



Injury in the line of duty...

A summary of a NIOSH fire fighter fatality investigation

April 17, 2009

Nine Fire Fighters from a Combination Department Injured in an Explosion at a Restaurant Fire – Colorado

SUMMARY

On February 22, 2008, a deputy chief and eight fire fighters were injured during an explosion at a restaurant fire in Colorado. At 1340 hours, dispatch reported visible smoke and flames through the roof of a commercial structure. At 1344 hours, police arrived and began evacuating the restaurant and the adjoining retail store. The restaurant was part of a block-long row of adjoining structures. Over the next 25 minutes, 3 engines, 2 ladder trucks, and 24 fire department members arrived on scene including the injured fire fighters.

A crew entered the restaurant with moderate smoke showing toward the rear and no flames visible. The crew backed out and entered the retail store (an adjacent building attached to the restaurant) to check for fire in the ceiling but found only light smoke visible. Another crew attempted to ventilate the retail store with a chainsaw, and when the roof was noticed to be spongy, they moved to the roof of the next building, two buildings down from the restaurant. Interior crews operating in all three buildings had backed out. A crew closed the front doors of the restaurant fearing the oxygen would feed the increasingly greenish-black smoke pushing out of the roof of the restaurant. Fireground personnel noticed the front windows of the restaurant and adjoining retail store were vibrating as flames from the roof of the restaurant intensified. At 1427 hours, the restaurant and two adjoining buildings exploded sending glass, bricks, and wood debris into the street. The crew on the roof located two buildings down from the restaurant, felt the front portion of the flat roof heave up about five feet, sending a fire officer to the ground below and temporarily trapping four other fire fighters; all incurred injuries. In addition, four fire fighters, positioned on the ground within 6 feet of the store fronts, were injured by flying debris.

Key contributing factors identified in this investigation included fire growth and smoke buildup in the common attic area of the buildings which pressurized and exploded, unrecognized building

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



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characteristics that contributed to the fire and explosion hazards, ineffective ventilation, execution of offensive operation SOPs and inadequate staffing.

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

- *ensure ventilation techniques are established and executed*
- *conduct pre-incident planning and inspections of buildings within their jurisdictions to facilitate development of safe fireground strategies and tactics*
- *ensure that standard operating procedures (SOPs) for offensive operations are followed, such as, cutting utilities and checking extension into void spaces*
- *ensure that standard operating procedures (SOPs) for a 360-degree size-up are followed*
- *ensure that staffing levels are sufficient to accomplish critical tasks*
- *ensure that the incident commander has sufficient aides on the fireground and has a visual view of the fire building*
- *ensure thermal imaging cameras are used to locate the seat of the fire and monitor fire growth*

Although there is no evidence that the following recommendations would have prevented these injuries, they are being provided as a reminder of a good safety practice.

- *ensure that radios are operable in the fireground environment*
- *ensure an adequate water supply is established*
- *ensure that any offensive attack on a commercial structure is conducted using at least a 2½ hoseline*
- *ensure that collapse zones are established when dealing with older commercial structures and worsening fire conditions*
- *train on the specific hazards of fighting fires in modified structures to include ingress/egress points, flashover, and structural collapse*
- *ensure training requirements are standardized across combination department personnel*



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In addition, municipalities should

- *establish and enforce building and inspection codes*
- *identify/mark buildings on the C-side (rear) when buildings share common walls or are in very close proximity to each other to aid fire fighters in identifying the fire structure*

INTRODUCTION

On February 22, 2008, nine fire fighters were injured when an explosion occurred at a restaurant fire. On February 25, 2008, the State Fire Chiefs' Association requested that the National Institute for Occupational Safety and Health (NIOSH) conduct an investigation of the incident. On February 28 through March 5, 2008, a general engineer and a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program visited the incident scene and conducted interviews with officers, fire fighters, and police who were at the incident scene. The NIOSH investigators reviewed the department's standard operating guidelines (SOGs), the officers' and fire fighters' training records, photographs of the incident scene, written witness statements, and medical records and met with a county communication center support specialist.

FIRE DEPARTMENT

The department has sixteen stations with 69 career (full-time paid positions), 80 volunteer (providing fire fighter functions when available), and 24 reserve fire fighters (a paid part-time position to get hands-on experience and to provide sick/vacation coverage for career staff), serving a population of over 48,300 residents in a geographic area of approximately 325 square miles.

TRAINING/EXPERIENCE

FF #1 (*injured*) was a career fire fighter with 8 years experience and had completed Fire Fighter I; Basic, Intermediate, and Paramedic Emergency Medical Technician (EMT) I; Introductory and 200-level Incident Command System (ICS); Introduction to National Incident Management System (NIMS); Basic Wildland; and various administrative and technical courses.

FF #2 (*injured*) was a career fire fighter with 3½ years of experience and had completed Basic EMT, HazMat Operations, Fire Fighter 1 Practical–Live Fire Training, Introduction to ICS and NIMS, and various other administrative and technical courses.

FF #3 (*injured*) was a career fire fighter with 8 years of experience and had completed Fire Fighter 1 and 2, Basic and Intermediate EMT, HazMat Technician, Basic and Intermediate Wildland, Introduction to NIMS, and various other administrative and technical courses.



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FF #4 (*injured*) was a volunteer fire fighter with 2¾ years of experience and had completed Basic EMT, HazMat Operations, Fire Fighter 1, and various other administrative and technical courses.

FF #5 (*injured*) was a reserve fire fighter with 10 years of experience and had completed Fire Fighter I and II, HazMat Technician, Basic Wildland, EMT Paramedic, Introduction to NIMS, and various other administrative and technical courses.

FF #6 (*injured*) was a volunteer fire fighter with 3 years of experience and had completed Fire Fighter I, HazMat Awareness, Introductory and Level 200 ICS, Fire Fighter Survival, Wildland-Line Boss, and various other administrative and technical courses.

FF #7 (*injured*) was a reserve fire fighter with 3½ years of experience and had completed Fire Fighter I, Basic and Intermediate EMT, HazMat Operations, Introduction to ICS and NIMS, and various other administrative and technical courses.

FF #8 (*injured*) was a career fire fighter with 4 years of experience and had completed Fire Fighter I, Basic, Intermediate, and Paramedic EMT I, HazMat Operations, Introduction to ICS, Basic Wildland, and various other administrative and technical courses.

