

Fire Behavior Case Study



Introduction

Developing mastery of the craft of firefighting requires experience. However, it is unlikely that we will develop the base of knowledge required simply by responding to incidents. Case studies provide an effective means to build our knowledge base using incidents experienced by others.

Aim

Firefighters and fire officers recognize and respond appropriately to the interrelated hazards presented by building construction and rapid fire progress in residential structures.

References

National Institute for Occupational Safety and Health (NIOSH). (2008). *Death in the line of duty, Report F2006-6*. Retrieved December 18, 2008 from <http://www.cdc.gov/niosh/fire/pdfs/face200806.pdf>

Learning Activity

Review the incident information and discuss the questions provided. Focus your efforts on understanding the interrelated factors that influenced the outcome of the incident including building construction, fire behavior, and tactical operations. Even more important than understanding what happened in this incident is the ability to apply this knowledge in your own tactical decision-making.

The Case

This case study was developed using National Institute for Occupational Safety and Health (NIOSH) Death in the Line of Duty Report F2008-06, United States Fire Administration (USFA) Firefighter Line of Duty Death Database, news media reports, and information obtained from the departments involved in the incident.

On February 29, 2008 Firefighter Brad Holmes and Lieutenant Scott King were assigned to perform primary search of Exposure Bravo at a fire in a wood frame duplex in Grove City, PA. During their search, rapidly deteriorating conditions trapped the search crew. After being rescued by the Rapid Intervention Team, both members were transported to Pittsburgh's Mercy Hospital Burn Unit. Firefighter Brad Holmes had burns over 75% of his body, and died from his injuries on March 5, 2008. Lieutenant King suffered less serious injuries and was treated and released. A 44 year old female occupant of the dwelling was trapped trying to rescue a pet and also died.

Figure 1. 132 Garden Avenue-Side Alpha



Note: Fire Department Photo - NIOSH Death in the Line of Duty Report F2008-06. This photo likely illustrates conditions after 0635, while Firefighter Holmes and Lieutenant King are searching Floor 2 of Exposure B.

