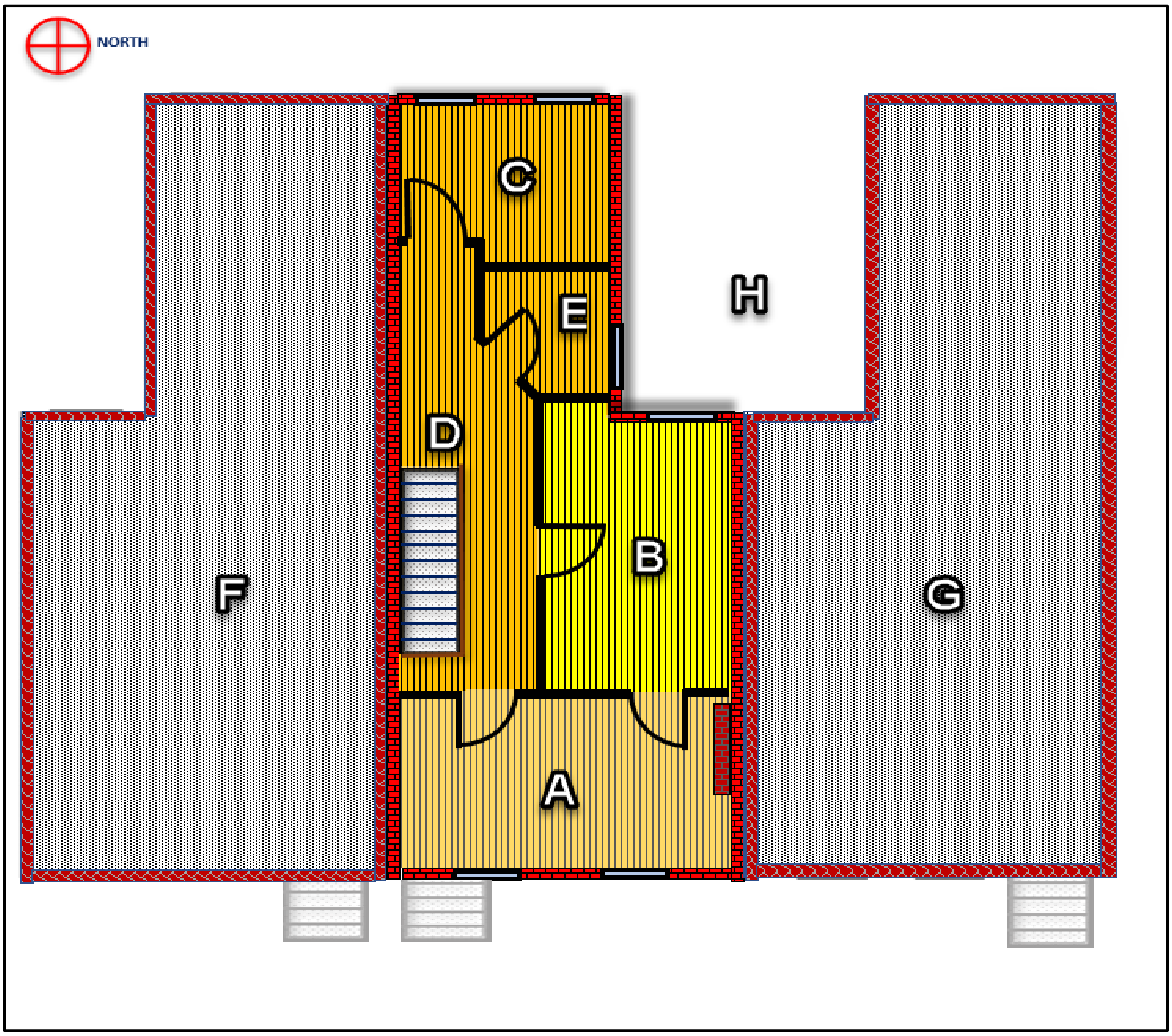


Appendix 2 Diagram 1. First-Floor Plan Graphic Courtesy of Buildingsonfire.com | C.J. Naum

First-Floor Plan: 15 ft. – 5 in. Front width x 37 ft. – 6 in. depth (10 ft. – 2 in. at rear width Kitchen)

1,038 Sq. Ft.

- A: Front Sidewalk and stoop (stairs)
- B: Entry Vestibule
- C: Front Living Room
- D: Straight Single-Run Stairs- UP to Second Floor
- E: Rear Kitchen with access to Rear yard (Charlie Division)
- F: Exposure-B Row house
- G: Exposure-D Row house
- H: Adjacent Adjoining Court Yard



Appendix 2 Diagram 2. Second Floor Plan (Adjacent Exposures shown) Graphic Courtesy of Buildingsonfire.com | C.J Naum

Second-Floor Plan: 15 ft. – 5 in. Front width x 37 ft. – 6 in. depth (10 ft. – 2 in. width at rear Bedroom) 1,038 Sq. Ft.

- A: Front Second Floor Bedroom (15'-2" x 12'-5")
- B: Middle Second Floor Bedroom (10'-0" x 10'-5")
- C: Rear Second Floor Bedroom (10'-2" x 9'-8")
- D: Straight Single-Run Stairs DOWN to First Floor and Second Floor Landing and Corridor
- E: Second Floor Bathroom
- F: Exposure-B Row house
- G: Exposure-D Row house
- H: Adjacent Adjoining Court Yard

Building Anatomy and Profile

- **Constructed:** circa 1880-1888 [1,16, 17]
- **Occupancy:** Single Family Residential
- **Condition:** Occupied and In-use; *Hoarding Conditions along with Degraded Building Conditions and evidence of interior occupiable spaces exposed to environmental elements*.[1,17,]
  - The row house was found to have evidence of physical, material and maintenance neglect and progressive physical building and structure deterioration.
  - The building apparently did not have an operable fixed heating system, had roofing and perimeter wall deterioration and had direct open areas to the environment with direct exposure and susceptibility to seasonal environmental cycles and conditions.
  - There was evidence that significant hoarding conditions of materials and a significant degree of clutter was present throughout the rooms and floors of the structure that imposed critical operations impediments and highly suggest, affected the structure during the early development stages of the fire within the room compartments and within concealed and exposed area of the building structural components, systems, assemblies and materials.
  - These hoarding, heavy content and clutter conditions also had significant contributions towards building compromise, collapse and concurrent and subsequent Fire Department fire suppression operations, mitigation efforts and resulting fire service personnel extrication and rescue effort resulting from the structural floor collapse.
- **Construction System:** Type III Ordinary Construction (based on National Building Code, circa 1900-1915 ed.)
  - **Floor Joists:** Full dimensioned 3 in. x 7.5 in. Floor joists were pocketed into the masonry bearing walls. There were no internal joint strap anchors or tie-backs to the masonry bearing or non-bearing walls. (no external spreader plates were used on the building facade) Bridging would not have been expected to be present between floor

joists based on the short spans.

- **Wood Joist: Eastern Hemlock (Tsuga canadensis)**[9,10] 3 in. x 7.25 in
  The wood is moderately lightweight, (about 28 pounds per cubic foot at 12- percent moisture content), moderately weak in bending strength, moderately strong in end compression, low in splitting resistance, and average in nail-holding capacity, moderately low in strength, moderately stiff, and moderately low in shock resistance.[9]

- **Hemlock** is similar to spruce in appearance, though much inferior as a building material. The wood is very brittle, splits easily, and is very liable to be shaky. Its grain is coarse and uneven, and though it holds nails much more firmly than does pine, the wood is generally soft and not durable. Hemlock is used almost exclusively as a cheap, rough-framing timber. [8]
- **NOTE:** A sample taken from the building by the PFD was identified to have a moisture content of **3.6%**[1,17]

- **Unique Feature of Note:** Within the Joist Void consisting of the 2nd Floor wood floor system; Commencing proximal to the first wood joist an approx. 1-inch x 1-inch notch was cut into the upper top portion of the wood joist to accommodate the installation of a pipe run into the occupancy for gas service to the residence in the late 1800's. These cut notches and legacy gas pipe run continues in each wood floor joist inward from the Alpha side wall area interior along an almost floor span center-line approx. 20 ft. or more.

- **Stairwell Area:** The Single-run stairway and stairwell was located directly adjacent to the interior Bravo Division wall and was accessible immediately upon entry through the front door and vestibule. The wood floor joists span fully wall to wall in all interior area except at the stairwell. An alternate method of assembly and structural system is present at this location
- **Flooring:** 3-inch x 1-inch wood plank flooring is common for this building type and vintage consisting of a rough under floor planking attached to the wood floor joist, a finished upper flooring treatment was not apparent
- Refer to Diagram for Typical Structural Floor System and Masonry Perimeter Wall and Floor Joist Orientation and Column Support Plan

* **Size:** Two Stories, with a full basement
  - Height: Curb line to Cornice- approx. 20 feet
* **Floor Area:** 37 feet approx. x 15 feet approx. [519 square feet per floor]
  - Total Floor Area: 1,038 Square feet est.
  - Closed- Compartmented Floor Plan

- **Interior Compartments:** Two (2) occupant spaces-rooms on the 1st Floor. Four (4) occupant spaces-rooms on the 2st Floor. Full basement; open space.
    - Compartment framing, wood timber construction, original plaster and lath wall treatment (fully, partial or removed)
    - As-found evidence of physical, material and maintenance neglect and progressive physical building and structure deterioration
    - Recommended practices and code ordinances at the time of the building's construction (1880-1888)
- **Roof:** Timber Rafters with Wood Deck and covering
    - The cornice had been modified and altered, with plywood panels partially installed to protect the roof cockloft void. Original brick and/or covering materials were absent at the time of the fire.
- **Masonry Perimeter Walls:** Masonry Brick Wall Construction Party Bearing Walls (Bravo and Delta Divisions; Brick walls and wood frame backing on Alpha and Charlie Divisions
    - Evidence of masonry brick wall deterioration of mortar joints, brick facing and wall integrity; Exposed rear walls and court-yard shape, Charlie Division.
    - The Front façade did not appear to have an observable deteriorated or compromising condition.
    - Window Treatments: Conventional window treatment and sizing for residential occupancy spaces (Basement, 1st and 2nd floors).

The building had vernacular architectural features in the use of masonry materials and construction for its perimeter enclosure walls which was common for buildings built in this timeframe (vintage and era). [8,11,12,13,21,28]

Unreinforced Masonry—unreinforced masonry walls, when they are not veneers, are typically several wythes thick (a wythe is a term denoting the width of one brick). Therefore, header bricks will be apparent in the exposed surface. Headers are bricks laid with the butt end on the exterior face, and function to tie wythes of bricks together.

Brick header courses typically occur every six or seven courses as was found in the construction of the building's walls. Sometimes, URM infill walls will not have header bricks, and the wythes of brick are held together only by mortar. The design and construction features, self-revealing of the building's wall system suggests criteria was followed in combination with recognized recommended standards and regulatory insights of the time and incorporated common empirical design principles.

Buildings of this and earlier vintage incorporated common empirical design principles, which is a procedure of proportioning and sizing unreinforced masonry elements based on known historical performance for a given application.

Empirical provisions preceded the development of engineered masonry design, and can be traced back several centuries. This approach to design is based on historical experience in lieu of analytical methods. Using empirical design, vertical and lateral load resistance is governed by prescriptive criteria which include wall height to thickness ratios, shear wall length and spacing, minimum wall thickness, maximum building height, and other criteria, which have proven to be effective through years of experience.

Construction and Occupancy characteristic prevalent in this Heritage Vintage Row house Building includes; [18,28]

- Type III Masonry- Ordinary Construction
- Row house Design and Function with Vernacular (Philadelphia) style
- Commonality of city block building occupancies and configuration
- Common adjacent building exposures (attached)
- Presence of Masonry Party Bearing walls
- Degree of Masonry Party Bearing walls integrity and openness
- Long, narrow streets
- Limited, rear yard-area accessibility
- Longevity of building use, function and age and impacts
- Compact semi-rectangular foot print (L-notch)
- Fully dimensional lumber structural floor system
- Limited Accessible and predicated floor plan
- Compartmentation of rooms
- Limited number of rooms
- Smaller room volume and square footage
- Limited corridors (flow/vent paths)
- Plaster and wood lath interior room finishes; wall and ceilings
- Presence and influence of transom storefront design and subsequent ceiling voids
- Limited Concealed spaces with combustible treatments
- Limited allocation of exterior windows along perimeter walls
- Limited Building accessibility from street -curb side
- Probability of alterations, renovations, approved and non-approved changes/modifications over time
- Varying occupancy loading and degree of mobility
- Age determinate & influential considerations
- Unique gable architectural design features
- Front Brick Façades and varying conditions/treatments of roof Cornice
- Occupant Hording, Heavy Contents, Clutter
- Occupancy use and habitability

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Appendix 2 Photo 2. 2240 North Colorado Street, Photo Courtesy of Google Earth. Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum

- Front Street View looking north on Colorado Street, with Stoop and Sidewalk access
- Bravo Division Two-story Brick & Joist Row house @ 2242 (Exposure- South side of 2240 occupancy)
- Delta Division Two-story Brick & Joist Row house @ 2238 (Exposure- North side of 2240 occupancy)
- Front Masonry non-bearing brick façade

Appendix 2 Photo 3 & 4. 2240 North Colorado Street, Photo: Analysis Courtesy of Buildingsonfire.com | C.J. Naum, Photo Courtesy of Google Earth

- The upper Second Floor windows are depicted for the Front Bedroom
- All windows and doors: Masonry cut-stone lintels and sills
- The modified remnants of the previous cornice are evident with the plywood panels applied and installed along the entire horizontal facia and cornice spanning both ends of the masonry bearing walls. Notice ornamental treatment of the masonry party walls on both sides
- Upper second floor windows with narrow passageways
- Front stoop (steps)
- Two quarter sized windows at sidewalk grade with installed security bars

IV. Anatomy and Mechanism of Floor Compromise and Collapse

Occupancy Risk Profile [19,20,21]

The inherent building, construction, design and characteristics in this row house structure have a recognizable predictability of expected building performance under fire conditions.

The building's anatomy and fire conditions upon arrival and during initial fireground operations have defined and expected performance, risks and hazards that define the conduct of fireground operations.[18,19,21]

This predictability of building performance has definable degrees of risk potential that once identified and assessed against an evolving fireground scenario can be aligned with recognized strategic and tactical measures that must be considered and assessed and possibly implemented in order to increase the probability of a safe and effective incident stabilization and mitigation. The time-demand identification and selection of tactical measures is borne with the arrival of the first-due company: the effectiveness and suitability of those tactical measures are validated or alter by the assuming command officer or incident commander.[18,19,20]

Understanding the building's anatomy, its current occupancy use and the characteristic of the building's internal compartments (occupied rooms and space use) are integral to effective and efficient firefighting operations within buildings on fire and are essential for all phases of fire engagement and suppression.[18] Tactical Company actions may be subject to adjustment and change as conditions become evident, self-revealing, assumptions are validated or confirmed as well as when assumptions, projections or other unknowns continue to be questionable- prompt associated actions must be taken that will have a potential positive tactical outcome or risk reduction or elimination in order to maintain company integrity, overall incident safety and firefighter survival.

Generally, when operating companies are confronted with intense fire conditions within a building of Type III construction with similar vintage, occupancy use and tenant space configuration; and those fire conditions have either impinged or propagated within or along concealed spaces, voids or compartment(s) for an extended period of time prior to arrival or during fireground operations, it is highly probable and predictable that the structural integrity of the various assembly, supports and structural floor joists and wall systems will be compromised and subject to varying degrees of degradation.[28]

Rapid or prolonged fire extension or exposure will result in probable building component and assembly compromise, deterioration, failure and collapse.[29,30] This will directly affect structural integrity that will lead to a limited compromised assembly(ies), isolated or catastrophic collapse of critical building anatomy elements that may impact firefighting operations based on proximity, exposure and operational phases. This must be anticipated by safety officers, company officers and commanders and considered in tactical plans and task assignments both within the interior and exterior of the structure. The potential and probability of an isolated or catastrophic structural collapse of a masonry perimeter wall or facade, degraded bearing or party walls, degrade interior compartment or ceiling or floor diaphragm would be considered a predominate building performance consideration and predictability variable for operations, if identified by command or company officers and assimilated as such into the initial on-scene size-up and incident risk assessment process during tactical plan development.[24,29]

- Type III buildings have a distinctive predictability of performance under fireground operations based on inherent building anatomy, design, compartment fire dynamics in the building and the correlation of firefighting, intervention, effectiveness and time. They are prone to both interior floor collapse and perimeter wall collapse within short operational periods based on influencing fireground factors and variables.
- In situations when suspected or actual degraded building, component or structural conditions are observed or suspected; or when heavy content clutter, hoarding conditions are experienced or when observations indicate significant additional live or dead loads, staging or placement of materials, products, debris or other are present that may have an adverse effect on structural loading, integrity or structural stability, strength or weight carrying capacity or transfer; THEN immediate actions appropriate to the tactical stage(s) of incident operations should be initiated at the company or incident command level forthwith and with considerations to the promptness, severity and growth of the proceeding anticipated or preceding conditions.

The on-going operations and concurrent tactical demands associated with incident priorities in complex and evolving incidents that involve escalating fire severity, undefined or invalidated fire location, extent or location(s) and concurrent demanding civilian life safety strategies, create a situation of decreasing managed defenses, high probability for error-likely conditions and operations proceeding into a high-risk environment.

The need for a pronounced understanding of Type III building construction, features and risk profiling in reading a building integrated with fluid operational monitoring and assessment is crucial to firefighting operations in these building types and associated occupancy risks. This is applicable to row house occupancies and fire incidents with prolonged fire suppression activities and when structural stability conditions may be subject to adverse influence from identified or suspected conditions. The challenge for today's incident commanders and operating companies on the modern fireground is to clearly recognize Type III building performance factors in both conventional Type III buildings and in applicable row house occupancies and inherent ordinary construction characteristics fundamental to the manner in which a building's anatomy (and fire conditions) presents itself at an evolving incident and to ascertain and distinguish how it will subsequently perform during fire duress and the continuum of elapsed incident time.[18,20,22,23]

Although the size, footprint and design of row houses have lesser fireground complexities than typically encountered with larger sized and more complex Type III building and occupancies, nonetheless company and command level sensitivity of potential compromising and catastrophic structural conditions that may evolve with fire incidents that do not have clearly identified operational benchmarks or prompt declarations of fire conditions under control or extinguished must have diligent and timely monitoring and decision-making.

