



Two Career Fire Fighters Die and 19 Injured in Roof Collapse during Rubbish Fire at an Abandoned Commercial Structure – Illinois

Executive Summary

On December 22, 2010, a 47-year-old male (Victim # 1) and a 34-year old male (Victim # 2), both career fire fighters, died when the roof collapsed during suppression operations at a rubbish fire in an abandoned and unsecured commercial structure. The bowstring truss roof collapsed at the rear of the 84-year old structure approximately 16 minutes after the initial companies arrived on-scene and within minutes after the Incident Commander reported that the fire was under control. The structure, the former site of a commercial laundry, had been abandoned for over 5 years and city officials had previously cited the building owners for the deteriorated condition of the structure and ordered the owner to either repair or demolish the structure. The victims were members of the first alarm assignment and were working inside the structure. A total of 19 other fire fighters were hurt during the collapse.



Collapse scene as viewed from building rear facing building front. Note portion of bowstring truss leaning against wall at right side of photo.

(Photo courtesy of fire department)

Contributing Factors

- Lack of a vacant / hazardous building marking program within the city
- Vacant / hazardous building information not part of automatic dispatch system
- Dilapidated condition of the structure
- Dispatch occurred during shift change resulting in fragmented crews
- Weather conditions including snow accumulation on roof and frozen water hydrants
- Not all fire fighters equipped with radios.

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Key Recommendations

- Identify and mark buildings that present hazards to fire fighters and the public
- Use risk management principles at all structure fires and especially abandoned or vacant unsecured structures
- Train fire fighters to communicate interior conditions to the Incident Commander as soon as possible and to provide regular updates
- Provide battalion chiefs with a staff assistant or chief's aide to help manage information and communication
- Provide all fire fighters with radios and train them on their proper use
- Develop, train on, and enforce the use of standard operating procedures that specifically address operations in abandoned and vacant structures



Photos show the deteriorated condition of bowstring roof trusses. Note the truss end in the left photo and the deteriorated condition caused by water damage in right photo.

(Photos Courtesy of Fire Department Office of Fire Investigations)

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH "Fire Fighter Fatality Investigation and Prevention Program" which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency's reports do not name the victim, the fire department or those interviewed. The NIOSH report's summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit.

For further information, visit the program Web site at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

On December 22, 2010, a 47-year-old male (Victim # 1) and a 34-year old male (Victim # 2), both career fire fighters, died when the roof collapsed during suppression operations at a rubbish fire at an abandoned and unsecured commercial structure. Nineteen other career fire fighters from the same department were injured in the collapse. On December 22, 2010, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health, Division of Safety Research, Fire Fighter Fatality Investigation and Prevention Program of the incident. That same day, the fire department was contacted by NIOSH investigators to initiate an investigation. At the request of the fire department, four NIOSH investigators traveled to Illinois on January 10, 2011, to conduct an investigation. The NIOSH investigators met with the Fire Commissioner and representatives of the fire department, fire marshal's office, the International Association of Fire Fighters local union, and the city's Department of Buildings (DOB). The NIOSH investigators visited the incident site to take photographs and measurements. The NIOSH investigators also visited the fire department's Breathing Apparatus Service Unit to inspect and evaluate the two victims' self-contained breathing apparatus (SCBA) and personal protective clothing. The NIOSH investigators visited the city's Office of Emergency Management and Communications (OEMC) which also houses the fire department's Fire Alarm Office. The investigators reviewed fire department standard operating procedures, training records, dispatch channel records, witness statements, and DOB records on inspections and citations for the incident structure, including photographs documenting the condition of the structure prior to the incident.

Fire Department

The career fire department involved in this incident has 98 stations with 4,314 uniformed members which serve a population of approximately 2,851,000 within an area of about 228 square miles. Specialty units consist of swift water, ice rescue, hazardous materials, and technical rescue teams.

Department members assigned to the Operations Division work a 24-on/48-off shift schedule with three platoons or shifts. The department operates 24 battalions in six divisions. The fire department currently has 96 engine companies, 61 truck companies, 4 squads (heavy rescue companies which are two-piece companies), 2 marine boats, 2 helicopters, plus various support apparatus for high-rise, hazardous materials incidents, and special operations. All fire department apparatus are maintained by the city's fleet maintenance division. Annual testing (e.g. pumps and ladders) as recommended by National Fire Protection Association (NFPA) Standards, is conducted by qualified vendors. In addition to fire suppression, hazardous materials mitigation, and special operations response, the fire department operates an Emergency Medical Services (EMS) Division which consists of 12 Basic Life Support (BLS) Ambulances, 59 Advanced Life Support (ALS) Ambulances, and support staff including EMS Field Officers. Also, the fire department operates an aircraft rescue fire fighting (ARFF) Division at two airports within the city.

The fire department has well documented written policies and procedures consistent with the requirements of NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*,¹ Section 4.1 and 8.8 which are available to all department members at each fire station and fire department office. Policies and procedures on incident command systems, engine company

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operations, truck company operations, SCBA and personal protective equipment (PPE) use, Mayday procedures, radio use, Rapid Intervention Team (RIT), and other topics were reviewed. The fire department has a training facility that is in operation from 0700 to 1600 hours Monday through Friday. The fire department's training academy literature included training materials related to bowstring truss construction, lightweight truss construction and steel bar truss construction.

The fire department dispatch center (Fire Alarm Office) is part of the city's Office of Emergency Management and Communication (OEMC). The Fire Alarm Office operates with 6 dispatchers plus a supervisor on each 8-hour shift. The Fire Alarm Office processes approximately 1,800 calls per 24 hours or approximately 600 calls per shift.

The fire department is rated as a Class 2 department by ISO.^a 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 Illinois requires that individuals complete a minimum of 180 hours of training certifying to NFPA 1001 *Standard on Fire Fighter Professional Qualifications* Fire Fighter I.² This training includes fire apparatus vehicle operations, hazardous materials operation, technical rescue awareness, cardio-pulmonary resuscitation (CPR) and basic first aid, National Incident Management Systems (NIMS) 100 and 700 certification, and completion of the National Fallen Fire Fighters Foundation (NFFF) course "Courage to Be Safe."³ In addition, fire fighters are required to complete and be certified to NFPA 1001, Fire Fighter II, which is an additional 60 hours of training.

The fire department operates its own recruit training academy and recruits attend for 6 months, exceeding the state requirement of 240 hours. Prior to completing fire fighter certification, each candidate must be certified as a state of Illinois EMT-Basic (EMT-B). After completing the recruit training, each probationary fire fighter is assigned to a company. Fire fighters are required to participate in two hours of training per work shift. Beginning in 2005, the fire department instituted a new requirement whereby new company officers receive 4 weeks of training that includes Management 1, Tactics 1, Instructor 1 and 1 week of departmental officer orientation and management training.

^a ISO is an independent commercial enterprise which helps customers identify and mitigate risk. ISO can provide communities with information on fire protection, water systems, other critical infrastructure, building codes, and natural and man-made catastrophes. ISO's Public Protection Criteria program evaluates communities according to a uniform set of criteria known as the Fire Suppression Rating Schedule (FSRS). More information about ISO and their Fire Suppression Rating Schedule can be found at the website <http://www.isogov.com/about/>.

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Victim # 1 joined the fire department in February 1998 and had more than 12 years of fire fighting experience at the time of the incident. He had received training in and was certified for Fire Fighter I, Fire Fighter II, hazardous materials awareness, hazardous materials first-responder operations, hazardous materials technician A, emergency response to terrorism basic concepts, in addition to documented training completed each work shift.

Victim # 2 joined the fire department in August 2009 and had previously worked for the city as a police officer. He had received training in and was certified for Fire Fighter I, Fire Fighter II, hazardous materials awareness, hazardous materials first-responder operations, hazardous materials technician A, weapons of mass destruction (WMD) standardized awareness, ICS 100 *Introduction to the Incident Command System*, ICS-200a *Incident Command System for Single Resources and Initial Action Incidents*, IS-700a *Introduction to National Incident Management System*, IS-800a *National Response Framework* in addition to documented training completed each work shift. Victim # 2 was also a registered Basic Emergency Medical Technician (EMT-B).

The initial Incident Commander (IC) joined the fire department in 1986 and had more than 24 years of fire fighting experience. He had worked as a battalion chief for the past 5 years and at the time of the incident was assigned as a relief battalion chief, requiring him to fill-in as needed anywhere in the 24 battalions within the fire department. He was a certified Fire Service Instructor I. He had received training in and was certified for Fire Fighter I, Fire Fighter II, hazardous materials awareness, hazardous materials first-responder operations, hazardous materials technician A, infection control, confined space / trench rescue awareness, passenger train emergency preparedness training, and airport fire fighter training in addition to documented training completed during each work shift. He also received a Bachelor of Science degree in Fire Science Management that exceeds the department's new company officer training requirements.

Equipment and Personnel

The fire department involved in this investigation provides two basic responses for reports of structure fires, which are a “Still” alarm” or a “Still and Box” alarm. The Fire Alarm Office will dispatch a “Still” Alarm assignment to initial reports of structure fire. The “Still” Alarm dispatch sends two engine companies, two truck companies, and a battalion chief. If the Fire Alarm Office receives additional reports of a fire or a company arrives on scene and reports a “working fire”, then a squad company, a command van, and a Rapid Intervention Team (RIT) will be dispatched. If the report of a fire is located in a squad company’s first due area (approximately 40 blocks), then the squad company will be sent automatically. A “Still and Box” alarm is usually requested by a fire officer, though there are situations where the Fire Alarm Office can transmit a “Still and Box” alarm. These situations can include a person trapped in the fire building, multiple structures on fire, a large commercial building on fire, a building collapse, train derailment, an airport alert (aircraft in distress), or smoke in a building with a high life hazard (e.g. hospital, nursing home, theater).

Extra Alarms are designated as 2-11, 3-11, 4-11, and 5-11 with defined response protocols for each. Any equipment needed above a fifth alarm (5-11) will be requested by the Incident Commander. *EMS Plan I, II, or III* are designed to be used when an incident escalates and the numbers of patients

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continue to increase. For example, the *EMS Plan I* consists of: 6 Ambulances (one being a basic life support (BLS) ambulance), 1 Engine, 1 Truck, 1 Battalion Chief, 1 EMS Field Officer, and 1 Assistant Deputy Chief Paramedic.

In 2002, the department implemented procedures for a RIT Response in which a truck company and a battalion chief are dispatched to and designated as a “rapid intervention team” on every working fire. A RIT Response is comprised of 1 Truck Company, 1 Battalion Chief, 1 ALS Ambulance, and 1 EMS Field Officer. Additionally, the department has procedures for a “Mayday Response” which follows closely with the “RIT Response.” In the event a “Mayday” is transmitted, protocol requires a “Still” alarm to be upgraded to a “Still and Box” alarm or if a “Mayday” is transmitted at a “Still and Box” alarm the incident is upgraded to a 2-11 alarm. If the incident is already a 2-11 alarm, the alarm level is upgraded at the discretion of the Incident Commander. The RIT Chief is also the designated Incident Safety Officer (ISO) at a structure fire unless the incident is upgraded to a 2-11 or higher alarm and additional chief officers are dispatched, at which time a separate ISO will be designated.

Note: This incident escalated into a 3-11 Alarm.

The fire was reported just prior to the 0700 hour shift change. Several companies responded with mixed crews consisting of 3rd platoon fire fighters who were finishing their shift and 1st platoon fire fighters just reporting for duty. This resulted in crew fragmentation among some first due companies. Some fire fighters (both going-off duty and reporting for duty) responded to the incident via their personally-owned vehicles. The department has officers: lieutenants, captains, and battalion chiefs who have a permanent assignment as a “relief officer.” Their assignments vary each shift based upon the staffing needs of the department on any given day. These officers move throughout the city to cover assignments due to leave, injury, or vacancy.

