2018
06

Death in the line of duty...

National Institute for Occupational Safety and Health NIOSH

A report from the NIOSH Fire Fighter Fatality Investigation and Prevention Program May 22, 2019

Structure Collapse at 140-Year Old Mill Building Kills 2 Career Fire Fighters and Injures 2 Others – Pennsylvania

Executive Summary

Crews work on Side Alpha on March 21, 2018 at 140-year old mill building. Time is approximately 1642 hours. Two fire fighters died following collapse on March 22, 2018. ***(Photo courtesy of Fire Department)***

On March 22, 2018, two male career fire fighters, ages 50 and 29, died following a structure collapse while working to extinguish hot spots following a structure fire in a 140-year old mill building. The previous day, March 21, 2018, the local career fire department was dispatched at 1616 hours, for a report of a structure fire with possible entrapment. The deputy chief arrived on scene and observed heavy smoke at the site of a large Type IV (heavy timber) construction mill building under renovation to create an apartment complex. He radioed dispatch and upgraded the incident to a working fire assignment and assumed incident command. Arriving crews were assigned to an offensive interior attack with 1 ¾-inch hand lines deployed through a door at Side Alpha. A fire fighter from Engine 99-5 was injured when he fell during interior search operations for a reported missing fire fighter. The Incident Commander ordered an evacuation of the structure and requested a personal accountability report after the fire rapidly spread throughout the 53,000-square foot structure. The reported missing fire fighter was accounted for and defensive operations were initiated with elevated master streams and ground monitors on all four sides of the structure. Approximately two hours into the incident, cracks began to form in the Side Bravo exterior wall and a large portion of the structure collapsed (Sides Bravo, Charlie and Delta) just minutes after Truck 89-1 was repositioned out of the collapse zone. Fire fighters from five fire departments worked overnight to extinguish the fire. **The next morning**, on March 22, 2018, Fire Department officials discussed the situation with the building owner and an engineer contracted by the building owner. The Incident Commander, the city building official, the owner, and the engineer entered the structure from Side Alpha to visually inspect floors one and two. Then they used an elevated aerial platform to visually inspect the roof and top two floors for structural stability. Following the inspection, fire department officials made the decision to use the elevated aerial platform for access to send a hose line crew onto the third and fourth floors to

extinguish the remaining hot spots. Truck 99-1 was repositioned at the Side Alpha / Delta corner so that fire fighters, supervised by the Incident Commander (located in the elevated platform), could access the fourth floor. At approximately 1515 hours, a collapse occurred that dropped three fire fighters and the shift commander (assistant chief) to the ground. The Incident Commander, located in the bucket of Truck 99-1 immediately radioed a Mayday and requested additional resources. Fire fighters worked for 29 minutes to free the four fire fighters trapped under the debris. Two fire fighters received fatal injuries in the collapse while the assistant chief and the fourth fire fighter were seriously injured.

Contributing Factors

- *Building under renovation with inactive sprinkler system*
- *Long-burning deep-seated fire could not be reached by exterior master streams*
- *Previous partial structure collapse*
- *Fire fighters entered collapse zone following defensive operations*
- *Inadequate risk versus gain analysis.*

Key Recommendations

- *Fire departments should ensure that all fire fighters are trained to understand the collapse hazards of various building construction types including mill construction.*
- *Fire departments should train all fire fighters on the hazards of working within a collapse zone.*
- *Fire departments should ensure that an initial risk assessment is performed and continuous risk assessment is accomplished throughout the incident and the strategy and tactics match the conditions encountered as part of the continuous size-up.*

Additionally, state, local, and municipal governments, building owners and authorities having jurisdiction should:

- *Consider requiring the use of sprinkler systems in commercial structures and residential apartment complexes including during renovation work.*

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Introduction

On March 22, 2018, two male career fire fighters, ages 50 and 29, died following a structure collapse in a 53,000-square foot Type IV (heavy timber) mill building which had been burning for over 24 hours. On March 23, 2018, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On April 17, 2018, a safety engineer, a general engineer and an occupational safety and health specialist with the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to Pennsylvania to conduct an investigation. The NIOSH investigation team met with the city mayor, his chief-of-staff, the fire chief and deputy fire chief, representatives of the International Association of Fire Fighters local union, and a chief officer from a neighboring mutual aid fire department. The NIOSH investigators visited the incident site and took photographs. The NIOSH investigators interviewed members of the career fire department who were involved in the incident, along with members of five neighboring mutual aid fire departments who were on scene during the incident. The NIOSH investigators also met with a city police detective and reviewed and inspected self-contained breathing apparatus and turnout gear worn by the injured and deceased fire fighters during the incident.

On April 24 through April 27, 2018, the NIOSH investigation team returned to Pennsylvania to continue the investigation. The NIOSH investigation team visited the communications center and met with the quality assurance supervisor for the county department of emergency services. The NIOSH investigators traveled to the county medical examiner's office to meet with the county medical examiner. The NIOSH investigation team also met with the city's deputy director for permits, planning and zoning, and representatives from the city's emergency management office. The NIOSH investigators continued conducting interviews with fire fighters and chief officers who responded to the incident.

On May 7 through May 10, 2018, the safety engineer and general engineer returned to Pennsylvania to continue the investigation and complete fire fighter interviews. The NIOSH investigators obtained copies of the fire fighter's training records, fire department standard operating procedures, building information and the dispatch audio records for the incident.

Fire Department

This combination fire department provides fire suppression and other emergency services within the city limits where this incident occurred. The fire department serves a population of approximately 43,896 residents within an area of about 5.3 square miles. The daytime population increases to over 75,000.

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The fire department employs four platoons that operate with a minimum staffing level of 10 career fire fighters per shift. The fire department currently operates out of four stations within the city. Each platoon is supervised by an assistant fire chief (shift commander) and a captain. Each platoon works two consecutive 10-hour day shifts (0700 to 1700 hours) and two consecutive 14-hour night shifts (1700 to 0700 hours) followed by four consecutive days off. Minimum staffing levels and responding fire apparatus at each station include:

- **Station 1**
  Engine 99-1 – three fire fighters
  Shift Duty Vehicle – assistant chief and captain

- **Station 2**
  Truck 99-1 (aerial platform) – three fire fighters

- **Station 5**
  Engine 99-5 – two fire fighters

- **Station 9**
  Engine 99-9 – two fire fighters

- **Reserve fire apparatus**
  Engine 99-2
  Engine 99-6
  Engine 99-7
  Truck 99-2 (aerial platform)

The fire department is managed by the Fire Chief and a Deputy Fire Chief. The Fire Chief reports directly to the city Mayor. The Deputy Fire Chief serves as the training officer. The fire department also employs an assistant fire chief and a captain in the Fire Prevention Bureau. The fire department had a dedicated safety officer until 2012 when the safety officer retired and the position was not filled. At the time of this incident, the fire department employed 1 civilian and 54 uniformed members including the fire chief, deputy fire chief, five assistant chiefs, five captains, 40 fire fighters and the two fire prevention bureau members. In addition, a number of volunteer fire fighters supported the department by staffing the air truck, refilling air cylinders, assisting with personnel rehab and other duties as necessary. Five volunteer members were qualified for interior fire suppression activities at the time of this incident. The city EMS provides fire fighter rehab at all working fires. Rehab includes hydration and monitoring of vital signs. The fire department enforces a policy where fire fighters must report to rehab after consuming two SCBA air cylinders. All interior fire fighters get fit tested on an annual basis.

All on-duty fire fighters respond when dispatch receives a report of a structural fire within the city. The fire department has a working agreement with a nearby county combination fire department that responds on all confirmed working fires within the city to provide automatic rapid intervention team

(RIT) support. When a working fire is confirmed, the city automatically recalls four off-duty fire fighters and one officer to provide coverage for the city.

Total emergency call responses for the calendar years 2013 through 2017 included:

2013 – 2730 total calls
2014 – 2792 total calls
2015 – 2980 total calls
2016 – 3106 total calls
2017 – 3527 total calls

At the time of the incident, the fire department had received a Class 3 rating during the most recent Insurance Services Office (ISO) Public Protection Classification survey. In the ISO rating system, Class 1 represents exemplary fire protection, and Class 10 indicates that the area's fire-suppression program does not meet ISO's minimum criteria.

Training and Experience

The State of Pennsylvania does not have mandatory minimum training requirements for a fire fighter to be an interior fire fighter. The state of Pennsylvania also does not have minimum training requirements for fire officers. It is up to each fire department or authority having jurisdiction to implement training requirements to meet their own needs. In the State of Pennsylvania, fire fighters are required to receive 36 hours of training each year, and each Fire Chief is responsible for setting departmental training requirements.

At the time of this incident, the fire department required new recruits to complete a 13-week career fire academy at a local community college. The fire academy included five weeks of emergency medical services (EMS) training and eight weeks of basic fire fighter training. Fire fighters with previous documented experience could opt out of the EMS training but not the eight week fire fighter training.

Fire fighters are hired as a city employee through a civil service process. Selected candidates report to the fire department for a two-week orientation process and then go the fire academy for the 13-week training period. After completing the 13-week training period, the candidates receive Fire Fighter I and Fire Fighter II certification, along with EMS National Registry Emergency Medical Technician (NREMT) certification. After completing the 13-week training period, the recruits serve as probationary fire fighters. They can ride on fire apparatus and may float as needed at any of the four department station houses. The current contract calls for a one-year probationary period. Probationary fire fighters cannot bid on an open position but the fire department can assign a probationary fire fighter to fill a permanent opening.

Fire department members receive annual live fire training at the local community college consisting of various fire scenarios such as high rise, hoarder fires, simulated basement fires, and forcible entry. Fire fighters receive street familiarization training where every fire fighter will cover every box

location (pre-determined address locations for computer-aided dispatch) within the city every 3 to 4 years.

The shift commander is responsible for on-shift training but there is no department standard-operating procedure (SOP) specifying how much time is to be spent in training per shift. The fire department allows fire fighters to attend off-site training and the fire fighters can apply to the fire department to be reimbursed for the cost of training but not for actual hours worked.

The fire department will also reimburse a fire fighter up to 50 percent of the cost of training to take fire science and business classes through an officer development program. Actual fire officer development training from the department is limited and consists of hands-on officer training. To be promoted to the captain position a fire fighter must:

- Pass a civil service written test
- Pass an oral test
- Interview with the Fire Chief.

Under the current contract, a fire fighter must have eight years of service to test for the captain position and two years as a captain to test for the assistant chief position (all service must be with the city fire department).

Training records for the Incident Commander (deputy fire chief) listed a total of 780 individual classes totaling over 6342 training hours.

Equipment and Personnel Dispatched

This incident involved the local municipal fire department (Department 99) being dispatched for the report of smoke coming from a commercial structure. On March 21, 2018, a box alarm was dispatched. Per department standard operating procedures, the entire fire department was dispatched. The following units from Department 99 responded to the initial dispatch:

- Engine 99-1 responded from station 1
  - Acting officer (victim 1), engineer, fire fighter.
- Engine 99-5 responded from station 5
  - 2 fire fighters on board, Acting officer (injured on 3/21/2018), engineer.
- Engine 99-9 responded from station 9
  - 2 fire fighters on board, Acting officer, engineer.
- Truck 99-1 responded from station 2:
  - 3 fire fighters on board, Acting officer, engineer, fire figher.
- Car 99-8 responded from station1: assistant chief (injured) and captain on board

- Car 99-7 responded from fire headquarters with deputy fire chief on board.

The deputy fire chief was the first fire department member on scene and he immediately assumed incident command. He radioed dispatch and reported a working fire. The working fire assigment resulted in the following combination fire department units being dispatched per automatic mutual aid procedures:

- Truck 89-1 responded from station 89-3: captain and 2 fire fighters
- Battalion 89-1
- Battallion 89-3
- Engine 89-1 with 2 fire fighters
- Engine 89-2 with 2 fire fighters
- Engine 89-3 with 2 fire fighters

Department 9 – automatic mutual aid for Rapid Intervention Team (RIT) operations on all working fires within the city. Four fire fighters responded on Rescue 9. Two lieutenants responded on utility vehicle.

Engine 25-2 – crew of 5 fire fighters.

Truck 502

Engine 501

2nd Alarm

- Truck 1-2 with 6 fire fighters on board Dispatch at 1621 arrive at 1630 Assisted Department 89 on Side B at BC-corner. After Mayday and defensive operations were declared, Truck 1-2 set up at Side A-D corner for master stream operation.

3rd Alarm

- Fire Chief Department 89.
- Engine 89-5 with 2 fire fighters Supply water to Truck 11 Side D.
- Battalion 89-3.

Call Back on 3/22

Due to the size and complexity of the fire, the fire department called fire fighters to work extra duty on March 22nd to allow for coverage throughout the city and to continue fire suppression operations at the fireground. Fire fighters working overtime included these key members:

> Station 99-2 Fire Fighter 1(injured in collapse) and Fire Fighter 2 were assigned to Station 99-2 covering the city, then went to the fire scene to relieve the Truck 99-1 crew and went up in the bucket with the Incident Commander (assistant chief). Both fire fighters also worked on the 4th floor.
>
> Victim # 2 was working overtime on B-Shift with the Engine 99-1 crew.
>
> Truck 99-2 operator was called in for extra duty on the night of 3/21 and then stayed over to work day shift on 3/22. He was assigned to Station 2 (Truck 99-2) with Victim # 2 to cover the city. Truck 99-2 was called to the incident scene around 1300 hours (time approximate) because Truck 99-1 was getting low on fuel. He was working the turntable on Truck 99-1 when the Incident Commander and two fire fighters went up to 4th Floor to hit hot spots. He was carrying extra SCBA air cylinders up the elevated ladder to the platform when the collapse occurred.