Captain #1 had 10 years career fire fighting experience and had completed Fire Fighter 1 and 2, Basic and Intermediate EMT, HazMat Operations, Incident Safety Officer, Leadership I, Introductory and Level 200 ICS, Introduction to NIMS, several Weapons of Mass Destruction courses, and various other administrative and technical courses.

Captain #2 had 30 years career fire fighting experience and had completed Fire Fighter 1 and 2, Basic EMT, HazMat Operations, Incident Safety Officer, Leadership I, Introductory and Level 200 ICS, Introduction to NIMS, Leadership Challenge 2006 & 2007, and various other administrative and technical courses.

Deputy Chief (DC) (*injured*) had 37 years of career fire fighting experience and had completed Fire Fighter 1 and 2; Introduction, Intermediate, and Advanced ICS; Introduction to NIMS; Buddy to Boss Leadership; Incident Safety Officer; Command/Control of Incidents Operations; several Wildland courses; and various other administrative and technical courses.

Battalion Chief (the incident commander) had 30 years of career fire fighting experience and had completed Fire Fighter 1 and 2, Introductory and Level 200 ICS, Introduction to NIMS, National Incident Management System, Buddy to Boss Leadership, and various other administrative and technical courses.

Note: Fire Fighter 1 and 2 training are equivalent to NFPA 1 and 2.



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PERSONAL PROTECTIVE EQUIPMENT

At the time of the incident, each injured fire fighter was wearing personal protective equipment consisting of turnout coat and pants, gloves, a helmet, hood, boots, portable radio, and a SCBA with an integrated PASS device.

APPARATUS, PERSONNEL, and ON-SCENE ARRIVAL TIMES

Note: For placement of apparatus, see Diagram 1.

1345 hours

Fire #4 (F4)—fire marshal

1348 hours

Engine #2 (E2)—Captain #2, engineer, FF #1 (*injured*), and FF #2 (*injured*)

Engine #1 (E1)—DC (*injured*), Captain #1 (initial incident command (IC) then Operations Chief), engineer, and FF #3 (*injured*)

EMS #1 (EMS1)—driver/paramedic

Medic #2 (M2)—paramedic and fire fighter

1349 hours

Ladder #2 (L2)—driver/fire fighter (coming from refueling station due to prior run)

1352 hours

Battalion Chief #1 (BC1)—Battalion Chief (IC)

1356 hours:

Ladder #1 (L1)—captain, mechanic, and a fire fighter

1348–1356 hours

Personally Owned Vehicles—FF #4, FF #5, FF #6, FF #7, and FF #8 (*all injured*)

1408 hours

Engine #9 (E9)—Lieutenant

1410 hours

Fire Chief—Fire Chief

BUILDING INFORMATION

The fire structure was part of a late 1890s building—a single story, high ceiling, non-sprinklered commercial structure, constructed of brick and mortar walls with overhead supporting timber beams



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and a wooden plank, gradually sloped (approximately 6" per 12' pitch) roof covered with tin and a tar and pea gravel mixture. The building's front was brick with large plate glass windows and a parapet wall covered with a wooden façade (see Photo 1). Other adjoining buildings were of similar construction and had been completed by 1905 (see Diagram 1).

Over the years, the building had been remodeled several times which included dividing the building in half via a stud wall running front to back, lowering the ceiling in both halves yet sharing a common attic space (see Photo 2 and Diagram 2). This remodeling effort created two adjoining structures: the fire structure and the retail structure. The roofing material had been upgraded with a rubber membrane. Evaporative coolers (swamp coolers) and exhaust fans were added to the roof.

In 1994, the fire structure was remodeled into a restaurant, which incorporated a vent hood and duct work over a wood-fired grill. According to the Fire Marshal, the duct work for the grill did not conform to the 1991 Uniform Mechanical Code requirements for an 18" clearance from combustible materials and for all weld seams to be liquid tight.¹ The duct work over the wood-fired grill had a 6" clearance and the seams were spot welded.

INVESTIGATION

At 1340 hours, dispatch reported visible smoke and flames through the roof of a commercial structure. At 1344 hours, police arrived and began evacuating the fire structure (a restaurant) and an adjoining retail store (see Diagram 1). *Note: The restaurant was part of five adjoining structures, with an office building on the B-side and a retail store and two other structures on the D-side.*

At 1345 hours, F4 arrived on scene and reported light smoke visible. At 1346 hours, the fire structure and exposure D1 were evacuated. At 1348 hours, E2 arrived and deployed a 1¾" hoseline to the fire structure. Seconds later, E1 arrived and connected to the hydrant. M2 arrived and was assigned to the alley which became the C-side. At 1349 hours, L2 arrived on scene and a supply line was laid from E1 to L2 and E2. *Note: L2 had been at a prior incident and was en route to fuel at the time of the page which is why there was only one person in the ladder truck at deployment.*

At 1350 hours, L2 positioned the aerial to the roof of the D2 exposure. At 1352 hours, BC1 arrived on scene and assumed incident command (IC) (see Diagram 1).

Captain #1, who was initially the IC, became the Operations Chief. Captain #2, FF #1, FF #2, and FF #5 prepared to enter the fire structure. Captain #1 assigned a rapid intervention team (RIT) comprised of FF #3, FF #7, and another fire fighter. At 1355 hours, a 1¾" hoseline from E2 was charged in front of the fire structure. Additional staff responded and reported to command for assignments.

At 1356 hours, L1 arrived and set up on the B-side of exposure B. The E2 crew exited the fire structure and reported light smoke. They then entered exposure D1 where they reported light smoke in the interior. The electrical company arrived and cut off power to the fire structure and all exposures. At



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1357 hours, an E2 crew member (FF #5) exited exposure D1 and acquired a thermal imaging camera (TIC) to be used in the interior of exposure D1.

At 1358 hours, the DC climbed the L2 aerial onto the roof of exposure D2. The DC crossed over a parapet wall onto the roof of the fire structure and knocked over an air conditioning unit (swamp cooler) to assist in ventilation. He reported to command that the roof of the fire structure was getting soft.