Per department procedures the following companies were dispatched to the initial report of a structure fire through the time of the collapse:

Still Alarm

- Engine 72: (E-72; Lieutenant, driver, 3 fire fighters) - all assigned to 1st Platoon
- Tower Ladder 34: (TL-34; Lieutenant (relief officer), driver, 3 fire fighters including Victim # 2) - Victim # 2 was finishing up his shift on 3rd Platoon and had not yet been relieved.
- Engine 126: (E-126; Lieutenant, driver, 3 fire fighters) - Lieutenant was just starting work on 1st Platoon; the rest of the crew were 3rd Platoon fire fighters.
- Truck 49 (T-49; Lieutenant, driver, 3 fire fighters) – Lieutenant and two fire fighters were just starting work on 1st Platoon. The driver and the other fire fighter were finishing up work on the 3rd Platoon.
- Battalion Chief 23: (BC-23 – initial Incident Commander)

RIT Alarm

- Truck 16 (T-16; Lieutenant, driver, 3 fire fighters including Victim # 1)

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Squad 5 (SQD5; Officer and five fire fighters) *Note: A squad consists of one heavy rescue and a 55' Snorkel with a pump; Staffing is an officer and three fire fighters on the heavy rescue and two fire fighters on the Snorkel.*
Battalion Chief 18 (BC-18)
Ambulance 22
Ambulance 50
458 (EMS Field Officer)
274 (Command Van)

Still and Box Alarm

Engine 63 (E-63; Lieutenant, driver, 3 fire fighters)
Truck 30 (T-30; Lieutenant, driver, 3 fire fighters)
Battalion Chief 17 (BC-17)
Battalion Chief 22 (BC-22)

Timeline

An approximate timeline summarizing the sentinel events in this incident up to the time of the collapse is listed below. The times are approximate and were obtained by studying the available dispatch channel records, witness statements, run sheets and fire department records. Due to the location of the fire and the distance from the Fire Alarm Office, the fireground radio transmissions were not recorded and thus are not a part of the record of this investigation. The following timeline was developed by starting the initial dispatch at 00 seconds and moving forward using a constant running time for reference. In some cases, the times are rounded to the nearest minute. The timeline is not intended, nor should it be used, as a formal record of events. Only those dispatch channel communications directly related to the fatal incident are included. *Note: This department uses the following terminology to designate the geographical sides of a structure/building: Sector 1 – front of the building, address side of the structure, or where “Command” is located; Sector 2 – side to the left of Sector 1(going clockwise); Sector 3 – rear of the building or opposite of Sector 1; Sector 4 – side to the right of Sector 1 when facing Sector 1.*

- 0648 Hours**

Dispatch for a **Still Alarm** for “Smoke in the area:” E-72; TL-34; E-126; T-49; BC-23

- 0649 Hours**

E-72, E-126 and TL-34 enroute

- 0650 Hours**

BC-23 and T-49 enroute

- 0651 Hours**

E-72 on scene, reporting an empty lot and needing more information on location; BC-23 on scene, established command and requests a callback for a working fire [*Note: address given by dispatch was incorrect.*]; TL-34 on scene and stages behind E-72 on street in front of structure

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- **0652 Hours**

Dispatch initiates a RIT response – dispatches T-16, BC-18, Ambulance 22; E-126 arrives on-scene and backs down alley behind structure from the west; T-49 arrives on-scene, drives past front of structure and parks in alley to the east of the structure

- **0653 Hours**

BC-23 reports size up – fire in 1-story ordinary construction, vacant commercial structure approximately 40 feet X 125 feet; TL-34 forces entry through door at Sector 1; E-72 stretches a preconnected 2 ½-inch hoseline with a gated wye and 150-feet of 1 ¾-inch hand line to front door; BC-23 radios dispatch for traffic control to shut down street in front of structure; Dispatch checks on status of Squad 5, then dispatches Squad 5 to fire

- **0654 Hours**

BC-23 updates address of fire building

- **0657 Hours**

BC-23 reports frozen hydrants, requests a **STILL & BOX ALARM**, and designates a nearby staging area; Dispatch for **STILL & BOX ALARM** includes E-63, E-47, T-30, BC-17, BC-22, and Ambulance 50; T-16 re-assigned to Box Truck; B-18 reassigned to Box Chief; T-16 arrives on-scene

- **0700 Hours**

BC-17 assigned to RIT Chief; BC-18 on-scene; Squad 5 enroute; T-30 assigned to RIT

- **0701 Hours**

BC-23 reports 2 lines on fire and fire is under control – positive water supply is established

- **0702 Hours**

E-63 on-scene

- **0703 Hours**

E-47 and T-30 on-scene

- **0707 Hours**

BC-18 calls “Mayday” for building collapse and requests **2-11 Assignment PLUS EMS PLAN I** due to a collapse in the rear of the building (**2-11 Assignment**: 4 Engines, 2 Trucks, 1 Tower Ladder, 2 Battalion Chiefs, 1 District Chief, 1 Air Mask Truck, Media Affairs); (**EMS Plan I**: 6 Ambulances, 1 Engine, 1 Truck, 1 Battalion Chief, 1 EMS Field Officer, 1 Assistant Deputy Chief Paramedic).

- **0708 Hours**

BC-18 requests Squad 5 moved to rear (Sector 3) for rescue tools, Hurst tool, air bags, etc.; BC-21 dispatched to 2-11

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- **0711 Hours**

District Chief 6 (DC-6) on scene taking over Incident Command

- **0713 Hours**

DC-6 requests E-46 to take line to rear – also requests 2 ambulances to the rear of the building

- **0714 Hours**

DC-6 reports 2 fire fighters are out and 2 more fire fighters are trapped; rescue operations continue

- **0718 Hours**

Deputy Fire Commissioner calls for **3-11 PLUS EMS PLAN II**, states 4 more fire fighters are trapped, more hoselines are needed at the rear of the building and fire is extending

- **0723 Hours**

Deputy Fire Commissioner 2110 advises that they are “working on removing 1st victim”

- **0724 Hours**

Ambulance 22 enroute to hospital with 1st victim

- **0731 Hours**

Ambulance 50 enroute to hospital with 2nd victim; request that traffic be blocked on freeway

Personal Protective Equipment

At the time of the incident, Victim # 1 was wearing structural fire fighting turnout pants, coat, hood, boots, helmet and gloves. Victim # 1 was wearing a SCBA and was found with his facepiece on. It was not clear whether his PASS device was sounding or not. Victim # 2 was also wearing structural fire fighting turnout pants, coat, hood, boots, helmet and gloves. Victim # 2 was wearing a SCBA and was found with his facepiece on. Fire fighters interviewed by NIOSH investigators reported that Victim # 2's PASS device was sounding at the time he was found.

NIOSH investigators inspected the SCBA and turnout clothing worn by the two victims. The fire department conducted functional testing on both SCBA soon after the incident and deemed that the personal protective equipment worn by the victims was not a contributing factor to the outcome of this incident. NIOSH did not initiate performance testing on the SCBA or turnout clothing or determine compliance with the applicable NFPA standards.

Neither victim was carrying a radio at the time of the incident. The fire department's normal procedure is to assign three radios per engine and truck company. The officer and driver carry radios. The third radio is assigned during roll call at the beginning of each work shift to a fire fighter based upon their assigned duties for the work shift. Duties requiring a fire fighter to carry a radio could include, but would not be limited to, the hydrant fire fighter on engine companies, ventilation or

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forcible entry, roof ventilation, elevator management at high rise fires, search and rescue and other truck company duties.

Each engine and truck company carries a thermal imaging camera. Thermal imaging cameras were not used during the initial fire suppression operations but were used to search for the location of fire fighters underneath the collapsed roof.

Weather Conditions

At the time of the incident, the weather was overcast with an approximate temperature of 22°F and relative humidity of 82 percent. West-northwest winds were recorded at approximately 10 miles per hour with gusts to 20 miles per hour.⁴ Light snow was forecast for the area and light snow had fallen the previous two days. Fire fighters on scene told NIOSH investigators that approximately four inches of snow covered the roof of the building when the crews arrived on-scene. The first arriving crews encountered frozen water hydrants which delayed the establishment of a continuous water supply.

Structure

The structure involved in this incident was a one-story commercial structure of Type III ordinary construction originally built in 1926. City records listed the structure at 6,700 square feet. The structure was constructed with brick masonry walls and separated into two sections – front and back. The front section had a flat roof and the back section had a bowstring truss roof (see Diagram 1). The two separate roof types suggest the back section (with bowstring truss roof) may have been added after the original construction. Parapet walls at the front and rear obscured the roof from street level. The front of the structure was adjacent to a major east-west street. The west wall and the front portion of the east wall were common to adjoining businesses. The building to the west was still in use at the time of the incident. An enclosed open courtyard was located to the east of the back section of the structure. The structure showed evidence of prior substantial renovation work with exterior doors and window openings bricked up, especially at the rear and courtyard areas. A 12-foot wide public alley was located directly behind the rear of the structure (see Photo 1 and Diagram 1).

The flat roof at the front and the bowstring truss roof at the rear both consisted of layers of asphalt rolled roofing covered with tar. The roof deck was constructed of 1-inch tongue and groove planks supported by 2-inch X 12-inch full nominal dimension sawn lumber. The rear portion of the roof was supported by two bowstring trusses parallel to the front street (Sector 1) and rear alley (Sector 3). These trusses were supported at both ends by brick pilasters built into the east and west load bearing walls (Sector 2 and Sector 4; see Photo 2 and Photo 3). At the rear of the structure near the Sector 3/4 corner, a room had been added that was constructed with ordinary concrete masonry unit (cement block) walls and to the west of this room, a second room had been constructed using ordinary framing materials and gypsum wallboard. Most of the gypsum wallboard had been previously removed, leaving the wall studs in place. Also at the rear of the structure, framing materials were used to construct a storage area suspended within the truss void space.

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Photo 1. 12-foot wide public alley directly behind structure (Sector 3).
(Photo courtesy of fire department)

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Photo 2. Photo shows the Sector 2 wall that supported western end of the bowstring truss roof. The two arrows indicate the truss-end pockets in the brick masonry wall at the top of the brick pilasters where the ends of the two bowstring trusses rested. The roof was supported in the middle by the two bowstring trusses while the north and south ends were supported by the front and rear non-load bearing walls. The line indicates the approximate curvature of the roof.

(NIOSH photo)

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Photo 3. Photo shows the truss support pilasters built into the Sector 2 (west) wall. The Sector 4 (east) load bearing wall also contained support pilasters. The Sector 4 wall partially collapsed during the incident and was demolished after the recovery operations.