Structure

The fire occurred in a detached four-story Type IV (heavy timber) mill building originally constructed in the 1870s [NFPA 2018a]. From 1882 to 1959, the structure was the site of an organ and piano manufacturing business. Several additions over the years increased the structure to a 4-story heavy timber mill building enclosing approximately 53,000 square feet of floor space (see Photo 1 through Photo 4). From 1959 to 2013, the structure housed a number of businesses including an auto parts store, an indoor salvage yard, and a storage facility. At the time of the fire, the structure was vacant and was being heavily renovated for conversion to a 42-unit apartment complex.

Exterior walls were constructed of multi-course (three and four course) bricks typical for mill construction of this era. The structure had a flat roof supported by wooden beams. Large plank floor boards were reported to be up to three inches thick. A basement area was located near the front (Side Alpha) of the structure. Recent renovation work included adding a new flat roof with a waterproof membrane. A number of commercial air handling units had been added to the roof as part of the renovation to an apartment complex. The exposed wooden beams and original plank flooring were being refinished to highlight the original architecture. It was reported to NIOSH investigators that the fourth floor (Division 4) was nearly ready for occupancy. It was reported that the third floor (Division 3) was approximately 60 – 70 percent completed and the second floor (Division 2) was roughly laid out with wall studs set in place. *Note: NIOSH was not able to obtain additional information concerning the renovation work. The building owner did not respond to requests by NIOSH for information.*

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The building contained a sprinkler system that was inoperative at the time of the fire. Previous building deterioration had damaged the piping system to the point where the water supply to the system had to be shut off.

Note: Members of the fire department and the fire prevention office had performed a walk-through inspection of the structure in October 2017, during the initial renovation phase. Following that inspection, the building was added to the fire department's NO ENTRY list. An email notice was sent to all fire department members on October 15, 2017, notifying members that they should not enter the structure under fire conditions. The email notice identified several floor / roof collapses as well as holes rotted through floors in various locations. The email notice identified that the existing sprinkler system was not in service due to breaks in the system.

The fire department reported that the city has approximately 25 – 50 similar buildings of mill construction type that have already been converted into apartment complexes.

Photo 1. Overhead view of four-story Type IV (heavy timber) commercial mill structure where the incident occurred. Structure is highlighted in yellow.
(Photo adapted from Google Earth satellite view)

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Photo 2. Side Alpha view of structure before the fire. Initial attack crews entered the structure through the man door at the Side Alpha / Bravo corner.
(Photo adapted from Google Earth street view.)

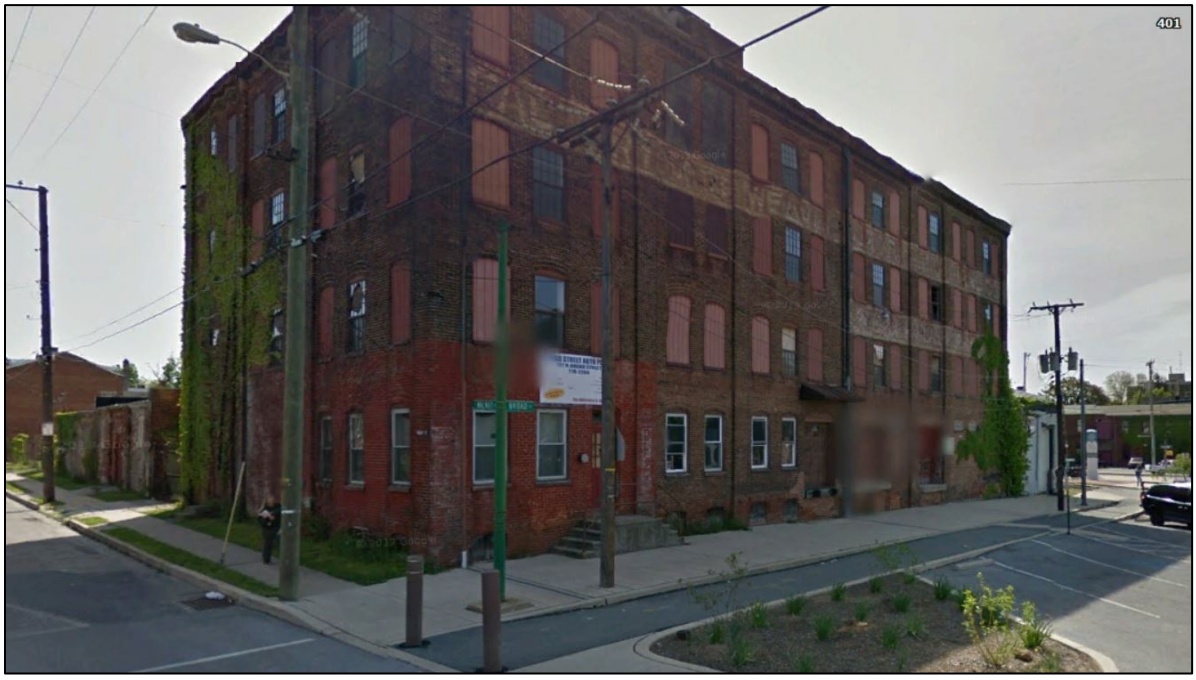

Photo 3. View of structure as seen from Side Alpha / Bravo corner facing south.
(Photo adapted from Google Earth street view.)

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Photo 4. View of structure as seen from Side Delta facing north.
(Photo adapted from Google Earth street view.)

The structure was serviced by both natural gas and electrical utilities. The electrical service entrance was located on Side Alpha through an overhead feed. The natural gas service entrance was located on Side Delta where the service line fed into multiple gas meters. A railroad track was located in close proximity to the Side Alpha / Delta corner. It was reported to NIOSH investigators that trains had to be delayed during fire suppression operations on March 22, 2018 and fire apparatus had to be repositioned to allow trains to pass (See Diagram 1).

The U.S. Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) conducted an origin and cause investigation of this fire. The ATF investigators determined that the fire originated on the first floor and the cause of the fire was undetermined [Merinar 2019].

Diagram 1. Overhead View of structure. Hydrant locations are shown. Railroad track was active at time of the fire.
(Photo adapted from Google Earth satellite view.)

Timeline

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

- **1616 Hours (time approximate) on March 21, 2018**
  EMS crew, responding to an EMS call, advised dispatch that they observed smoke coming from a commercial structure and to dispatch the fire department.

- **16:17:27 Hours on March 21, 2018**
  Local municipal fire department dispatched for a report of smoke coming from a commercial structure. Engine 99-1, Engine 99-5, Engine 99-9, Truck 99-1, Car 99-8 and Car 99-2 dispatched. Deputy Chief 99 responded in fire department vehicle.

- **16:17:49 Hours**
  Deputy Chief 99 advised dispatch of a working fire in a four-story warehouse structure. Deputy Chief assumed incident command.

- **16:19 Hours (time approximate)**
  Working fire assignment for a structural fire with possible entrapment. Department 89 Truck 89-1, Battalion Chief 89-1, and Department 25 Truck 25 dispatched for automatic mutual aid. Department 9 dispatched for automatic RIT assignment.

- **16:20 Hours (time approximate)**
  Truck 89-1 enroute with captain and 2 fire fighters

- **16:20:32 Hours**
  Command reported heavy smoke showing from the second floor and requested a second alarm.

- **16:20:00 – 16:34:00 Hours (time approximate)**
  Crew made entry through man door on Side Alpha near Alpha / Bravo corner. Crews operated on Division one and basement. Crews backed out (see Photo 5).

- **16:22:31**
  Fire Chief called dispatch to request call back for 8 fire fighters and 2 officers.

- **16:29:00 Hours**
  Shift Commander (Assistant Chief) radioed dispatch to request a second radio channel for all interior fire fighters. Incident commander advised dispatch to leave fireground on Operations (OPS) Channel 3 and set OPS Channel 4 for staging and exterior operations.

- **16:34:21 Hours**
  Incident commander requested evacuation tone to evacuate structure.

- **16:36:55 Hours**
  Command requested third alarm.

- **16:45:00 to 16:55:00 Hours (time approximate)**
  Discussion about missing fire fighter reported by shift captain. RIT activated. Engine 99-1 and 99-5 acting officers along with Engine 99-1 fire fighter made entry to search for missing fire

fighter. Engine 99-5 acting officer fell while searching for missing fire fighter injuring ankle and wrist.

- **16:57:55 Hours**
  Command requested second evacuation tone. Command wanted all fire fighters out of the building.

- **16:58:09 Hours**
  Command advises dispatch to announce defensive fire at this time.

- **17:18:09 Hours**
  Dispatch advised command that they are 60 minutes into the incident.

- **17:35:17 Hours**
  EMS command requests city bus to the scene to be set up for fire fighter rehab.

- **17:40:18 Hours**
  Command advises dispatch that large 4-story Type 3 warehouse building has fire on all four floors (divisions) and crews will be tied up for an extended period of time. Also corrected address.

- **18:05:21 Hours**
  Command advises dispatch of partial building collapse on Side Charlie. Requests announcement to avoid Side Charlie.

- **18:30 Hours (time approximate)**
  Engine 99-5 acting officer transported to hospital for treatment (sprained ankle and broken wrist)

- **21:20:30 Hours**
  Command advises dispatch that operations are beginning to scale down. Defensive operations will continue throughout the night.

- **21:21:13 Hours**
  Truck 11 clears fireground and is available

- **21:33:36 Hours**
  Truck 1-2 clears fireground and is available

- **21:44:29 Hours**
  Engine 89-3 clears fireground and is available

- **21:57:33 Hours**
  Truck 89-1 clears fireground and is available

- **22:11:41 Hours**
  Engine 89-5 clears fireground and is available

- **23:27:12 Hours**
  Engine 89-1 clears fireground and is available

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- **00:32:05 Hours**
  Engine 25-2 clears fireground and is available

- **02:20:54 Hours**
  Engine 505 and Truck 502 clear fireground and are available

- **0700 – 1100 Hours (time approximate)**
  Shift change with call back of additional staffing to allow for coverage throughout the city while day shift crews work at fire scene (see Photo 5 and Photo 6).

  Units on-scene at 0900 Hours include Engine 99-1, Engine 99-7, and Truck 99-2.

  Incident Commander, city building official, building owner, and building owner's engineer conduct interior visual inspection on Division one and Division two (floors one and two) and then inspect Division three (floor three), Division four (floor four), and roof of the remaining structure from an elevated aerial platform.

  Excavation equipment brought in to attempt to dig out hot spots burning under collapsed debris.

- **1300 Hours (Time approximate)**
  Fire fighters use an elevated aerial platform to gain access at Side Alpha onto the third floor deploying a 1 ¾-inch hand line from the platform and walked onto the third floor to extinguish hot spots.

  Aerial platform is repositioned to Side Alpha / Delta corner to gain access onto the fourth floor to again deploy the hand line by walking onto the fourth floor to extinguish more hot spots.

- **14:29:11 Hours**
  Fire Chief 99 advises dispatch that there is still active fire at the scene.

Photo 5. Photo shows heat damage to the rear of the building containing the beer distributor near the Side Delta / Charlie corner.
(Photo courtesy of the Fire Department.)

Photo 6. Photo shows defensive master stream operation on March 22, 2018 at Side Alpha / Delta corner.
(Photo courtesy of the Fire Department.)

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- **15:15:30 Hours (time approximate)**
  Collapse on Division four traps four fire fighters in debris pile.

- **15:15:57 Hours on March 22, 2018**
  Incident Commander radios Mayday and requests 2nd alarm

- **15:16:01 Hours on March 22, 2018**
  Incident Commander radios collapse with fire fighter entrapment

- **15:16:27 Hours**
  Engine 89-3, Truck 89-1, Rescue 89-3, and Battalion 89-1 dispatched.

- **15:17:12 Hours**
  Truck 99-2 Fire Fighter 1 radios that he is trapped and cannot get out but no active fire around him

- **15:17:52 Hours**
  Fire Chief radios Dispatch and requests the county advanced technical rescue team (ATR).

- **15:19:25 Hours**
  Rescue 89 enroute with 3 fire fighters. Engine 89-3 enroute with 2 fire fighters. Rescue 69 enroute with 5 fire fighters. Rescue 61 enroute with 5 fire fighters.

- **15:25:14 Hours on March 22, 2018**
  Command advises dispatch that 4 fire fighters are trapped.

- **15:26:05 Hours**
  Command advises dispatch that 2 fire fighters have been located.

- 15:29:49 Hours
  Fire Chief calls dispatch to request call back of 8 fire fighters and 2 officers.

- **15:30:02 Hours**
  Ambulance A268 enroute to hospital.

- **15:36:24 Hours**
  Command advises dispatch that crews are working on freeing the last trapped fire fighter.

- **15:40:29 Hours**
  52-year old fire fighter in trauma arrest being transported to hospital in Mobile Intensive Care Unit (MICU) 89-5.

- **15:47:40 Hours**
  Everyone accounted for per Incident Commander (Deputy Fire Chief). Collapse Mayday cancelled.