This is especially true for fireground operations involving transitions from offensive interior operations to defensive operational tactics and the transition back again to offensive interior or proximal building tactical engagements. These operational periods tend to lead to increasing risk severities and highly probable adverse conditions or events to occur that will impact the safety of fire companies and personnel. *Predicting a potential structural collapse is one of the most challenging tasks facing an incident commander at a fire scene. Usually the lack of information on the construction of the building, fire size, fire location, fire burn time, condition of the building, fuel load, etc., makes the task nearly impossible.*

The incident parameters confronted by operating companies at the fire provided a clear indication of demanding operational priorities and task assignments, concurrent operational assignments and challenges with determination of fire location, propagation and extent and the effects of time compression on the operational period from arrival time at 08:51 hrs., to the time in which adverse building performance due to fire exposure precipitated the building collapse at 09:33:15 - :30 hrs.

The presence of observed or suspected heavy contents, hoarding and or clutter are clear signs that highly suggest deliberate actions and tactical assignments that maintain or enhance company integrity and firefighter safety during the evolving incident.

Buildings on Fire Risk Assessment Matrix

Levels	Severity of Risk
Catastrophic	May Result in personnel Death; grave personnel injury; large scale destruction and perilous conditions
Critical	May cause severe personnel injury, possible death; major property loss or significant degraded conditions
Marginal	May cause or result in personnel injury, prominent property loss or degraded and compromised conditions
Normal	Hazards and conditions are consistent with generally accepted Fire Service work practices and operational parameters for adequately resourced and trained companies. Operations may cause or result in some personnel injury; corresponding property loss or damage conditions consist with firefighting principle & practices
Negligible	Conditions have minimal threat to the safety and wellbeing of companies operating under generally accepted Fire Service work practices and parameters

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Operational Probability of Event

Severity of Risk

Category	**Unlikely** Unlikely to occur	**Seldom** Not likely to occur, but a possible	**Occasional** May occur under normal operational time	**Likely** Quite Likely to Occur during operational time	**Frequent** Likely to occur immediately or in short operational time period ; Expected to occur frequently
Catastrophic	H	E	E	E	E
Critical	M	H	H	E	E
Marginal	L	M	M	H	E
Normal	L	L	M	M	H
Negligible	L	L	L	M	M

Appendix 2. Figure 1. **Buildings on Fire Risk Assessment Matrix** [18,19,25,26] Courtesy of the Command Institute, Center for Fireground Leadership additional information can be accessed at http://buildingsonfire.com/buildings-on-fire-risk-assessment-matrix

The building's anatomy, operational risk and probability of performance in a Type III Row house structure for operating firefighting personnel and in the management of the incident is suggested as Marginal-Critical risk, with a slightly higher emphasis toward the Critical band primarily due to the inherent building's anatomy, construction features and row house design and the increasing degree of fire severity and rapid escalation of the incident in a short time span and progression encountered.

The presence of observed or suspected heavy contents, hording and or clutter are clear signs that highly suggest deliberate actions and tactical assignments that maintain or enhance company integrity and firefighter safety during the evolving incident.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

The occupancy's severity of risk would be considered normal-marginal with the operational probability of an adverse event to be Moderate (M) to High (H) resulting in a probability of Occasional to Likely event to occur during operational times. The severity and magnitude of fire, building volume and size and structural support system characteristics increase the occupancy risk.

The Identified Severity of Risk Level for postulated incident conditions for the fire building suggests a defined level of:

> **Normal-Marginal;** Hazards and conditions are consistent with generally accepted Fire Service work practices and operational parameters for adequately resourced and trained companies. Operations may cause or result in some personnel injury; corresponding property loss or damage conditions consist with firefighting principle & practices | May cause or result in personnel injury, prominent property loss or degraded and compromised conditions. [25,26]

NOTE: The tactical changes from Offensive to Defensive to Offensive however influence the risk severity and probability and may nudge it to Marginal-Critical with a Likely operation probability and severity.

- The degree of fire involvement within a compartment(s) and first and second floors, concealed space or voids(s), the length of time of fire growth and impingement and concurrent fire suppression operations created building conditions that were highly predictable.
- The probability of a collapse was foreseeable, should have been anticipated and operational task assignments adjusted based on the row house floor design, inherent stairwell design and fire intensity and influencing hording, heavy content conditions, however this may have been impeded by concurrent operational priorities, time compression and concurrent reflex and actions parallel to the self-revealing adverse building conditions
- Structural stability & integrity must be closely monitored or considered a higher risk factor and overall operations conducted may be consider at-risk deployments that require fluid and concise risk-benefit assessment,
- Investigation or presumption of actual or projected supporting methods for beams, columns or secondary roof or diagram supports must be considered since building or structural integrity could be compromised. The need for concurrent tactical assignments to readily and promptly open up concealed spaces (ceilings, voids, transom areas etc.,) to determine identifiable structural assemblies, materials and systems and to determine the extent and severity of flame, heat or products of combustion that might be present.
    - *This is especially difficult at small square footage row houses when interior room configurations and operating room is crowed at best and the primary tactical objective with the greatest degree of benefit is time and effective fire suppression to stabilize or mitigate the incident.*

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

- Concise incident monitoring should be considered based on incident priorities, immediate or deferrable operational demands associated with life hazards and fire severity, growth or propagation.
- Pre-incident information, pre-fire plans and building knowledge are mission critical- at a minimum for the first-due area response. Prior incident response and operations provide some building insight and “reconnaissance data” if it was recognizable and recollectable.
- Understanding building construction, related engineering, reading key building indictors and having the skills to take those observations, comprehend, assimilate and apply predictive modeling and projected outcomes to tactical objectives and incident action plans thus increases exponentially the safety margin to have successful incident outcomes and not unexpected events.

The structural collapse potential and probability would be considered a predominate building performance consideration and predictability variable for operations, if identified by command or company officers and assimilated as such into the initial on-scene size-up and incident risk assessment process during tactical plan development, the key is knowledge based reflex that lessens the time to recognize key attributes, process their relevancy and act upon the recognition of importance and influence on the evolving incident operation.[19,22,28]

Timeline[17]

08:50:44	**First call 911 Call**
08:51:43	**Time of Dispatch**
08:55:57	**On-location**
09:07:34*	**Lt. Confers w IC; Operations goes Defensive**
09:07:57	**PD Cam: Hose Stream Water applied from Street to 2nd Floor**
09:10:37	**PD Cam: NO Water is being applied from Street to 2nd Floor**

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Predicting a potential structural collapse is one of the most challenging tasks facing an incident commander at a fire scene. Usually the lack of information on the construction of the building, fire size, fire location, fire burn time, condition of the building, fuel load, etc., makes the task nearly impossible. However, performance indicators, benchmarks and why-variables/determination support rapid assessment of assumed or actual factors that can support incident decision-making processes that are time-sensitive.[22,28]

09:10:26	**PD Cam: Hose Stream Water applied from Street to 1st Floor**
09:13:45**	**Operations transition from Defensive to Offensive Interior**
09:33:15-09:33:30	**Collapse**
10:48:58	**Under Control**

- Initial Fire Suppression during Rescue Operations: **13 minutes: 37 seconds (approx.)**
- Water applied to 2nd floor during defensive OPS: **3 minutes: 53 seconds (approx. +plus)**
- Transition to Offensive Interior OPS & Tactics: **19 minutes: 5 seconds (prior to collapse)**
- Elapsed Operations time to Collapse: **37 minutes: 18 seconds**

The elapsed time of Fire Suppression Operations, the magnitude, severity and degree of fire involvement within the structure alone would highly suggest that the elevating risk probability for a structural compromise or collapse could be highly expected and possibly imminent.

Whenever operations transition for Offensive-interior to Defensive-exterior and then back to Offensive-interior; The overall building risk profile and assessment must be made by Incident Command and a determination made on probable building integrity and operational benefits expected by placing companies back into a structure and compartments that have been subject to increased fire exposure and degradation, impacted by the introduction of large or small caliber hose streams during defensive operations and the potential effect of the water introduction, absorption, steam conversion and fall-out rate and run-off or containment in rooms, floors, voids or materials.

The probability for an isolated or comprehensive structural compromise or collapse could be highly expected and possibly imminent must be recognized, considered and management based on incident priorities and operations demands.

Mechanism of Floor Compromise & Collapse, Operational Perspective

Each building material and component is affected differently (over time) based on their material characteristics and fire resistance or vulnerability. This includes such factors as; applied structural load intensity, member/component type, member dimensions and boundary type, incident heat flux from the fire on the member or assembly, type of construction and effects of temperature rise within the structural member on the relevant properties of the member. Live loads introduced into the room compartments will also have an influence on fire propagation, severity and exposure on structural systems.

The mechanism and sequence of collapse of the second floor along the approx. centerline of the row house and concentrated within the center of the building suggests with high probability the floor collapse was precipitated and triggered by the compromise of the interior supporting wood floor joist assemblies and the subsequent concurrent succession of collapse of the second floor area between the stairwell (Bravo side), the second floor central bedroom area and floor leading to the Delta side wall due to the inherent legacy condition of the upper notching of each floor joist, the additional live load imposed on the floor system from heavy content and clutter found in the second floor bedrooms, a degree of fire degradation of supporting systems from possible flame impingement and exposure and the probable addition of water loading from the application of exterior hose streams into the upper interior during a brief defensive tactical time period that precipitated the compromise and collapse.

It is suggested and highly probable the second-floor collapse was triggered by;

- Overloading and excessive stress and loss of load transfer and carrying capacity of the existing structural wood floor joist assembly on the Second Floor from existing hoarding, heavy loads and clutter; The center bedroom area's floor area appears to have had significant live loading added based on occupant hording, heavy loads and clutter that placed additional stress and load transfer as fire extension or exposure from the first-floor fire resulting in probable building component and assembly compromise, deterioration and failure that lead to the V-shaped collapse along a vulnerable inherent condition.
- the ensuing compromising floor conditions lead to interior V-shaped floor collapse and the progressive succession of compromise of the floor diaphragm commencing from the from second floor bedroom inwards towards the second-floor center bedroom area.
- This resulted in a compromising floor condition at the front second floor bedroom, progressing towards the full collapse of the most susceptible second floor area within the center part of the second-floor resulting in a V-shaped collapse configuration bring both structural floor joists, flooring, partition and hording condition, heavy contents from the rooms above downward into the V-shaped collapse and onto the first floor.
- The central area of the second floor had a series of shorter floor joists that terminated at a framing joist that in turn framed the stairwell opening and did not extend to or were pocketed into the masonry bearing wall (Bravo Division)

- Wood floor joist #11 progressing from the front of the building inward was the last floor joist to full span from each bearing wall.
- The predominate compromising conditions that followed the legacy notch lines in the wood joists from building front- inward exhibited signs of load stress, failure and compromise; exhibited by the splitting and cracking of the wood joists. The line of structural compromise and failure followed the existing gas line and joist notching coincided with an apparent structurally weak area and aligned with the axis of the subsequent V-shaped collapse (versus a more common single-sided lean-to collapse of the floor diagram and assembly.
- Fire severity (unquantifiable) and extension within the interior ceiling spaces; within the joist channels or possible direct impinged from room and contents fire conditions in the absence of some of the existing plaster and lath ceiling may have had a contributing effect on the wood joists due to fire exposure to increase susceptibility of floor joist compromise with diminishing load transfer and load carrying capacity due to loss of wood mass (material charring and burn) coupled with the inherent characteristics of the aged wood.

- It is postulated and suggested that the addition of water introduced from the application of exterior hose streams into the upper interior from the street on the Alpha Division during a brief defensive tactical time period may have added additional live load (weight) that fall-out rates (non-evaporation) of water from the hose streams, would have soaked or saturated into porous or other soak-prone clutter and hoarding materials, thus increasing overall live loads that further exasperated floor structural stability, increased floor deflection and loss of load transfer and load carrying capacity that precipitated the compromise and resulting catastrophic collapse.
- The existing wood joist notches, creating a vulnerable condition on multiple adjacent floor joists, excessive hoarding and heavy clutter adding significant live load to an aged existing floor assembly and a varying degree of fire within the interior compartment and structural void space area suggest an apparent and highly probable series of conditions that aligned in such an manner at this row house fire that provided the sequence of events and mechanism of collapse that had adverse consequences to operating companies within the structure.

Uniqueness and Variances for this Row house and Fire

- The inherent legacy notching of the existing wood floor joists was a primary contributor to create an existing floor system that was highly susceptible and prone to be affected by an interior compartment or structural fire or affected by existing or in the addition of live or dead loads.
- Existing Hoarding, Heavy Contents and Clutter introduced to the rooms by the occupant significantly contributed towards the potential for floor instability and compromise.
- Deterioration and exposure of the interior rooms and occupancy to environmental exposure and elements and their suggested impacts on the building structural components, materials and systems may have had a contributing effect on structural stability and integrity of building components. Possible degraded load transfer and load capacity of the existing wood floor joists

due to age, creep, the effects of loss of moisture content or cyclical exposure to environment elements**.**
- The small size of the row house structure, when impacted by unstable or compromising structural stressors may not have the resiliency or resistance to recover from those conditions or allow for load transfers and still maintain its structural stability and integrity.

The alignment of seven separate conditions correlated in this row house occupancy to create a variance an irregularity that made this incident and fire operation unique that contributed to the collapse conditions and outcome;

- The Existing Hoarding, Heavy Contents and Clutter
- The presence of the legacy notch lines in the wood joists from building front inward created an existing condition that made each of the floor joists highly susceptible and prone to the effects of fire, heat and failure.
- Inherent building support systems (Wood joist) degrade or affected material conditions & postulated diminished structural integrity
- Floor joist framing at the stairwell and floor area above that creates a susceptible and prone interior condition (to fire) that is inherent in all row houses of this layout type, floor plan and configuration (Workingman's Row House)
- The suggested impact of water introduced during fire suppression affecting hoarding and clutter conditions
- The location and extent of fire
- The transitional tactics from Offensive to Defensive to Offensive may not have considered structural integrity of critical internal building systems or components that may have been subject to varying degradation, damage or compromise and the compounded effects of imposed loads on the building from hoarding, heavy content and clutter.

Generally, when operating companies are confronted with intense fire conditions within a building of Type III construction with similar vintage, occupancy use and tenant space configuration; and those fire conditions have either impinged or propagated within or along concealed spaces, voids or compartment for an extended period of time prior to arrival or during fireground operations, it is highly probable and predictable that the structural integrity of the various assembly, supports and structural floor joists and wall systems will be compromised and subject to varying degrees of degradation.

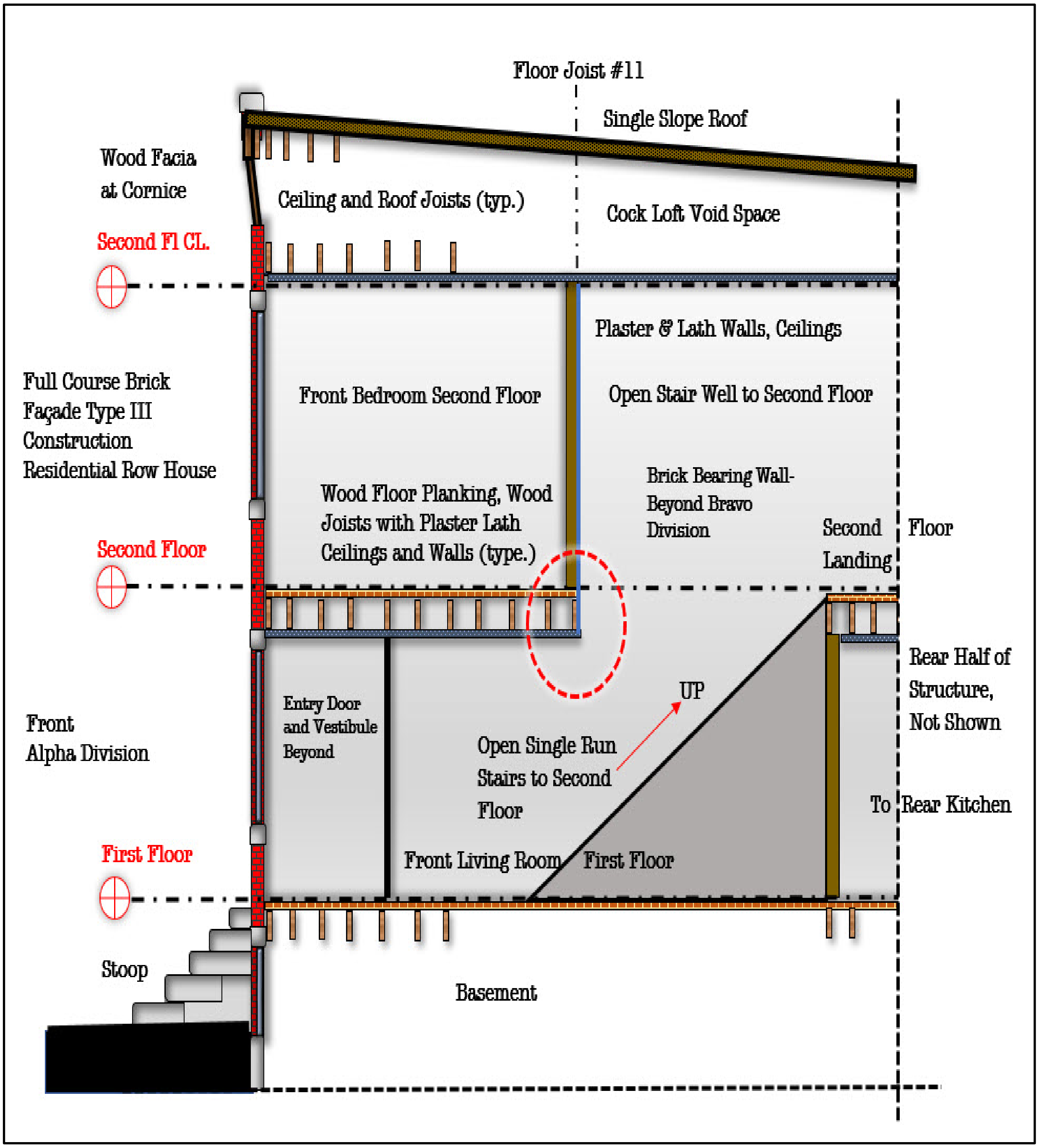
Rapid or prolonged fire extension or exposure within a compartment of floor area of a row house or building of Type III construction will result in probable building component and assembly compromise, deterioration, failure and collapse.[22,26,28,29,30]