(NIOSH Photo)

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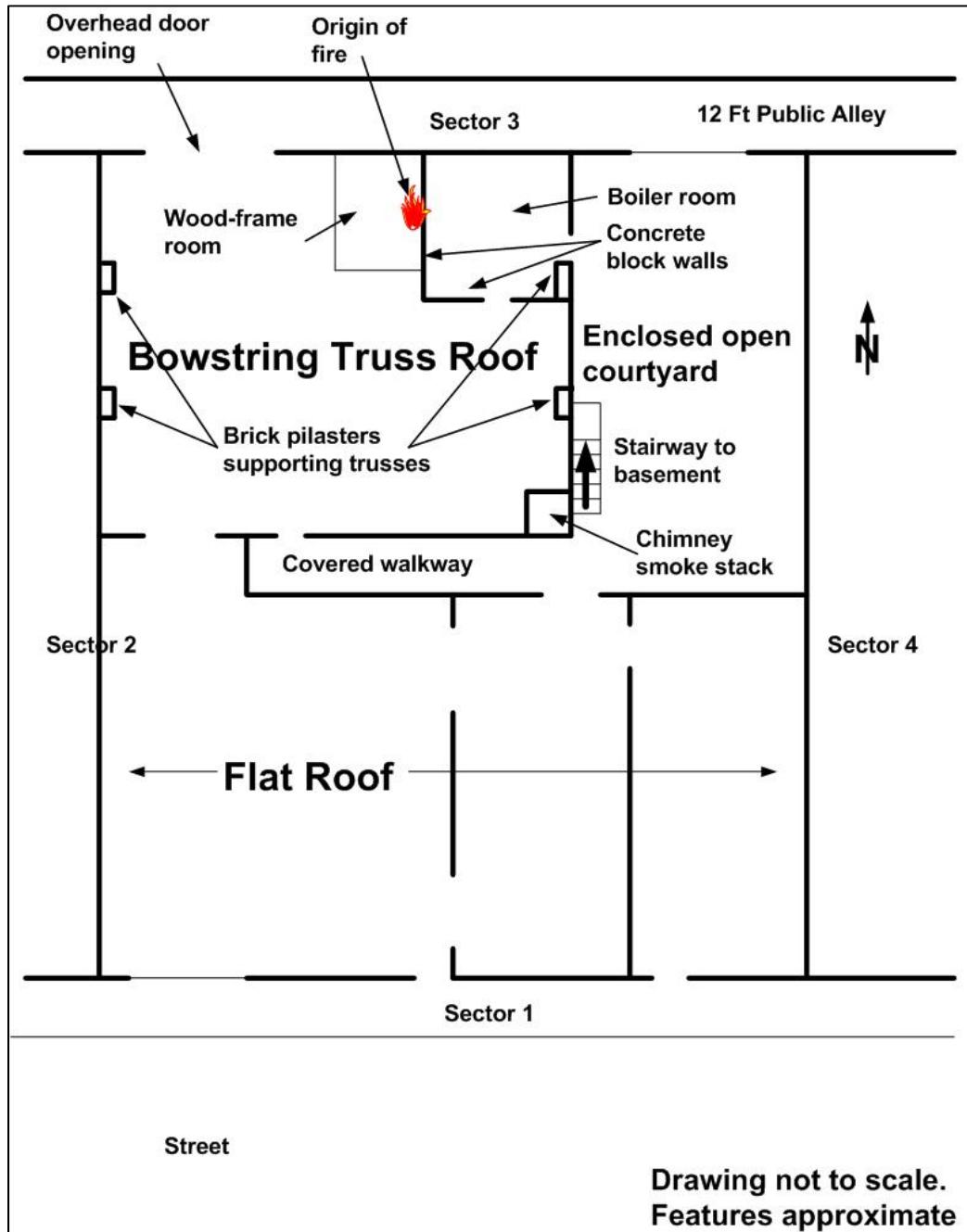


Diagram 1. Approximate layout of the fire building.

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The structure was located in an area that contained both vacant and abandoned buildings (see Photo 4). The structure had been abandoned^b by the owner for more than 5 years, and was formerly the site of a commercial laundry. The structure had never included a sprinkler system. It was reported that natural gas service to the building had been shut off since 2005 and electrical service had been shut off since 2009.



Photo 4. Elevated view of the block where the incident occurred, taken the day of the fire. The arrow marks the location of the collapse. The photo has been edited to remove names and identifying information from signs.
(Photo courtesy of fire department)

^b Many sources, including NIOSH, define “abandoned” as a structure that is not being used for any purpose and is not being maintained or preserved for some future use or occupancy. Abandoned buildings are often classified as a public nuisance and can be distinguished from a “vacant” building which is defined as a building not currently in use but which could be used in the future such as a property for sale or rent, undergoing renovations, or empty of contents during the period between the departure of one tenant and the arrival of the next. Reference the publication - *NIOSH ALERT: Preventing Deaths and Injuries of Fire Fighters using Risk Management Principles at Structure Fires*.⁵

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In 2007, the city Department of Buildings (DOB) cited the building owner for the deteriorated condition of the structure and ordered the owner to either repair or demolish the structure. When viewed from the street, the structure appeared to be in good repair (see Photo 5), but the structure was open and unsecured at the alley (Sector 3) and courtyard (Sector 4). An overhead roll-up door that fronted the alley (Sector 3) was missing and access doors to the courtyard had also been removed. The courtyard was overgrown with brush and small trees and had been used as a dumping area for rubbish and construction materials.



Photo 5. Front view of structure as viewed from the street (Sector 1). Buildings along the street appeared to be in good condition from this view. The deteriorated condition of the roof was not visible from street level. Photo taken the day of the incident.

(Photo courtesy of city Department of Buildings)

Some of the code violations cited in the 2007 written complaint included: failure to maintain parapet wall in good repair; failure to maintain lintel in good condition; failure to securely fasten loose plate glass in windows; failure to cut or remove weeds, grass and other growth; failure to remove accumulation of refuse and debris; failure to maintain roof in sound condition; failure to remove sewage and stagnant water from basement; failure to maintain exterior walls free from holes, breaks...or other conditions that might admit rain or dampness; and, failure to maintain building in a structurally safe and stable condition.

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The fire department estimated that there have been more than 50,000 foreclosures within the city in the past few years due to the depressed economy. Officials with the city's Department of Buildings reported that there are more than 18,000 vacant and abandoned structures within the city. When the Department of Buildings identifies a hazardous structure, the building inspector will note all code violations and file a report that results in a court citation. The Department of Buildings attempts to work with building owners to ensure that problem areas are corrected, following an established procedure. If the building owner cannot be identified or is unresponsive, the Department of Buildings can take possession of a property, following established procedure, and ultimately have an unsafe structure demolished. The Department of Buildings marks structures that are identified for demolition, but not all hazardous dilapidated structures. The Department of Buildings reported that over 1,500 structures are scheduled for demolition. During a meeting with the Department of Buildings officials, NIOSH investigators were allowed to examine photographs and records depicting the condition of the structure prior to the incident, but copies were not made available.

Photo 6 and Photo 7 show some of the deteriorated ceiling conditions observed by fire fighters when they entered the front portion of the structure during the incident. This deterioration appears to have been caused by water penetrating the roof.



Photo 6 and Photo 7. Photo 6 (left) and Photo 7 (right) show the deteriorated ceiling conditions inside the front part of the structure.
(Photos courtesy of fire department)

Currently, the fire department's fire prevention bureau inspects commercial structures greater than 10,000 square feet in size. Whenever the fire department identifies a structure that is unsafe and represents a hazard, such as following a structure fire, the Fire Commissioner will send a written report to the Commissioner of the Department of Buildings requesting that the identified structure be demolished. Any fire department member can report a hazardous building. Currently, there is no process for the Department of Buildings to notify the fire department whenever a hazardous structure is identified during normal building inspections or has been identified for demolition. In this incident, the building owners had been unresponsive to court citations. The Department of Buildings had not

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taken possession of the structure and the structure was not marked as being hazardous. The structure had never been pre-planned by the fire department.

When viewed from the street, the structure appeared to be a vacant structure awaiting a new tenant. Homeless persons frequently entered the structure through the rear. Just a few weeks prior to the fire, a person was arrested at the structure for burning wiring that had been removed from the buildings. A large vacant commercial structure, located just north of the public alley, was formerly used as a manufacturing facility and the fire department had been dispatched to the manufacturing site several times for small structure fires. This contributed to the confusion concerning the correct address during the initial dispatch.

The fire department's Office of Fire Investigations identified the origin of fire and concluded that the cause of the fire was open flame ignition of available class "A" combustible materials in the form of rubbish.

Bowstring Truss Roof Construction

The fire department estimated that there are more than 20,000 structures with bowstring truss roofs within the city. Bowstring truss roofs are easily identified by the roof's arched or curved outline.

Bowstring truss roofs became popular in the 1930's. Prior to 1960, the bowstring truss roof design was one of the most common design types for large commercial and industrial structures. The bowstring truss roof was commonly used in facilities such as automobile dealerships and repair facilities, bowling alleys, grocery stores, and industrial complexes wherever large open floor spaces with limited interior supports were needed. The curved top chord members were made either by sawing straight lumber into curved shapes or laminating multiple smaller pieces bent over a jig to the desired shape. Bottom chord members were typically constructed with large, straight lumber members joined with either wood or metal bolted splice plates, located near mid-span, to achieve the required length. The top and bottom chord members were fastened together at the truss ends with U-shaped steel heels, or end shoes, bolted to both chord members.

The principles of bowstring truss construction are similar to other types of truss construction in that web members are used to form multiple series of triangles that transfer tension from the bottom chord and compression from the top chord of the truss onto the load bearing walls. One big difference with the bowstring truss is that the compressional forces within the top chord act to force the load bearing walls outward as well as downward.

Bowstring truss roof systems may suffer from a little-known phenomenon related to inaccuracies in early industry-accepted truss design assumptions. One significant design deficiency involves the tensile strength of the bottom chord. Early truss designs assumed wood tensile strength could be defined by bending tests of small straight-grained wood samples free of common wood defects. Prior to the 1960s, large scale test facilities were uncommon so full-size lumber tests were rarely conducted. During the 1960s, full-size lumber tests revealed that construction grade lumber with natural imperfections such as knots, checks and irregular grain, provides in-service tensile strength

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significantly less than that predicted by the earlier small scale, clear wood tests. By 1968, lumber industry standards established a reduction factor of 0.55 to relate tensile strength to bending strength. Current building codes have increased this factor to 0.60, meaning the allowable tensile strength design values are only about 40 percent of those listed in the early codes. Thus, all trusses constructed prior to the late 1960s have a common code deficiency; the bottom chord members may have inadequate tensile strength to support code-prescribed roof loads.⁶ Diagram 2 and Photo 8 represent the bowstring roof trusses found in the building involved in this incident. Photo 9 provides additional roof details.

Investigation

This fire was reported at 0648 hours just prior to the morning's shift change. A fire lieutenant, on his way to work, smelled smoke while driving through the commercial area where the fire occurred. This area contained a number of vacant and abandoned buildings intermixed with working businesses. The fire department had responded to a number of fires in the area including fires at a large vacant manufacturing facility located just north of the fire building. The lieutenant arrived at his station, called the Fire Alarm Office reporting an odor of smoke, and requested a "Still" alarm for the address.

Following fire department procedures, a "Still" alarm was dispatched. Engine 72 (E-72), Tower Ladder 34 (TL-34), Engine 126 (E-126), Truck 49 (T-49), and Battalion Chief 23 (BC-23) were dispatched.

Engine 72

E-72 was the first apparatus to arrive on-scene and carried a crew of five (lieutenant, driver, and three fire fighters). Upon arrival to the reported address, E-72 found an empty lot and the lieutenant radioed the fire alarm office for clarification of the address. The E-72 lieutenant and his crew observed light grey smoke rising over the rear of a nearby commercial structure. An alley just past the empty lot led to the rear of the structure and a hydrant was located approximately at the corner of the alley and vacant lot. The E-72 lieutenant decided to position the engine on the street in front of the structure (Sector 1). The E-72 lieutenant and the fire fighter assigned to water supply walked to the hydrant while the other two fire fighters pulled 200 feet of 2 ½-inch preconnected hoseline with a gated wye that had 150 feet of 1 ¾-inch hand line to the front entrance. Tower Ladder 34 had arrived on-scene and the TL-34 crew forced open the metal security gate blocking the entrance. Battalion Chief 23 (BC-23) arrived on-scene and assumed "Command" of the incident (IC). BC-23 quickly sized up the structure and radioed the Fire Alarm Office that they had a fire in a one-story vacant commercial structure of ordinary construction approximately 40 feet by 125 feet in size. The IC also requested traffic control to shut down the street in front of the building, and advised the Fire Alarm Office of the correct address for the fire location.