- **15:49:20 Hours**
  29-year old fire fighter in trauma arrest being transported to hospital in Mobile Intensive Care Unit (MICU) 89-3.

- **15:57:22 Hours**
  Captain 99-3 advises that all EMS units are off the scene

- **15:59:59 Hours**
  Captain 99-3 advises that all city fire personnel are to report to the city garage for debriefing

Personnel Protective Equipment

At the time of this incident, the four fire fighters injured in the structural collapse were all wearing a full firefighting ensemble consisting of a turnout coat and pants, helmet, hood, gloves and leather fire boots. All four fire fighters were wearing self-contained breathing apparatus and were on air. All four carried a fire department-issued portable radio.

On April 18, 2018, the NIOSH investigators met with the city police detective who had custody of the personal protective clothing, equipment, and self-contained breathing apparatuses worn by the injured and deceased fire fighters. The NIOSH investigators inspected and visually evaluated the personal protective clothing, equipment and SCBA. These items were not considered to be contributing factors to the outcome of this event.

Weather Conditions

The weather on March 21, 2018 at approximately 1521 hours (the day and approximate time of the fire dispatch) was overcast with snow and fog in the area. The temperature was approximately 31 degrees Fahrenheit with 92 percent relative humidity and winds from the west / northwest at 9 miles per hour. Heavy snow storms had passed through the area earlier that day which adversely impacted local street traffic. Approximately 10-12 inches of snow were reported to be on the ground at the time of the fire. Temperatures and wind conditions remained steady throughout the night and light snow continued to fall until after midnight (see Photo 7).

The weather on March 22, 2018 (the day of the fatal collapse) at approximately 1500 hours was clear. The temperature was approximately 41 degrees Fahrenheit and winds were from the northwest at 16 miles per hour [Weather Underground 2018].

Photo 7. View of Side Alpha / Bravo corner soon after initial crews arrived on scene. Time approximately 1626 hours.
(Photo courtesy of the Fire Department.)

Investigation

On March 21, 2018 at approximately 1616 hours, the local combination fire department (Department 99) was dispatched for the report of a fire in a commercial structure with possible entrapment. A snow storm had recently passed through the area dropping 10-12 inches on snow in the city. Snow continued to fall during the incident which impacted unit response times in some cases.

All companies on duty in the city were dispatched per established fire department procedures. The deputy fire chief responded at 1616 hours from fire department headquarters and was the first fire department member to arrive on-scene. He observed Sides Alpha and Bravo on arrival and staged his

fire department command vehicle in the street in front of Side Alpha facing north. The deputy fire chief radioed dispatch and assumed Command. He told dispatch to upgrade the response to a working fire response which resulted in Fire Department 9 being dispatched for mutual aid as the rapid intervention team (RIT) along with mutual aid units Truck 89-1 (Department 89) and Truck 25 (Department 25). *Note: Department 9 is dispatched for RIT assignment to all working fires within the city per mutual aid arrangement. Department 89 and Department 25 were dispatched for automatic mutual aid for a commercial structure fire.* The deputy fire chief began to walk around the structure for a 360 degree size-up, but a chain link fence around the construction site on Side Bravo and the Side Charlie corner prevented a full 360-degree walk-around. He was able to visually observe all four sides.

The deputy fire chief (incident commander) also radioed Dispatch and requested automatic callback of four fire fighters and an officer for additional resources per fire department SOPs.

Engine 99-1 responded from Station 99-1 with three fire fighters and arrived on scene just after the deputy fire chief. Truck 99-1 responded from Station 99-2 with three fire fighters and set up in front of the structure on Side Alpha near the Side Alpha-Bravo corner facing north.

Engine 99-5 supplied water to Truck 99-1 from a hydrant north of the structure. Engine 99-5 responded from Station 5 with two fire fighters.

Engine 99-9 responded from Station 99-9 with two fire fighters. The shift commander (assistant chief) and the shift captain responded from Station 99-1 in the assistant chief's fire department duty vehicle. The assistant chief for fire prevention arrived on-scene and assisted with setting up accountability. *Note: During the interview process, it was reported to NIOSH investigators that there were issues with accountability due to so many mutual aid crews arriving on-scene. County crews are supposed to report to the incident commander but many did not report directly and an effective accountability system was not set up until later in the incident.*

Engine 99-1 initial activities

Engine 99-1 staged on Side Bravo just past the Side Alpha-Bravo corner. The Engine 99-1 acting officer and fire fighter set up a ground monitor near the middle of the structure at Side Alpha. Then they pulled a 1 ¾-inch preconnected hand line from Engine 99-1 and pulled it to the front door (see Photo 7). The Engine 99-1 acting officer had the nozzle and the Engine 99-1 fire fighter handled the hose line. At approximately 1620 hours, they advanced the hose into the structure. The Engine 99-1 crew did a right hand search looking for possible victims since the original dispatch was for possible entrapment. They searched the basement and the first floor (Division 1) but never flowed any water. The hose line got stuck in the front door. The Engine 99-1 fire fighter went outside to retrieve a thermal imager and returned inside the structure where he met up with the shift captain in the basement. The interior crew reported high heat, moderate smoke, and no visible fire in the areas they searched.

Engine 99-5 initial activities

Engine 99-5 responded with two fire fighters from Station 99-5. Engine 99-5 was assigned to supply Truck 99-1 from a hydrant at the corner just south of the fire building. After laying a five-inch supply line to Truck 99-1, the Engine 99-5 crew was assigned to open the boarded up windows on Side Alpha. They pulled off plywood and also forced open a roll-up door on Side Alpha. Heavy thick smoke pushed out of the windows after the boards were removed. After opening the windows, Command instructed the Engine 99-5 crew to pull a 1 ¾-inch preconnected hand line off Engine 99-5 to the man door at the Side Alpha-Bravo corner. The Engine 99-5 acting officer pulled the hand line, assisted by fire fighters from Truck 99-1. At approximately 1625 hours, the Engine 99-5 crew entered the structure a short distance and encountered thick smoke. They backed out and were directed to take the hose line (250 feet preconnected 1 ¾-inch) around to Side Delta where they worked the hose line on fire blowing out of the windows. The Engine 99-5 engineer pulled a ground monitor off 99-5 and set it up for operation on Side Alpha. The Engine 99-5 acting officer and the Truck 99-1 fire fighters consumed an air cylinder while flowing water on Side Delta and went to change out their air cylinders again. Crews pulled ground ladders off Engine 99-1 and set them up to the second floor windows on Side A for access.

Engine 99-9 initial activities

Engine 99-9 responded from Station 99-9 with two fire fighters. Command instructed Engine 99-9 to hit a hydrant on the street adjacent to Side B. A car was stuck in the snow-covered street which delayed Engine 99-9's arrival. Their assignment was changed to assist Engine 99-1 on the initial hose line making entry on Side A. The Engine 99-9 crew reported seeing fire blowing out of the windows on Side Delta as they walked up to Side Alpha.

The two Engine 99-9 fire fighters talked to the shift captain at the front door. A 2 ½-inch preconnected hand line (uncharged) was already pulled to the front door. The Engine 99-9 fire fighters picked up the 2 ½-inch hand line and followed the Engine 99-1 crew inside the front door. They advanced to where the stairway had been removed and a new stairwell was being formed. The shift captain directed the Engine 99-9 fire fighters to take the 2 ½-inch hand line down to the basement. No fire was visible in the basement so they returned to the first floor where the shift captain directed them to go back outside and take the hose line around to Side Bravo (see Photo 8). They advanced the hose line to Side Bravo and flowed water on visible fire blowing out the garage door.

While flowing water on Side Bravo, the Engine 99-9 crew observed the Engine 99-1 acting officer bail out a Side Bravo first floor window (the Engine 99-1 acting officer had run out of air while searching on Division 1(floor 1)).

Initial Defensive Operations

Fire conditions rapidly escalated with fire showing on all four sides of the building (see Photo 8 and Photo 9). The incident commander radioed the interior crews that the fire was getting worse and ordered an evacuation. At approximately 1634 hours, the incident commander radioed dispatch and

requested an evacuation tone. The incident commander called for a personnel accountability report (PAR) but due to issues with radio traffic, he had difficulty getting responses from crews across the fireground.

During the evacuation, the Engine 99-1 acting officer ran low on air. The Engine 99-1 acting officer was forced to bail out a first floor window on Side Bravo. The Engine 99-1 acting officer was uninjured and quickly changed out his SCBA cylinder after the bailout.

Second Offensive Interior Operations

The Engine 99-1 crew regrouped and talked to the incident commander about re-entering the structure. The Engine 99-1 acting officer reported to command that he had been involved with the building walk-through the previous fall and thought he knew the layout of the second floor. The incident commander sent the shift captain, the Engine 99-1 acting officer, and two Department 99 volunteer fire fighters inside through the Side Alpha door to survey the second floor to size-up the interior conditions. The crew advanced inside the Side Alpha door and proceeded to the ground ladder used by construction crews to access the second floor. *Note: The ground ladder was being used to access the second floor by the construction crews and was located where the stair well had been torn out and was being rebuilt.* The shift captain and one volunteer fire fighter remained on the first floor while the Engine 99-1 acting captain and the other volunteer fire fighter moved up the ladder to the second floor. While the fire fighters were searching the second floor, the incident commander observed fire conditions getting worse and radioed for fire fighters to evacuate the structure.

As the interior fire fighters backed out of the structure, there was some confusion as to whether or not all the interior fire fighters had exited the structure. The incident commander radioed dispatch and requested a third alarm at 1636:55 hours.

Search for reported missing fire fighter

As crews were backing out of the structure through the Side Alpha door, the shift captain reported to command that a fire fighter believed to have been inside the structure did not come outside and was believed to still be on the second floor. The incident command immediately radioed a Mayday for a missing fire fighter (time approximately 1645 hours) and activated Department 9 for RIT operations. While Department 9 was preparing to enter the structure, the Engine 99-1 acting officer teamed up with the Engine 99-5 acting officer to go inside to look for a reported missing fire fighter. The Engine 99-1 and Engine 99-5 acting officers entered the building through the man door at the Side Alpha-Bravo corner. They encountered high heat and near-zero visibility due to the thick smoke conditions. They climbed up the ground ladder to the second floor and advanced across the second floor about 20

Photo 8. Photo shows fire at door on Side Bravo soon after initial crews arrived on scene. Time approximately 1626 hours on March 21, 2018.
(Photo courtesy of the Fire Department.)

Photo 9. Photo shows fire at the Side Delta / Charlie corner soon after fire department arrived on scene on March 21, 2018.
(Photo courtesy of the Fire Department.)

feet. The Engine 99-1 acting officer was in the lead. The Engine 99-5 acting officer became separated from the Engine 99-1 acting officer in the thick smoke. He yelled out for the Engine 99-1 acting officer and attempted to find the hose line to follow it out. He yelled out for the Engine 99-1 acting officer again, but did not get a reply. While crawling on hands and knees, he came to an unguarded opening in the second floor and dropped through the opening. He was able to roll and fell feet first to the first floor, injuring his left ankle and left wrist. He was disoriented but able to find his way to the front door where he reported to the shift commander that the Engine 99-1 acting officer was still on the second floor. *Note: At this point, there was confusion as to whether one fire fighter or two fire fighters were missing.*

The shift commander ordered the Engine 99-5 acting officer to report to EMS staff for treatment. While talking to the shift commander, the Engine 99-5 acting officer and the shift commander observed the Engine 99-1 acting officer exit the front door.

Command attempted to conduct a personal accountability report (PAR) of the crews on the fireground. It was determined that the fire fighter originally believed to be missing was accounted for and the RIT entry was cancelled almost immediately. The incident commander radioed dispatch and cancelled the Mayday which should have cancelled the third alarm but the third alarm was not cancelled by dispatch. At this point, fire was blowing out all four sides of building.

At approximately 1658 hours, the incident commander radioed dispatch and advised dispatch that the fire would be a defensive operation.

The Engine 99-5 acting officer was transported to a local hospital for treatment at approximately 1830 hours where he was treated for a sprained ankle and fractured wrist.

DAY 1: Defensive Operations at 1700 Hours March 21, 2018

The 2 ½-inch preconnected hand line pulled off Engine 99-1 and advanced inside the structure was repositioned to Side Bravo by the Engine 99-9 crew to hit fire showing through the garage door.

Truck 99-1 was set up for aerial operations near the Side Alpha / Bravo corner but was not able to be set at a good angle and therefore was not very effective at hitting fire showing at the Bravo and Charlie sides.

Station 89 supplied water to Engine 99-9 which was staged in the street on Side Bravo. A ground monitor, two 1 ¾ inch preconnected hand lines and one 2 ½ inch preconnected hand line were pulled from Engine 99-9 and operated on Side Bravo. Engine 25-2 arrived with a crew of five fire fighters and provided assistance on Side Bravo working hand lines and ground monitors. Water would knock down the fire, then seconds later the fire would flair back up. Fire fighters reported that when the fire flared up smoke could be seen sucking back into the building.

The Engine 99-9 crew advanced the 2 ½ inch hose line inside the Side Bravo garage door about 5 feet. The shift captain advised the Engine 99-9 fire fighters to switch to defensive operations. They discussed a collapse zone. Crews had to re-enter the collapse zone to pull out the remaining hose lines and the ground monitor.