At 1359 hours, the E2 crew exited exposure D1. The TIC had shown heat in the void space, across the ceiling of exposure D1 and to the wall that was common with exposure D2. The E2 crew had not found fire in the fire structure or exposure D1. *Note: Twenty minutes had passed since the call and there had been no direct intervention on the fire from the fire crews. The attack crew was unable to access the void spaces between the drop ceilings and the roof in each building.*

At 1400 hours, the DC requested a chainsaw to attempt to ventilate the roof of exposure D1 because the roof of the fire structure was too soft to operate on. At 1401 hours, FF #6 proceeded to the roof of exposure D1 with a chainsaw to assist the DC with ventilation efforts. The E2 crew was assigned to extend a hoseline up the aerial to the exposure D2 roof. At 1402 hours, the natural gas was turned off to the fire structure. At 1404 hours, L2's crew was in the process of evacuating exposure B. Two fire fighters, on the C-side of exposures D1 and D2, went to assist the gas utility company in getting the natural gas turned off to both adjoining exposures, but both gas meters were buried in ice and snow. *Note: It had snowed days before and the flat roofs had been shoveled off. The snow from exposure D2's roof had buried the meters on the common wall of exposures D1 and D2.* At 1405 hours, the IC requested a page out to recall off-duty personnel.

At 1408 hours, E9 arrived on scene and was assigned to the C-side. Two 1¾" hoselines were pulled from E9. E9 was not connected to a hydrant. No flames were visible at this time on the C-side. The roof crew had made the initial cuts for ventilating exposure D1 but had difficulty due to heavy smoke emanating from the cuts and did not get the cut section to drop. Exposure D1 started to show heavy brown smoke in the interior. At 1410 hours, smoke was getting heavier inside the fire structure and exposure D1. The Fire Chief arrived on scene and aided the IC. At 1411 hours, the L2 crew proceeded to the roof of exposure B using the stairwell and reported that light brown smoke was venting from an old chimney in the common wall of the fire structure and exposure B.

At 1415 hours, the fire structure had self-vented and flames 4 to 5 feet high were coming through the roof. The E9 crew (C-side) and the roof crew (FF#1, FF#2, and FF#5 on exposure D2) flowed water on the flames and on the common wall of the fire structure and exposure B. After trying another location, the ventilation crew (DC and FF #6) were still unable to vent the D1 exposure's roof. At 1418 hours, FF #3 requested that command have the doors closed on the A-side of the fire structure and exposure D1 to give the vent crew more time to ventilate. *Note: the C-side doors were left open.* The roof crew attempted to vent the roof of exposure D1 by using the water pressure from the hoseline to open up the cut sections of roof, but was unsuccessful. At 1419 hours, the smoke was getting darker at floor level and was beginning to roll inside the fire structure and exposure D1. At 1420 hours, E9 had to connect



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to a hydrant, the roof of exposure D1 was still not vented, the natural gas to exposures D1 and D2 still was not turned off, and the A-side plate glass windows on the fire structure and exposure D1 were beginning to vibrate.

At 1421 hours, an interior attack team (Lieutenant, FF #4, and FF #8) with a TIC and 1¾” hoseline entered exposure D2 to look for fire extension. With light smoke visible, they checked the temperature near the ceiling with a TIC (92–100 degrees Fahrenheit) and moved toward the interior rear of exposure D2. The DC noticed the roof on exposure D1 getting soft and ordered everyone onto the roof of exposure D2. *Note: One member of the roof crew indicated that they were beginning to feel hot and one member thought they heard a pop.* The crew on the C-side of the exposure D1, working with the gas utility company, managed to turn off the gas to exposure D1; the gas to exposure D2 was still on. The roof crew broke the skylight on the roof of exposure D2 and light smoke vented from inside the structure. *Note: This skylight was framed in (boxed) to the lowered ceiling of exposure D2. Thus, the large void space (attic) was not vented when the skylight was broken.* The interior attack crew, located inside exposure D2, elected not to enter the basement. They exited exposure D2 to have a face-to-face with command on their next move due to the large volume of radio traffic. The Lieutenant went to talk to command while FF #4 and FF #8 staged on the exterior A-side of exposure D2, a few feet from the door. *Note: At this time, there were no interior crews in any of the structures.* The vent crew (DC and FF #6) had moved to the A-side of the roof of exposure D2. The roof team (FF #1, FF #2, and FF #5) were halfway back on the roof near the parapet wall common to exposures D1 and D2. The DC noticed white smoke beginning to come from the vents in the C-side of exposure D2. FF #7, on the ground by the L2, heard a loud pop.

At 1427 hours, an explosion sent debris horizontally from the A-side of the fire structure and exposures D1 and D2, covering fire fighters on the street with glass, wood, and bricks. *Note: Flying debris injured FF #4 and FF #8 staged near the door of the D2 exposure and FF #3 and FF #7 staged several feet from the A-side of exposure D1. The officer-side window of L2 was broken by debris from the blast. Debris was found on the sidewalk across the street, approximately 40 feet away.* The A-side portion of the roof of exposure D2 heaved up about 5 feet, sending the DC into the air and to the ground. The roof underneath FF #6, who was beside the DC, pulled away from the parapet wall leaving him standing on a beam several feet below the roof line. On exposure D2’s roof, FF #1, FF #2, and FF #5 were knocked off their feet.

Following the explosion, the aerial from L2 was repositioned to the roof of exposure D2 in order to reach the trapped fire fighters. Fire fighters on the aerial were able to get FF #6 off the beam, and the roof crew was able to crawl over the heaved portion of roof and slide down to the aerial. Nine fire personnel were transported to the hospital: the vent team (DC and FF #6), the roof team (FF #1, FF #2, and FF #5), and the four fire fighters (FF #3, FF #4, FF #7, and FF #8) on the ground near the A-side doors of exposures D1 and D2.



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FIRE BEHAVIOR

The Fire Marshal's report stated that the fire originated in the upper portion of the hood system in the fire structure (restaurant) and subsequently involved the duct work over the wood-fired grill. Radiant heat, from an insufficient 6" clearance and possibly direct flame from the spot-welded duct work seams, impinged on the wood wall. The 1991 Uniform Mechanical Code which was in place at the time of the hood system installation required the duct work to have a minimum clearance of 18" from combustibles and liquid-tight, welded seams.¹ The Fire Marshal reported that the hood fire suppression system had deployed, but was ineffective. The fire extended up the wall assembly and vented into the common attic.²