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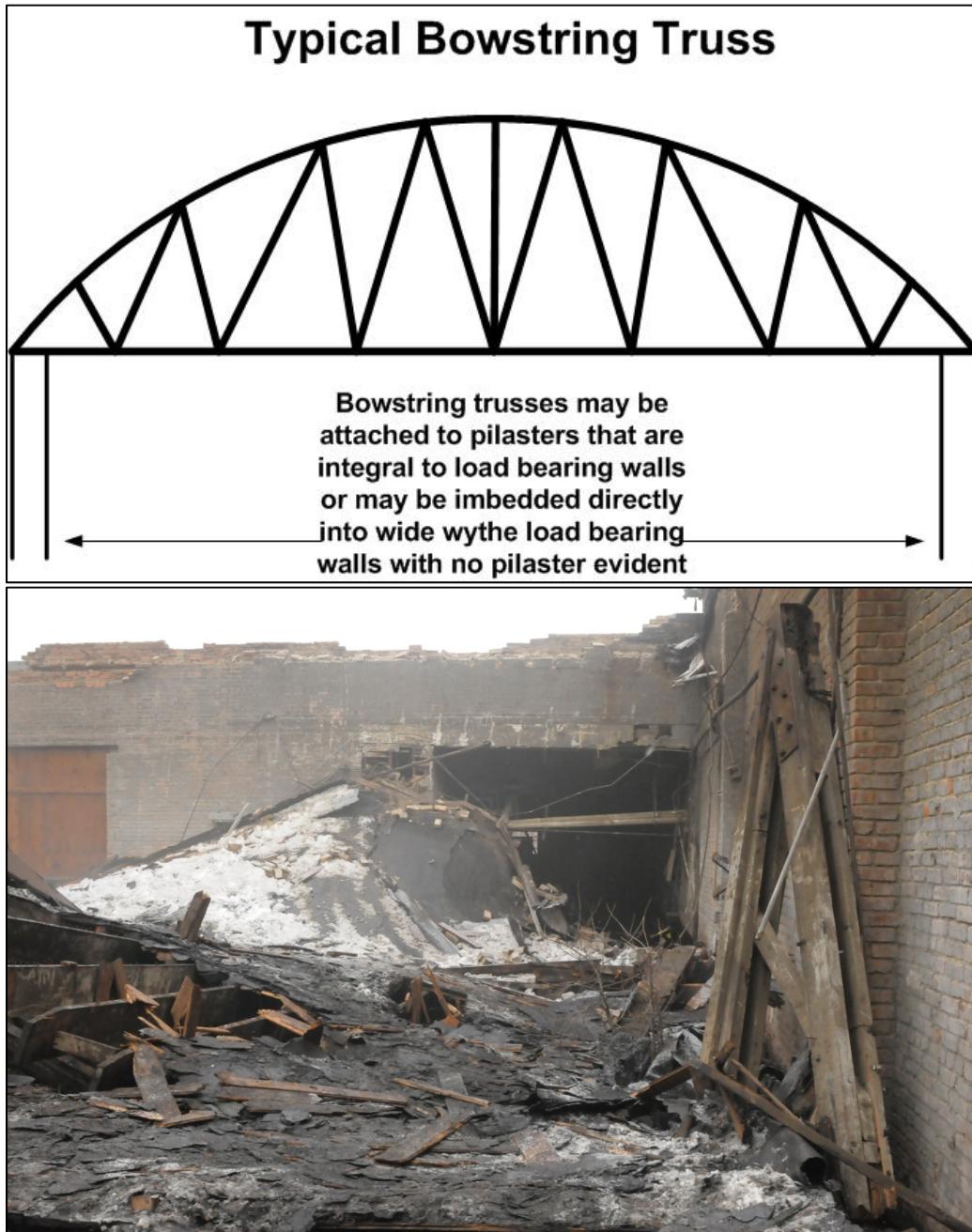


Diagram 2 (top) and Photo 8 (bottom). Diagram 2 shows typical bowstring truss design. Photo 8 shows portion of bowstring truss leaning against support pilaster built into Sector 2 wall at right.

The foreground in Photo 8 is the area where Victim # 2 was recovered.

(Photo courtesy of fire department)

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Photo 9. Photo shows connection of the front and rear portions of the structure as viewed from Sector 3 facing Sector 1 (same view as Photo 8). Note the roof purlin still attached to the Sector 1 wall (A) and the remains of tongue and groove roof deck boards attached to the top of the purlin(B). Also note how the end of the remaining purlin sets into a recessed pocket in the brick masonry wall and the locations where other roof purlins pulled away from wall (C). Vertical marks on the wall above the opening indicate where the roof purlins contacted the wall as the roof collapsed.

(Photo courtesy of fire department)

T-16, BC-18 and Ambulance 22 were dispatched for rapid intervention team (RIT) response following the confirmation of a working fire. T-16 became the designated RIT Team and BC-18 became the designated RIT Chief.

The E-72 fire fighter assigned to water supply found the fire hydrant was frozen and the E-72 lieutenant reported the frozen hydrant to the IC. The IC radioed the Fire Alarm Office for a "Still and Box" alarm due to the difficulty in establishing a water supply and identified the staging area for the

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additional resources. While still enroute, T-16 was reassigned as the “Box” truck (the third due truck company) and BC-18 was reassigned as the “Box” chief. *Note: this designation meant that BC-18 was now the operations chief and T-16 was committed to assist with structural fire fighting activities.* The E-72 fire fighter proceeded west to the next hydrant. One outlet was frozen shut but he was able to open the other outlet. E-72’s driver and a captain from the 3rd platoon (who had just gone off duty and drove his personal vehicle to the scene) dragged the 4-inch supply line off E-72 to the hydrant.

The E-72 lieutenant heard the E-126 lieutenant radio that they had found a small fire at the rear of the structure and were preparing to hit the fire with tank water. The E-72 lieutenant and two E-72 fire fighters entered the structure through the front entrance with their charged hoseline and walked through the empty building toward the rear. They found the structure actually consisted of two separate structures (see Diagram 1). The E-72 crew maneuvered the hose line through the front structure into the walkway separating the two structures and then entered the dilapidated rear structure that was strewn with rubbish. The E-72 crew observed a small amount of fire burning on the floor and also observed that a number of bare wall studs were burning from floor to ceiling level. The conditions inside the structure included good visibility with little smoke. *Note: Many fire fighters reported to NIOSH investigators that they could see through the structure from front to rear and many fire fighters did not don their SCBA face pieces or “go on air.”* The E-72 crew did not observe any fire burning overhead. In some parts of the structure, the 2’ x 12’ roof joists could be seen overhead. The E-72 fire fighters began to hit small fires and hot spots with their hose line. The E-72 fire fighter with the nozzle briefly stopped to don his face piece and “go on air” because the hose stream hitting the floor was causing smoke, steam and debris which affected his breathing. The other E-72 fire fighter was positioned on the hoseline a few feet behind the nozzle. *Note: The department uses the term “pipeman” for the fire fighter that has the nozzle and “heelman” for the fire fighter backing up the “pipeman”.*

After water supply to E-72 was established, the E-72 hydrant fire fighter donned his SCBA and then proceeded to follow the hoseline through the front entrance (Sector 1) to meet up with his crew. He followed the hoseline through the front structure and had just entered the walkway between the front and rear buildings when he heard the roof collapse. The E-72 Lieutenant was positioned just inside the overhead door opening (Sector 3) when the collapse occurred. The lieutenant was pushed into the alley and covered with bricks and debris from the collapse. Three fire fighters were able to dig him out and remove him from the collapse area. The two fire fighters on the hoseline from E72 were covered by the collapse. The fire fighter behind the fire fighter on the nozzle was able to get free and move towards the fire fighter that had the nozzle. The E72 fire fighter with the nozzle was trapped and had to be extricated.

Tower Ladder 34

TL-34, which is housed with Engine 72 and Ambulance 22, was the first-due truck company and arrived on scene just behind E-72 with a crew of five, including a lieutenant, driver, and three fire fighters (one of whom was Victim # 2). *Note: The lieutenant was a 1st platoon “relief” officer assigned to TL34 for the shift.* The lieutenant had just arrived at the station, relieved the 3rd platoon

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lieutenant, and completed his equipment checks when TL-34 was dispatched to the fire. Victim # 2 worked 3rd platoon and had not yet been relieved. The rest of the TL-34 crew worked on the 1st platoon and were just coming on duty.

TL-34 was positioned on the street in front of the building (Sector 1) just east of the front entrance. The TL-34 lieutenant and two fire fighters (including Victim # 2) went to the front entrance and used bolt cutters to open the metal sliding security gate. They then forced open the front door so that the E-72 crew could advance their hoseline through the front door. The TL-34 driver and the other fire fighter set the tower ladder for operation, got into the “platform,” and raised the platform to the roof.

The TL-34 lieutenant and two fire fighters followed the E-72 hoseline through the front part of the building, through the covered walkway and then entered the rear part of the structure. They did not observe any smoke or fire until they entered the rear part of the building where they observed a small amount of fire burning on the ground. They also observed fire burning upward along the wooden wall studs at the rear of the building. The smoke conditions were light and they could see other crews working at the rear of the building. They stopped and donned their facepieces before continuing toward the rear. As the engine crews worked to knock down the fire, the TL-34 lieutenant and two fire fighters (including Victim # 2) began to search for the presence of civilians inside the rubbish filled building. The TL-34 lieutenant observed a window in the Sector 4 wall and moved toward it to see if it needed to be ventilated. At the same time, a fire fighter (Victim # 1) from Truck 16 entered the fire building and also walked over to the window. The TL-34 lieutenant observed that some of the glass panes had been previously broken by vandals and was sizing up the need to remove the rest of the window when he heard the sound of wood cracking, followed by a loud boom.

The other two TL-34 fire fighters inside the structure helped the E-72 crew pull the hoseline and then began searching for civilians, working their way toward the overhead door at the rear (Sector 3) where other crews were working. As they made their way toward the rear, they thought they observed the roof overhead begin to sag. They decided to report this observation to their lieutenant but were unsure of his location. They had just decided to split up and look for the TL-34 lieutenant when the roof collapsed. One fire fighter was able to run out the overhead door. The other TL-34 fire fighter (Victim # 2) was trapped under the collapse.

The TL-34 roof crew placed the platform of the aerial ladder near the roof at the front of the building and exited the platform. Once on the roof, they observed openings in the roof and also observed that the roof felt soft. The entire roof was covered with up to approximately 4 inches of snow. They radioed this information and moved along the west side of the roof (Sector 2) to make their way to the rear and accessed the truss roof. They sized up the roof and used a power saw to cut an opening approximately 3' x 3' near the Sector 4 wall. By this time, the lieutenant and two fire fighters from T-49 had climbed to the roof using the 20-foot ground ladder in the alley. As the T-49 roof crew used hand tools to pull up the roof flashing along the north (Sector 3) wall, the TL-34 roof crew moved to the west (Sector 2) side of the roof to cut another opening. The TL-34 driver had made one cut about 5 feet from the Sector 2 wall when the roof collapsed underneath them, dropping them to the ground.