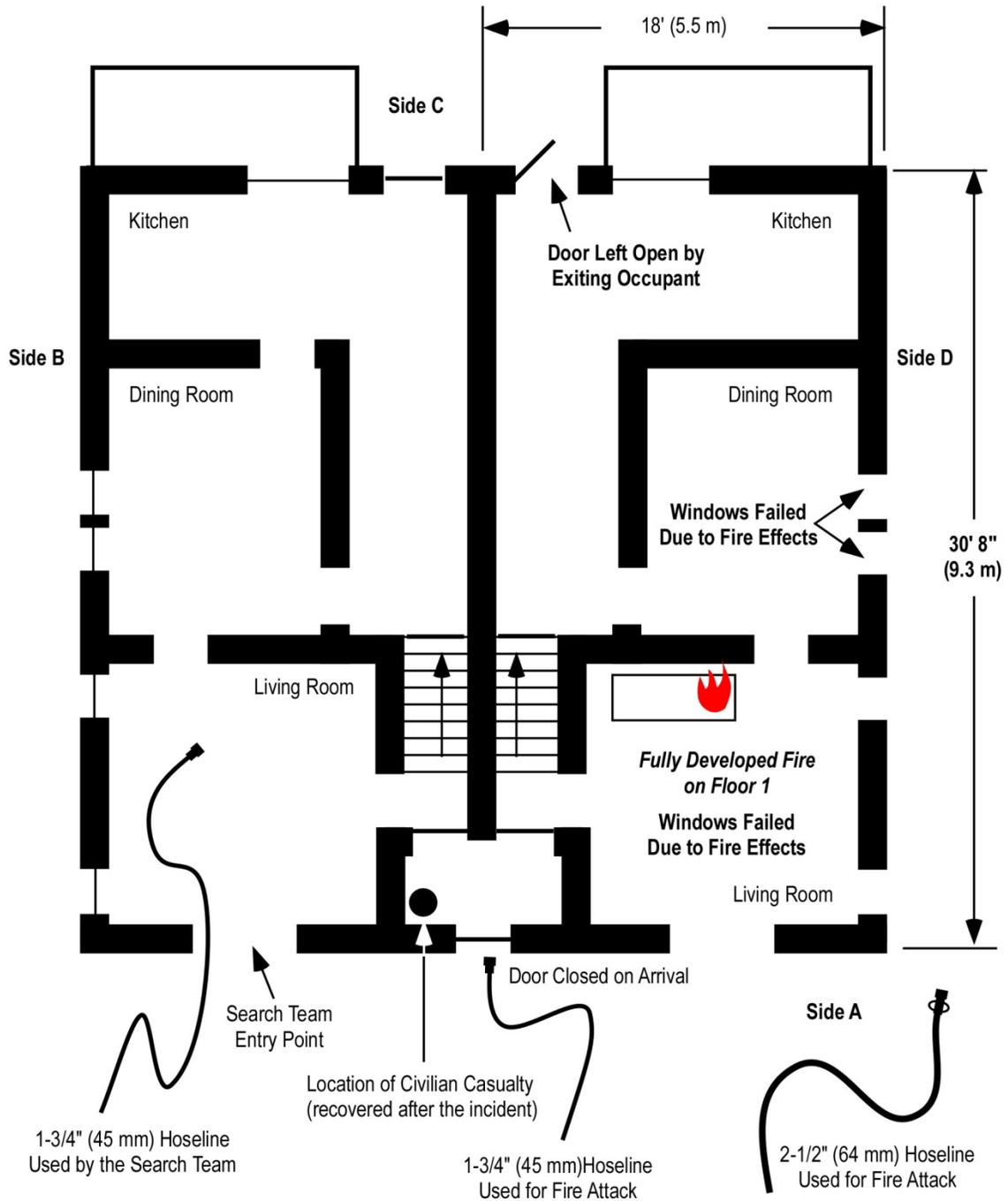
Building Information

The fire originated in the D Side unit of a two-story, wood frame duplex at 132 Garden Avenue in Grove City, Pennsylvania. The building was originally built in the 1930s and remodeled into two separate dwelling units in the 1960s.

The 36' x 30' structure was of balloon-frame construction and had a basement. Interior construction was plaster over wood lath with carpeting over hardwood floors. The unit on Side D (fire unit) had wood paneling throughout the first floor. Exterior construction was wood clapboards over wooden framing. The building was not insulated and did not contain a rated fire wall between the units. The roof covering was asphalt shingles over an undetermined type of wood sheathing.

As illustrated in Figures 2 and 3, the floor plan of each unit was a mirror image of the other. The first floor had a living room, dining room and kitchen and a deck on Side C. The units shared a common entry on Side A. The second floors had two bedrooms and a bathroom.