Significant indicators of fire behavior

- Dispatch reported visible smoke and flames through the roof of a commercial structure; upon arrival, 8 minutes after being dispatched, the fire department saw no flames or smoke.
- On arrival, the fire department found light smoke in the interior of the fire structure and adjacent building (exposure D1). The thermal imaging camera (TIC) had shown heat across the ceiling to the wall that was common with the next adjacent building (exposure D2). (See Diagram 1.)
- Eighteen minutes after arrival, an evaporative cooler was knocked over on the fire structure's roof to assist in ventilation and the roof crew reported that the roof was getting soft.
- Twenty minutes after arrival, the interior attack crew had not found fire in the fire structure or exposure D1.
- Twenty-two minutes after arrival, smoke was getting heavier inside the fire structure and exposures D1 and D2.
- Twenty-seven minutes after arrival, the fire structure had self-vented and flames 4 to 5 feet high were coming through the roof.
- Thirty minutes after arrival, command approved a request to close the doors at the front (A-side) of the fire structure and exposure D1 to give the vent crew more time to ventilate.
- Thirty-one minutes after arrival, the smoke on the floor level of the fire structure was getting darker and beginning to roll.
- Thirty-two minutes after arrival, the A-side plate glass windows on the fire structure and exposure D1 were beginning to vibrate.
- Thirty-three minutes after arrival, exposure D2 had light smoke visible and the TIC temperature reading toward the ceiling was 92–100 degrees Fahrenheit.
- After approximately twenty minutes of trying to vent the roof of exposure D1, the smoke in the common attic space became pressurized.
- Thirty-four minutes after arrival, the DC noticed the roof of the exposure D1 getting soft. A member of the roof crew indicated that they were beginning to feel hot and one member heard a pop.
- The roof crew broke the skylight on the roof of exposure D2 and light smoke vented from inside the structure. *Note: This skylight covered a framed-in shaft that extended from the*



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roofline 9 feet deep to the lowered ceiling of exposure D2. Thus, the large void space (attic) was not vented when the skylight was broken.

- Thirty-eight minutes after arrival, white smoke was beginning to come from the vents on the C-side of exposure D2 at the time that a fire fighter on the ground on the A-side of exposure D1 heard a loud pop.
- Thirty-nine minutes after arrival, an explosion sent debris horizontally from the A-side of the fire structure and exposures D1 and D2. The force was so great that the A-side portion of the roof of exposure D2 heaved up about 5 feet sending the DC into the air and to the ground, and the roof pulled away from the parapet wall; the officer's side window of L2 was broken by debris from the blast and debris was found on the sidewalk across the street, approximately 40 feet away.

As indicated by the fire marshal's report, the fire started in and around the duct work above the wood-fired grill, which was about three quarters of the way down the D-side wall (see Photo 3). As the fire extended up the wall, the smoke filled the common attic space (see Diagram 2). As the fire grew and built up pressure, the smoke from the common attic space was pushed through the deteriorated 100-year-old mortar joints and several 2- x 4-inch rectangular holes in the brickwork of the common wall between exposures D1 and D2 (see Photo 4). Gray smoke was noticed puffing out of the parapet walls due to the smoke in the common attic space of the fire structure and exposure D1, becoming more pressurized. The roof of the fire structure self-vented. Smoke on the ground level floors of the fire structure and the adjoining exposure D1 became dark and rolling. The A-side plate glass windows and glass door began to vibrate and eventually broke the top glass pane of the door. The heat was building up in the common attic space of exposure D1. White smoke was observed coming from the vents in the rear of exposure D2, followed by popping sounds. Shortly thereafter, the explosion occurred, sending debris 40 feet horizontally and heaving up the roof of exposure D2 by 5 feet. No flames were observed in the explosion.

These accounts lead to the hypothesis that a smoke explosion occurred. A smoke explosion involves a contained layer of flammable smoke existing within its temperature limits of flammability coming in contact with a source of ignition. Perhaps the ignition source was an ember or fire from along the common wall of exposures D1 and D2. Smoke explosions usually occur with a smoke/gas/air pre-mix below 650 degree C. White smoke conditions may offer a warning sign of an impending smoke explosion. A smoke explosion produces pressure waves, which usually cause structural damage, with no flames involved.³

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 injuries of nine fire fighters:

- Fire growth and the accumulation of pressurized smoke in common attic and void spaces.



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- Unrecognized building characteristics that contributed to the fire and explosion hazard.
- Ineffective ventilation techniques.
- Execution of offensive operation SOPs.
- Inadequate staffing of firefighting personnel.

CAUSE OF INJURIES

According to the medical records, all of the fire fighters' injuries were due to the explosion resulting in concussive, debris impact, and fall-related injuries. Of the fire personnel on the roof, the DC sustained chest, shoulder, hip, and hand injuries; FF #5 had a hand injury; FF #6 had a serious knee injury; and the other two roof team fire fighters (FF #1 and FF #2) had minor injuries. Of the fire fighters on the ground, one had a serious neck injury (FF #3), one had smoke inhalation (FF #7) from the explosion, and the other two (FF #4 and FF #8) were held for observation, treated and released.

RECOMMENDATIONS

Recommendation #1: Fire departments should ensure that ventilation techniques are established and executed.

Discussion: Ventilation is performed to remove the products of combustion, allowing fire fighters to advance on the fire. When venting, the principle is to pull the fire, heat, smoke, and toxic gases away from victims, stairs, and other egress routes.⁴ Ventilation is necessary to improve a fire environment so that fire fighters can approach a fire with a hoseline for extinguishment and to avoid the smoke buildup and flammable gases that can lead to an explosion or flashover as occurred here. Command should determine if and where ventilation is needed. It is one of the IC's most important tactical considerations. The type of ventilation should be based on an evaluation of the structure and conditions on arrival. Decisions regarding ventilation should be communicated to all fire fighters on the scene.

Proper ventilation can have a positive effect on all three fireground priorities (life safety, extinguishment, and property conservation). However, if ventilation is inadequate, an offensive attack will be adversely impacted, allowing fire spread and conditions to develop for a backdraft or smoke explosion.^{4,5}

In this incident, a ventilation crew made several attempts to open up the roof. However, the chainsaw they used was unsuccessful in removing enough material to allow the rectangular section of roof to open due to the layers of antiquated and modern roofing materials and smoke choking the chainsaw. The attempts to vent the roof of exposure D1 continued for approximately 20 minutes. After several failed attempts, an alternate tactic or strategy could have been considered, such as using a concentrated water stream, from a water monitor or several large hoselines, to cool the roof surface and the potentially explosive gases or to pouch open the roof cut areas.



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A skylight was vented on exposure D2, but this action only vented the light smoke from the ground floor. Removing the large boxed-in area of the skylight would have vented the void space, removing the heavier smoke. In addition, the horizontal ventilation, via the front doors of the fire structure and exposure D1, was stopped in order to restrict oxygen, but this may have elevated smoke conditions for a backdraft or smoke explosion.