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Engine 126

E-126 was the second-due engine company and arrived with a crew of five, including a lieutenant, driver, and three fire fighters. The lieutenant worked 1st platoon and had relieved the 3rd platoon lieutenant. The driver and fire fighters all were finishing their 3rd platoon shift. E-126 drove east past the structure (Sector 1) turned down a side street, and then backed down the narrow alley to size up a vacant factory building that had been the scene of several previous fires. The E-126 crew heard the radio traffic from BC-23 sizing up the fire building and also the radio traffic about the frozen hydrants. E-126 backed down the alley to the rear (Sector 3) of the fire building and then repositioned west several feet to be out of the potential collapse zone. The crew observed light hazy grey smoke. What appeared to be a rubbish fire could be seen through the opening where an overhead door had been removed. The crew immediately began to pull their standard preconnect (200' of preconnected 2 ½-inch hose line with a gated wye that had 150 feet of 1 ¾-inch hand line attached to one side of the wye) while the lieutenant walked through the overhead door opening to size up the structure. The E-126 lieutenant observed that most of the fire appeared to be a rubbish or trash fire on the ground and that there were also a few 2" x 4" wall studs burning. A fire fighter from E126 responsible for the water supply walked down the alley and turned north to find a hydrant. The E-126 lieutenant told the other two E-126 fire fighters to stay outside the structure and they began to hit the fire using water from the engine's 500-gallon tank.

The E-126 lieutenant heard radio traffic about the roof being soft and spongy. He discussed the radio traffic with the IC and they determined that the spongy roof was the roof on the front of the building (Sector 1) and not near the rear of the building (Sector 3) the fire structure. The E-126 lieutenant climbed the ground ladder that Truck 49 had raised to the roof so that he could observe the roof conditions. He observed a few hot spots burning along the top of the Sector 3 wall and the E-126 fire fighters raised their hand line to the roof so that the lieutenant could hit the hot spots with water. The E-126 driver reported that approximately half of the water in the E-126 booster tank was used inside the structure and another one-quarter was used on the roof. The IC radioed the E-126 Lieutenant and asked if the fire had gotten into the trusses. An uncovered scuttle hole was located in the roof near the Sector 3/4 corner and the lieutenant stuck his head down inside the scuttle hole to observe the condition of the trusses (see Photo 10). He did not see any fire burning in the trusses and told the IC that he did not see any fire. The lieutenant looked inside the scuttle hole a second time and again told the IC that he did not see any fire in the trusses. The E-126 lieutenant returned to the ground while the roof crews from T-49 and TL-34 continued opening the roof to check for fire extension. The IC reported to NIOSH investigators that his operational plan was to go to a defensive operation as soon as E-126 established water supply to the rear of the structure.

The E-126 lieutenant was on the ground walking toward his crew near the overhead door opening when the roof collapsed. The E-126 lieutenant was buried by bricks from the Sector 3 wall up to his waist. The E-126 fire fighter was finishing the hydrant connection when he heard the Mayday over the radio. He ran back to the structure to assist with rescue operations.

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Photo 10. Photo shows the scuttle hole in the roof where the E-126 lieutenant looked into truss void for fire extension. Note condition of roof rafters indicates little fire damage in this area.
(Photo courtesy of fire department)

Truck 49

Truck 49, which is housed with Engine 126 and Ambulance 50, was the second-due truck company and arrived on-scene with a crew of five fire fighters. The T-49 lieutenant and two 1st platoon fire fighters were just coming on duty while the driver and the other fire fighter were working the 3rd platoon. E-126 was backing down the alley behind the fire structure when T-49 arrived. The T-49 crew arrived on-scene and turned down the alley east of the vacant lot and positioned at the east end of the 12-foot public alley behind the fire structure. The T-49 crew raised a 20-foot ground ladder in the alley near the Sector 3/4 corner to access the roof. After sizing up the building and talking to the E-72 lieutenant about the radio report of the soft roof, the T-49 lieutenant, driver and one fire fighter climbed the ladder to the roof. They observed smoke and a small amount of fire coming through the roof along the Sector 3 wall. The crew used hand tools to pull back the roof material and flashing so that the E-126 lieutenant could hit this area with the E-126 hand line. After the E-126 lieutenant returned to the ground, the T-49 crew continued to pull roof material and flashing to search for any fire

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extension. The other two T-49 fire fighters (one from each platoon) walked up the alley to the overhead door opening. Their forcible entry tools were not needed as the building was unsecured.

The E-126 lieutenant ordered everyone to stay outside the building as the E-126 crew pulled a hose line to the overhead door and began knocking down the fire. After sizing up the structure, the T-49 fire fighters waited as the engine company crews knocked down the fire, then followed the E-126 crew inside the structure. They reported that they did not need to wear their SCBA face pieces since the smoke conditions inside the structure were light. One of the T-49 fire fighters was raking through the smoldering debris on the floor and asked the E-72 lieutenant if he should pull down the wooden wall studs. The E-72 lieutenant told him no. The other T-49 fire fighter (from the 3rd platoon) was pulling sheetrock near the corner of the concrete block room when he heard a loud snap like wood breaking. He stepped against the block wall as the roof overhead collapsed. The T-49 fire fighter (from the 1st platoon) was in close proximity to the E-72 hoseline crew and a T-16 fire fighter when the roof collapsed.

The collapse pushed the 3rd Platoon fire fighter from T-49 down onto his hands and knees. He was briefly tangled in debris but was quickly able to free himself.

Truck 16

T-16 was originally dispatched as the RIT truck when E-72 confirmed the presence of smoke in the area. T-16 was about 5-6 blocks from the scene when the Fire Alarm Office upgraded the incident to a “Still and Box” alarm due to the frozen hydrants. T-16 was reassigned as the 3rd due truck company or the “Box” truck which changed their assignment from RIT activities to additional resources for the IC to assign as needed. The T-16 crew arrived on-scene with a crew of five fire fighters including Victim # 1. The T-16 lieutenant and 3 fire fighters were just starting to work their regular shift on the 1st platoon. Victim # 1 had not yet been relieved so he was the only 3rd platoon fire fighter to respond on Truck 16.

After positioning the truck in the street in front of the structure, the entire T-16 crew followed the E-72 hose line through the front door (Sector 1) and proceeded to the rear. They walked through the courtyard at Sector 4 to size up the structure and observed an open stairwell leading to an underground basement. The crew stopped to remove a door from a side entrance and placed the door over the hole to prevent anyone from stepping into the open stairwell. The T-16 crew proceeded into the structure and observed a small amount of rubbish burning on the ground. They walked up to the E-72 crew to see if they needed any help with the hand line. One of the T-16 fire fighters stirred the rubbish fire with a pike pole while the other T-16 fire fighters, including Victim # 1, went to remove windows in the Sector 4 wall. Metal mesh security screens prevented the removal of the windows. Victim # 1 remained in this area while the other fire fighters walked back toward the rear of the structure. The T-16 lieutenant briefly talked with the E-72 lieutenant and observed the E-72 crew hitting small spot fires with their hand line.

The T-16 driver began to pull the ceiling above the area enclosed by the wooden wall studs. The ceiling appeared to be about ¾-inch plywood and as he pulled the ceiling small pieces of burning

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debris began to fall down around him. As he continued to pull the ceiling, he heard a loud cracking sound and then was knocked to his knees by the collapsing roof. The T-16 lieutenant was standing about 8 – 10 feet inside the overhead door with a T-16 fire fighter just to his left when the roof collapsed. The collapse pushed the lieutenant and fire fighter out into the alley where they were buried by the debris from the brick wall. The other T-16 fire fighter was walking toward the rear of the structure when the roof collapsed. The fire fighter was knocked momentarily unconscious by the collapse, then came-to and found that he was unable to free himself. He had a radio but did not think to radio a Mayday. He heard rescue crews digging through the debris so he waited to be rescued.

After the Collapse

Thirteen fire fighters (E-72 lieutenant and 2 fire fighters, TL-34 lieutenant and 2 fire fighters, T-16 crew and 2 fire fighters from T-49) were inside the structure and 5 fire fighters (T-49 lieutenant, driver and fire fighter and TL-34 driver and fire fighter) were working on the roof when the bowstring truss roof collapsed. The E-126 lieutenant, driver and two fire fighters were in the alley near the Sector 3 wall. The collapsing roof pushed the brick masonry walls at Sector 3/Sector 4 outward. The E-126 lieutenant and two fire fighters were struck and partially buried by the collapsing Sector 3 wall. See Diagram 3.

The fire fighters working near the overhead door at the Sector 3 wall were pushed out into the alley by the collapse (E-72 lieutenant, T-16 lieutenant, T-16 fire fighter and TL-34 fire fighter). The TL-34 lieutenant was standing near the window at the Sector 4 wall. The collapsing roof hit him in the back and pushed him against the Sector 4 wall. His upper body was bent forward with his arms out to his sides. His upper body was pinned and the weight on his back made it difficult to breathe. The lieutenant was “on air” at the time of the collapse and his facepiece was dislodged. He tried to reposition his facepiece with his left hand but did not have enough freedom of movement to do so. His right hand and arm were completely pinned. After the collapse, the fire began to intensify and smoke began to build up under the collapse. The TL-34 lieutenant suffered respiratory injuries from inhaling smoke while he was trapped.

The five fire fighters working on the roof were dropped to the ground with the collapsing roof. All five fire fighters were injured in the collapse.

At the time of the collapse, Victim # 1 was to the right of the TL-34 lieutenant and near the Sector 4/Sector 1 corner. Victim # 1 was trapped under the collapse. Soon after the TL-34 lieutenant was extricated, Victim # 1 was found and extricated. He was transported to an area hospital at approximately 0724 hours.

The Truck 49 fire fighter who was working the 3rd platoon was pulling ceiling near the corner of the concrete block room when he heard a cracking sound and he heard someone yell that the roof was coming down. He stepped in against the block wall and was pushed to his knees by the collapsing roof. He was momentarily entangled in the debris but was able to quickly free himself. The collapsing roof was partially supported by the concrete block wall, creating a “lean-to” along the block wall that

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was approximately 3-4 feet high and extended a few feet toward the center of the structure where the roof had “pancaked” down onto the floor. He turned on his light and called “Mayday” on his radio but did not identify himself or his location. He started to crawl forward and was able to crawl along the block wall under the lean-to until he reached the east (Sector 4) exterior wall that had partially collapsed. He saw the TL-34 lieutenant to his right and saw that he was pinned. He could hear the sound of fire fighters digging through the rubble from above. He found an opening in the Sector 4 wall and was able to crawl out into the courtyard. He briefly talked to fire fighters digging to free the TL-34 lieutenant. He could not return to T-49 through Sector 3 because of the debris pile, so he walked through the front building (Sector 1), and then down the side street to the alley to the rear of the fire building (Sector 3) where he located his crew.

Five fire fighters were working in close proximity to the area enclosed by the wooden wall studs west of the concrete block room. The E-72 fire fighter working the nozzle was closest to the Sector 3 wall. The collapsing roof pushed the E72 fire fighter down to a crouching position (during the interview with NIOSH investigators, he referred to the position as a baseball catcher’s position). His head and shoulders were pinned by the collapsed roof so that he could not move and his facepiece was dislodged. He began to yell out for help and the Truck 30 crew along with the E-126 lieutenant and other fire fighters began to dig the bricks and roof material from around his head (see Photo 11).

The E-72 fire fighter backing up the E-72 fire fighter with the nozzle, the T-49 fire fighter working the 1st platoon, and the T-16 driver were knocked to their knees by the collapse. The other T-16 fire fighter was knocked unconscious and fell to the floor. The T-49 fire fighter and the E-72 fire fighter heard the E-72 fire fighter with the nozzle calling for help and crawled toward his location. The collapsed roof was suspended about 2 feet off the floor in this area. The T-49 fire fighter had to remove his SCBA harness and mask to crawl forward. The E-72 fire fighter was to the right of the T-49 fire fighter as they crawled forward. The T-49 fire fighter was the first to reach the E-72 fire fighter and tried to move debris from around his head as the fire fighters above also worked to free him (see Photo 11). The E-72 fire fighter cut the shoulder straps on his crewmember’s SCBA harness. The T-49 and E-72 fire fighters were able to remove the SCBA from the pinned E-72 fire fighter’s back which freed him. By this time the Truck 30 crew and other fire fighters had enlarged the opening enough that the pinned E-72 fire fighter was able to wiggle his way through the opening to the outside. The T-49 and E-72 fire fighters talked with the E-126 and T-16 lieutenants about other fire fighters who might still be missing. The T-49 fire fighter told the T-16 lieutenant that he had seen the T-16 driver crawling toward Sector 1. The T-16 lieutenant said that other T-16 fire fighters were still missing so the T-49 and E-72 fire fighters crawled back under the collapse about 12 -15 feet where they found the T-16 fire fighter who had been working near the corner of the concrete block room. The T-49 and E-72 fire fighters worked to free the T-16 fire fighter and assisted him back to the hole where he was able to crawl outside. The T-16 lieutenant told the T-49 and E-72 fire fighters that a T-16 fire fighter (Victim # 1) was still missing. The T-49 and E-72 fire fighters crawled back under the collapse a second time and used their lights to search again, but did not see any other fire fighters. They did hear a PASS device sounding to the west. The T-49 and E-72 fire fighters returned to the hole and crawled outside.