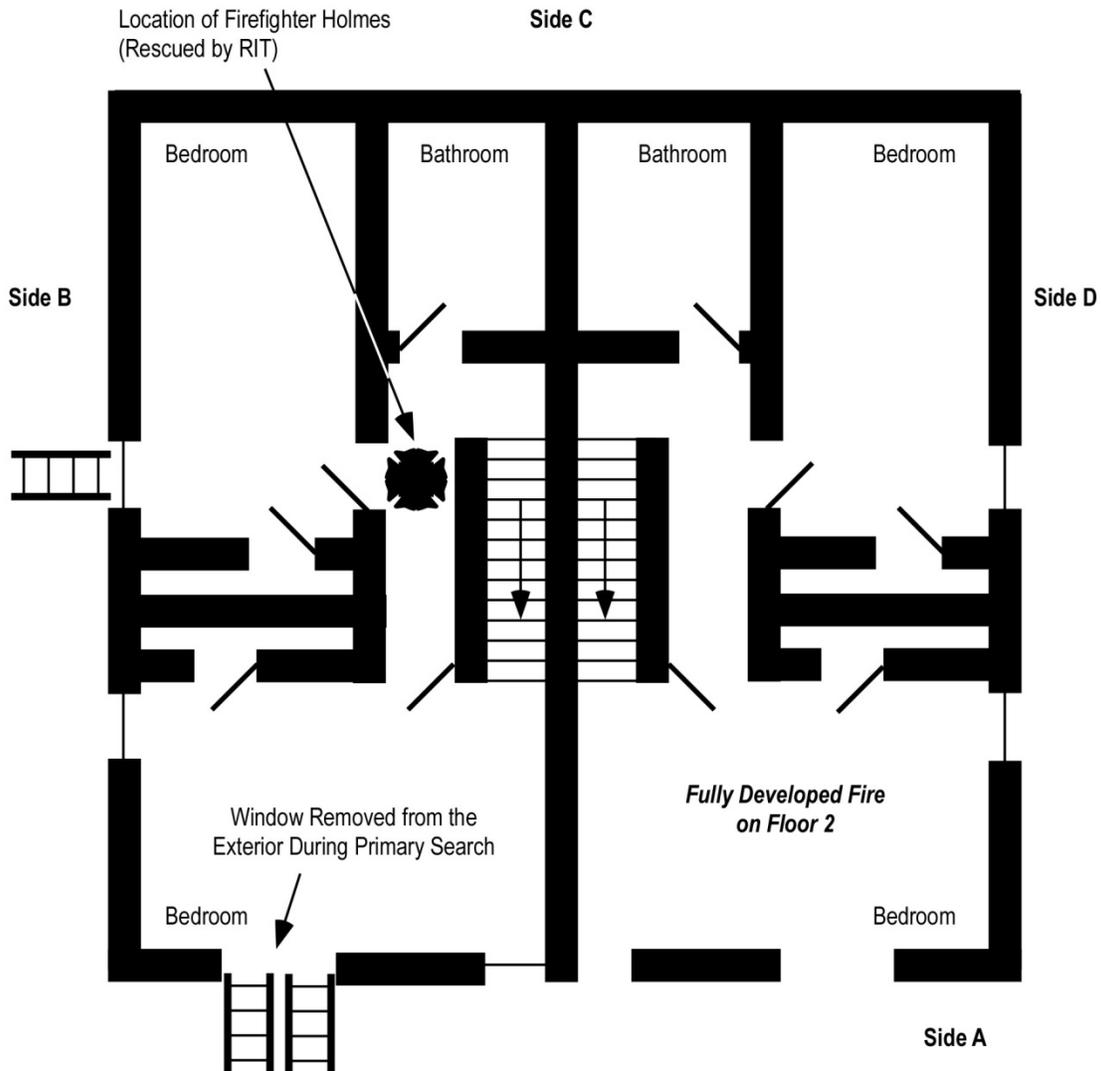
Figure 2. Fire Unit and Exposure Bravo Floor 1



Note: This floor plan is based on data provided in NIOSH Report F2008-06 and is not drawn to scale. Windows shown as open are based on the narrative or photographic evidence. Door position is shown

based on information provided by NIOSH Investigator Steve Berardinelli (this differs from the NIOSH report which includes a hand drawn fire investigators sketch showing all doors open). Windows shown as intact are not visible in the available photographs, but may be open due to fire effects or firefighting operations (particularly those in the fire unit).

Figure 3. Fire Unit and Exposure Bravo Floor 2



Note: See the prior comments regarding windows and door position.

The Fire

The fire originated on the couch in the living room of the D Side unit. The female occupant had been using a hair drier for warmth and left it running under blankets on the couch in the living room. Her husband discovered the fire and went to the kitchen to get a pan of water to extinguish the fire. However, when he returned his wife was gone and he was unable to extinguish the fire and exited the unit through the door on Side C, leaving the door open. He called 911 using a cell phone immediately on exiting the house.