Recommendation #2: Fire departments should conduct pre-incident planning and inspections of buildings within their jurisdictions to facilitate development of safe fire-ground strategies and tactics.

Discussion: National Fire Protection Association (NFPA) 1620 *Recommended Practice for Pre-Incident Planning*, 2003 Edition, § 4.4.1 states “the pre-incident plan should be the foundation for decision making during an emergency situation and provides important data that will assist the incident commander in developing appropriate strategies and tactics for managing the incident.” This standard also states that “the primary purpose of a pre-incident plan is to help responding personnel effectively manage emergencies with available resources. Pre-incident planning involves evaluating the protection systems, building construction, contents, and operating procedures that can impact emergency operations.”⁶ A pre-incident plan identifies deviations from normal operations and can be complex and formal, or simply a notation about a particular problem such as the presence of flammable liquids, explosive hazards, common attic, drop ceilings, roofing materials, modifications to structural building components, or structural damage from a previous fire.^{5,7}

In addition, NFPA 1620 outlines the steps involved in developing, maintaining, and using a pre-incident plan by breaking the incident down into pre-, during- and post-incident phases. In the pre-incident phase, for example, it covers factors such as physical elements and site considerations, occupant considerations, protection systems and water supplies, hydrant locations, and special hazard considerations. Building characteristics—including type of construction, materials used, occupancy, fuel load, roof and floor design, and unusual or distinguishing characteristics—should be recorded, shared with other departments who provide mutual aid, and if possible, entered into the dispatcher’s computer so that the information is readily available if an incident is reported at the noted address.

In this incident, no pre-incident inspections were available. A building inspection and pre-incident plan for this single-story commercial building could have potentially identified the common void space, the modified construction, the roofing materials, the boxed-in skylight, and the construction type and materials. The pre-incident planning process could have provided this information which may have aided the incident commander in developing a safer and more effective offensive or defensive strategy.

Recommendation #3: Fire departments should ensure that standard operating procedures (SOPS) for offensive operations are followed, such as, cutting utilities and checking extension into void spaces.

Discussion: During an offensive attack, the fire fighters are responsible for a wide range of important tasks, such as primary search, rescue, and forcible entry; checking for fire extension; ventilating;



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accessing concealed/void spaces; cutting utilities; and laddering the building. To conduct these tasks, fire fighters need to carry the proper tools, e.g., TIC, utility bar, pike pole, axe. It is critically important to properly staff companies that are charged with ladder company duties. Safety and control dictate that operating units work as groups. Given the variety of tasks and that many of these tasks can be performed by two-member teams, it may be necessary to split into separate crews.⁵ At a working structure fire, two members may be required to conduct primary search, while a second two-member crew may check for fire extension.

In this incident, an engine company consisting of an officer and three fire fighters, instead of a ladder company, entered the fire structure and saw light smoke in the grill area but did not have a TIC and did not utilize a pike pole to check the void spaces for fire. Using a TIC to locate the seat of the fire or pulling the ceiling just inside the doorway in the fire structure may have provided adequate information for a different and more expeditious fire-fighting tactic. A TIC was utilized in the adjoining buildings.

Recommendation #4: Fire departments should ensure that standard operating procedures for a 360-degree size-up are followed.

Discussion: The process of conducting a size-up includes the consideration of many factors, which include a 360-degree walk-around and assessment of the type of building construction, location of doors and access to the structure, occupancy and contents of the structure, location of the fire event in the structure, time of day, weather conditions, time of the alarm, and day of the week.⁸ A 360-degree walk-around implies a circle around the structure, but when situations permit it should also include an aerial view or overview of the roof. Complete size-ups of fire incidents assist the IC in determining needed and available resources and in making a sound strategy prior to initiating an offensive, interior attack that increases safety risks for firefighters.⁵

In this incident, the dispatch reported fire and smoke, but when the fire department arrived, only light to medium smoke was visible at ground level. The fire structure shared common walls with adjoining structures. One of the adjoining structures was much taller than the fire structure; it is possible that flames could have been visible from the upper floors of the adjoining structures looking down on the roof of the fire structure. The aerial on the ladder truck could be utilized for this purpose as well. Initially, the C-side of the fire structure was not sized up until E9 arrived.

Recommendation #5: Fire departments should ensure that staffing levels are sufficient to accomplish critical tasks.

Discussion: The National Fire Protection Association (NFPA) 1710 Standard identifies the minimum resources for an effective fire fighting force to perform critical tasks. These tasks include establishing water supply, deploying an initial attack line, ventilating, performing search and rescue, and establishing a rapid intervention team (RIT). NFPA 1710 recommends that four is the minimum staffing level for fire fighting personnel for an engine company to perform effective and efficient fire suppression tasks.²



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The rear of the fire building has the potential for rapid, undetected fire spread. A response to the rear of the structure must be accomplished by at least one engine and one ladder or a second engine.

In this case, the initial staffing was below that recommended by NFPA, especially at the rear of the structure. E9 arrived with an officer and was the only engine assigned to the rear of the structure.

Recommendation #6: Fire departments ensure that the incident commander has sufficient aides on the fireground and has a visual view of the fire building.

Discussion: Aides are personnel assigned to assist the Incident Commander (IC). During large operations, sector leaders also may have aides to assist them. Aides do this by managing information and communications. Aides can keep track of assignments, locations, and the progress of companies; assist with tactical worksheets; or access reference materials and pre-incident plans. Another important function aides may perform is to provide reconnaissance and operational details for the IC (his eyes and ears). Some jurisdictions assign full-time aides to command officers to perform routine administrative functions and to act as drivers in addition to their fireground role. It is important that aides have the experience and authority to conduct the required tasks.¹⁰

Safety officers are the mobile eyes of the IC and aid in monitoring the safety of the fire fighters. 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. Also, they must monitor which companies are responding, fireground activity, fire conditions, and additional information from dispatch. If possible, they should also monitor all incoming information from dispatch and the fireground in order to make important decisions. Aides could assist in processing information, without distraction to the IC, and complete the necessary tasks en route to the scene.