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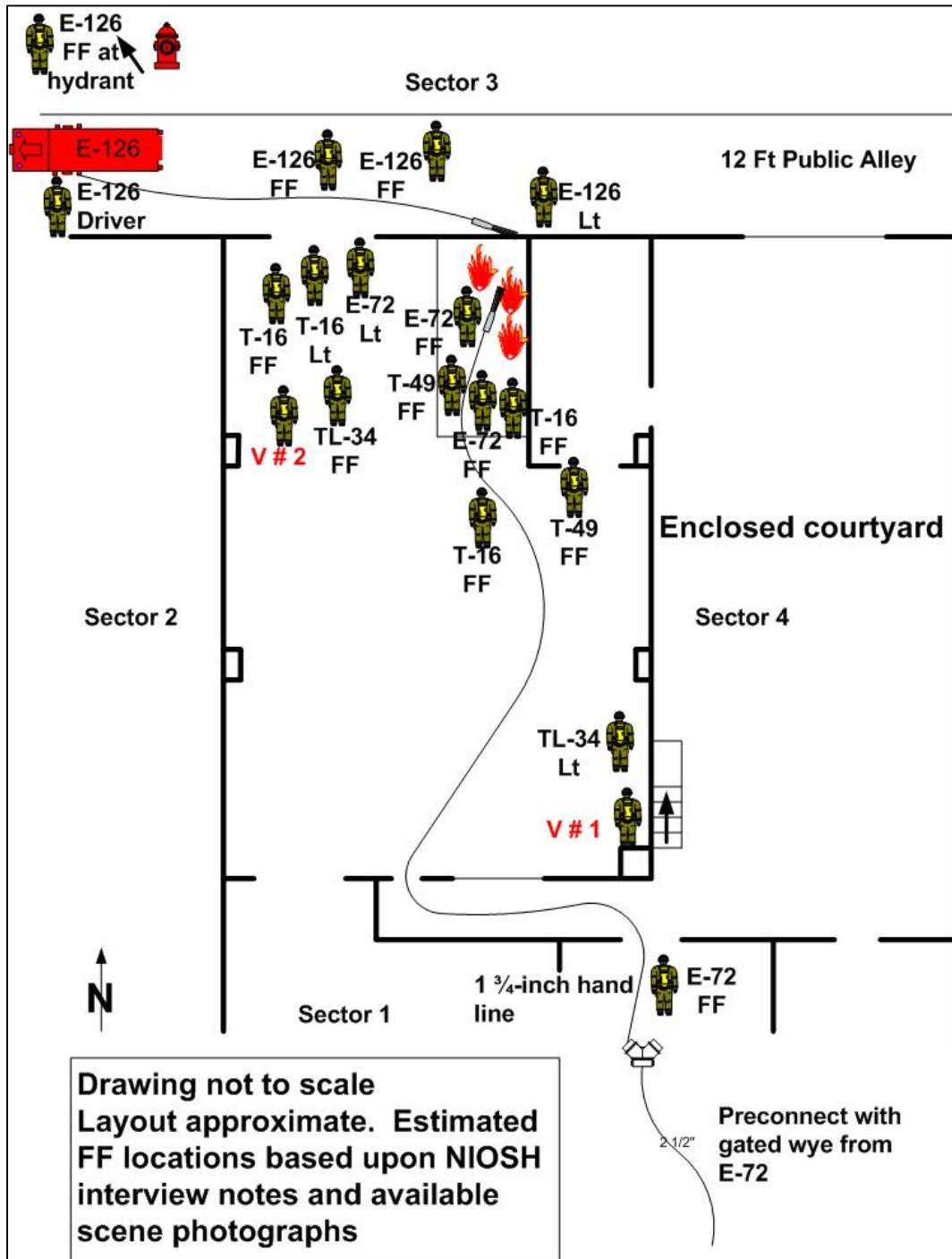


Diagram 3. Approximate location of the fire fighters inside structure and in alley at time of the roof collapse. Five fire fighters were also on the roof at the time of the collapse.

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Truck 30

T-30 was dispatched as the RIT Truck following the “Still and Box” alarm. T-30 arrived on-scene with a crew of five including a lieutenant and 4 fire fighters. T-30 staged west of the fire building and the crew was getting the RIT tools off the truck when they heard the “Mayday” over the radio. The T-30 crew was initially told to go to Sector 1 then were told to take lifting tools to the rear of the building (Sector 3). They observed a hand sticking up from the debris near the center of the building. The T-30 crew used lifting tools to raise the collapsed roof up enough so that the trapped fire fighter (E-72 fire fighter with the nozzle) could be freed. They quickly enlarged the opening enough so that the other E-72 fire fighter, T-49 fire fighter, and T-16 fire fighter could escape through the opening.

An accountability roll call was taken after the four fire fighters were extricated. It was determined that Victim # 2 was still unaccounted for. Crews continued to search under the debris and Victim # 2 was soon located under the debris. Crews had to cut through the collapsed roof materials to extricate him. Victim # 2 was transported to an area hospital at approximately 0731 hours.



Photo 11. Crews work to free fire fighters from Engine 72, Truck 49 and Truck 16 trapped under collapse.

(Photo courtesy of fire department)

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Contributing Factors

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

- Lack of an abandoned / hazardous building marking program within the city
- Vacant / hazardous building information not part of automatic dispatch system
- Dilapidated condition of the structure
- Dispatch occurred during shift change resulting in fragmented crews
- Weather conditions including snow accumulation on roof and frozen water hydrants
- Not all fire fighters equipped with radios.

Cause of Death

According to the medical examiner's office, the cause of death for both victims was listed as compressional asphyxia due to a roof collapse.

Recommendations

Recommendation #1: Fire departments and city building departments should work together to identify and mark buildings that present hazards to fire fighters and the public.

Discussion: Abandoned buildings can and do pose numerous hazards to fire fighters' health and safety as well as the general public.⁷ Hazards should be identified and warning placards affixed to entrance doorways or other openings to warn fire fighters of the potential dangers. Such hazards can be structural as the result of building deterioration or damage from previous fires. Gutted interiors also increase the amount of exposed flammable materials and contain open pathways for rapid flame spread. Structural hazards can occur when building owners or salvage workers remove components of the building such as supporting walls, doors, railings, windows, electric wiring, utility pipes, etc. Abandoned materials such as wood, paper, and flammable or hazardous substances, as well as collapse hazards, constitute additional dangers fire fighters may encounter. Collapse hazards can include chimney tops, parapet walls, slate and tile roof shingles, metal and wood fire escapes, HVAC or other mechanical equipment, solar electrical collectors and cells, advertising signs, and entrance canopies. A warning placard may be a 12-inch-square piece of metal painted reflective yellow so that it reflects light in the dark and indicates to fire fighters that hazards exist inside the building. Figure 1 illustrates symbols used on warning placards developed and used by the New York City Fire Department (FDNY).⁵ Note: The checkbox with one slash indicates the building is vacant and there are interior hazards that fire fighters need to be aware of. The checkbox with an X in it indicates the building is seriously compromised and fire fighters should not enter, but rather initiate an exterior attack.

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Fire departments should work with city and local authorities to develop and implement a strategy to identify, mark, secure, and where possible demolish unsafe structures within their jurisdictions. The IAAI / USFA Abandoned Building Project, conducted by the International Association of Arson Investigators and the US Fire Administration, is one example of a program that can be utilized to aid and assist fire fighter safety and health by identifying, marking, and removing unsafe structures.⁷ The Abandoned Building Project Toolbox can be found at the Web site:

<http://www.interfire.org/features/AbandonedBuildingProjectToolBox.asp>.

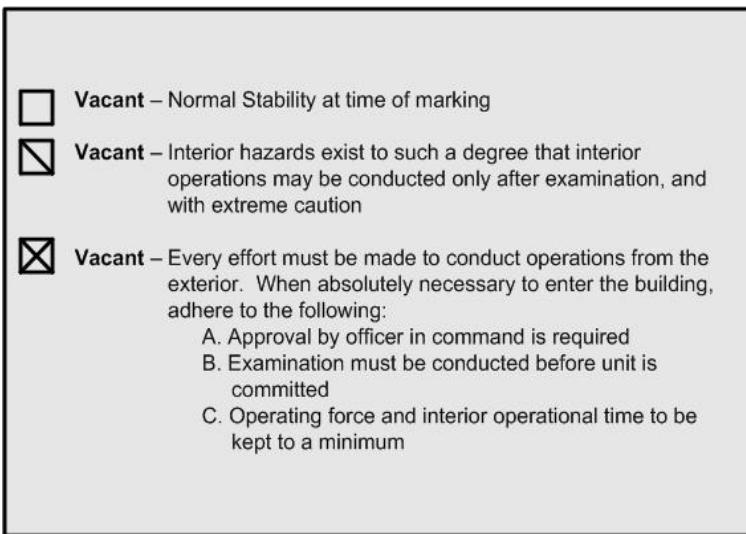


Figure 1
Warning placard used by FDNY to identify hazards in vacant buildings

The toolbox contains the Abandoned Building Project report *Managing Vacant and Abandoned Properties in Your Community* and other reference materials. This report includes recommendations on how fire departments can work with governmental authorities to reduce the public safety hazard created by unsafe and abandoned buildings. A number of locations across the country have developed laws and regulations that address the public safety hazards created by vacant and abandoned buildings. Examples are the *Commonwealth of Massachusetts, Abandoned or Dangerous Building Regulations 780 CMR and 527 CMR*⁸ and the City of Cincinnati Vacated Building Maintenance License.⁹ The *NFPA 1 Fire Code, Annex Q Fire Fighter Safety Building Marking System* makes direct reference to the potential resolution to identifying hazardous structures and contents through building marking programs.¹⁰

In this incident, the fire department responded to a structure that had been abandoned for more than five years. The building was not marked with any type of sign or warning information that identified the potential hazards. When viewed from the front, the building appeared to be a vacant building, in good repair, awaiting a new tenant. Businesses located on the same block were open for business. In 2007, the city's Department of Buildings (DOB) cited the building owners for the deteriorated condition of the structure and ordered the owner to either repair or demolish the structure. The structure had been in the judication process for several years. There was no formal process for the DOB to mark dangerous and abandoned buildings and there was no process for the DOB to notify the fire department when hazardous buildings were identified. The fire department did have a process in which the fire department notified the DOB in writing whenever the fire department identified hazardous structures.

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Recommendation #2: Fire departments should use risk management principles at all structure fires and especially abandoned or vacant unsecured structures.