Dispatch Information

The initial call reporting this incident was 0606 hours, but was disconnected prior to communication of the nature of the emergency. A law enforcement unit was initially dispatched to the address to investigate the interrupted call. A second call was received from an occupant of the fire unit (Side D) at 0609 reporting the fire at 132 Garden Street and that his wife was trapped.

Station 95 (Chief 95, Accountability Officer (POV), Engine 95, Engine 95-2, Squad 95) and Ambulance 100 were dispatched at 0610 followed by Stations 85 (Engine 85, Engine 85-2, Squad 85) and 87 (Rescue 87) at 0611.

The law enforcement officer initially dispatched to the disconnected call arrived at 0612 and reported a working fire with entrapment. Based on this report, the Station 95 Assistant Chief (unit not specified) requested an additional engine prior to arrival. Station 77 (Engine 77, Brush 77, and Water Tender 77) was dispatched at 0614.

Weather Conditions

The temperature was 6° F (-14° C) with no wind. Ambient temperature was a significant factor in this incident as the two closest hydrants were frozen, rendering them inoperative.

Conditions on Arrival

Chief 95 arrived at 0616 and established Command. Fire was showing from the first floor unit on Side D extension and there was significant involvement of Floor 2 of the same unit. The IC did a quick 360° size-up and determined the structure was a duplex by the two separate decks at the rear of the structure. However, this information was not communicated to the responding companies. The IC spoke to law enforcement and confirmed that there was an occupant trapped, but received no information about the occupant's last known location.

Firefighting Operations

Command assigned Engine 95 (officer and five firefighters) to fire suppression. They deployed a 1-3/4" (45 mm) line to the door on Side A, but were unable to make entry due to the volume of fire in the involved unit. Engine 95 also deployed a 2-1/2" (64 mm) handline to the A/D corner. Both lines were immediately placed into operation. NIOSH Report F2008-06 indicated that the 1-3/4" line stretched to the door on Side A was "unable to make entry due to heavy fire conditions". However, exact placement and operation of the 2-1/2" handline was not specified. This line may have been used to protect

Exposure D (a wood frame dwelling approximately 20' from the fire unit), for defensive fire attack through first floor windows, or both.

Second due, Engine 95-2 performed a forward lay from a hydrant on Craig Street (see Figure 4) and supplied Engine 95 with tank water while waiting for the supply line to be charged.

Engine 85 (chief, lieutenant, and three firefighters) was assigned to primary search and rescue of the trapped occupant. Tasked to conduct primary search in Exposure B, Firefighter Holmes and Lieutenant King were performed a 360° reconnaissance prior to making entry. While this was being done other members of the company placed a ladder to a window on Floor 2 Side B (see Figure 3). *NIOSH Report F2008-06 does not specify if the search team was aware of ladder placement.*

The Officer of Engine 95 vented the window on Floor 1 Side A of Exposure Bravo and observed that the ceiling light was on (indicating that there was limited optical density of the smoke on Floor 1 of the exposure). Firefighter Holmes and Lieutenant King entered through this window (see Figure 2) to conduct primary search of the exposure and observed that the temperature was low and there was limited smoke on Floor 1. Engine 95 passed the search team a 1-3/4" (45 mm) handline through the window and the search team knocked down visible fire extension and completed their search of the first floor. At this point, Firefighter Holmes and Lieutenant King left the hoseline on Floor 1, went up the stairs to Floor 2 and began a left hand search.