The location of the command post should provide a vantage point from which to view the incident. A good location would be in front of the fire structure with a view of the two most critical sides of the structure or the direction toward which a fire may spread.¹⁰

In this incident, the safety officer did monitor the front (A-side) of the fire structure; however, an aide could have been directed to go to the rear of the structure and help facilitate tactics and request additional resources if needed (e.g., to establish a water supply, shut off utilities, and observe fire conditions). The IC's view of the fire structure was partially blocked by L2. If the IC's vehicle had been staged between E1 and L2, a more comprehensive view of the fire structure and exposures may have been possible.

Recommendation #7: Fire departments should ensure thermal imaging cameras are used to locate the seat of the fire and monitor the fire growth.

Discussion: A thermal imaging camera (TIC) can be a useful tool for initial size-up by assisting fire fighters in quickly locating the source (seat) of the fire. This information is critical for planning an effective response with the entire emergency team. Knowing the location of the most dangerous and



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hottest part of the fire may help fire fighters determine a safe and effective approach. Ceilings and floors that have become dangerously weakened by fire damage and are threatening to collapse may be spotted with a TIC. A fire fighter about to enter a room or structure can use a TIC to assist in judging if fire or hot gases are in the walls, attic, or void spaces. The use of a TIC may also provide additional information for the IC during the initial size-up. TICs should be used in a timely manner, and fire fighters should be properly trained in their use and be aware of their limitations.⁵

In this incident, a TIC was not utilized in the fire structure to locate the seat of the fire. A TIC was used effectively to check for fire extension and hot gases toward the ceilings of exposures D1 and D2. The temperature readings taken toward the ceiling were 92–100 degrees Fahrenheit, which helped in the hypothesis of a smoke explosion.

Although there is no evidence that the following recommendations would have prevented these injuries, they are being provided as a reminder of a good safety practice.

Recommendation #8: Fire departments should ensure that radios are operable in the fireground environment.

Discussion: The fireground communications process combines electronic communication equipment, a set of standard operating procedures, and the fire personnel who will use the equipment. To be effective, the communications network must integrate the equipment and procedures with the dynamic situation at the incident site, especially in terms of the environment and the human factors affecting its use. The ease of operation may well determine how consistently fire fighters monitor and report conditions and activities over the radio while fighting fires. To ensure that fire fighters consistently monitor radio transmissions from the IC and respond to radio calls on the fireground, fire departments should review both operating procedures and human factors issues to determine the ease of use of radio equipment.¹¹ The need to have properly functioning equipment during fire operations is critical.

In this incident, fire fighters inside the exposure building and in the rear (C-side) had difficulty transmitting and receiving communications with their VHF radios, causing fire fighting operations to be hindered by not hearing orders and stopping to interface with command face-to-face. The primary problems seemed to be ambient noise from the apparatus and the volume of radio traffic. *Note: An 800-MHz system is planned in the future along with the use of head sets which may greatly improve communications.*

Recommendation #9: Fire departments should ensure an adequate water supply is established.

Discussion: Relying solely on water from the apparatus water tank can be dangerous. A 1,000-gallon tank can be depleted within ten minutes using a 1½” hoseline, leaving an advancing attack crew without water before exhausting their air in their SCBAs. Attacking a fire with anything less than a water supply from a source that is capable of supplying water over an extended period of time is a significant risk.⁵ Rural fire fighters responding to calls in suburbs and towns must be trained to look for hydrants.



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In this case, E9, responding from a rural area station, had depleted its tank water prior to connecting to a hydrant. Thus, fire suppression in the rear was halted during hookup, allowing for fire growth.

Recommendation #10: Fire departments should ensure that any offensive attack on a commercial structure is conducted using at least a 2½ hoseline.

Discussion: Successful fire suppression depends upon discharging a sufficient quantity of water to remove the heat being generated. Selection and placement of hoselines include several factors, such as, the building's construction, size, fire load, and occupancy. Other important factors include location and extent of fire, mobility requirements, and personnel available to handle the hoseline.⁵ Some experts recommend that a 2½" attack hoseline routinely be used with commercial/industrial structures. A single 2½" hoseline may do as much work as two 1¾" hoselines.

In this incident, when the fire department arrived there was no fire showing and the fire building itself was not large. However, the adjoining structures compounded the building's size and created the possibility of rapid fire growth which required a larger hoseline.

Recommendation #11: Fire departments should ensure that collapse zones are established when dealing with older commercial structures and worsening fire conditions.

Discussion: During fire operations, two rules exist about structural collapse: (1) the potential for structural failure always exists during and after a fire, and (2) a collapse danger zone must be established.^{5,12,13} A collapse zone is an area around and away from a structure in which debris might land if a structure fails. The collapse zone area should be at least 1½ times the height of the building—the height of the building plus an additional allowance for debris scatter.⁷ For example, if the wall was 20 feet high, the collapse zone would be established at least 30 feet away from the wall. In this incident, the structure was approximately 18 feet high at the top of the parapet wall, and the collapse zone extended at least 27 feet from the structure.

Fire fighters must recognize the dangers and take immediate safety precautions if factors indicate the potential for a building collapse. An external load—such as a parapet wall, steeple, overhanging porch, awning, sign, or large electrical service connections—reacting on a wall weakened by fire conditions may cause the wall to collapse. Other factors include fuel loads, building damage, renovation work, pre-existing deterioration as well as deterioration caused by the fire, support systems, and truss construction.⁵ Whenever these contributing factors are identified, all persons operating inside the structure must be evacuated immediately and a collapse zone should be established around the perimeter. Once a collapse zone has been established, the area should be clearly marked and monitored to make certain that no fire fighters enter the danger zone. Positioning companies at the corners of the building is usually safer than a frontal attack.⁵ In this incident, a safety zone should have been established given the age of the structure and deteriorating fire conditions.



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Recommendation #12: Fire departments should train on the specific hazards of fighting fires in modified structures to include ingress/egress points, flashover, and structural collapse.

Discussion: A large number of old and antiquated buildings still exists throughout the country and have since been modified in numerous ways (e.g., lowered ceilings, dividing walls erected/removed, utilities rerouted, ingress/egress points closed off, modifications made for commercial applications). To minimize the risk of injury or death to fire fighters, fire departments should train on structural operations, the size-up and risk assessment associated with the age of the building (i.e., construction type, deterioration of structural members, evidence of weathering, use of lightweight materials in new construction), occupancy, and renovations or modifications to the building.^{4,14} Fire departments training on the size-up and risk assessment associated with the age of the building may be more aware of the possibility of common and/or large void spaces, roofing materials, skylight boxes, and building modifications. A pre-incident plan of the building would aid greatly in knowing what modifications were made, however, they are not always available (see Recommendation #2).