Truck 89-1 was positioned in the Side Bravo parking lot and set up for master stream operation. Defensive operations were initiated and the incident commander attempted to complete a PAR, but there was difficulty with getting a PAR due to issues with excessive radio traffic.

Defensive operations at this point in the incident consisted of:

- Truck 99-1 on Side Alpha
- Truck 89-1 at Side Bravo / Charlie corner

- Engine 25-2 on Side Bravo
- Truck 11 at Charlie / Delta corner
- Truck 502 at Side Delta

Engine 12 and Truck 11 came on the 3rd alarm. Engine 12 was cancelled and sent back. Truck 11 was put into service on the fireground at Side Delta.

Crews operating on Side Bravo began to notice cracks developing in the Side Bravo exterior wall. The Truck 89-1 officer radioed that the exterior wall was beginning to crack, and Truck 89-1 had to be repositioned out of the collapse zone. Approximately 10 minutes after Truck 89-1 was repositioned, a large portion of the rear of the structure (Sides Bravo, Charlie and Delta) collapsed (see Diagram 2).

Command began relieving crews from Department 99 for the next shift change around 1730 hours. Defensive operations continued throughout the night with hose lines and master streams deployed for exterior operations on all four sides of the structure. Ground monitors and elevated master streams were repositioned as necessary.

Truck 99-1 was repositioned on Side Alpha near the Alpha / Delta corner. Truck 1 (mutual aid from Department 1) set up at the A-B corner. Both Truck 1 and Truck 99-1 were supplied by Engine 99-5. Truck 502 was set up on Side Delta to protect a beer distributor. Truck 502 was supplied by Engine 501. Truck 11 also set up on Side Delta to hit the fire building and was supplied by Engine 19.

Around 2200 hours, the deputy fire chief transferred command to the C-shift assistant chief (shift commander) and left the fireground to go home. Mutual aid crews were gradually released.

Day 2: Defensive Operations on March 22, 2018

Defensive operations continued throughout the night (see Photo 10). The deputy fire chief returned to the fireground around 0730 hours and assumed command from the C-shift assistant chief. Engine 99-7 was staged in the street at the Side Bravo / Charlie corner. Engine 99-5 and Truck 99-1 were in the street on Side Alpha.

The building owner had a trac-hoe machine brought in to support the fire suppression operations to dig through the piles of brick and debris to uncover hot spots so that water application would be more effective. The fire chief and the city building official arrived on scene and met with the building owner. The building owner called in his own engineer to evaluate the building's structural stability in an attempt to determine if the remaining portion of the building could be saved. The engineer arrived at approximately 1030 hours and the incident commander, the city building official, the building owner and engineer entered the structure through the Side Alpha door to visually inspect the interior. They were able to visually inspect the interior of the remaining structure still standing on both Division 1 and Division 2 (floors 1 and 2). The only access to Division 3 and Division 4 (floors 3 and 4) was via an elevator shaft that was located in the collapsed area of the building. *Note: It was reported to NIOSH investigators during interviews that the engineer stated the remaining structure was stable based upon the visual observations. This could not be confirmed as the building owner did not respond to NIOSH*

requests for information. Truck 99-2 was positioned on Side Alpha so that the engineer could access Division 3 through a Side Alpha window. Division 3 (floor 3) was accessed but due to the position of Truck 99-2, Division 4 (floor 4) could not be accessed so Truck 99-1 was repositioned near the Side Alpha / Delta corner to allow access to Division 4 and the roof.

Photo 10. Defensive operations with Truck 99-1 master streams in operation at Side Alpha / Delta corner. Defensive operations continued throughout the night of March 21, 2018 and continued into March 22, 2018.
(Photo courtesy of the Fire Department.)

Structure Collapse at 140-Year Old Mill Building Kills 2 Career Fire Fighters and Injures 2 Others – Pennsylvania

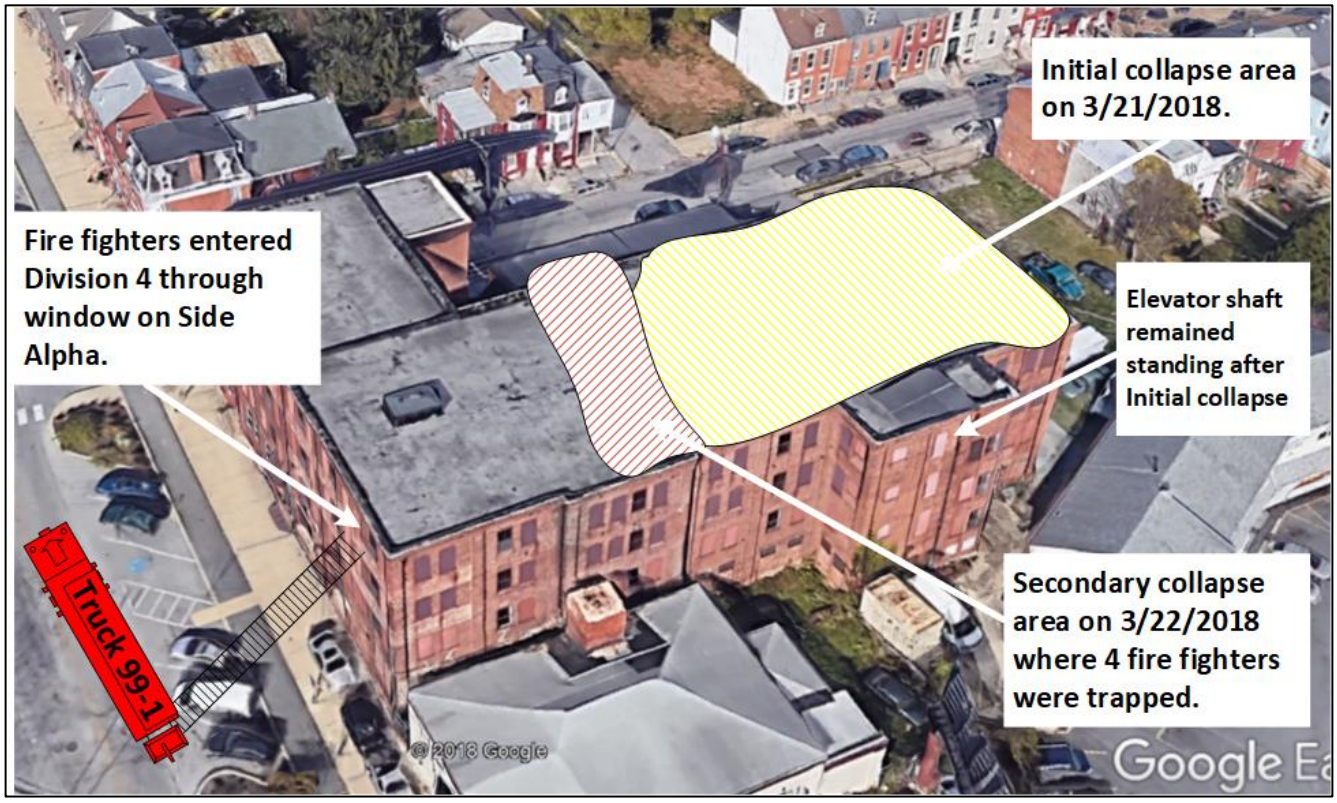

Diagram 2. Initial collapse occurred on March 21, 2018 at approximately 1805 hours. Secondary collapse occurred on March 22, 2018 at approximately 1515 hours after fire fighters used elevated aerial platform to access Division 4 to extinguish hot spots which could not be extinguished using master streams in defensive mode outside the collapse area. All locations are approximate.
(Adapted from Google Earth Satellite View.)

The deputy chief (incident commander) briefly left the fireground to get food for the crews working on the fireground after transferring command to the assistant chief (shift commander). Upon returning to the fireground, the deputy chief assumed command again. The deputy chief and the shift commander discussed the need to get inside the structure to extinguish hot spots burning in the roof and ceiling areas on Division 3 and Division 4. Following the initial collapse the previous evening, large portions of the recently installed waterproof roof membrane hung down and prevented master streams from reaching these burning hot spots (see Photo 11). The decision was made to use the elevated aerial platform so that fire fighters could extend a hose line from the platform onto the third and fourth floors to extinguish the burning hot spots.

Third Offensive Interior Operations

Two fire fighters who had been called in to work overtime on March 22, 2018 were assigned to the task of extending a hose line onto the fourth floor of the remaining structure to find and extinguish hot

spots. Truck 99-1 was positioned near the Side Alpha / Delta corner. The two fire fighters and the incident commander (deputy chief) entered the aerial platform. The platform was raised above the roof and water was directed onto a few visible hot spots. Then the platform was lowered to a fourth floor window on Side Alpha. The incident commander instructed the two fire fighters (both working overtime and assigned to relieve the Truck 99-1 crew) to search for burning hot spots in the ceiling and walls while staying back from the edge of the collapse area. The incident commander remained in the platform bucket while the two fire fighters (wearing SCBA and on air) sounded the floor and then advanced the hose line through the window onto the fourth floor. They advanced through three partition walls to where hot spots were burning in the ceiling. One fire fighter used a pike pole to open the ceiling and walls while the other fire fighter worked the nozzle to extinguish the hot spots. They reported finding two large areas smoldering and then ran low on air so they radioed for assistance. Three more fire fighters (Engine 99-1 acting officer, a fire fighter working overtime, and the shift commander (assistant chief) climbed up the aerial ladder to assist. A fourth fire fighter was assigned to carry extra SCBA cylinders from the ground to the platform. *Note: At this point, the fireground operations had changed from exterior defensive operations to interior offensive operations. A dedicated RIT team was not in place and a mutual aid company for RIT support had not been requested.*

The two Truck 99-1 fire fighters changed their air cylinders and returned to work on the fourth floor. At this point, four fighters and the shift commander were on the fourth floor working to extinguish hot spots. All five fire fighters were fully dressed in personal protective clothing, wearing SCBA and were on air.

One of the Truck 99-1 fire fighters ran low on air again and went to the window to speak with the incident commander and to transfer spare SCBA cylinders through the window while the other three fire fighters and the shift commander continued to work extinguishing the hot spots.

At approximately 1515 hours the rear portion of the standing structure (Sides Charlie and Delta closest to the previous collapse area) collapsed, dropping the three fire fighters and the shift commander to the ground, burying them in a debris pile of bricks and timbers. *Note: During the NIOSH interview process it was reported that the fire fighters working on the fourth floor worked cautiously and were conscious and observant of the previous collapse and stayed at least 10 feet from the edge of the collapse area while working. The surviving fire fighters reported hearing one or possibly two loud cracking sounds immediately before the collapse.* At the time of the collapse, the two fire fighters who climbed the aerial ladder with the shift commander were working the hose line. The Engine 99-1 acting officer was backing up the Truck 99-1 fire fighter on the nozzle and assisting with moving the hose line. The third fire fighter (working overtime to relieve the Truck 99-1 crew) was pulling ceiling and the shift commander was observing the work in progress (see Diagram 2).

Following the collapse, the incident commander immediately radioed a Mayday and requested a second alarm assignment. At 15:16:27 hours, the incident commander radioed Dispatch and reported the structure collapse with fire fighter entrapment. The incident commander radioed for a mass casualty event which automatically dispatched five advanced life support (ALS) ambulances and five more basic life support (BLS) ambulances.

Structure Collapse at 140-Year Old Mill Building Kills 2 Career Fire Fighters and Injures 2 Others – Pennsylvania

Photo 11. View from Side Charlie facing rear of remaining structure. Photo shows the partially melted roof membrane which deflected master streams and prevented water from reaching burning hot spots in roof and ceiling areas on the Division Three and Division Four. The inability to extinguish the burning hot spots ultimately led to the decision to enter the third and fourth floors to attempt to extinguish the remaining hot spots.
(Photo courtesy of the Fire Department.)

At 15:17:12 hours, the fire fighter who had been pulling ceiling was able to reach his radio. He reported that he was trapped and could not get out but there was no fire burning in the immediate area where he was trapped. At 15:17:52 hours the Fire Chief, who had been on Side Delta (and had witnessed the collapse) radioed Dispatch and requested the county advanced technical rescue team (ATR) be dispatched.

The Truck 99-1 aerial platform was lowered and all fire fighters on scene immediately rushed to the collapse area. Fire fighters quickly found the shift commander who was stunned and bleeding from a head wound. The Truck 99-1 fire fighter was initially unable to move but soon was able to move his arms and reach his radio lapel microphone so that he could radio his condition. The Truck 99-1 fire fighter continued to move as much as he could until he was able to start digging himself out of the

debris pile. At approximately 1526 hours the incident commander radioed Dispatch and reported that two of the trapped fire fighters had been located.

At least one PASS device could be heard under the debris pile as the rescue crews continued to search for the remaining two fire fighters. They quickly located the Engine 99-1 acting officer who was unconscious. The Engine 99-1 acting officer was trapped by a large wooden beam across his legs. Chain saws and rescue saws were used to cut through a number of wooden beams and planks. The waterproof roof membrane hindered the rescue process and bogged down the saws multiple times before the Engine 99-1 acting officer was extricated and removed from the debris pile. The Engine 99-1 acting officer was transported at approximately 1530 hours to a local hospital where he was pronounced dead.