The Officer of Engine 95 noticed that the search crew had finished their search on the first floor and were advancing to the second floor. He placed a ladder and broke the window on Floor 2, Side A (See Figure 3). He stated that there was not much heat on the second floor because the plastic insulation on the window was not melted, but he did notice heavy black smoke beginning to bank down. *NIOSH Report F2008-06 did not specify the depth of the hot gas layer (down from the ceiling) or the air track at the window that was vented or Floor 1 openings (windows and door).*

The hydrant that Engine 95-2 laid in from was frozen as was the closest hydrant on Garden Avenue (several houses beyond the fire building). First alarm companies used tank water to support initial firefighting operations. The crew from Engine 95-2 began to hand stretch a 3" line to a hydrant on Craig Street, east of Garden Avenue. *Due to the complexity of water supply operations, additional detail is provided in a subsequent section of this case.*

After Firefighter Holmes and Lieutenant King partially completed their search of Floor 2, Lieutenant King's air supply was at one half and Firefighter Holmes was unsure of his air status, so the Lieutenant decided to exit. At approximately the same time, Engine 95 ran out of water and the Command ordered companies to abandon the building with Engine 85 sounding its air horn as an audible signal to do so. The Accountability Officer called for a Personnel Accountability Report (PAR), but received no response from Lieutenant King or Firefighter Holmes.

Almost immediately after Engine 95 ran out of water, conditions changed rapidly decreasing visibility and increasing temperature on Floor 2 of Exposure B and fire involvement of Floors 1 and 2 of both

units. With deteriorating conditions on the second floor, Lieutenant King became disoriented and separated from Firefighter Holmes. He radioed for help at 0638 hours. "Help! Help! Help! I'm trapped on the second floor!" In a second radio transmission, Lieutenant King indicated he was at a window on Side D.

Firefighter Rescue Operations

After hearing radio traffic that the search crew could not find their way out and they were by a window the Engine 95 officer accessed a window on Side B Floor 2 (using a ladder previously placed by Engine 85-2). He broke out the window to increase ventilation and attempt contact with the search team.

A crew from Engine 77 was tasked as a second search team and preparing for entry when the IC ordered companies to withdraw. However, when they heard the Lieutenant's call for help, they immediately went to Side D, not seeing the Lieutenant at the window, they continued to Side B. The officer from Engine 77 climbed the ladder they had placed earlier to attempt contact with the initial search team. There was heavy black smoke coming from this window, but no fire. He straddled the window sill attempting to hear any movement, a PASS device, or voices. He banged on the window sill as an audible signal to the search team, but received no response. He also attempted to locate the search team using a TIC, however, it malfunctioned.

Flames now pushing out the first floor windows of both the unit originally involved in fire as well as Exposure B. Lieutenant King managed to find his way to the staircase, stumbled down the stairs and out the door on Side A. His protective clothing was severely damaged and smoldering. He collapsed in the front yard and told the other firefighters that the victim was trapped on the second floor. The RIT (R87) made entry supported by a hoseline operated from the entry point by Engine 85-2. Firefighter Holmes was located approximately 10' (3 m) from the top of the stairs (as illustrated in Figure 3). He was semi-conscious and on his hands and knees. The RIT removed Firefighter Holmes via the stairway to Side A. Lieutenant King and Firefighter Holmes were transported to a local hospital where they were stabilized prior to transport to the Mercy Hospital's Burn Unit in Pittsburgh.

Water Supply Operations

As the two closest hydrants to the fire were frozen, water supply was a critical factor in this incident. In an effort to sustain firefighting operations while trying to establish a continuous water supply, tank water from multiple apparatus was transferred to the engines supplying handlines. Figure 5 illustrates the hose layout and water supply operations at the incident prior to the Incident Commander's shift to a strictly defensive strategy. Table 1 illustrates the pump, tank, and supply hose capacities of the apparatus used at this incident.