In this incident, the fire structure had been constructed in the late 1890s with rough-sawn timber framing and brick and mortar load-bearing walls. The fire structure and adjoining structures had been modified several times over the past 100 years. These modifications included attic spaces common with adjacent structures, egress lanes closed off, and the installation of updated roofing materials, false/lowered ceilings, dividing walls, utilities, and commercial restaurant applications. These factors of age, construction type, and modifications all affect the tactics and strategies of fire fighting—a matter for fire fighters as well as officers.

Recommendation #13: Fire departments should ensure training requirements are standardized across combination department personnel.

Discussion: Fire departments should assess whether the differences in training levels between career and volunteer personnel has an impact on safety. If so, then these differences should be identified and resolved before an emergency occurs where lives may be at stake. Training protocols must be developed for rank and skill levels regardless of career or volunteer status. Combination departments should make the same training available and affordable for both volunteer and career fire fighters. Combination departments should train volunteer and career personnel together and not wait until an incident occurs to attempt to integrate the personnel into a functional team.

Additionally,

Recommendation #14: Municipalities should establish and enforce building and inspection codes.

Discussion: Occupancy changes understandably occur with great frequency. However, every effort should be made as new permits are issued to aggressively inspect any occupancy change. It is critical that municipalities assess all renovations or remodeling for compliance to current codes. Building inspections should specifically consider building information relevant to fire fighter and civilian safety. This information can be collected and shared between building and fire departments.



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Recommendation #15: Municipalities should identify/mark buildings on the C-side (rear) when buildings share common walls or are in very close to each other to aid fire fighters in identifying the fire structure.

Discussion: Frequently, commercial buildings and row houses can occupy an entire street block making it difficult to identify the fire structure when it is not on the end of the block or when no fire or smoke is showing in the rear. Thus, a fire fighter's job can be more efficiently expedited by having the buildings identified or marked by building number or business name.

In this case, during the interview process, fire fighters noted that the fire structure and exposures were hard to identify from the rear due to all the buildings being connected.



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**Photo 1. The fire structure's front was brick with large plate glass windows and a parapet wall covered with a wooden façade.
(NIOSH photo)**



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Photo 2. This picture shows the restaurant (fire structure) on the right and the involved adjacent retail store on the left (exposure D1) (see Diagram 1). The building had been remodeled several times which included dividing the building in half via a wood stud wall (in middle of photo), lowering the ceiling in both halves yet sharing a common attic space.

(NIOSH photo)



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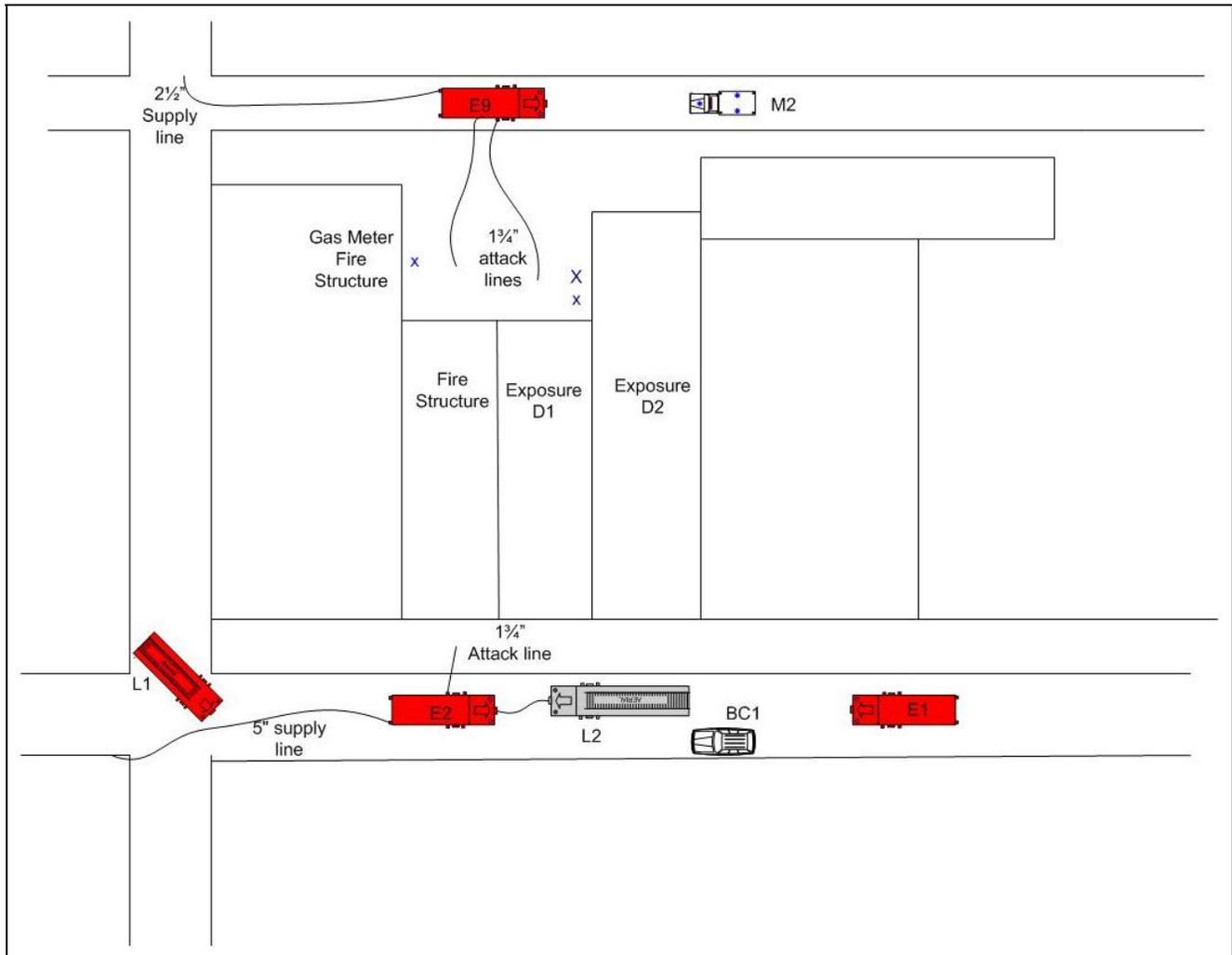