Discussion: While it is recognized that fire fighting is an inherently hazardous occupation, established fire service risk management principles are based on the philosophy that greater risks will be assumed when there are lives to be saved and the level of acceptable risk to fire fighters is much lower when only property is at stake. Interior (inside a structure) offensive fire-fighting operations can increase the risk of traumatic injury and death to fire fighters from structural collapse, burns, and asphyxiation. Established risk management principles suggest that more caution should be exercised in abandoned, vacant, and unoccupied structures and in situations where there is no clear evidence indicating that people are trapped inside a structure and can be saved.⁵

The IC, with input from the assigned Incident Safety Officer and/or Division/Group Supervisors, is responsible for evaluating conditions at a structure fire and determining safe tactics for fighting the fire. To accomplish this, the IC should use a standardized strategic decision-making model. First, the IC should size up the critical fireground factors.¹¹ The incident commander must make a determination that offensive (interior) operations may be conducted without exceeding a reasonable degree of risk to fire fighters before ordering an offensive attack 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 (but not limited to):

- 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
- 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.^{5,11}

These fireground factors must be weighed against the risk management plan. There is absolute recognition of the fact that 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 lesser than those to save lives.^{5,12} Risks to fire fighters versus gains in saving lives and property must always be considered when deciding whether to use an offensive or defensive attack. The Incident Commander should routinely evaluate and reevaluate conditions and radio progress reports in reaching objectives to dispatch and on-scene fire fighters. This process allows the Incident Commander to determine whether

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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.¹⁵

Retired New York City Deputy Fire Chief Vincent Dunn states the following: “When no other person’s life is in danger, the life of the firefighter has a higher priority than fire containment.”¹³ Chief Dunn also states “The protection of life is the highest goal of the fire service... When a life is clearly threatened, there is no risk too great. At most fires, however, lives are not clearly endangered. At most fires, then, the priority of firefighting is the protection of the fire fighters’ lives.” In general terms, the risk management plan must consider the following: (1) risk nothing for what is already lost—choose defensive operations; (2) extend limited risk in a calculated way to protect savable property—consider offensive operations; (3) and extend very calculated risk to protect savable lives—consider offensive operations.^{5,14} NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*, Chapter 8.3 addresses the use of risk management principles at emergency operations. Chapter 8.3.4 states that risk management principles shall be routinely employed by supervisory personnel at all levels of the incident management system to define the limits of acceptable and unacceptable positions and functions for all members at the incident scene. Chapter 8.3.5 states that at significant incidents and special operations incidents, the Incident Commander shall assign an incident safety officer who has the expertise to evaluate hazards and provide direction with respect to the overall safety of personnel. The annex to Chapter 8.3.5 contains additional information.¹

Modern incident demands on the fireground are unlike those of the recent past, requiring incident commanders and commanding officers to have increased technical knowledge of building construction with a heightened sensitivity to fire behavior, a focus on operational structural stability and considerations related to occupancy risk versus the occupancy type. Strategies and tactics must be based on occupancy risk, not occupancy type, and must have the combined adequacy of sufficient staffing, fire flow and tactical patience orchestrated in a manner that identifies with the fire profiling, predictability of the occupancy profile and accounts for presumptive fire behavior.¹⁵

This incident occurred in an area of mixed commercial use. Vacant, abandoned and unoccupied buildings were intermixed with businesses still in operation. The fire department reported that they had responded to numerous fires in vacant structures in the area. The fire occurred in a building that appeared to be in good condition when viewed from the front but was in a dilapidated condition. The front entrances were guarded by metal security gates while the back was wide open with entrance doors and an overhead roll-up door missing. Vagrants commonly entered the structure and just weeks prior to the incident, a person was arrested at the structure for removing and burning wiring. The unstable nature of the building, the apparent poor condition of the roof and inherent deficiencies in the structural support system construction created an operational risk profile that could not be readily identified through conventional size-up by arriving and deploying company and command officers.

The first-responding officer, as well as the IC, needs to make a judgment as to what is at risk – people or property. This will help determine the risk profile for the incident. Many fire fighters stand by the notion that all incidents are “people” events until proven otherwise. Historically, the fire service has a poor history of changing risk-taking based upon the people/property issue.¹⁶ Given that vagrants were

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known to frequent the structure, the decision to conduct an interior search for the presence of civilians was prudent. However, the numbers of fire fighters inside the structure clearly exceeded the number needed to suppress the amount of fire present and to search the vacant structure while being exposed to the risk of structural collapse. The IC reported having an operational plan to switch to a defensive strategy when water supply was established by E-126 at the rear of the structure but the roof collapsed before the plan could be implemented.

Recommendation # 3: Fire departments should train fire fighters to communicate interior conditions to the Incident Commander as soon as possible and to provide regular updates.

Discussion: Proper size-up and risk versus gain analysis requires that the Incident Commander have a number of key pieces of information and keep informed of the constantly changing conditions on the fireground. The IC must develop and utilize a system which captures pertinent incident information to allow continuous situational evaluation, effective decision making, and development of an incident management structure. Decisions can be no better than the information on which they are based. The IC must use an evaluation system that considers and accounts for changing fireground conditions in order to stay ahead of the fire. If this is not done, the incident action plan (IAP) will be out of sequence with the phase of the fire and the IC will be constantly surprised by changing conditions.^{17 - 19} Interior size-up is just as important as exterior size-up. Since the IC is staged at the command post (outside), the interior conditions should be communicated by interior crews as soon as possible to the IC. Interior conditions could change the IC's strategy or tactics. Interior crews can aid the IC in this process by providing reports of the interior conditions as soon as they enter the fire building and by providing regular updates. According to Chief Dunn, construction features discovered in a commercial structure should be immediately communicated to the IC. For example, drop ceilings and other features that could hide void spaces.¹⁹ Also, NFPA 1500, Chapter 8.2, *Communications*, section 8.2.1 states that the fire department shall establish and ensure the maintenance of a fire dispatch and incident communications system that meets the requirements of NFPA 1561 and NFPA 1221 *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems.*¹

Chief Brunacini states that critical fireground factors, including interior and exterior conditions, are among the many items that the IC must consider when evaluating tactical situations. These items provide a checklist of the major topics involved in size-up, decision making, initiating operations, and review and revision. The IC deals with these critical factors through a systematic management process that creates a rapid, overall evaluation; sorts out the critical factors in priority order; and then seeks out more information about each factor. The IC must train and prepare (through practice) to engage in conscious information management. Incident factors and their possible consequences offer the basis for a standard incident-management approach. A standard information approach is the launching pad for effective incident decision making and successful operational performance. The IC must develop the habit of using the critical factors in their order of importance as the basis for assigning the specific assignments that make up the incident action plan (IAP). The IC must create a standard information system and use effective techniques to keep informed at the incident. The IC can never assume the action-oriented responder engaged in operational activities will stop what they are doing so they can

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feed the IC with a continuous supply of top-grade objective information. It is the IC's responsibility to do whatever is required to stay effectively informed.²⁰

During this incident, roof crews reported conditions observed on the roof and this information was considered by the IC and company officers at the scene. However, no interior condition reports were broadcast over the radio (to the chief officers or other fire fighters) during this incident. Verbal exchanges between the interior crews and company officers took place but this information did not impact the tactics being used.

Recommendation # 4: Fire departments should consider providing battalion chiefs with a staff assistant or chief's aide to help manage information and communication.

Discussion: A chief's aide, staff assistant, or field incident technician (FIT) is a position designed to assist an IC with various operational duties during emergency incidents. The chief's aide is an essential element for effective incident management. At an emergency incident, the staff assistant can assist with key functions such as: managing the tactical worksheet; maintaining personnel accountability of all members operating at the incident (resource status and deployment location); monitoring radio communications on the dispatch, command, and fireground channels; control information flow by computer, fax, or telephone; and, access reference material and pre-incident plans.

The personnel accountability system is a vital component of the fire fighter safety process. The system is designed to account and track personnel as they perform their fireground tasks. In the event of an emergency or "Mayday," the personnel accountability system must be able to provide the rapid accounting of all responders at the incident. This is one of the chief's aide's essential responsibilities. Another important function is the role of a driver in addition to their role as part of the command team. Chief officers are required to respond quickly to emergency incidents. In their response, they have to be fully aware of heavy traffic conditions, construction detours, traffic signals, and other conditions. More importantly, the chief officer must also monitor and comprehend radio traffic to assess which companies are responding, develop a strategy for the incident based upon input from first arriving officers, develop and communicate an incident action plan which defines the strategy of the incident. A chief's aide can assist the battalion chief or chief officer in processing information without distraction and complete the necessary tasks en route to the scene.²¹ In the case of this investigation, the Battalion Fire Chief was a relief officer and was not assigned an aide. Thus, the individual is responsible for operation of the vehicle during emergency response in any of the department's 24 battalions.

Departments should consider the aide to be an individual that has the experience and authority to conduct the required tasks. Other potential roles for the chief's aide include assisting with the initial size-up, completing a 360-degree size-up, coordinating progress reports from sector/division officers and many others. The aide position can be used as a training position to help facilitate officer development. There are non-emergency functions for the chief's aide that are vital to the daily operations of the department. Some jurisdictions assign a chief's aide to command officers to perform daily administration functions (such as position staffing and leave management).

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Recommendation # 5: Fire departments should provide all fire fighters with radios and train them on their proper use.

Discussion: In September 2003, NIOSH released the document, *Current Status, Knowledge Gaps, and Research Needs Pertaining to Firefighter Radio Communication Systems*.²² Page 13 states: “It is critical for firefighters to communicate with one another within a structure and with units operating outside the structure, regardless of the building construction.” The best way this can be done when crews are separated or in trouble is through the use of a personal portable radio.

National Fire Protection Association (NFPA) 1561, *Standard on Emergency Services Incident Management System*, Section 6.3 Emergency Traffic, states in section 6.3.1: “To enable responders to be notified of an emergency condition or situation when they are assigned to an area designated as immediately dangerous to life or health (IDLH), at least one responder on each crew or company shall be equipped with a portable radio and each responder on the crew or company shall be equipped with either a portable radio or another means of electronic communication.”²³ The joint U.S. Fire Administration (USFA) and International Association of Fire Fighters (IAFF) report, *Voice Radio Communications Guide for the Fire Service*,²⁴ provides an overview of radio communication issues involving the fire service. Effective fireground radio communication is an important tool to ensure fireground command and control as well as helping to enhance fire fighter safety and health. Every fire fighter on the fireground should be provided with their own radio in case they become lost or separated from their crew. It is every fire fighter’s and company officer’s responsibility to ensure radios are properly used. Ensuring appropriate radio use involves both taking personal responsibility (to have your radio, having it on, and on the correct channel) and a crew based responsibility to ensure that the other members of your crew are doing so as well. Radios should be designed and positioned to allow the fire fighter to monitor and transmit a clear message. These radios should be well maintained and inspected by qualified personnel on a regular basis.

The fire department involved in this incident typically issues three radios per fire apparatus. The company officer and the driver carry a radio. On engine companies, the hydrant fire fighter is assigned a radio. On truck companies, the fire fighter responsible for forcible entry at the rear carries a radio. During this incident, only 5 of the 13 fire fighters inside the structure at the time of the collapse were carrying radios. Following the collapse, only one of these 5 fire fighters reported to NIOSH investigators that he radioed a Mayday. Both the International Association of Fire Chiefs (IAFC)²⁵ and the International Association of Fire Fighters (IAFF)²⁴ 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 emergency distress feature.”²⁶ The IAFF *Fireground Survival Program* contains training on radio communication procedures in emergency operations including how to call a Mayday.²⁷

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Recommendation # 6: Fire departments should develop, train on and enforce the use of standard operating procedures that specifically address operations in abandoned and vacant structures.