Figure 4. Apparatus Position and Water Supply Operations Prior to 0643 Hours

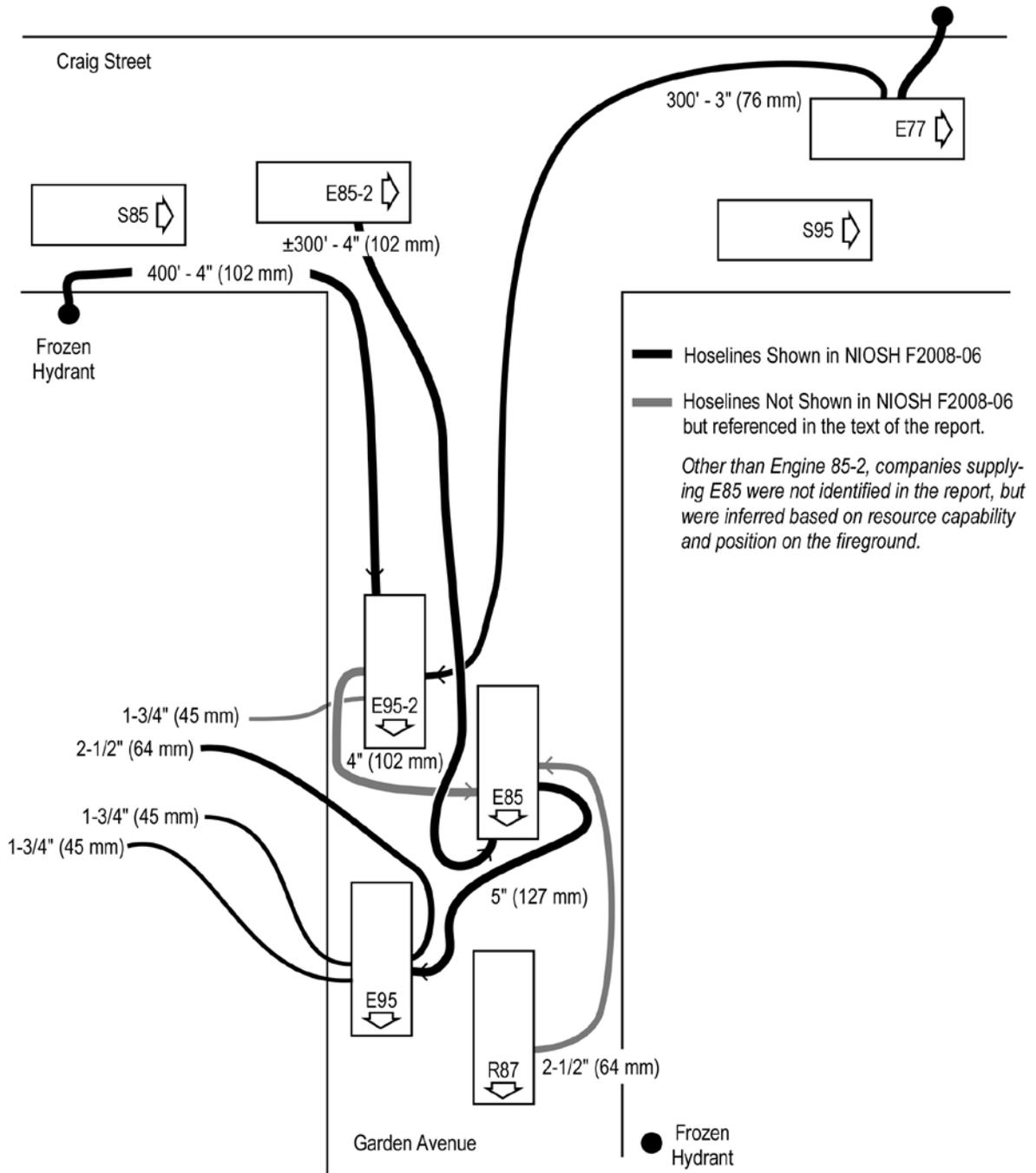


Table 1. Apparatus Capability

| Unit Designation | Pump Capacity | Tank Capacity | Supply Hose |
|-------------------------|----------------------|----------------------|--------------------------|
| Engine 95 | 1500 gpm (5678 lpm)* | 500 gal (1893 L) | 1000'-4" (305 M-102 mm)* |
| Engine 95-2 | 1500 gpm (5678 lpm)* | 750 gal (2838 L) | 1000'-4" (305 M-102 mm)* |
| Engine 85 | 1500 gpm (5678 lpm) | 750 gal (2839 L) | 1000'-5" (305 M-127 mm) |
| Engine 85-2 | 2000 gpm (7571 lpm) | 1500 gal (5678 L) | 1000'-5" (305 M-127 mm) |
| Rescue 87 | 1500 gpm (5678 lpm) | 500 gal (1893 L) | 1000'-4" (305 M-102 mm) |
| Engine 77 | 1500 gpm (5678 lpm) | 1000 gal (3785 L) | 1250'-5" (381 M-127 mm) |
| Water Tender 77 | 1250 gpm (4732 lpm) | 1800 gal (6814 L) | n/a |

Note: Pump capacity and Supply Hose data for Engines 95 and 95-2 are estimated (this information will be updated in Version 1.1 of this Case Study).

Information in NIOSH Death in the Line of Duty Report F2008-06 indicates the following general sequence of water supply operations:

1. Engine 95 initiated operations supplying a 1-3/4 handline and a 2-1/2" handline using tank water. A short time later, a second 1-3/4" line was placed into service to support search operations in Exposure B.
2. Engine 95-2 laid a 400' of 4" hose from a hydrant and deployed a 1-3/4" line. It is unspecified when Engine 95-2 provided a 4" line to provide water supply to Engine 95 (however, this is inferred based on information in the NIOSH report).
3. Engine 85 arrived while Engine 95-2 was in the process of laying in and supplied Engine 95 with its tank water through a 5" line.
4. Engine 85 2 staged on a cross street north of the incident and supplied Engine 85 with tank water through a 4" line.
5. 300' of 3" hose from Engine 95-2 was stretched to a hydrant. Engine 77 pumped the 3" line to supply Engine 95-2.