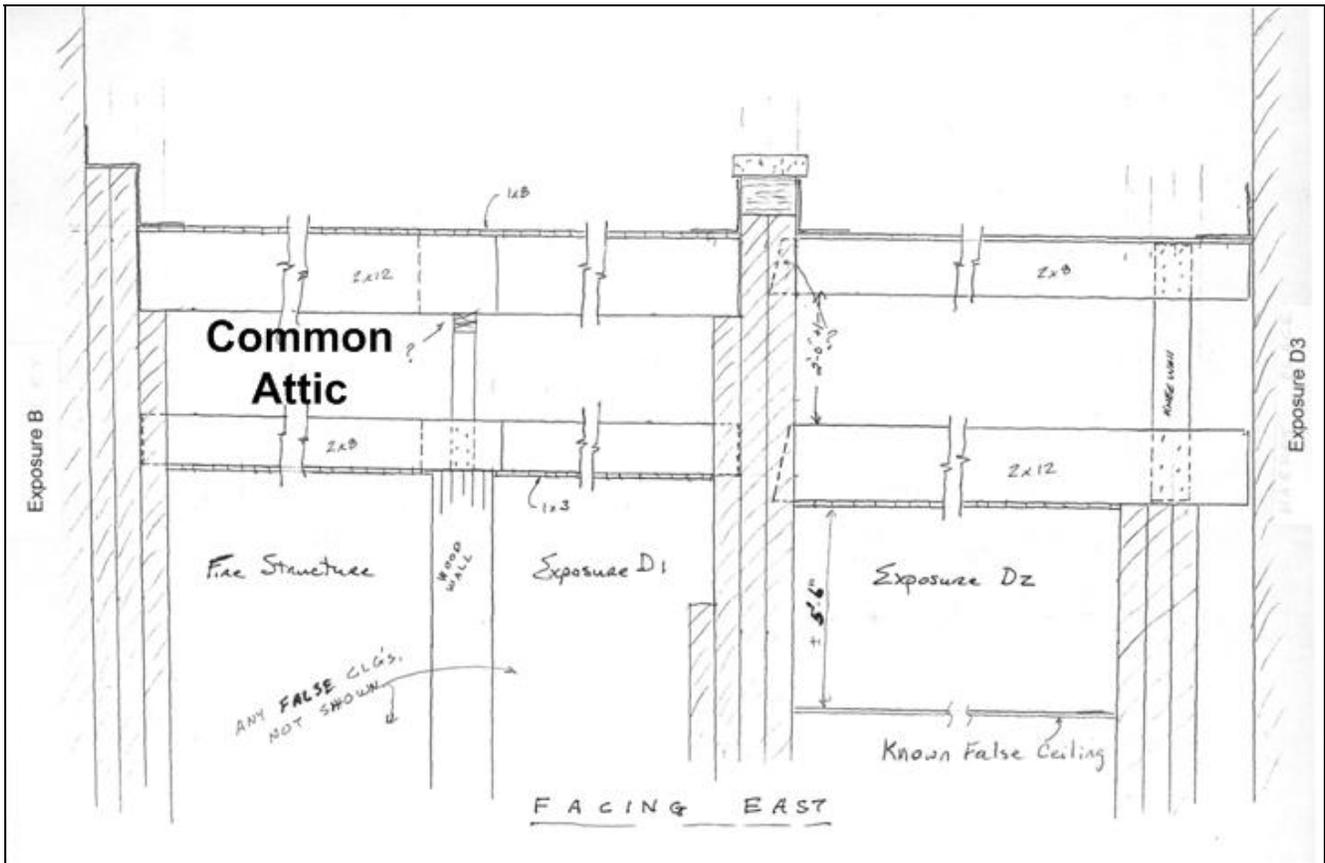
Diagram 1. Approximate locations of key apparatus and hoseline placement.



Photo 3. The fire structure's D-side wall where the fire originated in the duct work above the wood grill.
(NIOSH photo)



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**Diagram 2. Depicts front view showing construction of the fire structure in relation to the exposures, such as, the large shared common attic space and common wood framed wall of the fire structure and exposure D1. The attic and void space account for approximately 108 inches empty space in exposure D2.
(Courtesy of the Fire Department)**



**Photo 4. Exposure D2's B-side wall with existing 2" x 4" holes in the void space area.
(NIOSH photo)**



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REFERENCES

1. IAPMO (International Association of Plumbing and Mechanical Officials) [1991]. Uniform mechanical code.
2. Fire Marshal Office [2008]. Fire Investigation (Cause & Origin) Report; Incident #08000718.
3. Firetactics.com [2008]. WHITE SMOKE WARNING for FIREFIGHTERS – SMOKE EXPLOSION.
4. International Fire Service Training Association [2000]. Fire service ventilation, 7th ed. Stillwater, OK: Fire Protection Publications, Oklahoma State University.
5. Klaene BJ, Sanders RE [2000]. Structural fire fighting. Quincy, MA: National Fire Protection Association.
6. NFPA [2003]. NFPA 1620: Recommended practice for pre-incident planning. Quincy, MA: National Fire Protection Association.
7. International Fire Service Training Association [2008]. Essentials of fire fighting and fire department operations, 5th ed. Stillwater, OK: Fire Protection Publications, Oklahoma State University.
8. Brunacini, Alan V [1985]. Fire command. Quincy, MA: National Fire Protection Association.
9. NFPA [2004]. NFPA 1710: Standard for the organization and deployment of fire suppression operations, emergency medical operations, and special operations to the public by career fire departments. Quincy, MA: National Fire Protection Association.
10. Smith JP [2002]. Strategic and tactical considerations on the fireground. Upper Saddle River, NJ: Prentice Hall.
11. Fire fighter's handbook [2000]. Essentials of fire fighting and emergency response. New York: Delmar Publishers.
12. NIOSH [1999]. NIOSH alert: preventing injuries and deaths of fire fighters due to structural collapse. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 99-146.
13. Brannigan FL [1999]. Building construction for the fire service. 3rd ed. Quincy, MA: National Fire Protection Association.



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14. Dunn V [1988]. Collapse of burning buildings, a guide to fireground safety. Saddle Brook, NJ: Fire Engineering Books and Videos.

INVESTIGATOR INFORMATION

This incident was investigated by Matt Bowyer, General Engineer and Stacy Wertman, Safety and Occupational Health Specialist, with the Fire Fighter Fatality Investigation and Prevention Program, Division of Safety Research at NIOSH. An expert technical review was conducted by John Salka, Jr., Battalion Chief, Fire Department of New York.