The probability for isolated and catastrophic building compromise and structural collapse could have been readily apparent to all operating personnel and fundamentally recognized as one of the foremost operational considerations during the incident management, command and control and in the overall tactical assignment.[29,30]

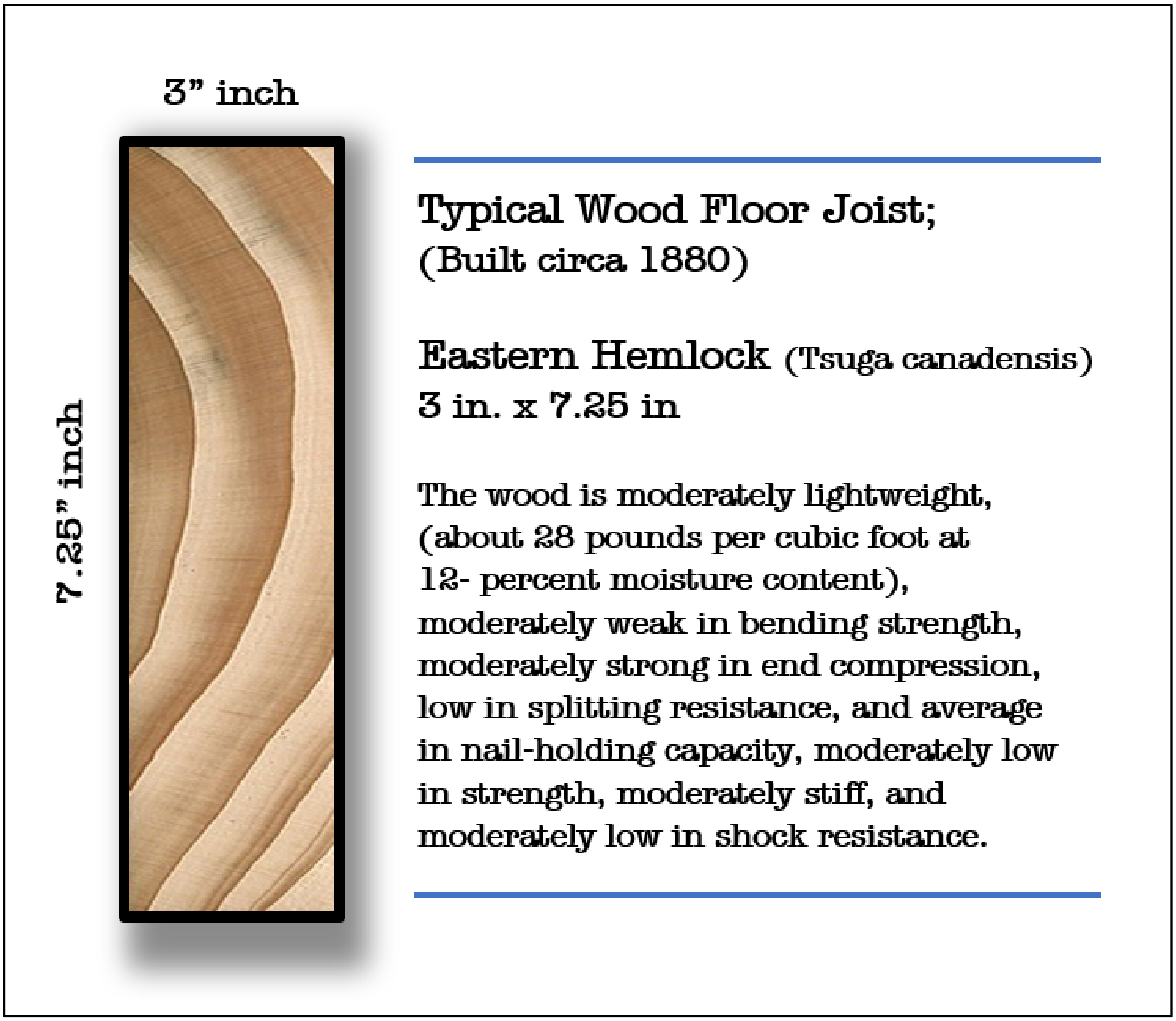
The performance characteristics of wood and wood joists when exposed to fire are readily known. Thermal degradation of structural wood components and the effects of fire impingement on wood members and assemblies responding to heating; decompose or pyrolyzes into volatiles and char. As wood burns and chars the loss of wood cross-section (mass) of single or multiple structural wood members such as dimensioned wood floor joists continue in direct fire growth phases leading to the loss of redundancy capabilities a structural component, assembly or system, resulting in deflection, loss of load carrying capacity, compromise or collapse.[11,31,32,37,38]

- Operational safety considerations during initial or subsequent fire operations when confronted with compartment or concealed ceiling or floor space fire impingement, extension and structural stability are very fluid demanding command and tactical decision-points that can dramatically change in an instant transitioning from benchmarking tactical progress by operating companies to that of a highly demanding and rapidly escalating collapse, mayday, rapid intervention team deployment and rescue efforts.
- The complete loss of wood cross-section of wood floor joists due to flame impingement results in structural compromise of the component to perform as designed to carry and transfer loads or to carry attached loads present within this structure at the time of the fire.
- Uneven deterioration or burn thru of wood floor joists, wall/floor connections, floor joist and joist bearing in masonry wall pockets and the possible loss of joist stability would lead to structural compromise. This would result in the collapse of the floor joists and the corresponding collapse of the floor diaphragm affecting stability and integrity of floor, wall and compartment integrity and sustainability.

V. Graphics and Diagrams

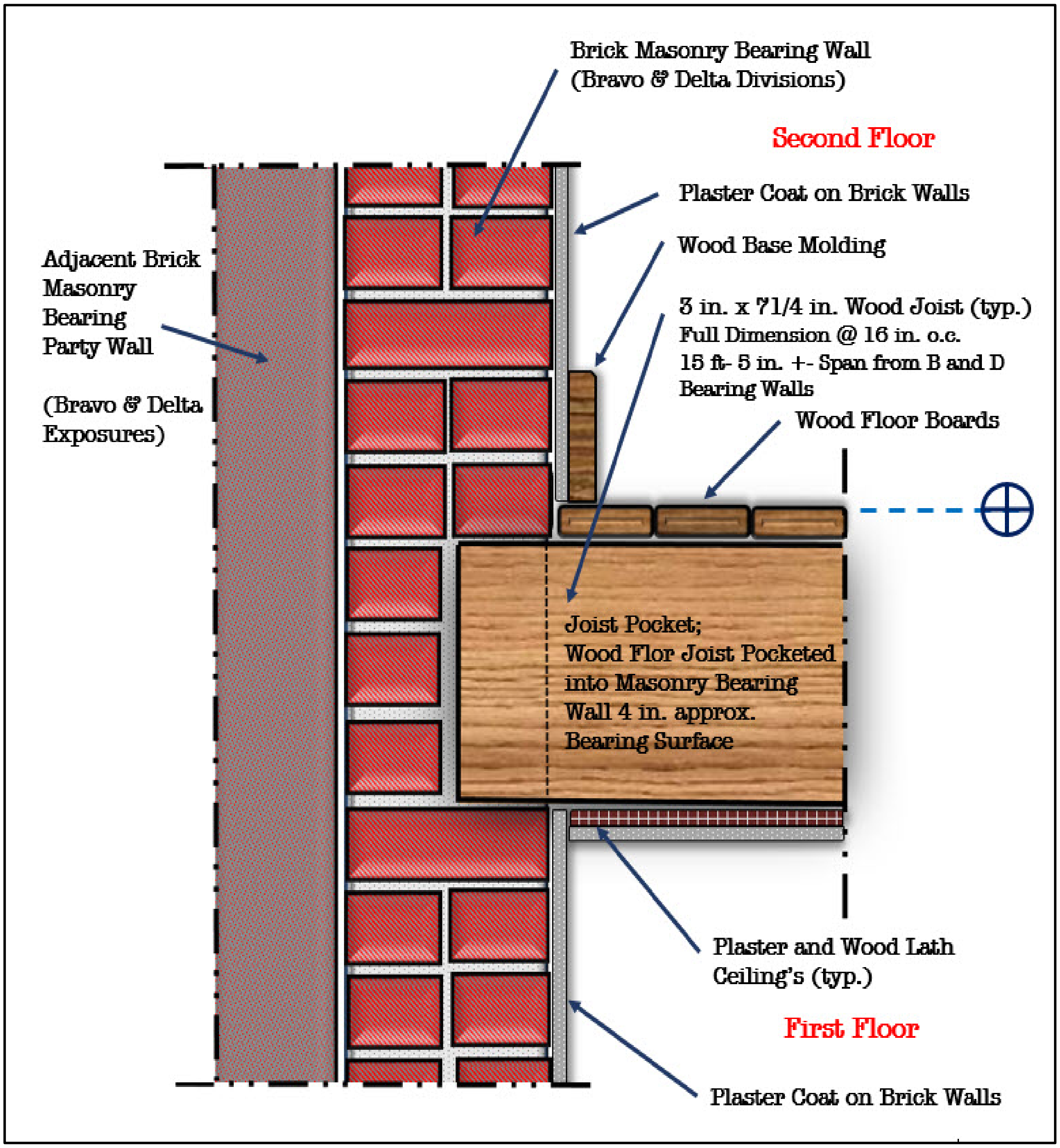


Appendix 2 Diagram 3. Cross-Section of Row house 2240 North Colorado Street Graphic Courtesy of Buildingsonfire.com | C.J. Naum



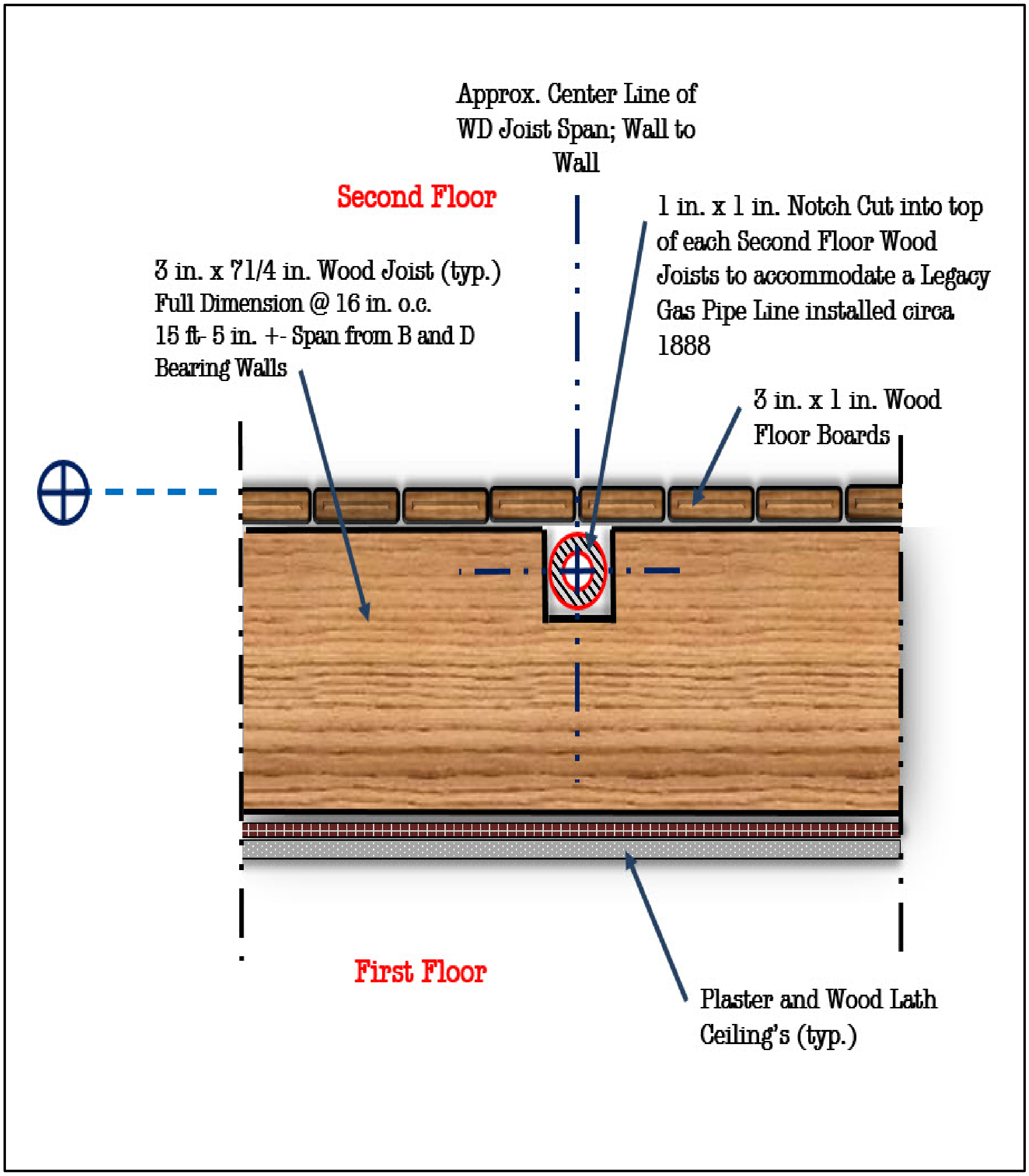
Appendix 2 Diagram 3a. Typical Wood Floor Joist. Graphic Courtesy of Buildingsonfire.com | C.J. Naum

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

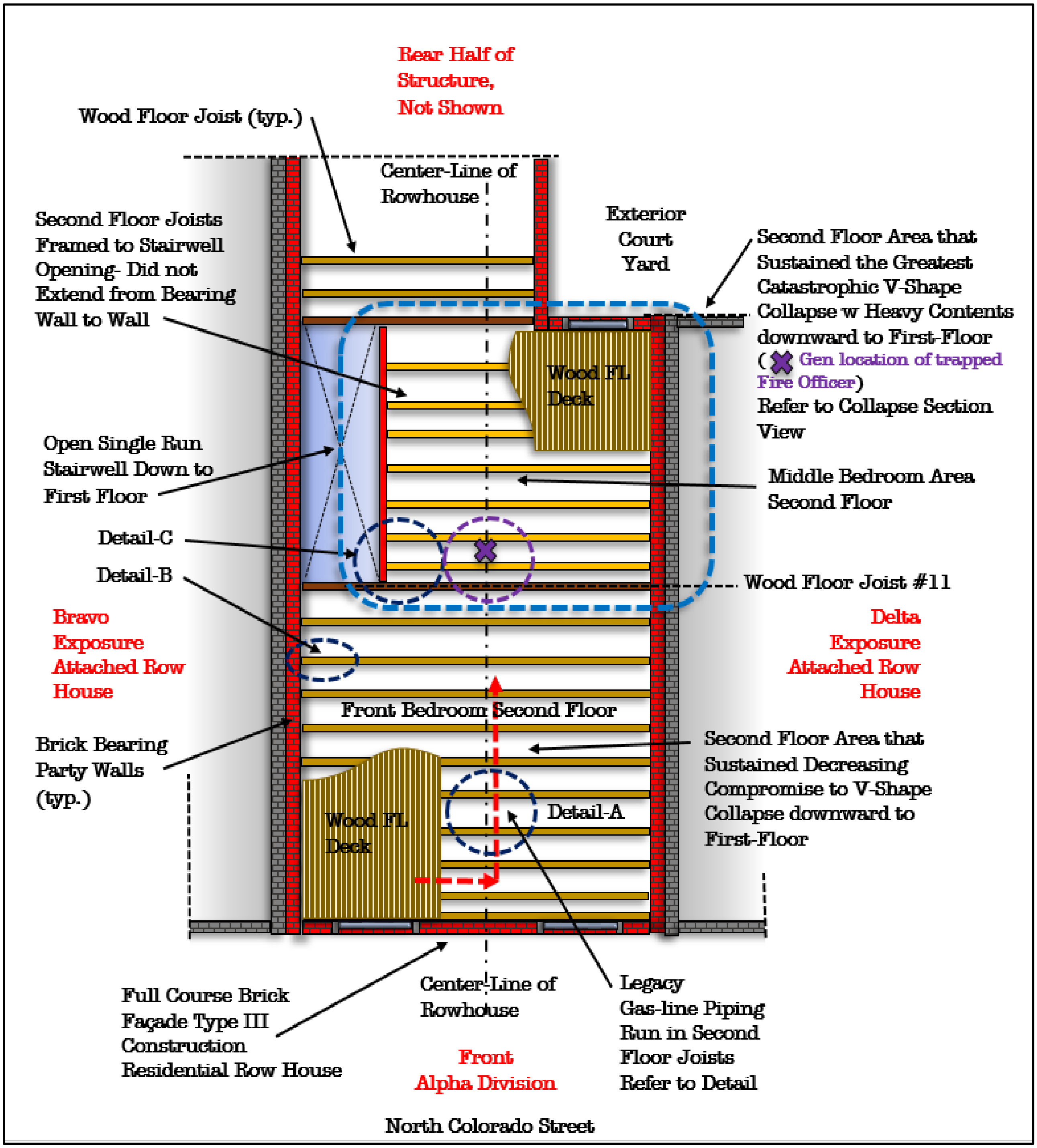


Appendix 2 Diagram 4. Detail-B Masonry Party Wall and Floor Joist Section & Detail-A Gas-line & Notch

Graphic Courtesy of Buildingsonfire.com | C.J. Naum



Appendix 2 Diagram 4a. Detail-B Detail-A Gas-line & Notch. Graphic Courtesy of Buildingsonfire.com | C.J. Naum