Discussion: In 1999, fire fighters entered a burning vacant cold storage building to search for a homeless couple reported to have been in the building. Two fire fighters became disoriented, and others went to their aid. Six became trapped and died in the fire. The homeless couple had left the premises after the fire began. The fire fighters' deaths became national news and highlighted the fact that one of the major costs of vacant and abandoned properties is the inherent risk to fire fighters and the public.²⁸

According to the NFPA report *Vacant Building Fires*, 31,000 structure fires, on average, were reported in vacant buildings per year. Fires in vacant buildings (defined by the NFPA report as any building that was unoccupied and without a tenant, including but not limited to abandoned buildings) have become a matter of increasing concern as the economy has weakened. These fires resulted in an average of 50 civilian deaths, 141 civilian injuries, 4,500 fire fighter injuries, and \$642 million in direct property damage per year.²⁹

According to the joint IAAI/USFA *Abandoned Building Project* program report, uninhabited buildings that are not secure - open to unauthorized entry - have a very high probability of intentionally set fires. When fires occur in these buildings, they present a host of unusual problems to firefighters. Since the buildings are uninhabited, fires may develop for significant periods of time before they are detected and reported. The buildings may contain unprotected hazardous materials and fuel packages that would not be found in occupied buildings. The removal of equipment or structural components and deterioration due to age or weather can weaken the structure causing rapid failure early in a fire. Firefighters may encounter open shafts, stairways, pits or holes in floors that would not be found in occupied structures. All of these factors contribute to the danger these structures pose to firefighters operating in vacant or abandoned structures. The joint IAAI/USFA *Abandoned Building Project* program report cites NFPA estimates that 6,000 firefighters are injured every year in vacant or abandoned building fires.⁷ Annex Q to the NFPA Fire Code makes direct reference to the potential resolution to identifying hazardous structures and contents through building marking programs.¹⁰

Recommendation # 7: Fire departments should develop, implement and enforce a detailed Mayday Doctrine to ensure that fire fighters can effectively declare a Mayday.

Discussion: Dr. Burton Clark, EFO, CFO, and noted Mayday Doctrine advocate with the U.S. Fire Administration, National Fire Academy has studied the need for enhanced Mayday training across the country. According to Dr. Clark, "There are no national Mayday Doctrine standards to which fire fighters are required to be trained."³⁰ The NFPA 1001 fire fighter I & II standard² does not include any Mayday Doctrine performance, knowledge or skills. The word Mayday is not defined or referenced in the standard. In addition there are no national or state standards related to required continuing recertification of fire fighters to insure their continued Mayday competency throughout their career. In several investigations conducted by NIOSH, the recommendation was made that fire departments should train fire fighters on initiating emergency traffic.³¹⁻³⁵

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The fire department involved in this incident has a written procedure (general order) on “Mayday” and emergency alert procedures that describes how fire fighters are to use their radios to alert members of a “Mayday” or emergency. Only 5 of 13 fire fighters inside the structure at the time of the collapse had a portable radio. Only one of those five radioed a Mayday.

The National Fire Academy has two courses addressing fire fighter “Mayday” Doctrine: Q133 “*Firefighter Safety: Calling the Mayday*” which is a 2-hour program covering the cognitive and affective learning domain of firefighter Mayday Doctrine and H134 “*Calling the Mayday: Hands on Training*” which is an 8-hour course that covers the psychomotor learning domain of firefighter “Mayday” Doctrine. These materials are based on the military methodology used to develop and teach fighter pilots ejection doctrine. A training CD is available to fire departments free of charge from the US Fire Administration Publications office. ^{36, 37}

An equally important training program is the IAFF Fireground Survival Training Program. The IAFF *Fireground Survival Program* contains training on radio communication procedures in emergency operations including how to call a Mayday. ²⁷ This program contains dedicated sections on preventing a Mayday, being ready for a Mayday, radio communications, and self-survival procedures and skills.

Recommendation # 8: Fire departments should ensure that the Incident Commander maintains close accountability for all personnel operating on the fireground

Discussion: Personnel accountability on a fireground means identifying and tracking all personnel working at the incident. A fire department should develop its own system and standardize it for all incidents. Accountability on the fireground can be maintained by several methods: a system using individual tags assigned to each fire fighter, a riding list provided by the company officer, a SCBA tag system, or an incident command board. ^{1, 23, 38} Modern radio systems also incorporate a means of tracking the identity of fire fighters at an incident scene. Some personal alert safety system (PASS) devices incorporated into SCBA have the ability to communicate automatically with a command / control module at the incident command post, establishing an automatic accountability system. NFPA 1500 Chapter 8, Section 8.4 and NFPA 1561, Chapter 4, Section 4.5 contain guidelines for the development of an accountability system for fireground and other emergency operations. ^{1, 23}

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

In this incident, accountability was not maintained for all fire fighters responding to the incident. The incident dispatch occurred during a shift change, which resulted in crews being assembled with fire fighters from both the outgoing shift and the incoming shift. This resulted in fragmented crews and possibly contributed to instances where fire fighters were not working within a buddy system. Following the collapse, company officers had to make visual confirmation of all crew members, since many fire fighters did not have assigned radios.

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Recommendation # 9: 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 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.²⁷

Fire fighters must act promptly when they become lost, disoriented, injured, low on air, or trapped.³⁹⁻⁴⁴ 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.¹⁶ The use of an operational retreat is designed to quickly remove fire fighters from operations in an unsafe or potentially unsafe environment. The IC 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

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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.⁴⁵

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.

Recommendation #10: Fire departments should ensure that all fire fighters are trained in and understand the hazards associated with bowstring truss construction.

Discussion: Comprehensive training is an important aspect of safe fire ground operation. Both officers and fire fighters need to be aware of different types of building construction and their associated hazards.⁴⁶⁻⁴⁹ A bowstring truss roof is supported by four load-bearing walls. The ends of the trusses are supported by the side walls. The front and rear walls support roof joists or hip rafters that slope downward from the nearest trusses. A collapsing bowstring truss roof often puts outward pressure on the supporting walls, so that outward wall collapse should be expected as well.⁴⁷ While heavy timber roof systems will withstand more degradation by fire than lightweight engineered-wood roof trusses, both types are subject to failure (see Photo 12).⁴⁷

Establishing priorities is another primary factor in safe fire ground operation that should be included in fire fighter training programs. One source of training on different structure types and their associated risk is available on the internet at the CommandSafety.com website in a downloadable power point file titled “*Operational Safety Considerations at Ordinary & Heavy Timber Constructed Occupancies.*”^{50,51} This training program states that structural collapse events involving Type III (Ordinary) and Type IV (Heavy Timber) construction features are typical and can be assumed to occur at any time resulting from:

- Fire
- Construction/renovation/alterations/ demolition/deconstruction
- Age and deterioration
- Weather & Environmental factors
- External factors (vehicle running into a building etc.)

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Photo 12. One end of heavy timber roof truss can be seen in center of photo. The truss has rolled over onto its side with the end penetrating through the Sector 4 wall. Photo was taken from the court yard on the Sector 4 side (facing west).

(Photo courtesy of Fire Department)

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Understanding collapse indicators, precursors, construction features and conditional factors will aid in incident operations and personnel safety. The NFPA 5000 Building Construction and Safety Code has specific information on all building construction and types. This information can be used to design and develop training curriculums for building construction.⁵²

As noted previously, bowstring truss roof systems may suffer from a little-known phenomenon related to inaccuracies in early industry-accepted truss design assumptions. All trusses constructed prior to the late 1960s have a common code deficiency: the bottom chord members have inadequate tensile strength to support roof loads allowed by the existing codes.⁶

In this incident, the structure had been vacant for several years and had been abandoned by the owner. Citations issued by the city's Department of Buildings included concerns with deteriorated (rotted) truss members, deterioration of the roof due to water penetration, and penetrated mortar joints on the east wall. It is likely that a number of factors contributed to the roof collapse, including the deteriorated condition of the structure, several inches of snow on the roof, the combined weight of fire fighters working on the roof, and the effects of ventilation and fire suppression activities. The fire department's training academy literature included training materials related to bowstring truss construction, lightweight truss construction and steel bar truss construction.

Recommendation # 11: Fire departments should ensure that fire fighters wear a full array of turnout clothing and personal protective equipment appropriate for the assigned task while participating in fire suppression and overhaul activities.

Discussion: Although there is no evidence that this recommendation would have prevented the fatalities, it is being provided as a reminder of a good safety practice. NFPA 1500 *Standard on Fire Department Occupational Safety and Health Program*, Chapter 7 contains general recommendations for fire fighter protective clothing and protective equipment.¹ Chapter 7.1.1 specifies that “the fire department shall provide each member with protective clothing and protective equipment that is designed to provide protection from the hazards to which the member is likely to be exposed and is suitable for the tasks that the member is expected to perform.” Chapter 7.1.2 states “protective clothing and protective equipment shall be used whenever the member is exposed or potentially exposed to the hazards for which it is provided.” Chapter 7.2.1 states “members who engage in or are exposed to the hazards of structural fire fighting shall be provided with and shall use a protective ensemble that shall meet the applicable requirements of NFPA 1971 *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting.*”⁵³ Chapter 7.9.7 states “when engaged in any operation where they could encounter atmospheres that are immediately-dangerous-to-life-or-health (IDLH) or potentially IDLH, or where the atmosphere is unknown, the fire department shall provide and require all members to use SCBA that has been certified as being compliant with NFPA 1981 *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services.*”⁵⁴ Additionally, the OSHA Respirator Standard requires that all employees engaged in interior structural fire fighting use SCBAs.⁵⁵ The fire department involved in this incident had a written procedure requiring that SCBA be used at all structure fires. During this incident, several fire fighters reported to NIOSH

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investigators that they entered the structure and engaged in fire suppression activities without donning their facepieces. Some fire fighters reported opening their SCBA cylinder valves so that their PASS devices would be activated. Both victims were found with their facepieces on. It is unclear whether Victim # 1's PASS device was sounding when he was found. Victim # 2's PASS device was reported to be sounding when he was found.

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Investigator Information

This incident was investigated by Timothy R. Merinar, Safety Engineer, Matt Bowyer, General Engineer, Murrey Loflin, Investigator, and Steve Miles, Occupational Safety and Health Specialist, with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, located in Morgantown, WV. An expert technical review was provided by Christopher Naum, Chief of Training, Command Institute. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division. This report was authored by Tim Merinar and Murrey Loflin. Some text provided by expert reviewers was incorporated into the final report.

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Additional Information

DO YOU KNOW WHERE THEY ARE? THE DANGERS OF THE BOWSTRING TRUSS ROOF
by Jeffrey Pindelski, Battalion Chief, Downers Grove, IL, Fire Department. Health and Safety for Fire and Emergency Services Personnel, Vol 21, Issue 5, May 2010. Fire Department Safety Officers Association, Ashland, MA.

http://www.fdssoa.org/news/getpdf.htm?file=/www/docs/fdssoa/pdfs/membersonly/articles/past_articles/2010_05_newsletter.pdf.

Buildingsonfire.com is a website dedicated to art and science of building construction, fire fighting and command risk management for operational excellence, and fire fighter safety.

<http://www.Buildingsonfire.com>

Near-miss at grocery store fire results in local wood truss roof warning sign legislation. Illinois truss sign law. <http://www.lib.niu.edu/1994/im940809.html>.

Command Safety is a website dedicated to building construction, command risk management, and fire fighter safety for field operations. <http://commandsafety.com/>.

Chicago: Anatomy of a Building and its Collapse.

<http://commandsafety.com/2010/12/chicago-anatomy-of-a-building-and-its-collapse/>.

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

<http://www.iaff.org/HS/FGS/FGSIndex.htm>.

Many fire departments, cities, and authorities having jurisdiction (AHJ) have developed policies and procedures dealing with vacant and abandoned hazardous buildings. The New York City Fire Department (FDNY) and the Detroit Fire Department are just two examples. More information about the Detroit Fire Department vacant building procedure can be found at

<http://www.clickondetroit.com/news/28237327/detail.html>.

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