A PASS device and low air alarm could be heard further down in the pile where the hose line was buried. The remaining portion of the Side Delta wall was leaning outward. A fire fighter was positioned in the elevated Truck 99-1 platform to monitor the building while the crews on the ground worked to locate the last trapped fire fighter. At approximately 1536 hours, the incident commander radioed Dispatch and reported that they were working on freeing the last trapped fire fighter. The rescue crews continued to move debris by hand until the fourth fire fighter was located. At approximately 1547 hours the incident commander radioed Dispatch and reported that everyone was accounted for. At approximately 1549 hours the fourth fire fighter (last fire fighter to be extricated) was transported to the local hospital in trauma arrest where he later died. Cardio-pulmonary resuscitation (CPR) was performed on both victims on-scene and while in transit to the hospital.

The two injured fire fighters were transported to a local hospital and treated for non-life threatening injuries.

At approximately 1559 hours on March 22, 2018, Department 99 was taken out of service by incident command. All Department 99 fire fighters were instructed to report to a nearby city maintenance garage for debriefing and counseling. Command was transferred to Department 89.

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 this fatality:

- Building under renovation with inactive sprinkler system
- Long-burning deep seated fire could not be reached by exterior master streams
- Previous partial structure collapse
- Fire fighters entered collapse zone following defensive operations
- Inadequate risk versus gain analysis.

Cause of Death

According to the County Coroner Office report, the cause of death for the Engine 99-1 acting officer (victim 1) was multiple blunt force trauma to the torso.

The County Coroner Office also determined that the cause of death for the fire fighter working overtime on Truck 99-2 (victim 2) died of blunt force trauma with traumatic asphyxia, and the manner of death was accidental.

Recommendations

Recommendation #1: Fire departments should ensure that when a collapse zone is established, the collapse zone is properly managed and enforced by the division supervisor and/or assistant safety officer. Command should also consider designating exclusion zone(s) or no-entry zones as needed due to dangerous or hazardous conditions.

Discussion: In most fireground situations involving a structure fire, the probability of and anticipation for structural collapse or compromise are often minimized, overlooked, or at times disregarded until the catastrophic conditions present themselves with little to no time to react accordingly. The loss of situational awareness, coupled with distracted attention to subtle or obvious pre-collapse building indicators and knowledge gaps in building and construction systems combine to elevate operational risks to fire fighters on the fireground. [Naum 2012].

Understanding the influence that building design and construction have on structural collapse has a direct correlation to safe fire-fighting operations and fire fighter survivability. In virtually every case, structural collapse results from damage to the structural system of the building caused by the fire or by firefighting operations. The longer a fire burns in a building, the more likely the building will collapse. Older buildings that have been exposed to weather and that have been poorly maintained are more likely to collapse than newer, well-maintained buildings. The walls of buildings, especially curtain walls, false fronts, marquees, and parapet walls, and heavy signs can all come falling down [NIOSH 2014].

Today's evolving fireground demands a greater understanding of buildings, occupancy risk profiling, and building anatomy by all operating companies. The identification, assessment, probability, predictability, and intrinsic characteristics of building performance under fire conditions must not only be comprehended, but also postulated into an adaptive fire-management model with flexible and fluid incident operational parameters.

Structural collapse is a significant cause of injury and death to fire fighters, and the potential for a structural collapse is one of the most difficult situations to predict. The predictability of a building's performance and risk of structural collapse, compromise, or failure must be foremost in the development and execution of the incident action plan (IAP). The collapse precursors or indicators,

such as developing cracks in the exterior walls, must be identified, monitored, and managed on the strategic-, tactical-, and task levels [Naum 2013].

A collapse zone is defined as the area around the perimeter of a structure that could contain debris if the building collapsed. This area is often defined by establishing a perimeter at a distance from the building that is equal to 1½ times the height of the structure.

As noted in the NIOSH document *Preventing Deaths and Injuries to Fire Fighters by Establishing Collapse Zones at Structure Fires*, determining when to establish a collapse zone starts with a community risk assessment program. Community risk assessments satisfy many fire department objectives, but one of the most important aspects is to evaluate the fire risk associated with occupancy and construction classifications. A community risk assessment program, coupled with a pre-incident planning initiative that evaluates building construction, structural integrity, fire load, and fire protection systems, is a vital tool for safely fighting fires. Fire departments should ensure all members are trained in the organization's rules of engagement, risk assessment, and situational awareness procedures [NIOSH 2014].

When conditions warrant that an area becomes an exclusion zone or no-entry zone [NFPA 2018b], Command needs to take appropriate actions to designate these areas. An exclusion zone or no-entry zone may be needed for an area where a collapse zone is not sufficient. The incident commander and the safety officer have a responsibility to establish and enforce the collapse zones plus the exclusion or no-entry zones. Also, if a division supervisor is assigned to a side (division) of a structure, they must have the responsibility to determine the conditions as they relate to the safety of fire fighters. Everyone has a responsibility to abide by the decisions made for the established collapse zones and exclusion/no-entry zones. If the fire is not contained and an exterior (defensive) attack becomes necessary, the collapse zone should be moved far enough away from the structure to place the fire fighters outside of the collapse zone. The collapse zone then becomes an exclusion/no-entry zone [Klaene and Sanders 2007; NFPA 2018b, NFPA 2019].

During this incident, defensive operations were declared at approximately 1800 hours and less than two hours after fire fighters first arrived on-scene. All fire fighters were evacuated from the structure and fire suppression operations were limited to exterior hose lines and master stream applications. Defensive operations continued throughout the night and throughout the next day. A collapse zone was established sometime during the evening hours on March 21st, but fire fighters had to enter the collapse zone to retrieve hose lines and move ground monitors. The following day, the incident commander, the city building official, the building owner and the owner's engineer entered the building for a visual inspection to survey the building conditions. Civilian contractors also entered the collapse zone with excavation equipment to attempt to dig out hot spots burning within the debris piles at the sight of the initial building collapse.

Recommendation #2: Fire departments should ensure that all fire fighters are trained in and recognize the importance of situational awareness.

Discussion: The book, *Essentials of Fire Fighting and Fire Department Operations*, defines situational awareness as an awareness of the immediate surroundings [IFSTA 2008]. On the fireground, every fire fighter should be trained to be constantly alert for changing and unsafe conditions. This applies not only to the conditions found within a burning structure, but to the exterior fireground as well. Fire fighters may encounter a wide variety of surface features that they must walk across while performing fireground tasks. For example, surfaces may be wet, slippery, ice-covered, or uneven and may be vegetation-covered or include debris from the burning structure. Downed power lines, broken or leaking natural gas meters and distribution lines, unstable structures, and other environmental factors are just some of the hazards that may be present on the fireground.

One of the most critical aspects of coordination between crews is maintaining situational awareness. The opposite of situational awareness is tunnel vision where the fire fighters become so focused on fire fighting or other operational assignments that they fail to sense changes in their environment. Fire fighters can maintain their situational awareness by looking up, down, and around themselves as well as listening for new or unusual sounds and feeling vibrations or movement. Fire fighters and officers should communicate any changes in their environment to other members as well as to the incident commander. Each first responder is responsible for their safety plus the personnel they are working with. Every fire fighter should be empowered to speak up and report unsafe conditions. Maintaining situational awareness protects against complacency and tunnel vision. The incident scene creates a significant risk to fire fighters, and it is the responsibility of the incident commander and command organization officers to minimize fire fighter exposure to unsafe conditions and stop unsafe practices [IAFC 2012].

This incident occurred in a 140-year old heavy timber mill building that was being renovated into an apartment complex. The fire quickly escalated into a conflagration. A partial collapse occurred at approximately 1800 hours and defensive operations were conducted until the next afternoon. A number of hot spots continued to burn in the roof and ceiling areas of the remaining structure that could not be reached by exterior master streams. While crews operated on the fourth floor with a hand line attempting to extinguish hot spots, a collapse occurred. Four fire fighters were trapped by the collapse including two who were fatality injured.

Recommendation #3: State, local, and municipal governments, building owners, and authorities having jurisdiction should consider requiring the use of sprinkler systems in commercial structures, including during renovation work.

Discussion: This recommendation focuses on fire prevention and minimizing the impact of a fire if one does occur. The National Fire Protection Association (NFPA) *Fire Protection Handbook* states: "Throughout history there have been building regulations for preventing fire and restricting its spread. Over the years these regulations have evolved into the codes and standards developed by committees concerned with fire protection. The requirements contained in building codes are generally based upon the known properties of materials, the hazards presented by various occupancies, and the lessons

learned from previous experiences, such as fire and natural disasters" [NFPA 2008]. Although municipalities have adopted specific codes and standards for the design and construction of buildings, structures erected prior to the enactment of these building codes may not be compliant. Such new and improved codes can improve the safety of existing structures [NFPA 2008]. Sprinkler systems are one example of a safety feature that can be retrofitted into older structures. Sprinkler systems can reduce fire fighter and civilian fatalities since such systems can contain and may even extinguish fires prior to the arrival of the fire department.

Fire development beyond the incipient stage is one of the greatest hazards that fire fighters face in today's combustible environment. This exposure and risk to fire fighters can be dramatically reduced when fires are controlled or extinguished by automatic sprinkler systems. NFPA statistics show that most fires in sprinklered buildings are controlled prior to fire department arrival by the activation of one or two sprinkler heads. The presence of automatic fire sprinklers also reduces the exposure risk to fire fighters in rescue situations by allowing the safe egress of building occupants before the fire department arrives on-scene. Finally, the exposure to hazards such as building collapse and overhaul operations are greatly reduced, if not eliminated, when fire development is arrested and controlled.

The commercial structure involved in this incident was originally constructed in the 1870s and remodeled several times before sprinkler systems were required by code. A sprinkler system was added, but at the time of the fire, the sprinkler system was not working. The structure was being renovated and converted into a residential apartment complex. The presence of a working sprinkler system at the time of this fire may have extinguished the fire prior to the fire department's arrival. *Note: Members of the fire department and the fire prevention office had performed a walk-through inspection of the structure in October 2017 during the initial renovation phase. Following that inspection, the building was added to the fire department's NO ENTRY list. An email notice was sent to all fire department members on October 15, 2017 notifying members that they should not enter the structure under fire conditions. The email notice identified several floor / roof collapses as well as holes rotted through floors in various locations. The email notice identified that the existing sprinkler system was not in service due to breaks in the system.*

Recommendation #4: Fire departments should ensure a dedicated rapid intervention crew (RIC) is present and ready to respond before fireground operations change from exterior defensive to interior offensive operations.

Discussion: Adequate resources are needed at incident scenes to ensure rapid incident stabilization and to promote fire fighter safety. Fire departments should pre-plan the tasks that may be performed at any structural fire prior to response and develop response packages to address the tasks. From determining the required fire flow, to stretching hose lines, forcing entry, search, rescue, extinguishment and much more, fire departments should consider what the staffing needs are in order to simultaneously perform these tasks. The planning for the first-alarm assignment needs to include sufficient additional unassigned fire fighters (separate from the RIC personnel) to be on-scene, staged and ready to assist with fireground operations in the event of an emergency or to allow for on-scene fire fighter rehabilitation. Incident commanders should recognize the limits of available resources to complete fireground tasks and adjust their desired action plan to coincide with resources on hand [NIOSH 2017].

In order to ensure compliance with 29 CFR 1910.134, Respiratory Protection, [OSHA 1998] fire departments must maintain a rapid intervention crew or company when members are operating in an immediately dangerous to life and health (IDLH) or potentially IDLH atmosphere.

The RIC function should be incorporated into the department's incident management system and personnel accountability system [NFPA 2014]. Critical fireground operations and staffing needs should be continuously evaluated in regards to fire fighter safety. Resource assignments should be made with the goal of having the RIC 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 a RIC should be carefully assessed [NFPA 2014].

The following restrictions regarding the use of a RIC should be considered by incident commanders during fireground operations:

- The RIC should not be used for fire-fighting operations.
- The RIC is dedicated to assist, and if necessary, rescue members who become trapped, distressed, or involved in other serious life-threatening situations.
- The RIC should not be used to provide relief for operating companies until the fire/incident has been declared "Under Control" by Command.
- If assigned by a superior officer to other than RIC duties, the RIC unit officer should remind such officer of RIC designation [Toledo Fire & Rescue Department 2012; TSFRS 2014].

When the incident commander orders the RIC to work, the incident commander should immediately assign another on-scene company to stand by as the RIC. At a minimum, the incident commander should request an additional alarm and designate a company or companies to function as the RIC. The remainder of the companies should report to staging. If no units are available, the incident commander should assign at least two members to act as a rapid intervention team while awaiting a special-called RIC to arrive. An engine company may be designated as the RIC 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].

Upon deploying a RIC, incident commanders must expand the Incident Action Plan or IAP to reflect a high-priority rescue effort, focusing resources on the simultaneous tasks of controlling the fire and rescuing the endangered fire fighter(s). Such changes in the IAP need to be announced over the radio so that everyone on the incident scene ***and in the Dispatch Center***, understands what is happening. Consideration should be given to expanding the Incident Organizational Structure to include a Rescue Branch (focused on RIC activities) and a Suppression Branch (focused on fire fighting). In this way, Command assigns a Branch Director (a Chief Officer) to each branch and addresses both functions requiring immediate attention. This action also reduces the likelihood of overwhelming the incident commander with "task saturation," a condition in which auditory and sensory inputs overload an individual's ability to maintain situational awareness, leading to a potential failure at the command level.