Appendix 2 Diagram 5. Row house Floor Joist Plan-Second Floor. 2240 North Colorado Street.
Graphic Courtesy of Buildingsonfire.com | C.J. Naum

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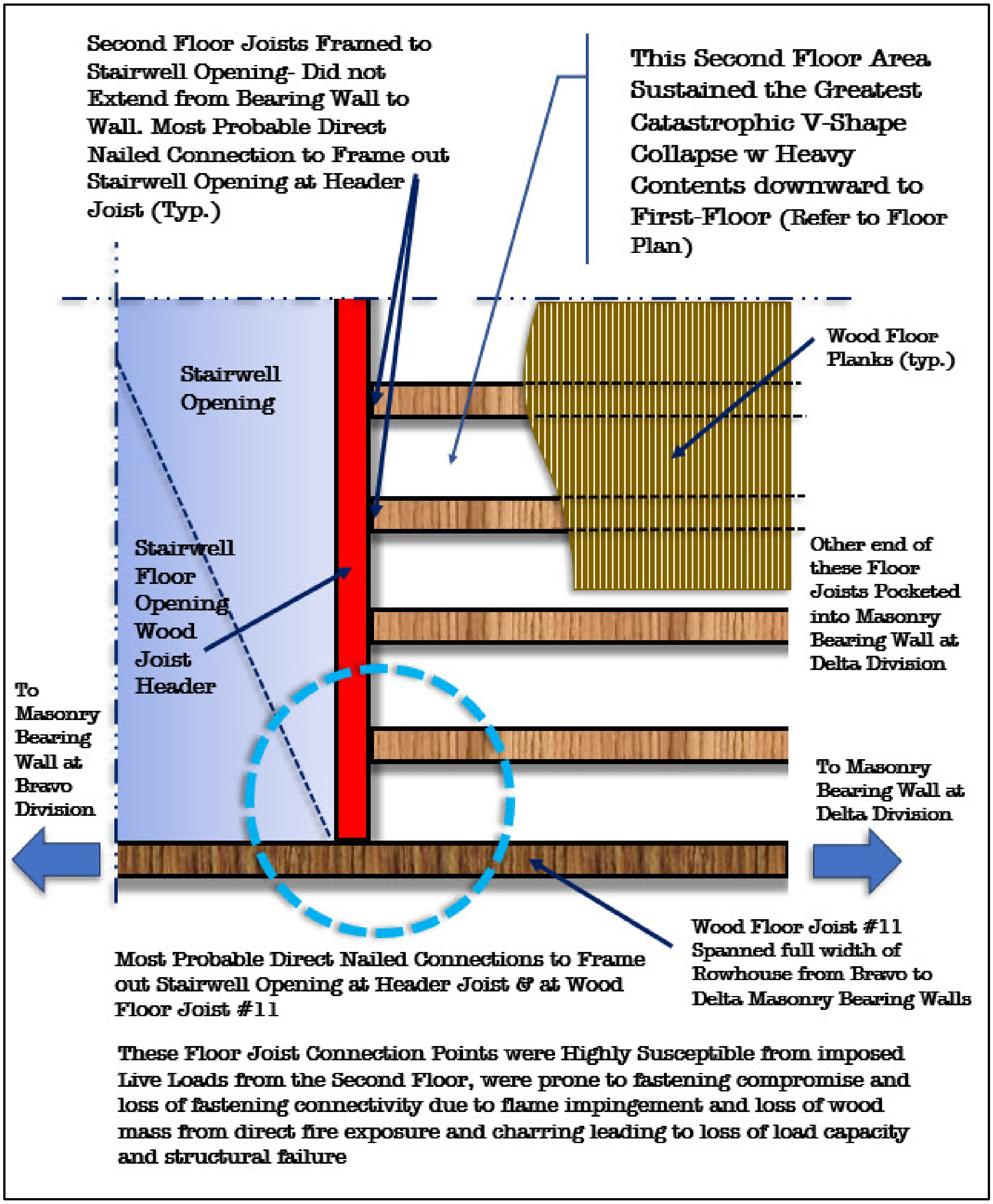
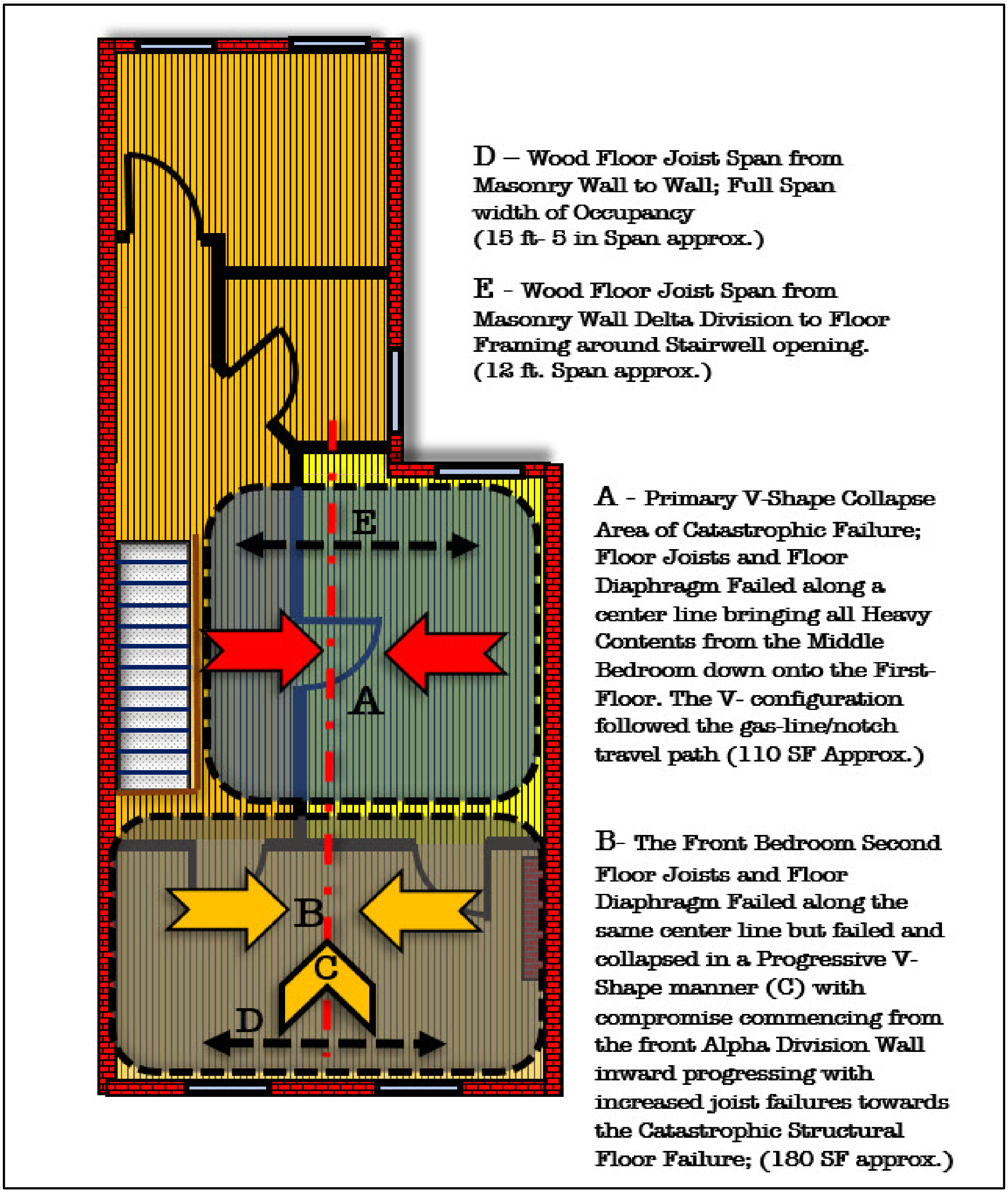


Appendix 2 Diagram 5a. Detail-C Stairwell Opening Framing and Second Floor Joists. Graphic Courtesy of Buildingsonfire.com | C.J. Naum



Appendix 2 Diagram 6. Second Floor Collapse Areas. Photo: Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum

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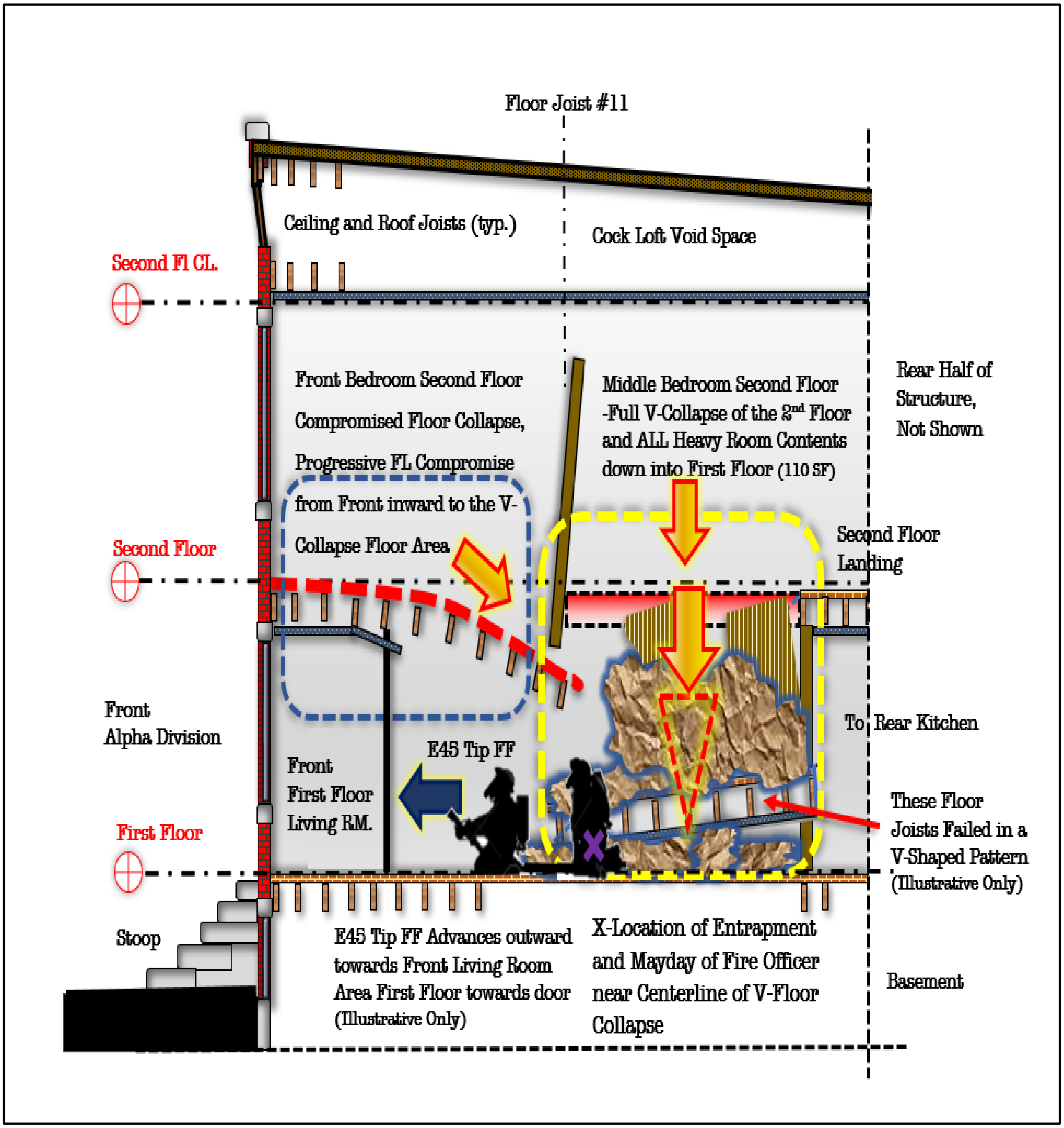

Appendix 2 Diagram 7. Cross-Section of Second Floor Collapse Configuration 2240 North Colorado Street Graphic Courtesy of Buildingsonfire.com | C.J. Naum

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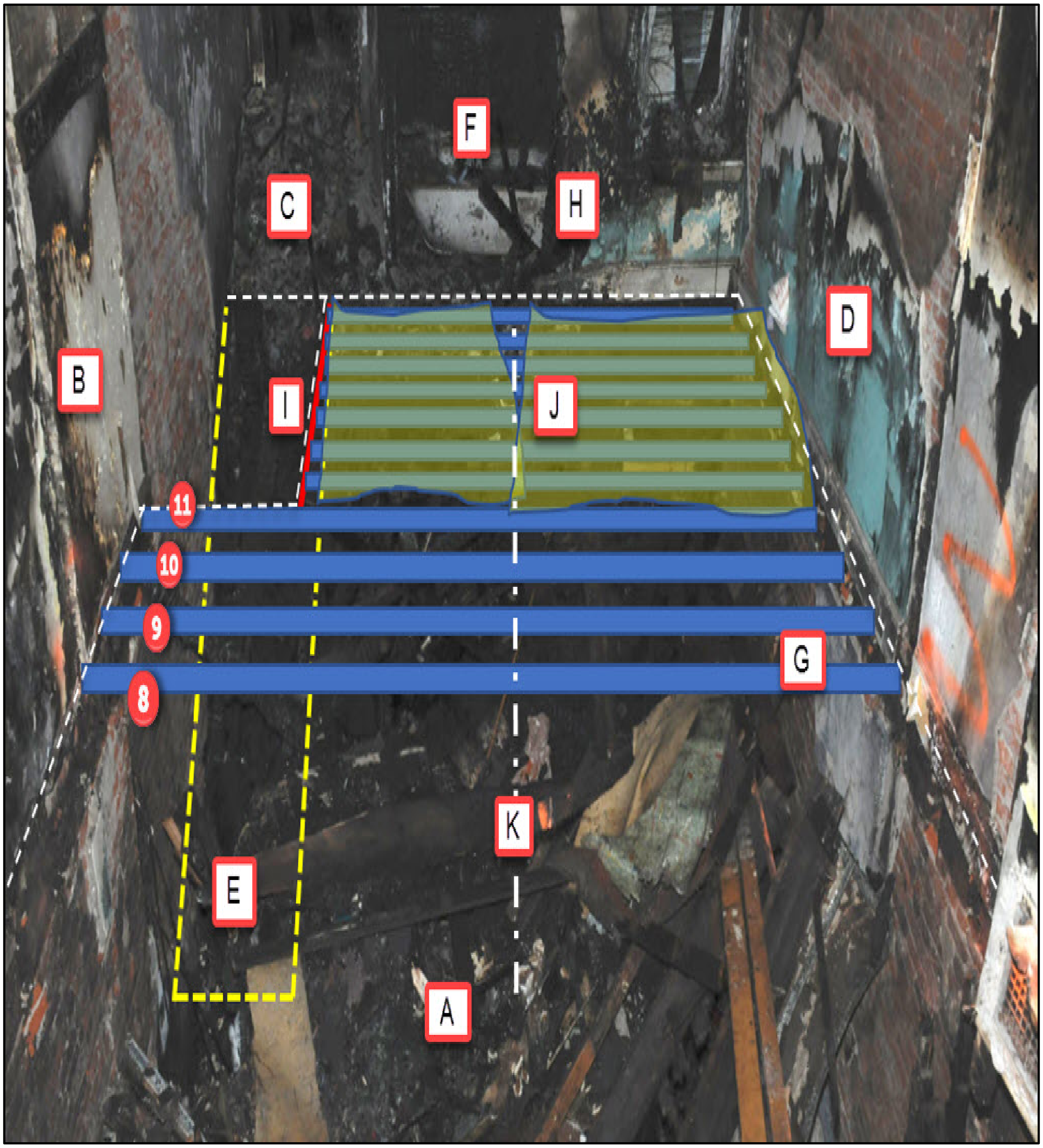
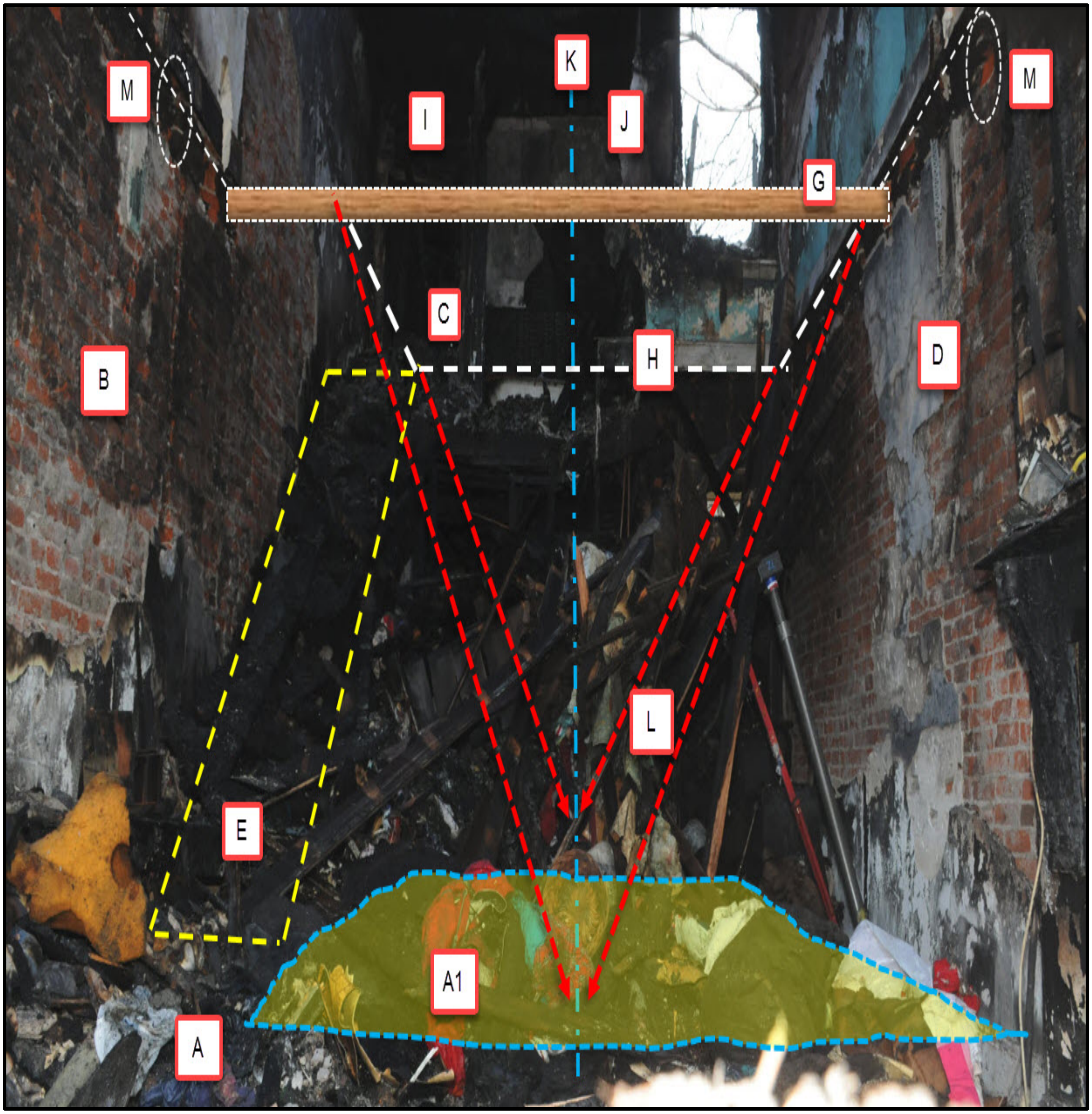