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Many fire departments have a defined response plan for the dispatch of an additional company (engine, truck, squad, or rescue) to respond to an incident and stand by 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 RICs by location or function [NFPA 2014].

Upon arrival or upon appointment, the RIC officer should meet face-to-face with the incident commander. The RIC officer should establish an area to stage the RIC and the necessary RIC equipment. The RIC equipment should include:

- A tool staging tarp
- Rescue SCBA (RIC Pack)
- Forcible entry tools such as a Halligan bar or other pry tool
- Stokes basket
- 150-foot rope for search and rescue
- Wire cutters
- Rebar cutter
- Saws
- Thermal imager
- Emergency strobe lights
- Life-saving rope/life belt
- Elevator keys for buildings with elevators [FDNY 2011; LAFD 2001; TSFRS 2014].

It is important to stage all necessary RIC equipment in an expedient manner (see Photo 12). The RIC officer (equipped with a thermal imager), accompanied by one member of the RIC, should perform an incident scene survey while the remaining RIC members assemble the RIC equipment. If the size of the structure negates a 360-degree survey of the building, this fact should be relayed to the incident commander as soon as possible. This should be a benchmark for Command to designate another RIC in order to effectively cover all sides of the building.

During the 360-degree survey, the RIC officer and members should look for ways in and out of the structure, including window configuration, fire escapes, and construction features. The RIC officer should note the feasibility for placement of ground ladders for rescue or escape purposes. The RIC officer should 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 RIC has determined the need for an egress ladder, the window glass should be removed. This should only be done after conferring with Command that the removal of the window will not affect firefighting operations. Once approved by Command, the egress ladder should be placed at the window. The location of the egress ladder(s) shall be announced over the radio by the RIC officer [Toledo Fire & Rescue Department 2012].

After the above tasks are completed, the RIC officer should inform Command that a 360-degree survey has been completed and the RIC is ready to intervene, if necessary. Once the incident scene survey has been completed and the RIC equipment is in place, the entire RIC should be located in an area immediately accessible to the building in order for rapid deployment plus maintaining radio contact with Command. The RIC officer should brief all members of the RIC as to the results of his/her

incident scene survey. The RIC should operate as one unit. Additional crews may be added to or in support of the 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 & Rescue Department 2012].

Photo 12. This is an example of the equipment needed for rapid intervention crew (RIC) operations. One of the most important pieces of equipment is the strobe light, which can be used to identify/mark an exit in a building in the event a rapid egress is needed by a fire fighter or fire fighters.
(*Photo courtesy of the Google Bing.com Free Photo Search.*)

The RIC officer and RIC members will coordinate with Command to formulate rescue plan contingencies and continue to monitor the radio and fireground conditions. RIC 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 RIC function is a critical component for fire fighter safety.

In this incident, the fire department depended upon a mutual aid agreement with a neighboring fire department to provide rapid intervention team (RIT) support during working structure fires within the city. This combination mutual aid department was dispatched to the incident scene on March 21st, and was on scene until the fireground operations were limited to defensive exterior operations. On March 22nd, a dedicated RIC was not in place at the time of the collapse. While there is no evidence that a dedicated RIC could have prevented the two fire fighter fatalities, having a RIC team in place before fireground operations are switched from exterior defensive operations to interior offensive operations is an example of a recommended best practice for the fire service. At very large structures, command should consider the need for placing a dedicated RIC on each side of the structure to enhance RIC response times.

Recommendation #5: Fire departments should ensure that all fire fighters, company officers, and chief officers are trained in and follow proper radio discipline while operating at emergency incidents.

Discussion: One of the keys to both the success of fireground operations and to the safety of fire fighters performing those operations is effective communication [IFSTA 2008]. The NIOSH Fire Fighter Fatality Investigation and Prevention Program has identified a number of recent fatal incidents in which ineffective radio fireground communications was identified as a contributing factor [NIOSH 2009a, NIOSH 2009b, NIOSH 2011a, NIOSH 2011b, NIOSH 2012, NIOSH 2016].

Several recent incidents involving fire fighter fatalities where inadequate fireground communications were identified as contributing factors to the injuries and deaths prompted the U.S. Fire Administration (USFA) to study the potential causes of communication breakdown and to provide recommendations that would help departments improve operational communications. As with any tool, fire fighters need to receive training in proper operation, routine preventative maintenance, and limitations of the portable radio used by the department. Radio discipline is vital for effective communication among firefighters, dispatchers, and other emergency personnel. Systems with inadequate capacities can become quickly overwhelmed even during routine incidents, seriously compromising fire fighter safety. Allowing unlimited message transmission may create a situation where vital messages cannot be heard due to the number of less important transmissions being broadcast. By contrast, restricting radio traffic to only "vital" messages may prevent important information from being broadcast. The challenge is achieving a balance to ensure that all potentially important information is broadcast, but not at the expense of emergency transmissions or Mayday calls from interior crews. The best way to develop good listening and speaking skills is through training and continued practice during multi-company operations drills or simulations. It may also be helpful for command or training officers to use tapes of actual incidents, or drills, to critique procedures and reinforce the importance of these skills [USFA 1999].

There are several actions fire fighters can take to improve radio discipline. An obvious way is to *not* use radios for communicating when face-to-face dialogue is a better and available choice. Examples of these situations include: when the sender and receiver are located a short distance from one another, when conferring about strategic or tactical options, or when a complex, vital message (such as a change in strategy from offensive to defensive) must be conveyed. Face-to-face communication is generally more effective than radio communication since both sender and receiver have the added benefit of being able to see and interpret non-verbal cues that support conveying ideas or understanding (e.g., eye contact, physical contact, body language). Distractions are also reduced and people can ask questions or identify problems more readily during one-on-one dialogue. Command officers can use runners to deliver and obtain information from remote units. Using a runner has the potential added benefit of providing another view of the situation to the incident commander [USFA 1999].

A related issue is the tendency for fire fighters to not report problems completing an assignment; for example, forcing entry, procuring a water supply, or searching the fire floor. Fire fighters sometimes are reluctant to report difficulties for fear of being judged as slow, incompetent, or unaggressive, all of

which are contradictory to the fire department cultural values. Radio discipline, while important, must achieve a balance between limiting non-essential radio traffic and ensuring that potentially important information is regularly broadcast. Fire departments need to ensure that training is conducted to develop effective fire fighter communication skills [USFA 1999].

Some areas have taken a "no good news" approach to radio communications. In other words, only transmit when you have bad news – otherwise, complete your task and then advise your availability. Additionally, when units arrive on scene, they should not get on the radio and ask for an assignment. They should merely respond, arrive, and announce "level one staging" and then command can assign them as needed [Goldfeder, 2019].

Both the International Association of Fire Chiefs (IAFC) [IAFC 2009] and the International Association of Fire Fighters (IAFF) [USFA/IAFF 2016] recommend that all fire fighters be assigned a radio. In 1999, the U.S. Fire Administration technical report *Improving Firefighter Communications* identified a number of radio communication issues, including the need for all fire fighters to have portable radios. The report stated "Ideally, every firefighter working in a hostile environment should have a portable radio with an emergency distress feature [USFA 1999]." The IAFF Fireground Survival Program contains training on radio communication procedures in emergency operations including how to call a Mayday [IAFF 2012].

Issuing a radio to every fire fighter is not enough. **Training must accompany any effort to improve fireground communication.** First and foremost, the fireground radio frequency can become congested, especially during the early stages when the incident is not yet under control. As such, radio discipline is important and messages should be limited to those of an important tactical nature (Conditions-Actions-Needs or CAN report), accountability (PAR) report, and fireground emergencies (Mayday). Second, training must also encompass circumstances when an incident commander opts to change radio frequencies. This is a potentially dangerous action and should only be undertaken in the most extreme circumstances given the possibility of "losing" personnel in the movement from one channel to another. After switching frequencies, command should conduct a PAR to confirm that the appropriate units are operating on the correct channel. In this incident, the fire department later analyzed dispatch radio logs and confirmed that the radios carried by the victim and injured fire fighters had pinged nearby radio towers, indicating the radios were working properly at the time of dispatch.

In this incident, a number of radio discipline and fireground communication issues were revealed during interviews. Fire fighters reported attempting to broadcast messages which were not received as well as reporting key transmissions not being heard, such as personal accountability requests (PAR) transmitted by command. Too many fire fighters who were not assigned to the fireground were talking on the fireground channel. Dispatch was requested to assign a separate channel for interior fire fighters and exterior fire fighters. Dispatch attempted to move the fireground channel to Channel 4 and leave Channel 3 for exterior fire fighters. The Incident Commander had to change this assignment so that the fireground channel remained Channel 3 and Channel 4 was designated for use by fire fighters and companies in staging. It should be noted that following the collapse, a fire fighter injured

in the collapse was able to radio his location and condition, which was received by command and also noted on the dispatch logs.

Recommendation #6: Fire departments should ensure that appropriate staffing levels are available on scene to accomplish fireground tasks and be available for unexpected emergencies.

Discussion: Adequate resources are needed at incident scenes to ensure rapid incident stabilization and to promote fire fighter safety and health. A department should pre-plan the tasks that may be performed at any structural fire prior to response and develop response packages to address the tasks. From determining the required fire flow, to stretching hose lines, forcing entry, search, rescue, extinguishment and much more, fire departments should consider what the staffing needs are in order to simultaneously perform these tasks. The planning for the first-alarm assignment needs to include sufficient additional unassigned fire fighters to be on scene, staged and ready to assist with fireground operations in the event of an emergency or to allow for on-scene fire fighter rehabilitation. Incident commanders should recognize the limits of available resources to complete fireground tasks and adjust their desired action plan to coincide with resources on hand.

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* identifies the minimum resources for an effective firefighting force to perform critical tasks. These tasks include establishing water supply, deploying an initial attack line, ventilating, performing search and rescue, and establishing a rapid intervention team or RIT. NFPA 1710 recommends that the minimum staffing level for an engine company to perform effective and efficient fire suppression tasks is four fire fighters. 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 2016].

In addition, a study released by the National Institute for Standards and Technology (NIST), *Report on Residential Fireground Field Experiments,* concluded that a three-person crew started and completed a primary search and rescue 25% faster than a two-person crew and that a four or five-person crew started and completed a primary search and rescue 6% faster than a three-person crew [NIST 2010].

In this incident, the fire department was stretched to its limits in responding to the initial fire on March 21, 2018 and continuing defensive operations throughout the night and into the following day. The fire department had to call back off-duty fire fighters to provide coverage throughout the city during the incident. The fire department depended upon an automatic mutual aid agreement for rapid intervention team (RIT) support. “This should NOT discourage the use of whatever resources may be needed (and calling for them rapidly, either automatically or as needed), but should ENCOURAGE a regional policy and systems approach so accountability is assured from the start [Goldfeder, 2019].” In this incident, due to the large number of mutual aid departments on scene, an effective accountability system was not established until later in the incident.

Recommendation #7: Fire departments should ensure that all companies are staffed with an officer on the fireground.

Discussion: The company officer is responsible for organization, management, leadership, accountability, and safety of the fire fighters assigned to the company. The duties and responsibilities of the company officer focus on the operations of the company during emergency incidents and non-emergency activities.

NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program* defines a company as a group of members (1) under the direct supervision of an officer; (2) trained and equipped to perform assigned tasks; (3) usually organized and identified as engine companies, ladder (truck) companies, rescue companies, squad companies, or multi-functional companies (quint); (4) operating with one piece of fire apparatus (pumper, aerial fire apparatus, elevating platform, quint, rescue, squad, ambulance) except where multiple fire apparatus are assigned that are dispatched and arrive together (task force), continuously operate together, and are managed by a single company officer; or (5) arriving at the incident scene on fire apparatus [NFPA 2018b]. 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* defines a company officer as a supervisor of a crew/company of personnel. Moreover, each company shall be led by an officer who shall be considered a part of the company [NFPA 2016]. The rank structure could be either sergeant, lieutenant, or captain.

The company officer is responsible for the direct supervision of the members of the company. From an incident management standpoint, the company officer maintains the chain of command, unity of command, and an appropriate span of control. When a company arrives at an incident, the fire fighters assigned to the company report directly to the company officer (unity of command), who clarifies reporting protocol. This eliminates the confusion caused by conflicting or multiple orders. Additionally, this reduces the span of control of fire fighters reporting to Command [FEMA 2005]. Most importantly, the company officer can maintain accountability of the fire fighters assigned to the company. The company officer also serves as the focal point for company communications. Though each fire fighter should or has a portable radio, the company officer is the contact for company communications on the fireground unless otherwise specified.

Company officers determine, based upon conditions, the priority of the task-level functions for their company unless otherwise ordered by Command. The assignment of these task-level functions represents a standard strategy for tactical operations designed to improve the effectiveness and safety of all companies working together. Splitting companies into individual fire fighters without a company officer creates an issue with span of control, personnel accountability (freelancing), and unity of command. This is particularly problematic during the early stages of an incident. Without an assigned or designated company officer, it is much more difficult for the incident commander or tactical level management to account for the location and function of individual fire fighters.

The fireground is a rapidly changing and continuously evolving scene that requires command staff to process visible and audible information to affect a positive outcome for occupants and responders. The

incident commander and the company officers must be able to prioritize tasks, be proficient in task management, and recognize when task saturation or task overload occurs [Chadwick 2014]. Quickly sizing-up an incident scene and developing the appropriate strategy and tactics are essential functions required of a company officer upon arrival. A company officer must have the necessary knowledge, skills, and abilities to make the proper decisions on the fireground. Experience is necessary for fire officers to maintain proficiency and feel comfortable using their skills and apply the knowledge they have learned. The company officer must possess the ability to recognize risks and hazards in relation to their own safety and for the safety of their fire fighters. This ability is perhaps the most important individual factor to successful risk management and can have a direct effect in managing task saturation [FEMA 2005].

Changes in the modern fire environment have caused significantly dangerous alterations in fire dynamics and fire behavior. It is imperative to conduct a thorough size-up of the tactical area prior to the commencement of operations, and evaluate all fireground factors to determine the amount of fire fighter involvement necessary to bring the situation under control. The company officer must ensure that he/she has the necessary information to make effective and safe tactical decisions that lead to a successful outcome of the incident [TSFRS 2014].

Identifying and predicting fire behavior can be a challenge for experienced fire officers and fire fighters and even more difficult for a novice fire officer or fire fighter. While fire departments may have enough residential structure fire-fighting experience, the same tactics employed on fires at other structures - e.g., a multi-family or commercial structure may not yield the same results. Different styles of construction - e.g., those with significantly larger floor space or very high ceilings with large void areas that conceal fire and products of combustion make it harder to check overhead and the fire may get behind the crews stretching in.

Company operations during a structure fire are critical in terms of providing an organized system of tasks that ensures a positive outcome and provides the safety of the members. The company officer ensures the proper placement of the apparatus upon arrival and communicates the task assignment to the crew and how they will accomplish their assignment. The company officer maintains communications with the incident commander or division/group supervisor. As the members of a company enter a hazardous environment together, the company officer ensures that crew integrity and accountability is maintained.

In this incident, the fire department operates with one captain per shift. A permanent officer is not assigned to each company or fire apparatus. Fire apparatus respond with a crew of fire fighters who rotate through fire fighter, driver and company officer positions.

Recommendation #8: Fire departments should ensure that fire fighters are trained in fireground survival procedures.

Discussion: As part of emergency procedures training, fire fighters need to understand that their PPE and SCBA do not provide unlimited protection. PPE that is not properly donned, worn or activated may provide reduced protection or no protection at all, in the event that a fire fighter becomes trapped

and is unable to escape. In such cases, delay in egress to transmit a Mayday message may be fatal. However, the Mayday message should be transmitted as soon as the crew is in a defensible position. The International Association of Fire Fighters and the International Association of Fire Chiefs has developed the IAFF Fire Ground Survival program to ensure that training for Mayday prevention and Mayday operations are consistent between all fire fighters, company officers, and chief officers [IAFF 2012]. Fire fighters must act promptly when they become lost, disoriented, injured, low on air, or trapped [Carter, Childress, and Coleman, et. al. 2000; Hoffman 2002; DiBernardo 2003; Angulo, Clark, and Auch 2004; Sendelbach 2004; Miles and Tobin 2004].

After quickly assessing the tenability of their location, the fire fighter must transmit a Mayday while they still have the capability and sufficient air, noting their location if possible. As noted above, fire fighters may need to move away from untenable fire conditions before calling the Mayday. The next step is to manually activate their PASS device. To conserve air while waiting to be rescued, fire fighters should try to stay calm, be focused on their situation and avoid unnecessary physical activity. They should survey their surroundings to get their bearings and determine potential escape routes such as windows, doors, hallways, changes in flooring surfaces, etc., and stay in radio contact with the IC and other rescuers. Additionally, fire fighters can attract attention by maximizing the sound of their PASS device (e.g. by pointing it in an open direction), pointing their flashlight toward the ceiling or moving it around, and using a tool to make tapping noises on the floor or wall.

A crew member who initiates a Mayday call for another person should quickly try to communicate with the missing member via radio and, if unsuccessful, initiate another Mayday providing relevant information on the missing fire fighter's last known location. Training should include situations dealing with "uncontrolled" SCBA emergencies, egress through small openings, emergency window egress, building collapse, and other situations that could be encountered during a Mayday situation.

Additional emphasis must be placed on appropriate procedures for tactical withdrawal under worsening fire conditions, and/or pending building collapse [Dodson 2005]. The use of an operational retreat is designed to quickly remove fire fighters from operations in an unsafe or potentially unsafe environment. The Incident Commander shall initiate an operational retreat whenever the operational area is deemed unsafe for emergency personnel. All personnel operating in the unsafe area shall evacuate as the operational retreat procedures are initiated. Operational retreat shall begin with radio traffic announcing "EMERGENCY TRAFFIC" with directions for all emergency personnel to evacuate the operational area. An emergency egress signal shall be sounded. For example:

- Repeated short air horn blasts of approximately 10 seconds, followed by 10 seconds of silence
- The sequence of the air horn blast for 10 seconds followed by 10 seconds of silence should be repeated 3 times.

Upon hearing the operational retreat signal, all fire fighters should immediately withdraw from any operations they are performing and leave the operational area. All company officers should immediately perform a Personnel Accountability Report (PAR) of all personnel they are responsible for and report the results to the Incident Commander.

In addition, fire fighters need to understand the psychological and physiological effects of the extreme level of stress encountered when they become lost, disoriented, injured, run low on air or become trapped during rapid fire progress. Most fire training curriculums do not include discussion of the psychological and physiological effects of extreme stress, such as encountered in an imminently life threatening situation, nor do they address key survival skills necessary for effective response. Understanding the psychology and physiology involved is an essential step in developing appropriate responses to life threatening situations. Reaction to the extreme stress of a life threatening situation such as being trapped by extreme fire behavior or building collapse can result in sensory distortions and decreased cognitive processing capability [Grossman and Christensen 2008)].

As noted above, training is frequently limited to breathing apparatus emergencies, egress through small openings, emergency window egress, etc. Additional emphasis must be placed on appropriate procedures for tactical withdrawal under worsening fire conditions and structural collapse situations.

Following the collapse, the incident commander radioed a Mayday. In response to the Mayday, one of the injured fire fighters was able to radio his status and report this condition. The injured fire fighter began to self-extricate himself from the debris pile.

Recommendation #9: Fire departments should define fireground strategy and tactics for an occupancy that are based upon the organization's standard operating procedures. Incident commanders should base the strategy and tactics on the community risk assessment, building occupancy, pre-incident planning, critical building information system, staffing, and available resources.

Discussion: Since no two fire departments are alike, there is no standard scale to measure and evaluate frequency and severity of risk. Some fire departments will have a greater or lesser degree of tolerance for risk than others. The intent of the risk management process is for a fire department to develop a standard level of safety. This standard level of safety defines the parameters of the acceptable degree of risk for which members perform their job functions.

By definition, frequency is how often something does, or might, happen. Severity (risk) is a measure of the consequences if an undesirable event occurs (see Figure 1). Each risk will have its own set of factors that will dictate how a fire department will try to determine how severe the consequences might be. This scale is used to establish the degree of priority. Priority of the risk is in direct relation to inherent risks that have had a harmful effect on a fire department and its members [NFA 2004].

In this incident, the fire department responded to a working fire in a 140-year old vacant building of Type 4 construction. The structure was undergoing renovation work to convert the heavy timber mill building into an apartment complex. This working fire represented a low frequency event with high risk to fire fighters due to construction features that included on-going renovation work, limited ingress and egress (most windows and doors were boarded up and a chain-link fence had to be breached to gain access to side Bravo and Charlie) limited access between floors (stairways removed and in the process of being rebuilt), highly flammable contents (polyurethane and other flammable liquids, building materials, etc.) and a non-functional sprinkler system. The fire department did not have a

current pre-incident plan for the facility but some fire fighters and the fire prevention bureau had walked through the structure after the renovation work was initiated the previous year and determined it was unsafe at that time.

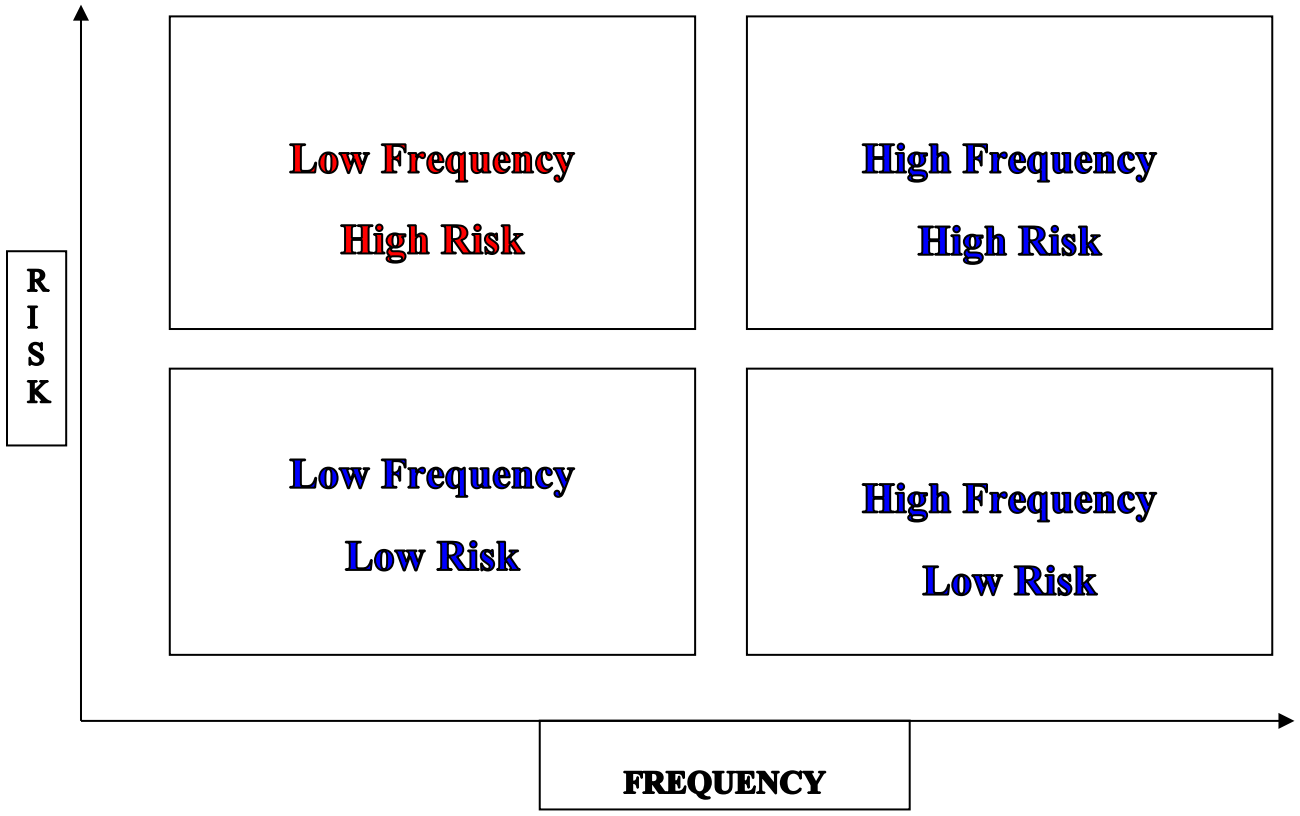

Figure 1.
Risk versus Frequency. Low frequency, high risk events can be especially hazardous to fire fighters and emergency responders.

Recommendation #10: Fire departments should utilize a functional personnel accountability system, requiring a check-in and check-out procedure with the designated accountability officer or incident commander.

Discussion: Although there is no clear evidence that fireground accountability was a contributing factor to the fatalities that occurred in this incident, this recommendation is provided as a reminder of recommended best practices for the fire service. Fire departments should review existing personnel accountability procedures to ensure that they are functional and effective. If no personnel accountability procedures exist, the fire department should develop, implement, and enforce standard operating procedures that ensure a personnel accountability system is utilized at all emergency

operations. The National Fire Protection Association (NFPA) 1561 *Standard on Emergency Services Incident Management System* (2014 edition), Section 4.5.1 states that the emergency services organization shall develop and routinely use a system to maintain accountability for all resources assigned to the incident with special emphasis on the accountability of personnel. Section 4.5.3 states that the system shall include a specific means to identify and keep track of responders entering and leaving hazardous areas, especially where special protective equipment is required. Section 4.5.10 states that responders who arrive at an incident in or on marked apparatus shall be identified by a system that provides an accurate accounting of the responders on each apparatus [NFPA 2014]. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, Section 8.4 identifies requirements for personnel accountability during emergency operations [NFPA 2018b]. Section 8.4.1 states that the fire department shall establish written standard operating procedures for a personnel accountability system that is in accordance with NFPA 1561. Section 8.4.4 of NFPA 1500 states that the incident commander shall maintain an awareness of the location and function of all companies or crews at the scene of the incident.

Personnel accountability systems can range in complexity from simple identification tags to complex electronic tracking systems, and should provide for a functional REGIONAL personnel accountability system to ensure accountability for all fire departments, units, and fire fighters who are predictably called on first alarm and greater assignments during automatic and special called mutual aid assignments. A variety of different personnel accountability systems have been used at emergency operations across the country. At emergency response incidents involving volunteer and combination fire departments, all emergency responders who respond in their privately-owned-vehicles should be required to immediately report to the incident command post and check in face-to-face with Command or the designated accountability officer prior to engaging in incident activities.