Appendix 2 Diagram 8. Second Floor Joist Reconstruction and Collapse Area, looking inward from the Alpha Division. Photo Courtesy of Fire Department, Photo Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania



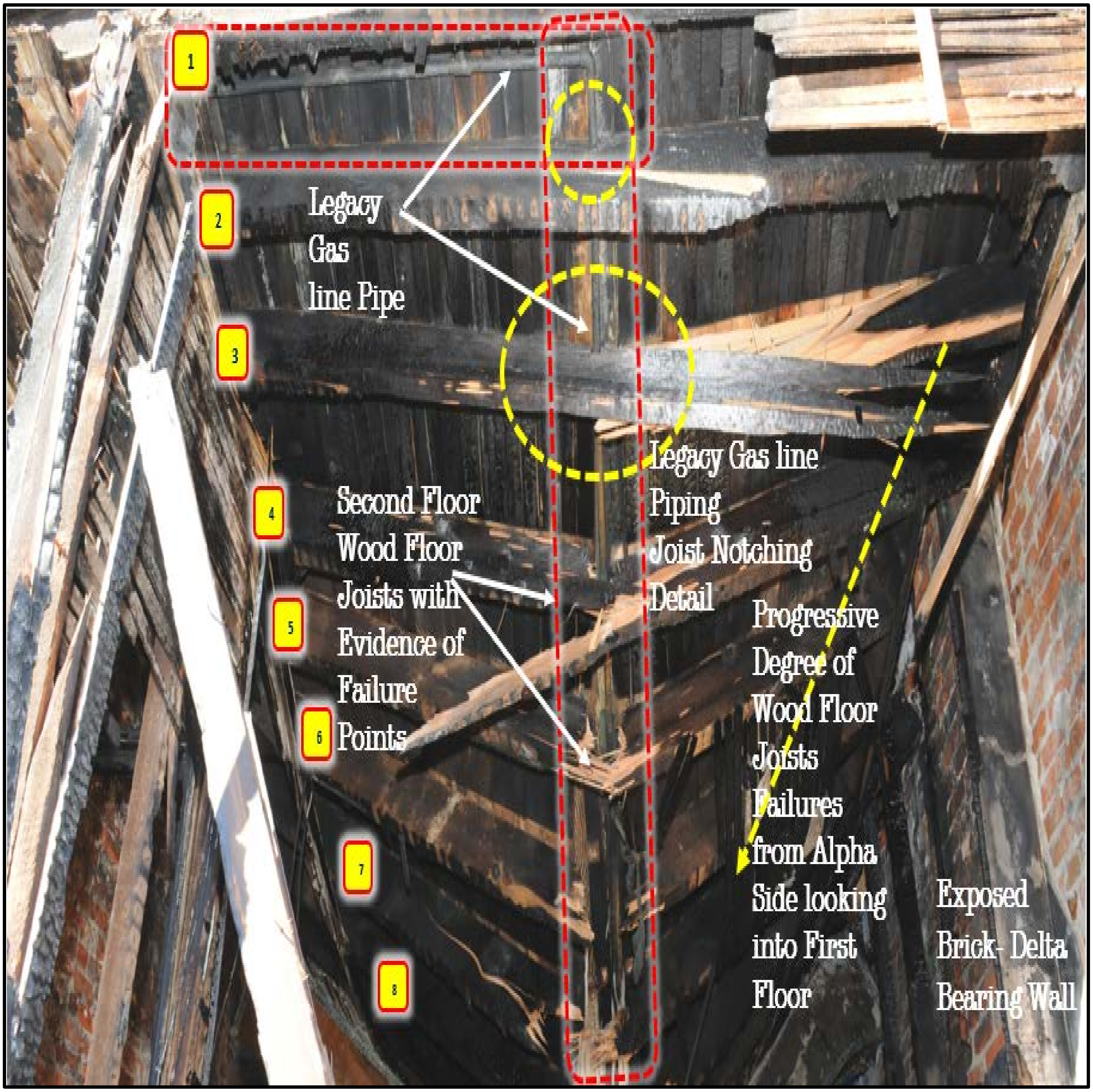
Appendix 2 Diagram 9. First Floor Collapse Zone Reconstruction and Orientation, looking inward from the Alpha Division. Photo Courtesy of Fire Department. Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum Post Collapse and after debris removal from both First and Second areas.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

A. First Floor Front Living Room Area

A1. Primary Collapse Zone under the area of the Middle Second Floor bedroom above. This area had the predominate level of collapse severity and catastrophic level of building materials and debris pile from the V-Floor collapse profile. This collapse area consisted of both building materials, structural components and heavy content (Hording material) furnishing, etc. that created a significant matrix of materials, loads and mass.

B. Masonry Brick Bearing Party Wall- Bravo (B) Division
C. Second Floor Stair Landing
D. Masonry Brick Bearing Party Wall- Delta (D) Division
E. Single Run Straight Stairway from First Floor to Second Floor
F. NA
G. Typical Wood Floor Joist; Location of Joist #11 spanning from Bravo (B) Division to Delta (D) Division Masonry Brick Bearing Party Walls; Approximate Span 16 feet
H. Second Floor Joist Outline at the Bathroom wall area not involved in the subsequent floor collapse
I. Second Floor Hallway leading to Rear Bedroom
J. Second Floor Bathroom
K. Approximate Centerline of the Row house floor-span & approx. CL of the Second Floor V-Collapse Profile
L. Depiction of the directional movement of the second-floor assembly and floor diaphragm failing approx. mid-span resulting in a V- Collapse profile
M. Typical Masonry Wall Pockets for Floor Joist bearing (Refer to Diagram 5)



Appendix 2 Diagram 10. Second Floor Collapse of Floor Joists Details of Failures, looking inward from the Alpha Division. Photo Courtesy of Fire Department. Analysis Diagram Courtesy of Buildingsonfire.com | C.J. Naum

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Appendix 2 Photo 5. Front First Floor Looking inward to Collapse Zone 1st Floor. Photo Courtesy of Fire Department. Hording, Heavy Content and Clutter from Second Floor Rooms into the V-Shaped Floor Collapse. Photo Courtesy of Fire Department.

Appendix 2 Photo 6. Front First Floor Looking inward to Collapse Zone and Second Floor Debris Heavy Content. Photo Courtesy of Fire Department. Foreground: Compromised front 2nd Floor Bedroom joists V-pattern. Background: Beyond the decorative wood "beam" is the catastrophic full V-pattern collapse of the Center 2nd Floor Bedroom

Appendix 2 Photo 7. Front First Floor Looking inward to Collapse Zone and Second Floor Debris Heavy Content. Photo Courtesy of Fire Department.

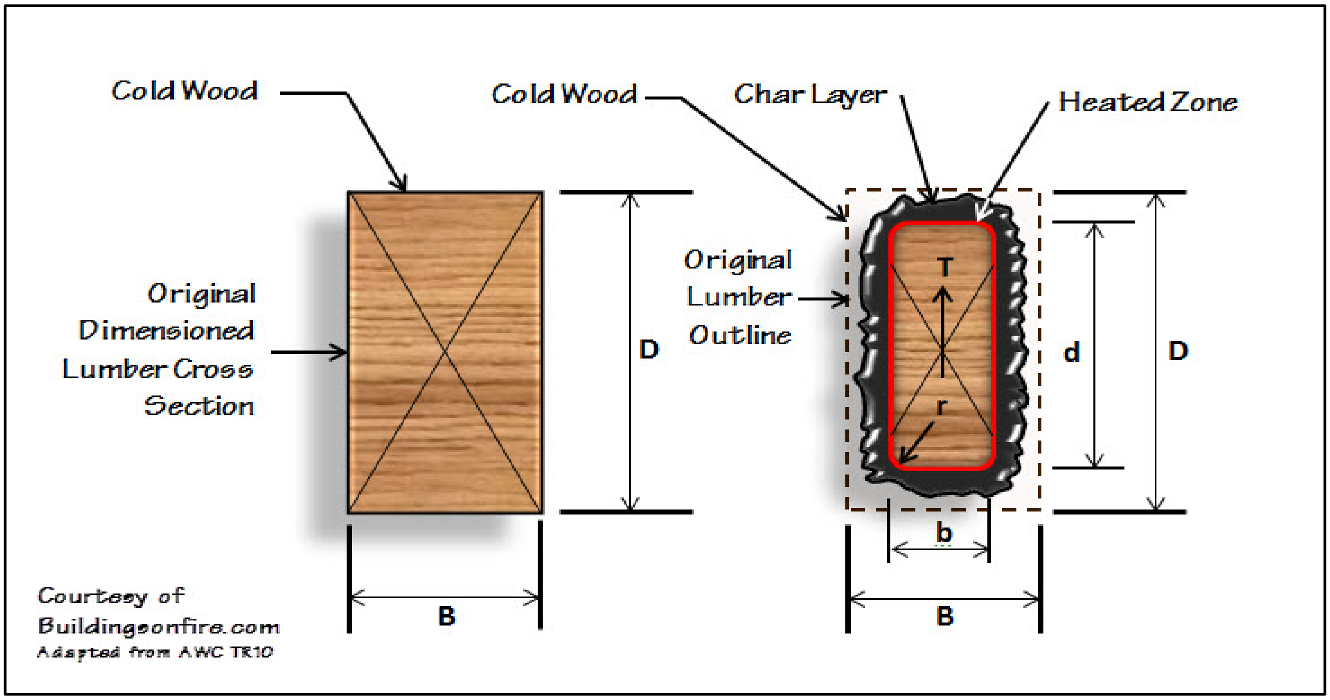
Appendix 2 Photo 8. Second Floor Collapse of Floor Joists. Photo Courtesy of Fire Department.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

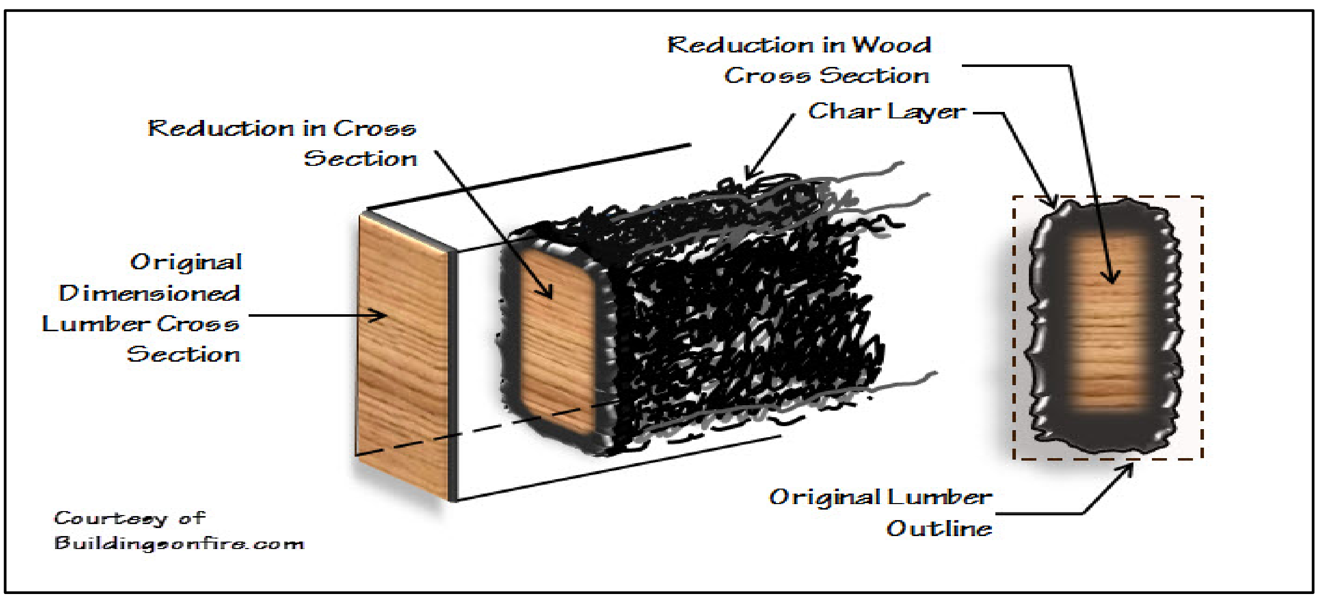
Appendix 2 Photo 9. Second Floor Collapse of Floor Joists. Photo Courtesy of Fire Department .

Appendix 2 Photo 10. Second Floor Collapse of Floor Joists at Fireplace. Photo Courtesy of Fire Department.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania



Appendix 2 Diagram 11. Reduction in Wood Floor Joist Component Breadth and Depth over time. **G**raphic Courtesy of Buildingsonfire.com | C.J. Naum. Adapted from AWC Technical Report #10 (2012)



Appendix 2 Diagram 12. Charring Effect on Wood Floor Joist Component and Cross Section Graphic Courtesy of Buildingsonfire.com | C.J. Naum

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Appendix 2 Photo 11. Fire Conditions Pre-Arrival of FD Time: 08:55:20. Photo: Courtesy of Fire Department (from resident video).

Appendix 2 Photo 12. Fire Conditions upon FD Arrival. Photo: Courtesy of Fire Department

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Appendix 2 Photo 13. Initial FD Operations; Transitional Attack Time: 08:57:49. Photo: Courtesy of Fire Department (video taken by area resident across the street).

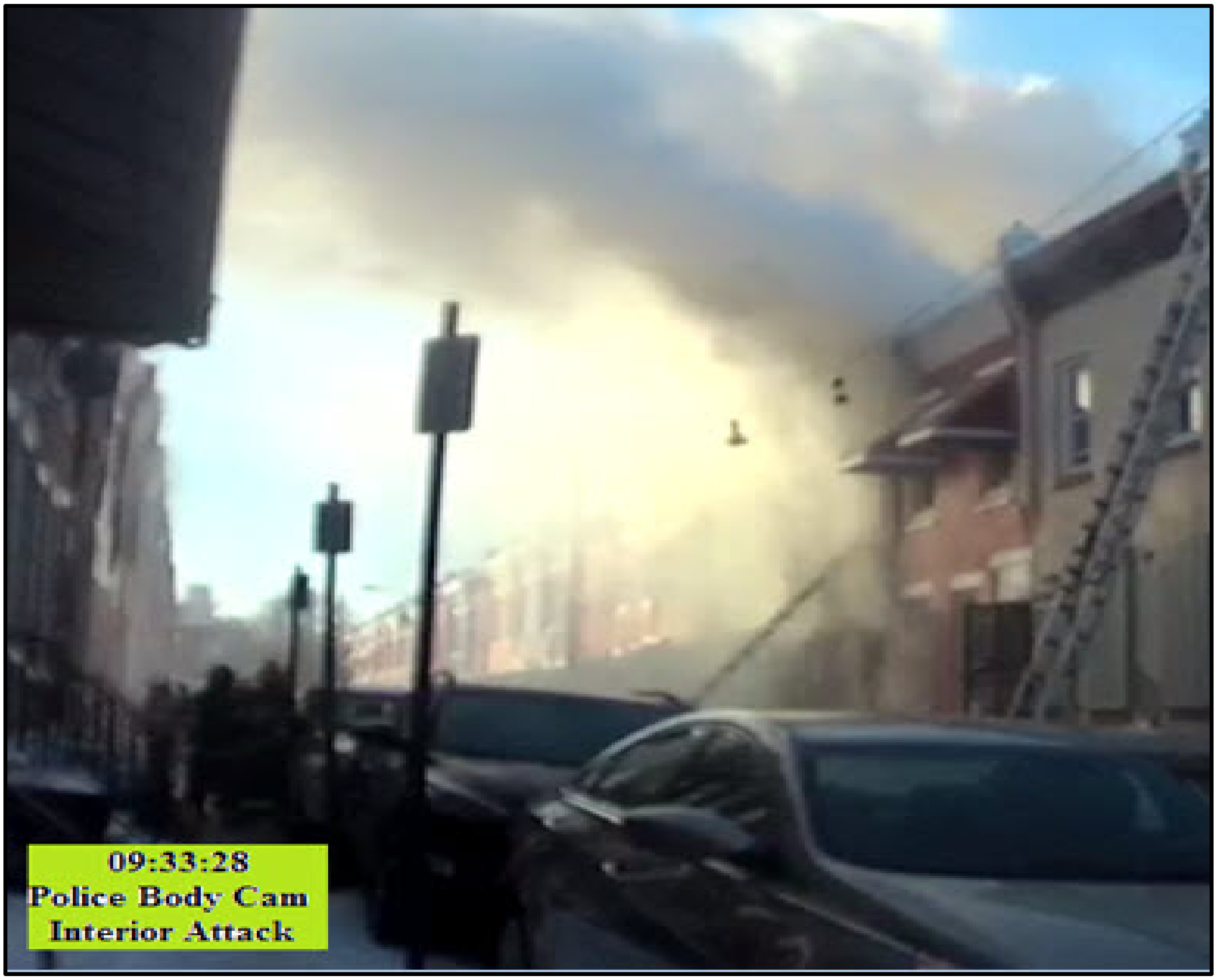
Appendix 2 Photo 14. Initial Fire Attack View from Police Body Cam Time: 09:05:16. Photo Courtesy of fire department obtained from Police Body camera

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

Appendix 2 Photo 15. Transitional Fire Attack from Offensive to Defensive Operations View from Police Body Cam Time: 09:07:57. Photo Courtesy of fire department obtained from Police Body camera

NOTE:

- Incident Command orders all companies out of the occupancy
- Introduction of Water Stream via hoseline from street exterior into front second floor window
- Note degree of smoke, density and colorization



Appendix 2 Photo 16. Transition back to Offensive Fire Operations and Initial Structural Collapse View from Police Body Cam Time: 09:33:28. Photo Courtesy of fire department obtained from Police Body camera.

VI. Appendix Report References

1. Philadelphia Fire Department, Health and Safety Department Provided Internal Information; Incident #18-0060250, Box 7743, 2240 North Colorado Street Fire
2. National Building Codes Recommended by the National Board of Fire Underwriters (1900-1915)
3. NFPA [2012] NFPA 220 Standard on Types of Building Construction, 2012 ed. Quincy, MA: National Fire Protection Association
4. City of Philadelphia, Philadelphia Planning Commission, Rowhouse Manual (2008); https://www.phila.gov/CityPlanning/resources/Publications/RowhouseManual_Final.pdf
5. History of the Philadelphia Rowhouse http://philadelphiaencyclopedia.org/archive/row-houses/
6. Donna J. Rilling. Making Houses, Crafting Capitalism: Builders in Philadelphia, Philadelphia: University of Pennsylvania Press. 2001.
7. Naum, C.J. [2012] Building Anatomy: Types and Classifications Firehouse Magazine, July 2012

8. Architecture and Building Construction, International Correspondence Schools, Scranton, PA [1899 & 1902] Carpentry Section 9-2 https://archive.org/details/textbookonarchit02inte
9. U.S. Department of Agriculture Forest Service American Woods—FS-239 Revised October 1970 https://www.fpl.fs.fed.us/documnts/usda/amwood/239hemlo.pdf
10. USDA Forest Products Laboratory (FPL) (2010) Wood Handbook: Wood as an Engineered Material FPL-GTR-190
11. NFPA Fire Protection Handbook, 13th edition (1969) National Fire Protection Association
12. Handbook of Building Construction Data, G. A. Hool (1929)
13. Architectural Graphics Standard, 6th Edition [1970] American Institute of Architects
14. HUD, Residential Structural Design prepared by the NAHB Research Center, Inc., for the U.S. Department of Housing and Urban Development, Washington, DC, 2000
15. U.S. Department of Housing and Urban Development Office of Policy Development and Research REVIEW OF STRUCTURAL MATERIALS AND METHODS FOR HOME BUILDING IN THE UNITED STATES: 1900 to 2000
16. Correspondence from NIOSH FFFIT, S. Miles to Philadelphia FD Dated May 9, 2018
17. Philadelphia Fire Department, Health and Safety Department Internal Incident Overview Presentation After Action Review Incident #18-0060250, Box 7743, 2240 North Colorado Street Fire, and/or correspondence from the PFD Health and Safety Dept. Staff.
18. Naum, C.J. [2012] Predictability of Performance of Buildings on Fire, Firehouse Magazine, June 2012, pp. 87-89
19. Naum, C.J. [2013] Reading the Building and Predictable Performance Indicators of Buildings on Fire. Fire Department Instructors Conference Proceedings, Indiana, April 2013
20. Naum, C.J. [2013] Reading the Building: The Importance of the Size-Up Firehouse Magazine, April 2013, pp. 128-131
21. Naum, C.J. [2012] Occupancy Profiling and Buildings on Fire Risk Assessment Matrix, Buildingsonfire.com additional information can be accessed at http://buildingsonfire.com/buildings-on-fire-risk-assessment-matrix
22. Naum, C.J. [2014] Adaptive Fireground Management and Operations. National Professional Development Symposium, National Fire Academy, Maryland, June 2014
23. Naum, C.J. [2015] Building Construction for Today's Fire Service Firehouse Magazine, January 2015, pp. 74-75
24. Naum, C.J. [2015] Today's Building: What Happens When They Burn Firehouse Magazine, February 2015, pp. 74-77
25. Buildings on Fire Risk Assessment Matrix Courtesy of Buildingsonfire.com and the Command Institute, additional information can be accessed at http://buildingsonfire.com/buildings-on-fire-risk-assessment-matrix
26. National Institute of Occupational Safety and Health, Death in the Line of Duty: Career lieutenant and fire fighter killed and two fire fighters injured by wall collapse at a large commercial structure fire - Pennsylvania. F2012-13 (2012)
27. National Institute of Occupational Safety and Health, Death in the Line of Duty: 4 Career fire fighters killed and 16 fire fighters injured at commercial structure fire –Texas. F2013-16 (2013)
28. Naum, C.J. [2016] Operational Considerations at Buildings of Ordinary and Heavy Timber Construction. Fire Department Instructors Conference Proceedings, Indiana, April 2016
29. Naum, C.J. [2015] Establishing Collapse Zones at Building Fires, Firehouse Magazine, April 2015 https://www.firehouse.com/operations-training/article/12054302/establishing-collapse-zones-at-building-fires
30. Naum, C.J. [2015] Buildings on Fire: Collapse Zones: Building Characteristics & Occupancy Risks, Firehouse Magazine, June 2015
31. American Wood Council (AWC) Technical Report N0.10 [2014] Calculating the Fire Resistance of Exposed Wood
32. American Society for Testing and Materials, ASTM E119 Fire Tests of Building Construction and Materials ASTM Fire Test Standards, ASTM, Philadelphia, PA,
33. Madsen, B. "Moisture Content- Strength Relationships for Lumber Subject to Bending" University of British Columbia
34. Gerhards, C. C [1980] "Effect of Moisture Content and Temperature on the Mechanical Properties of Wood: An Analysis of Immediate Effects"

35. Nolan, S., [2002] "New Loads for Old Structures" The Journal of the Entertainment Services and Technology Association
36. Cavalli, Cibecchini, Togni, Sousa, [2016] "A Review of the Mechanical Properties of Aged Wood and Salvaged Timber" https://www.researchgate.net/publications/299978150
37. Structural Integrity During Fire, Fire Protection Handbook 18th Edition, A.E. Cote
38. SFPE Handbook of Fire Protection Engineering, 2nd Edition (1995)
39. Bland, K.E., "Behavior of Wood Exposed to Fire: A Review and Expert Judgment Procedure for Predicting Assembly Failure," Master's Thesis, Worcester Polytechnic Institute, Worcester, MA, May 1994.
40. Underwriters Laboratories "Report on Structural Stability of Engineered Lumber in Fire Conditions"., Project Number: 07CA42520 Underwriters Laboratories Inc., Northbrook, IL. September 30, 2008
41. Klein, G., (2008) Naturalistic Decision Making http://www.ise.ncsu.edu/nsf_itr/794B/papers/Klein_2008_HF_NDM.pdf
42. Naum, C.J. [2009] Operational Safety Considerations at Ordinary & Heavy Timber Constructed Occupancies. http://www.firegroundleadership.com/2010/12/03/operational-safety-considerations-at-ordinary-and-heavy-timber-constructed-occupancies-training-download/

VII. Additional Information Provided by Chief Naum

Comments

In many building and structures and various residential and commercial occupancies that have had a long-life cycle (decades or in excess of 100 years plus) the likelihood of renovations and alternations affecting predictable building performance and fireground operations should be anticipated and considered in any incident action plans, tactical plans and task assignments.

Maintenance, age and damage and the desire for modernization usually results in renovations and alternations of many commercial and residential interiors. As was the case here, the ceiling system present at the time of the fire had multiple layers of materials added over time that consisted of original plaster and lath attached directly to the dimensioned lumber ceiling joists, wood tongue & grove panel boards, and gypsum wallboard.

Building materials, finishes, construction systems and assemblies will react differently and at different intervals when exposed to elevated temperature gradients and will individually or collectively react to fire, heat and physical load stresses, transfers and resiliencies leading to restraint, movement or loss of material integrity.

Each building material and component is affected differently (over time) based on their material characteristics and fire resistance or vulnerability. This includes such factors as; applied structural load intensity, member/component type, structural member dimensions and boundary type, incident heat flux from the fire on the structural member or assembly, type of wood construction and effects of temperature rise and impingement on the structural member or assembly and the relevant properties of the members.

Certainly, at the divisional and company supervisory level, task assignments must consider the implementation of area safety risk surveys and focused observations to identify subtle or obvious building anatomy, structural, architectural, engineering or aesthetic conditions or features that may have an impact on assignments, tasks or the simple presence in an area or establishment of exclusion zone restricting or limiting personnel access or operations.

This must be a practiced and learned skill set, since the implementation of such assessments and observations must be done in rapid and timely succession when confronted with highly demanding and time limiting incidents with both escalating fire extension and severity and civilian life safety considerations.

Anticipate Compromise and Collapse in Type III buildings with minimal to moderate fire in 0-15-minute elapsed time spans;

Expect Compromise and Collapse in Type III buildings with moderate to extending fire in 15-25-minute elapsed time spans, Plan, Prepare and Execute with Critical Thinking and Conservative-Biased Risk Management, Tactical Discipline and Tactical Patience.[12,18,19,20]

Compromise and Collapse Time & Benchmarks*

Fire | Heat | Smoke Propagation | Impingement | Severity | Growth	Predictability of Building Compartment | Assembly | System | Perimeter Wall-PW | Floor-FL | Roof-RF	Benchmark	Operational Risk Profile	
Duration (Minutes) Not Definitive & Variable Based	Compromise and Collapse Projections & Prediction	Engagement Time | Progress | Effects	Severity Risk	Operational Probability
0m -15m	Anticipate	10m	Normal	Occasional M
15m-23m	Expect	15m	Marginal	Likely H
23m-30m	Impending	20m	Critical	Likely E
30m +	Precipitated	25m	Catastrophic	Frequent E

*Suggested Times are highly expressive and are greatly influenced by a large number of fire ground variables that include but are not limited to elapsed time, building design, features, fire dynamics, personnel capabilities, deployment, resources, training and other industry recognized parameters. No liability is assumed or implied in the use or application of these suggested parameters and the user assumes all liability.
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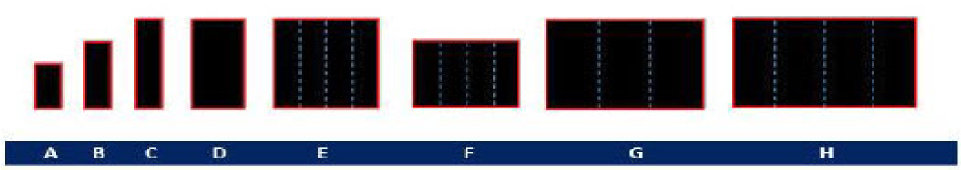
Appendix 2 Diagram 13. Compromise and Collapse Time & Benchmarks. Provided with Permission from the Command Institute, Center for Fireground Leadership. Fireground Operations Training Series on Type III & IV Buildings. Graphic Courtesy of C.J. Naum

Common Building Foot Prints – Floors & Sq. Ft. (Non-inclusive)

FL | SF	A	B	C	D	E	F	G	H
	25' x 50'	25' x 75'	25' x 100'	50 x 100'	100' x 100	150' x 75'	150' x 100'	175' x 100'
1 FL	1250	1875	2500	5000	10,000	11,250	15,000	17,500
2 FL	2500	3750	5000	10,000	20,000	22,500	30,000	75,000
3 FL	3750	5625	7500	15,000	30,000	33,750	45,000	52,500
4 FL	5000	7500	10,000	20,000	40,000	45,000	60,000	70,000
5 FL		9375	12,500	25,000	50,000	56,250	75,000	87,500
6 FL			15,000	30,000	60,000	67,500	90,000	105,000



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Page 5

Appendix 2 Diagram 14. Compromise and Collapse Time & Benchmarks. Provided with Permission from the Command Institute, Center for Fireground Leadership. Fireground Operations Training Series on Type III & IV Buildings. Graphic Courtesy of C.J. Naum

General Insights and Learnings

- Intuitive, tactically-driven versus risk assessed operations where rapid deployment or operational complacency may lack in critical thinking when confronted with an active of post

fire in a mixed occupancy Type III building space - that may require alternate tactics and increased operational safety considerations.
- Rapid Tactical Decision-making leading to Tactical driven operations must include Risk-Based influences
- Occupancy Risk Considerations versus Occupancy Type precursors
- Understand building construction, fire dynamics and company capabilities
- Understand the effects of fire on structural stability and resiliency of Type III buildings of various vintage and architectural styles
- Lack of building knowledge, ineffective profiling and size-up assessment, inadequate situational awareness, diminished sensitivity to time, intervention and compromise-collapse susceptibility and negligible formulation of predictable building, occupancy, systems feature effects can lead to adverse fireground conditions, operations and command compression.
- Understand a building's anatomy, occupancy risks and the characteristic of the building's internal compartments (occupied rooms and space use) they are integral to effective and efficient firefighting operations within buildings on fire and are essential for all phases of fire engagement and suppression.
- The probability for isolated and catastrophic building compromise and structural collapse in Type III buildings should be readily apparent and fundamentally recognized as one of the foremost operational considerations during the incident management, command and control and in the overall tactical assignment in structures fires in buildings of ordinary construction
- **Anticipate Compromise and Collapse** in Type III buildings with minimal to moderate fire in 0-15-minute elapsed time spans; **Expect Compromise and Collapse** in Type III buildings with moderate to extending fire in 15-25-minute elapsed time spans, Plan, Prepare and Execute with Critical Thinking and Conservative-Biased Risk Management, Tactical Discipline and Tactical Patience
- Conduct a Risk Assessment Profile and Size-up of the Building and Fire Conditions at all incidents
- Identify and manage Interior and Exterior Collapse Management Zones
- Incident Commanders must be cognizant of the span of operational time and the effects of fire dynamics on critical building systems and assemblies and the relationship to building integrity, compromise and collapse
- Identify secondary collapse potential and don't allow tunnel vision, distractions or command compression to disregard intervention or restriction before they occur; the results could be detrimental
- Understand the concept of building volume, space, connectivity, fire load package, occupancy load risks, and fire dynamics; they drive tactical options and selection
- Understand building, system, assembly, component; structural integrity and collapse predictability, precursors and operational considerations; they lead to preparedness, vigilance and actions before bad things occur
- Type III Buildings require prompt, aggressive and coordinated exploratory opening of ceiling spaces, transoms, concealed spaces (floors, ceiling, roofs, plenums, walls, shafts etc.) to

determine assumed or actual structural systems, assemblies and location, severity, magnitude and impacts of fire
- Progress reports and cursory status reporting by company may not identify critical structural integrity considerations, assessment profiling or risks
- Building type, style, size, age, condition and any subsequent alterations, renovations and modifications may alter expected building conditions or features and performance under fireground operations.
- With specific construction systems, features and vintage, various types and styles of Type III buildings and occupancies have defined predictable performance factors-that when recognized, assimilated and applied to adaptive tactical models for operations, a favorable balance of risk and incident demands may be correlated by command and company officers to achieve both operational excellence and mission requirements.
- Learn to Read the Building and comprehend what you see, with required actions; don’t let the experience of past successes disguise and mask the distinctive characteristics of the building
- Incident commanders and company officers should develop skill sets in Building Construction, Collapse indicators and Reading the Building profiling to support fireground observations and decision making.
- Develop and implement Fireground risk assessment consideration for structural collapse and protocols for establishing and managing collapse zone and exclusion areas.
- Identify and implement alternate of adaptive tactical procedures or protocols for buildings in your jurisdiction that have inherent structural collapse characteristics and may be prone to collapse or comprise during fireground operations.
- The recognition for and timely formation of effective collapse zones for both primary and secondary collapse must be a principal strategic fireground consideration when suspected or apparent collapse indicators are identified and assessed; Anticipate, Expect and implement controls proactively.
- All personnel should be trained to recognize subtle or readily apparent collapse indicators and be able to read the building and comprehend collapse considerations for primary and secondary collapse conditions for buildings in the jurisdiction.
- The design and implementation of a placarding system to identify high risk and high frequency collapse prone buildings to support timely size-up and IAP development for initial arriving companies.
- The incident commander should establish and manage Collapse zone early in an incident to preclude time delays and reactionary measures that place personnel in risk prone settings.
- In buildings of Type III Ordinary (URM or RM) or Type IV Heavy Timber construction including Mill and Semi-Mill construction, Incident command must be highly focused to the high probability of internal and external collapse, establish and control collapse zones in multiple divisions and possible exposure properties and expect collapse to occur.
- Catastrophic floor system-diaphragm and perimeter wall compromise or failure can occur without warning just as companies are commencing with initial interior operations within a building or space or during overhaul operations. Other historical incidents in which fires and

subsequent collapse of roofs, floors and wall systems that led to LODDs provide additional lessons learned.
- Commanders and Officers recognize and plan for the possibility of adverse latent problems and inherent risks even when projecting and expecting successful outcomes.