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

During this incident, the fire quickly grew in size and scope. The incident commander requested additional resources including calling back off-duty fire fighters. A second and third alarm was struck, resulting in a number of mutual aid departments arriving on scene. The assistant chief for fire prevention responded to assist with accountability. During the initial fire attack, a fire fighter was reported to be missing and crews were assigned to search for the reported missing fire fighter. During the search, a fire fighter fell from the second floor injuring his ankle and wrist. The fire fighter reported to be missing was later determined to have never been on the incident scene. *Note: During the interview process, it was reported to NIOSH investigators that there were issues with accountability due to so many mutual aid crews arriving on-scene. County crews are supposed to report to the IC but many did not report directly and an effective accountability system was not set up until later in the incident.*

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Recommendation #11: Fire departments should ensure that an initial risk assessment is performed and continuous risk assessment is accomplished throughout the incident, and the strategy and tactics match the conditions encountered as part of the continuous size-up.

Discussion: A risk management plan ensures that the risks are evaluated and matched with the actions and conditions. At any incident, life safety is always the first priority, followed by incident stabilization (second priority) and then property conservation (third priority). The ability to ensure for the safety of fire fighters is a continuous process throughout the incident. The following risk management principles should be utilized by incident commanders:

- Activities that present a significant risk to the safety of fire fighters should be limited to situations that have the potential to save endangered lives.

- Activities that are routinely employed to protect property should be recognized as inherent risks to the safety of fire fighters, and the actions should be taken to reduce or avoid these risks.

- No risk to the safety of fire fighters should be acceptable where there is no possibility to save lives or property [Brunacini 2002].

The strategy and tactics of an incident are dictated by the size-up, initial risk assessment, and initial report by the first arriving officer. As in this case, and at every structure fire, it is a priority that a 360-degree size-up is included in the risk assessment. Life hazard, fire extent and location, and building conditions are factors that need to be a part of the size-up and help to match the strategy and tactics with the conditions encountered and this information must be continual. If a 360-degree walk around cannot be completed, then a size-up of the areas can be accomplished through the assignment of personnel and apparatus to divisions starting with a priority of Division C or the rear of the building.

The incident commander is responsible for evaluating conditions at a structure fire and determining the strategy and tactics for fighting the fire. In many cases the first arriving officer is the initial incident commander and sets in motion the strategy and tactics. Command is later passed to a higher-level officer and a formal command is established. The incident commander needs to ensure that the strategy and tactics are appropriate with all of the size-up factors. To accomplish this, the incident commander should use a standardized strategic decision-making model.

First, the incident commander should size up the critical fireground factors [PFD 2009]. Before ordering an offensive attack, the incident commander must make a determination that offensive (interior) operations may be conducted without exceeding a reasonable degree of risk to fire fighters and must be prepared to discontinue the offensive attack if the risk evaluation changes during the fire-fighting operation. A full range of factors must be considered in making the risk evaluation, including the following:

- Presence of occupants in the building
- A realistic evaluation of occupant survivability and rescue potential
- Size, construction, and use of the building

- Age and condition of the building
- Nature and value of building contents
- Location and extent of the fire within the building
- Adjacent exposures (structures)
- Fire involvement or compromise of the building's structural components
- Residential or commercial structure
- Delayed discovery/reporting and its effect on burn time and structural stability
- Considerations of fire loading and fire behavior
- A realistic evaluation of the ability to execute a successful offensive fire attack with the resources that are available [PFD 2009; NIOSH 2010].

These fireground factors should be weighed against the risk management plan. Fire fighters are routinely exposed to certain known and predictable risks while conducting operations that are directed toward saving property. The incident commander is responsible for recognizing and evaluating those risks and determining whether the level of risk is acceptable or unacceptable. However, risks taken to save property should always be less than those to save lives [Grorud 2009; NIOSH 2010]. Risks to fire fighters versus gains in saving lives and property should always be considered when deciding whether to use an offensive or defensive attack.

The incident commander should continually match the actions against the conditions based upon continuous reports from all operating companies. This gives the incident commander the ability to control the situation by forecasting and staying ahead, rather than the fire dictating the actions taken. The incident commander should routinely evaluate and re-evaluate conditions and radio progress reports in reaching objectives to Dispatch and on-scene fire fighters. This process allows the incident commander to determine whether to continue or revise the strategy and attack plans. Failure to revise an inappropriate or outdated attack strategy is likely to result in an elevated risk of death or injury to fire fighters [NFPA 2018b; PFD 2009].

The risk assessment of a building during fire-fighting operations should be continuous with building intelligence and reconnaissance communicated on degrading conditions, fire extension and compromise, building integrity considerations, the effects of fire spread and suppression on the interior compartment(s), and the structural system and building envelope.

It is important that fire officers and fire fighters understand risk management principles and apply that knowledge to modern fire conditions, especially in commercial structures.

This incident occurred in a 140-year old heavy timber mill building that was being renovated into an apartment complex. All workers were accounted for when the fire department arrived. The fire quickly escalated into a conflagration. A partial collapse occurred at approximately 1800 hours and defensive operations were conducted until the next afternoon. A number of hot spots continued to burn in the roof and ceiling areas of the remaining structure that could not be reached by exterior master streams. A crew was sent onto the third and fourth floors with a hand line to extinguish the hot spots. While operating the hand line on the fourth floor, a partial collapse occurred. Four fire fighters were trapped

by the collapse including two who were fatality injured. It is important to note that the building becomes an "occupied structure" when the fire fighters entered it for extinguishment purposes. The decision to allow fire fighters to enter a burning building should be a calculated one based upon available information, not an automatic response. The Incident Commander should have a plan (and resources) in place to quickly and effectively remove fire fighters from the structure ***before*** allowing them to commit deeply into a fire fight.

Recommendation #12: Fire departments, local and municipal governments, and authorities having jurisdiction should consider adopting area-wide standard operating procedures for areas that depend on mutual aid response. All fire departments should participate in area-wide training exercises so that the procedures can be enforced.

Discussion: With automatic and special called mutual aid being common these days for a variety of reasons (primarily staffing and response times), it is essential that those departments and companies operate off the same policies, procedures and guidelines. Furthermore, those agencies must drill regularly to assure complete familiarization with each agency, their equipment, personnel and operating modes. Those drills must be based upon common policies. Additionally, equipment compatibility (including simple radio channel / talk group switching to assure reliable communications) must be determined prior to using nearby automatic or special called mutual aid agencies. Within this criteria of working together must also be an understanding of and training in fireground discipline to assure all personnel are where they are expected to be at all times and are following the same expected policies to assure their minimal risk of injury or death [Goldfeder, 2019].

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

Fire departments should develop and establish good working relationships with surrounding departments so that reciprocal assistance and mutual aid is readily available when emergency situations escalate beyond response capabilities. This incident quickly escalated into a major fire event due to the size of the structure, limited access due to active renovation work, weather conditions (major snow storm) and available resources. The incident commander quickly upgraded the alarm and called for additional resources. Automatic mutual aid response protocols dispatched several mutual aid departments including one department dispatched as the rapid-intervention team (RIT).

Recommendation #13: Fire departments should consider using search lines when conducting primary and secondary searches in large or smoke-filled areas.

Discussion: *Although there is no evidence that following this recommendation would have prevented this fatality, it is being provided as a reminder of a good safety practice*. Regardless of how large or

small a building may be, fire fighters almost always search the building if it is safe and reasonable to do so. Search teams should carry a radio, thermal imager, flashlights, and forcible entry tools whenever they enter a burning building and throughout the search. Some departments also require search teams to take a search rope with them when they enter the hazard zone [IFSTA 2008].

There are many types and variations of search lines and many different variations on procedures to using the search line in large or smoke-filled areas. The search line is anchored to a fixed object about 10 feet outside the entry point. A company identifier, such as a flag, metal tag, or other identifier, should also be attached to the end of the search line. An example of a search line is one consisting of 200 feet of 3/8-inch rope with abrasion and heat resistant sheathing to protect the rope. A series of knots and rings are placed at equal intervals along the length of the search line, usually about every 20 feet. A 2-inch steel ring is attached into the rope 20 feet from the end in a manner so that the ring will not slip or come loose from the rope. Immediately after the ring, one or more knots are tied in the rope to indicate the distance from the beginning point. The knots are placed after the ring to indicate direction. In this example, the knots indicate direction to the fire and the rings indicate direction to the exit. The rings are used as anchor points for lateral tether lines that allow fire fighters to search away from the main search line while having the tether as an aid in returning to the main search line [IFSTA 2008]. Using this example, a team of two or three fire fighters can quickly search a large area while maintaining some level of safety in being able to identify the location where they entered.

During this incident, a fire fighter was reported to be missing and fire fighters were sent inside to search for the reported missing fire fighter. The search crews did not deploy a search line during this incident. The use of a search line can be especially critical in structures where obstructed floorspaces and limited visibility make ingress and egress difficult. It was later determined that the missing fire fighter was accounted for.

Recommendation #14: Fire departments should train and empower all fire fighters to report unsafe conditions to Incident Command.

Discussion: *Although there is no evidence that the following recommendation would have prevented this fatality, it is being provided as a reminder of good safety practice*. 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 fire fighter and the incident commander (as well as command team officers) in risk assessment and "Go or No-Go" decisions. The fireground creates a significant risk to fire fighters, and it is the responsibility of the incident commander and command organization officers to minimize fire fighter exposure to unsafe conditions and stop unsafe practices [IAFC 2012].

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

proceed, the rules allow a process for that decision to be made while still maintaining command unity and discipline.

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

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

Life Safety Initiative number 4 is "Empowerment: All fire fighters must be empowered to stop unsafe practices." While this may appear to be a challenging or even controversial statement, it simply means that every organization should provide an environment that allows its members to speak up regarding personal and organizational safety, without negative consequences for doing so (within a prescribed context) and without decentralizing the authority of the formal leader. The goal is to have every member fully engaged during an emergency incident with a focus on doing the work in a proficient manner and looking out for one another to avoid injuries and potential line-of-duty death [NFFF 2004b].

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

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Investigator Information

This incident was investigated by Timothy R. Merinar, Safety Engineer, Matt E. Bowyer, General Engineer, and Karis Kline, Safety and Occupational Health Specialist, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, West Virginia. An expert technical review was provided by Assistant Chief William Goldfeder, Deputy Chief for the Loveland-Symmes Fire Department in southwest Ohio and host of the fire fighter safety and survival website www.FirefighterCloseCalls.com. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

Additional Information

Modern Fire Behavior

This website is meant to serve as a clearinghouse of news and training information related to Modern Fire Behavior and Modern Building Construction Research, Tactics, and Practices, along with actual street experiences (http://modernfirebehavior.com/). **ModernFireBehavior.com** is a joint effort between www.FirefighterCloseCalls.com and Underwriters Laboratories Fire Safety Research Institute.

IAFC Rules of Engagement for Firefighter Survival

The international Association of Fire Chiefs (IAFC) is committed to reducing fire fighter fatalities and injuries. As part of that effort, the nearly 1,000 member IAFC Safety, Health and Survival Section has developed the DRAFT "Rules of Engagement for Structural Firefighting" to provide guidance to individual fire fighters and incident commanders, regarding risk and safety issues when operating on the fireground. The intent is to provide a set of "modern procedures" for structural firefighting to be made available by the IAFC to fire departments as a guide for their own standard operating procedure development process. [http://www.safetyandhealthweek.org/wp-content/uploads/2012/05/Safety_ROE_Lesson_Plans.pdf]

IAFF Fire Ground Survival Program

The purpose of the International Association of Fire Fighters (IAFF) Fire Ground Survival Program is to ensure that training for Mayday prevention and Mayday operations is consistent among all fire fighters, company officers, and chief officers. Fire fighters must be trained to perform potentially life-saving actions if they become lost, disoriented, injured, low on air, or trapped. Funded by the IAFF and assisted by a grant from the U.S. Department of Homeland Security through the Assistance to Firefighters (FIRE Act) grant program, this comprehensive fireground survival training program applies the lessons learned from fire fighter fatality investigations conducted by the National Institute for Occupational Safety and Health (NIOSH) and has been developed by a committee of subject matter experts from the IAFF, the International Association of Fire Chiefs, and NIOSH. [http://client.prod.iaff.org/#contentid=46].

National Institute for Standards and Technology (NIST)—Fire on the Web

Fire on the Web is a collection of resources from the Building and Fire Research Laboratory's Fire Research Division at NIST. These webpages provide links to fire-related software, experimental fire data, and mpeg/quick time movies of fire tests, which can be downloaded and/or viewed with a Web browser. [http://www.nist.gov/el/fire_research/firesafety/fireontheweb.cfm].

Underwriters Laboratories (UL) Firefighter Safety Research Institute

An online course offered by the **UL Firefighter Safety Research Institute (FSRI)** highlights the tactical application of nearly two decades of research at the National Institute of Standards and Technology (NIST) and UL on how best to fight modern fires. In 2012, The New York City Fire Department (FDNY), NIST, and UL FSRI set fire to abandoned townhouses on Governors Island, New York, in a series of experiments to examine tactics for controlling fires and rescuing occupants inside

burning homes. [http://www.firecompanies.com/modernfirebehavior/governors%20island%20online%20course/story.html].

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