Reading the Building & Predictive Indicators

Of the many variables and factors that influence the fireground during the conduct of fire suppression operations, there are three (3) integral factors that can have the greatest impact on operational integrity, effectiveness and firefighter safety: (1) The Building; (2) The Compartment, and (3) The Company.[22,29,30]

Lack of building knowledge, ineffective building and fire profiling and size-up assessment, inadequate situational awareness, diminished sensitivity to time, intervention and compromise-collapse susceptibility can lead to adverse fireground conditions, operations and command compression.[23,24]

- The ability to accurately identify key building attributes and features or conditions- concurrent with compartment fire conditions; process that data -comprehend, synthesize and prioritize key aspects and correlate that to a fluid risk profile model that must be acted upon tactically within a compressed timeframe with company level resources is mission critical during fireground operations.
- Building features, Tenant space occupancy proximity, connectivity of these tenant spaces present influencing operational considerations that could affect incident operations in terms of access, size-up and assessment, smoke tunneling, compartment ventilation, single or multiple flow paths routes, physical compartment configurations and influence of size (SF) and volume (CF) for tenant space(s) and concealed spaces with impacts on ventilation-limited or fuel-limited conditions, structural integrity and collapse considerations, tenability for personnel within the space and connectivity of individual tenant spaces and fire dynamics.
- The probability for isolated and catastrophic building compromise and structural collapse based on fireground conditions in a Type III building should have been readily apparent at a much earlier time frame to all operating personnel (command and company levels) and should have been fundamentally recognized as one of the foremost operational considerations during the initial course of incident management, command and control.
- The presence and configuration of actual or presumed unprotected steel structural components is a predictive indicator for higher risk and higher probability of compromise or collapse when combined with actual or postulated fire dynamics and behavior in tenant spaces and room compartments.
- The presence of various construction requires an understanding of the presumed or known structural support system, the size and volume of the compartment fire, the intensity and propagation of flame and heat, ventilation features (shafts, vertical chases and ventilation shuts, vents, louvers, soffits etc.) and the consideration of time element.

- The need for augmented and adequate fire suppression capabilities in terms of sustained water delivery, stream penetration and reach and adequacy of flow rates based on open compartment fire conditions or presumed/actual concealed fire areas must be assessed, monitored and adjusted accordingly.

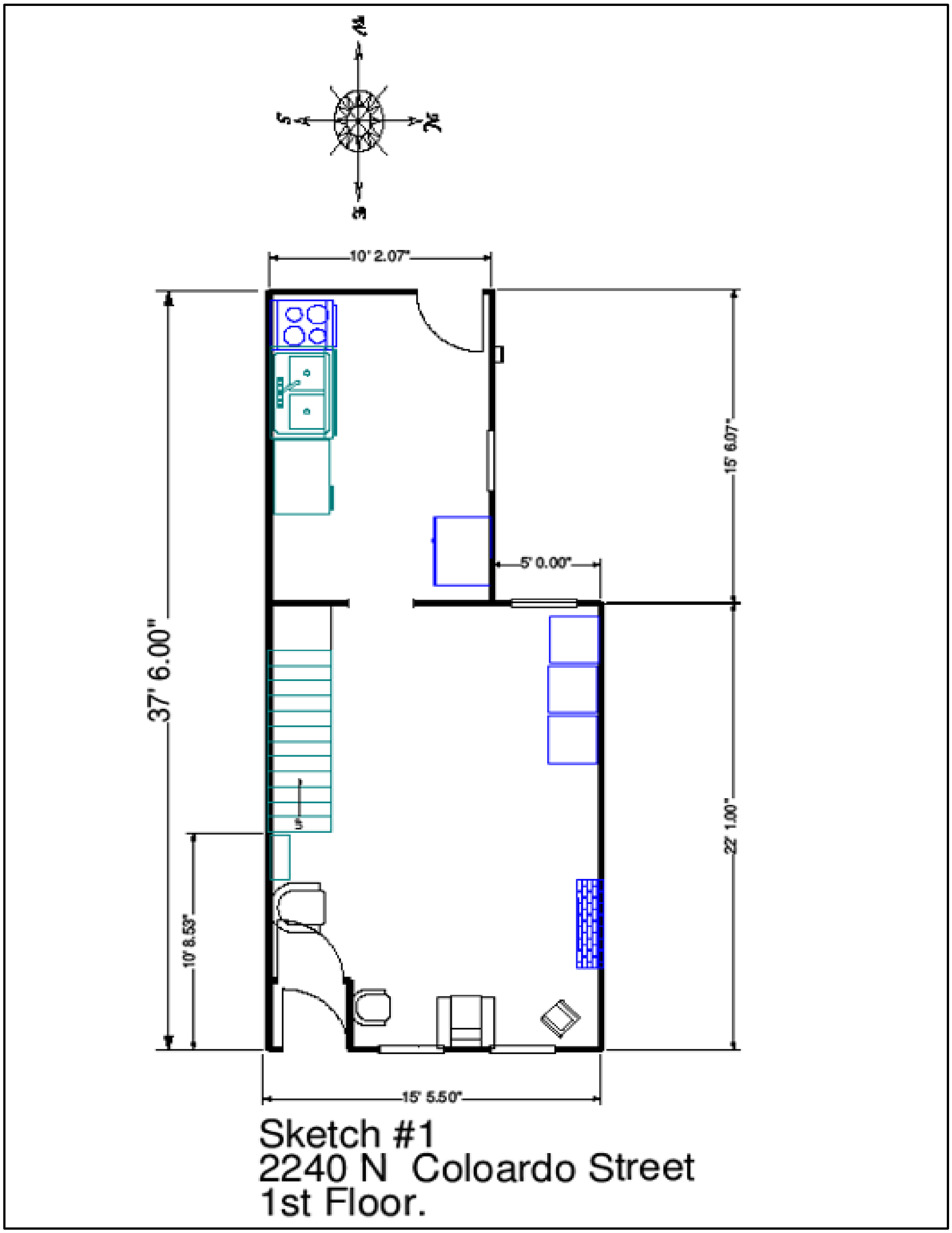
Reading the Building: Risk and Severity Considerations[19,20]

- Building Construction System and Type
- Building Age, Vintage and Condition
- Building Use and Function
- Likelihood of renovations and alternations affecting operations (building life span)
- Building Size and Volume: Tenant Spaces and individual Occupancy Compartments (Apts.)
- Time of Alarm
- Location and Progression of Fire and Fire Dynamics
- Degree of tenant space compartmentation: connectivity of concealed spaces and compartments and high probability for unstopped concealed spaces, voids and plenum spaces and the effect on structural systems, assemblies (steel, wood and masonry)
- Inherent Structural Compromise and Collapse potential-internal due to unprotected construction systems, materials and structural assemblies (steel, wood and masonry)
- Structural Collapse characteristics of Steel I-beams, Steel (or cast-iron) Columns and Wood Joist Systems, Masonry Assemblies; structural integrity and collapse considerations
- Physical arrangement of tenant occupancies and the relationship of upper floors and apartments (compartments) and impacts from smoke tunneling, compartment ventilation, single or multiple flow paths routes, ventilation-limited or fuel-limited conditions, tenability and connectivity of spaces-fire dynamics
- Fire Loading and potential for significant Heat Release Rates/effects on fire suppression based on commercial-retail tenant occupancy and building use
- Identifiable and Measurable Safety parameters
- Adequacy of Fire Flow Rates based on postulated fire growth and selected tactics and the ability to place into service adequate handlines with effective and sustainable delivery application rates
- Probability of Rapid Fire Travel and Extension growth
- Effect of fire impingement (extent and duration) and exposure to structural systems, components or assemblies that affect both internal or external building integrity
- Uncertainty of Civilian Occupancy Load
- Uncertainty of Civilian Occupancy Reaction Time and Responsiveness to Emergencies
- Probability of Fire Department Life Hazard and Risk Threat
- Resource Intensive Deployment Requirements
- Identified Severity of Risk Level and Acceptability of Risk to Organization

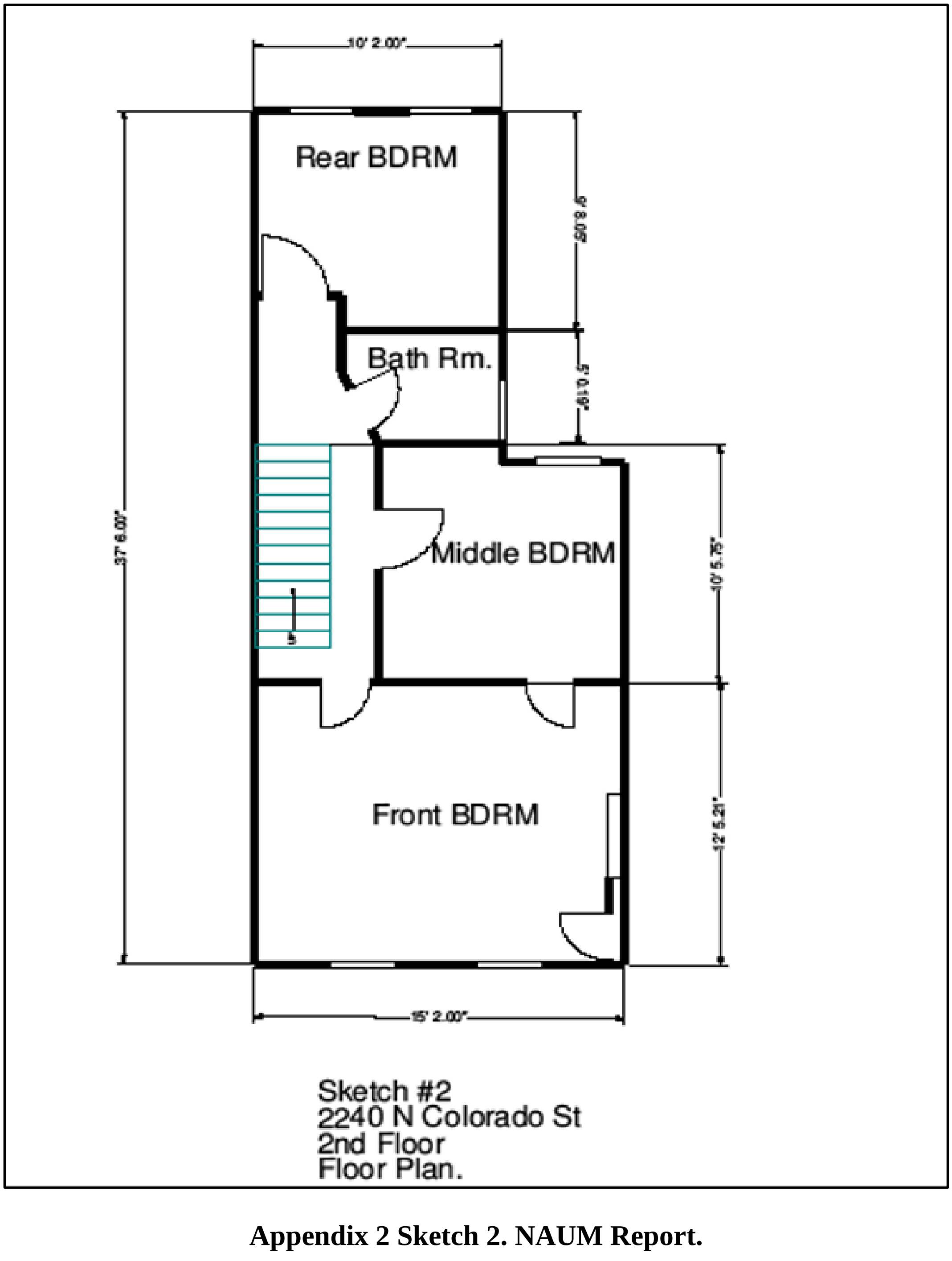
Based on potential severity and urgency factors given a fire of any great magnitude or other initiating event, this would require judicious and thoughtful pre-fire planning at the company or Battalion level to not only identify postulated incident events and occurrences, but to also assess the potential demands for escalating incidents, resource needs and suggested incident management scenarios, situations and consequences.

The probability for an escalating multiple alarm fire occurring in this building and occupancy creating limiting conditions of operations, high resource demands, operational severity, urgency and escalating incident growth issues were highly probable and could be expected based on fire location within a given tenant location, the occupancy use of that tenant space, the time of day of the incident and the operational readiness and availability of the fire department to respond, deploy and intervene. An understanding and application of inherent building system anatomy, presenting fire conditions upon arrival combined with increased situational awareness and application of predictable building performance considerations based on the building's construction, may have provided additional considerations for an enhanced fire suppression operation.[7,18]

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania



Appendix 2 Sketch 1. NAUM Report.



Appendix 2 Sketch 2. NAUM Report.

Appendix 3

National Institute of Standards and Technology

Findings from the Materials and Structural Systems Division

Engineering Laboratory

Inorganic Materials Group (Mr. Paul Stutzman)

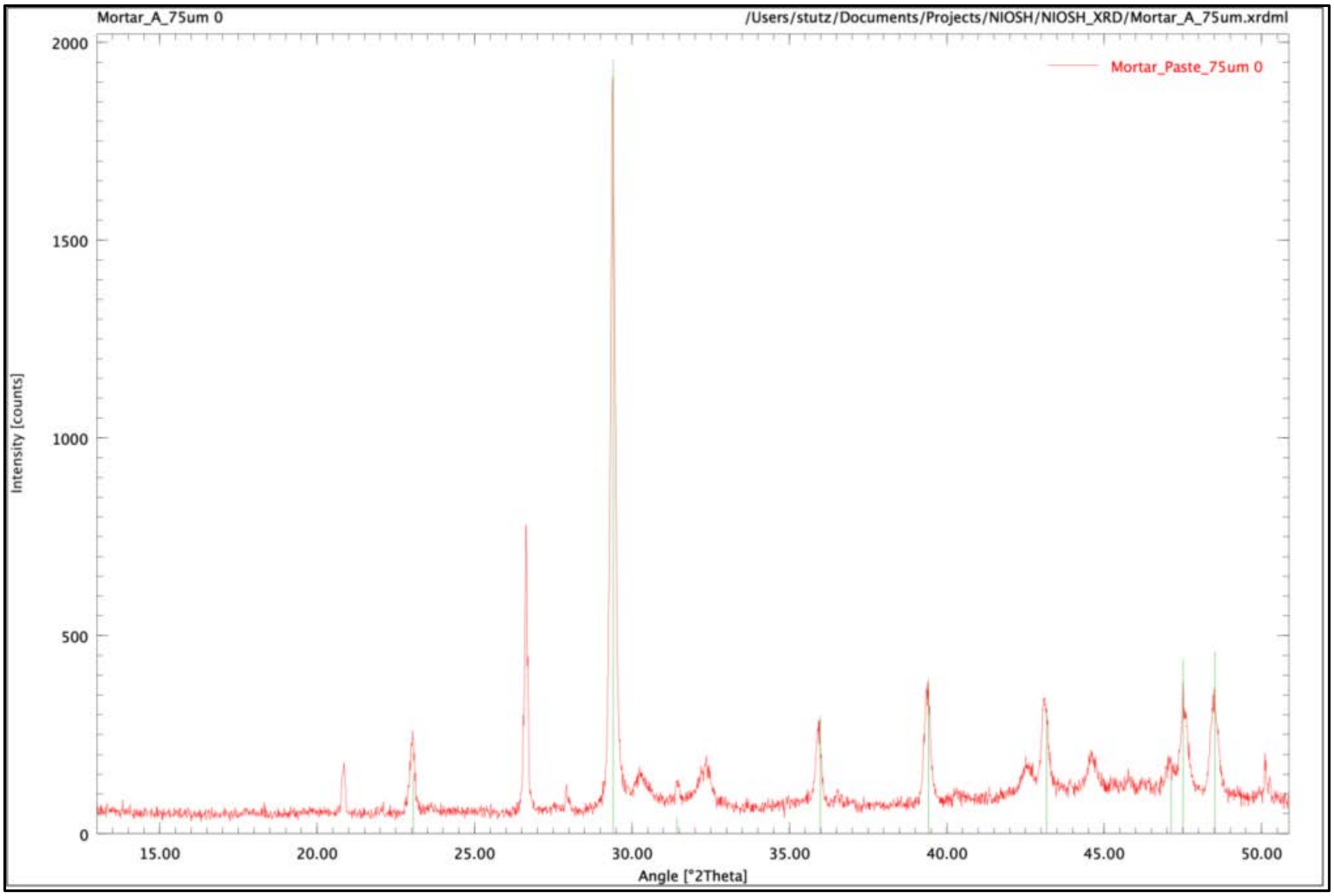
100 Bureau Drive, Gaithersburg, MD 20899-8615

Description provided by NIST:

I received two bricks, one (A) that had a light-colored mortar adhered to the top faces and a second (B) that had a dark material on the top face.

The binder on A is a lime-based mortar with no evidence of portland cement as part of the binder from scanning electron microscopy with X-ray microanalysis and X-ray powder diffraction (XRD). A SEM image of mortar from A (Mortar_2_SE.jpg) shows the mottled, porous binder and that it is chemically calcium and magnesium with little silicon or aluminum. The XRD data shown in Mortar_A_Binder.png shows it is comprised primarily of calcite (the black stick figures in the peaks is a reference for calcite) and quartz. Generally portland cement hydration products would contain some portlandite ($Ca(OH)2$) which would have a peak at 18 degrees two-theta. Given this mortar is relatively old the portlandite may have carbonated to calcite however, SEM imaging does not show any of the textural characteristics of a portland cement mortar.

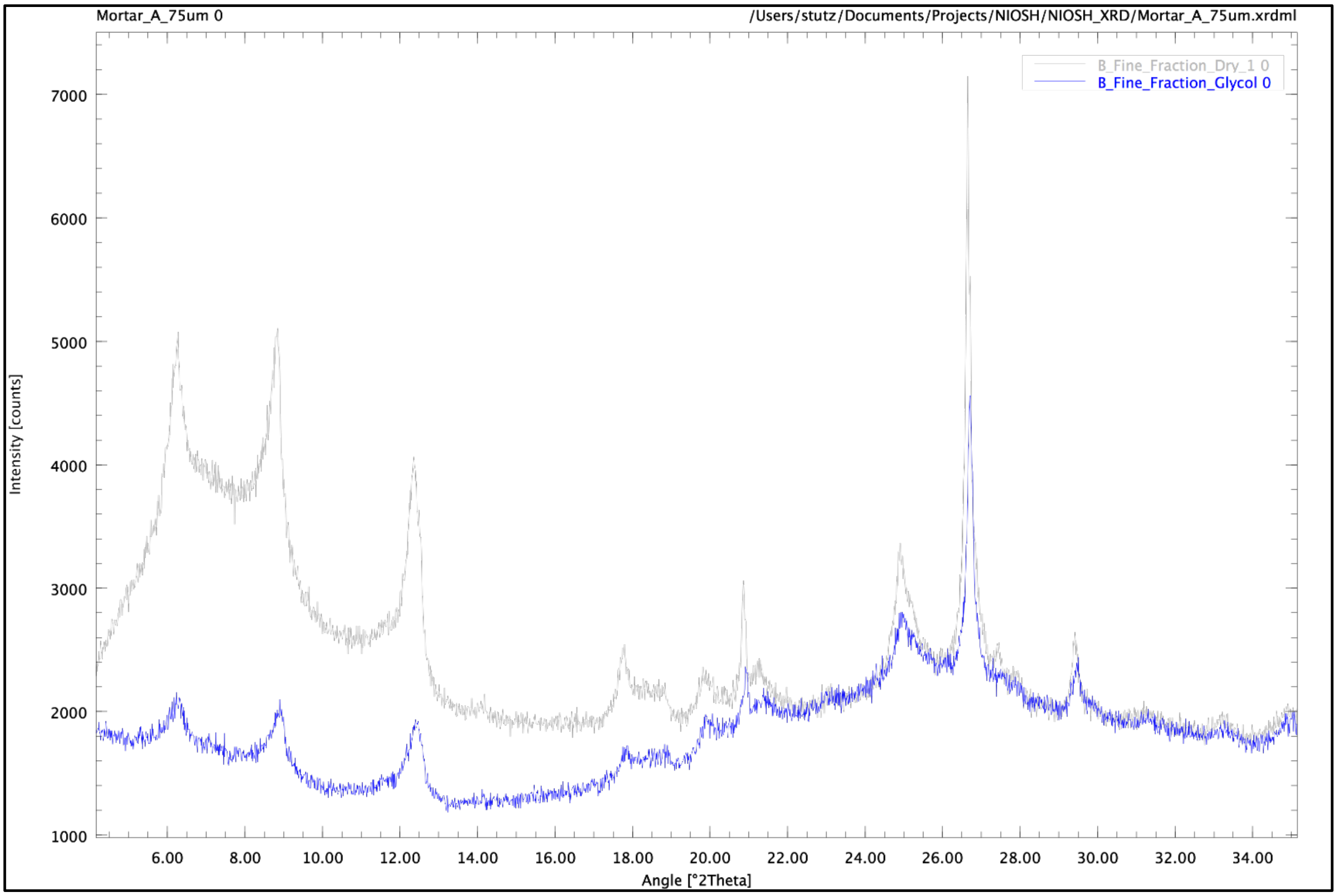
The darker material of B appears to be a soil based upon the clay minerals (chlorite and possibly kaolinite, illite/mica) in the binder (the glue binding the sand grains) based upon X-ray powder diffraction, but also contains minor black fragments and what appear to be slag or ash grains. The dark material on B is very friable relative to the mortar on specimen A and does not contain any portland cement. The XRD patterns of a clay fraction (size separation to remove the sand-size particles, file=B_Binder_clay_Fraction.png) shows peaks at the low angle region typical of common clays found in soils as mentioned earlier (the first three peaks from the left side are characteristic of these clays).



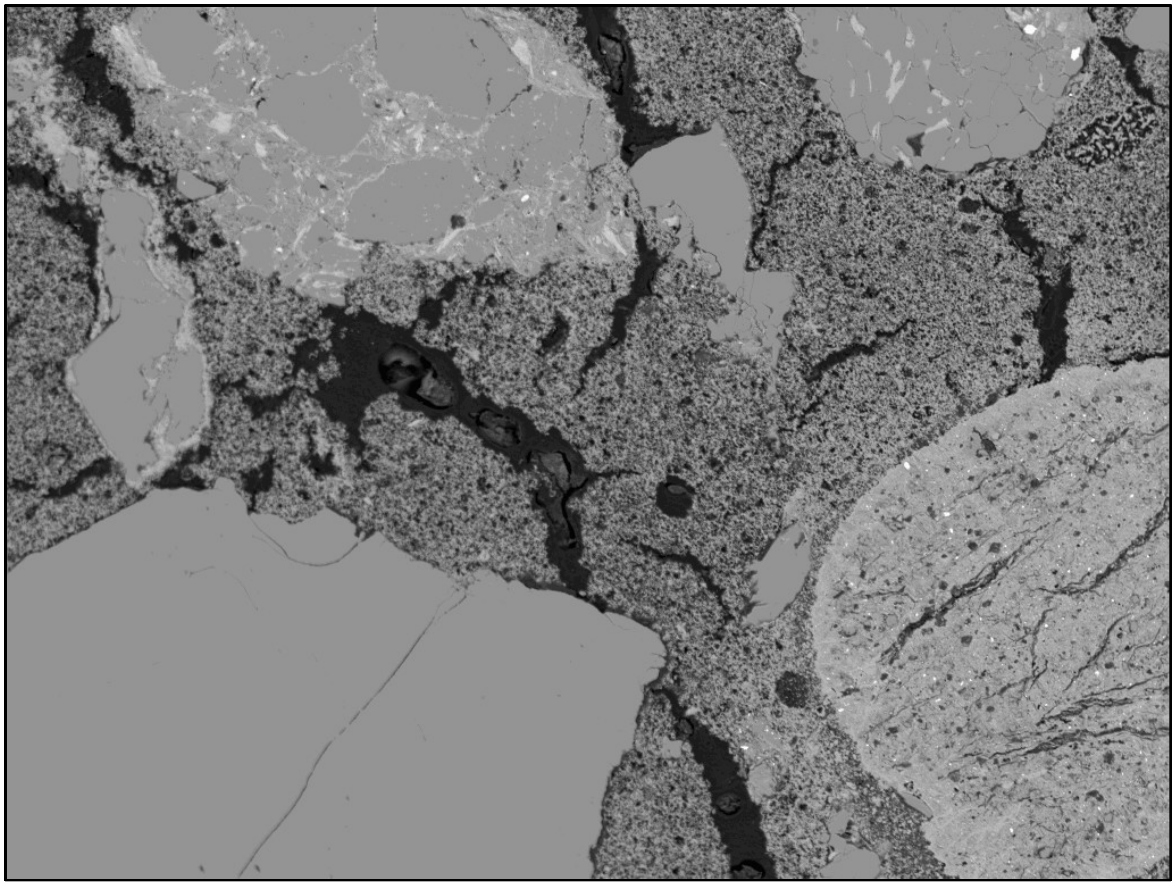
Appendix 3 Diagram 1. Mortar A

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania

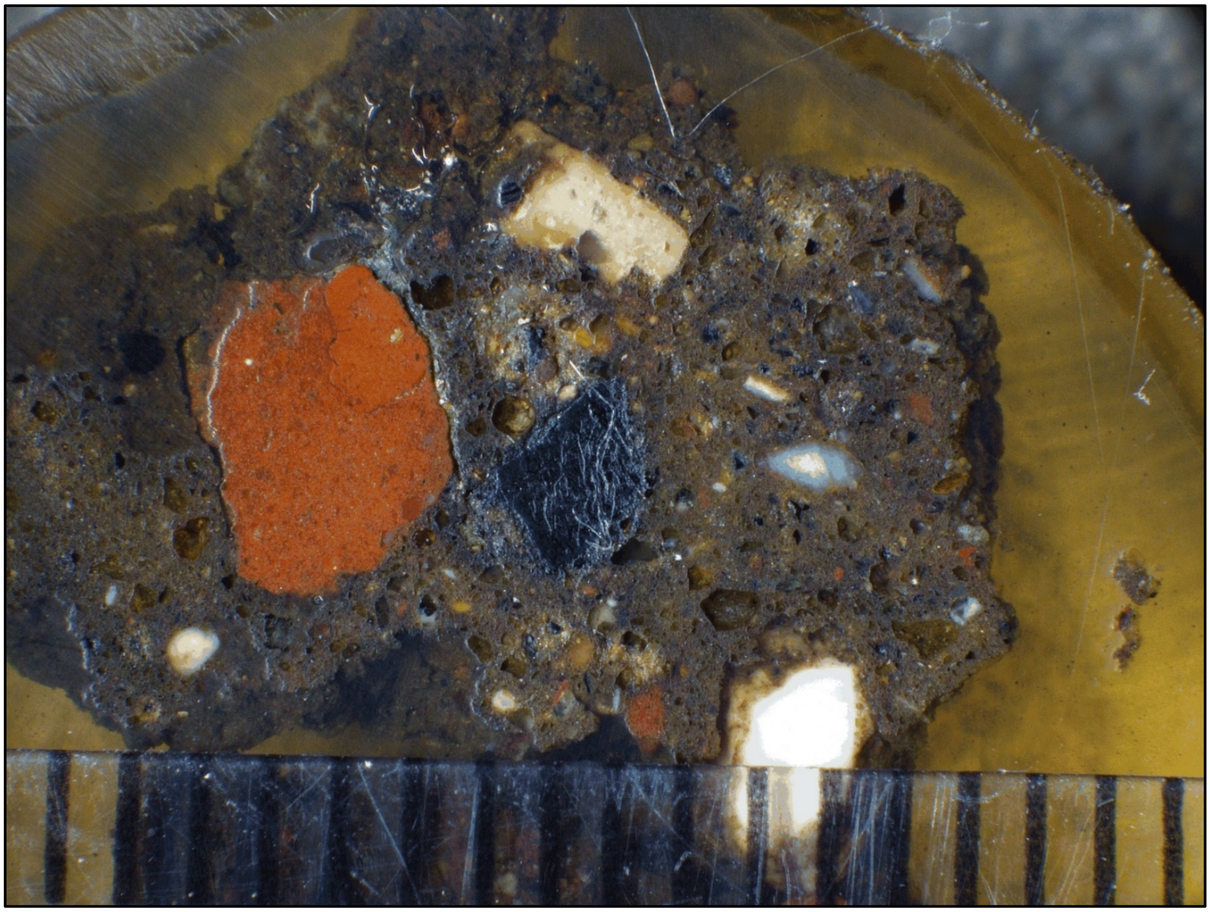
Appendix 3 Photo 1. NIST Report to NIOSH, Micro Photo, Brick A.



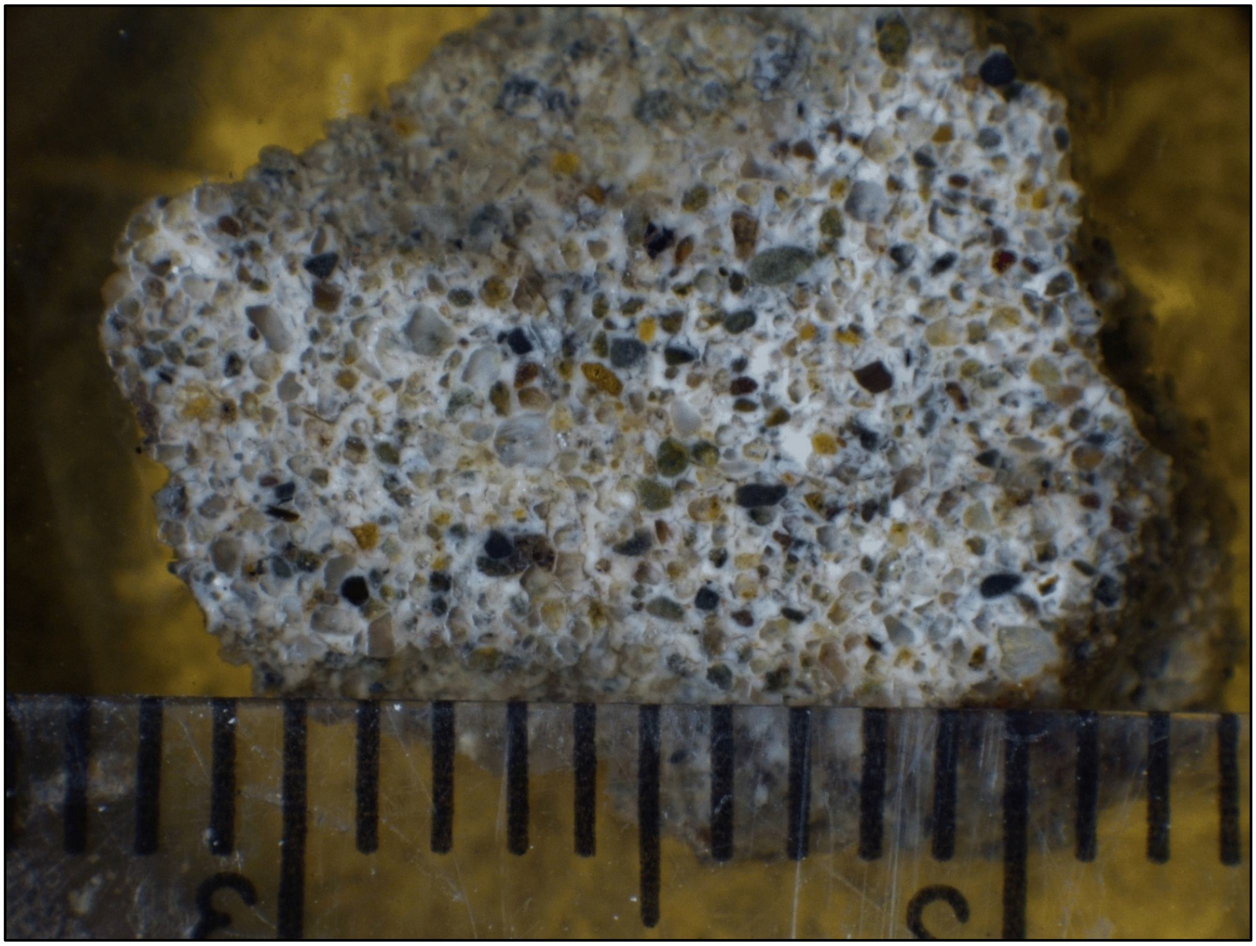
Appendix 3 Diagram 2. Graft of mortar composition, NIST Report to NIOSH. B Binder clay fraction.



Appendix 3 Photo 2 .NIST Report to NIOSH, Mortar 2 SE.

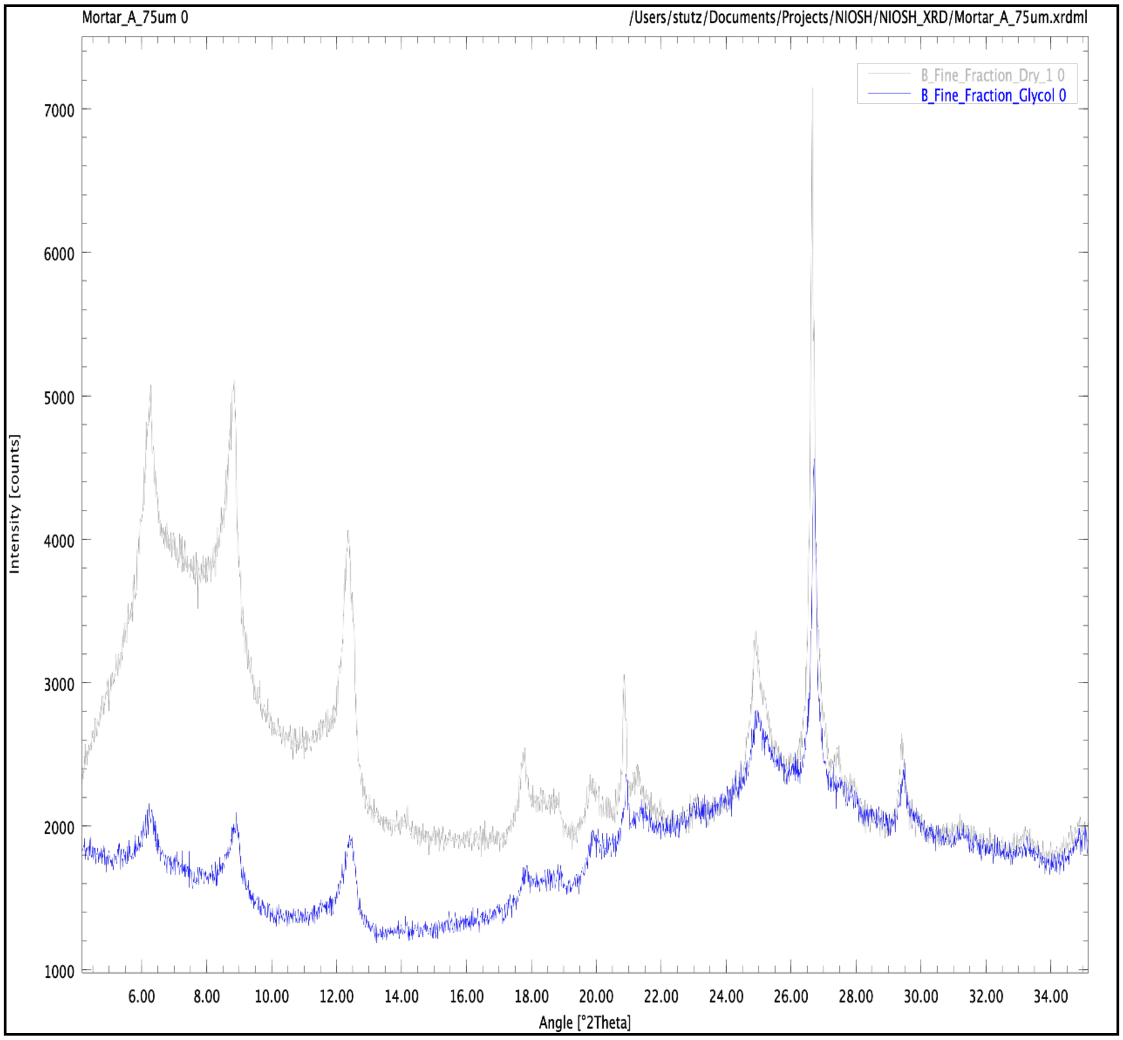


Appendix 3 Photo 3. NIST Report to NIOSH, Mortar B SEM 1.



Appendix 3 Photo 4. NIST Report to NIOSH, Mortar A SEM 1.

Career Lieutenant Killed in Building Collapse While Fighting Row House Fire—Pennsylvania



Appendix 3 Diagram 3. Graft of mortar composition, NIST Report to NIOSH.