After Firefighter Holmes was rescued and strategic mode was shifted to defense, Water Tender 77 supplied Engine 85-2. The report states that the tender dropped a portable tank at Engine 85-2 and established a shuttle from an unspecified water supply point. However the scene diagram included in the NIOSH Report F2008-06 illustrates the tender supplying the engine through a hoseline (diameter unspecified) and the portable tank deployed to the rear of the tender.

Incident Timeline

The timeline in NIOSH Report F2008-06 is limited to information that was likely to have been communicated over the radio. The following timeline contains data from the NIOSH report and estimated times based on sequence and estimated time required for task completion. This timeline is

provided to provide a general sequence and flow of operations and may differ slightly from the events as they occurred.

The clock icon is used to identify events for which NIOSH Report F2008-06 identified a specific time. Events which were estimated based on the narrative, photographic evidence, or other information are shown in italic text.

Figure 5. Incident Timeline

| Fire Behavior Indicators & Conditions | Time | Response & Fireground Operations |
|---|------|--|
| Unknown to dispatch or responders, the occupant attempted to fight the fire for some time before calling 911. | 0606 |  Initial 911 call (disconnected), law enforcement dispatched to investigate |
| | 0607 | |
| | 0608 | |
| | 0609 |  Second 911 call reporting a fire at 132 Garden Street with a trapped occupant |
| | 0610 |  Station 95 & Ambulance 100 dispatched |
| | 0611 |  Stations 85 & 87 dispatched |
| | 0612 |  Law enforcement arrived, reports a working fire with entrapment |
| | 0613 | |
| | 0614 |  Assistant Chief 95 (no unit specified) requests an additional engine from Station 77. |
| | 0615 | |
| Flames from windows on Floors 1 and 2 of the unit on Side D (Chief 95) | 0616 |  Chief 95 arrived, assumed command, performed 360° reconnaissance, & confirmed the entrapment of an occupant with law enforcement. Accountability Officer 95 arrived. |
| | 0617 | |
| | 0618 | |
| | 0619 | <i>Command assigned Engine 95 to perform fire attack.</i> |
| Smoke and flame from Floors 1 and 2 | 0620 |  Engine 95 arrived |

| Fire Behavior Indicators & Conditions | Time | Response & Fireground Operations |
|--|-------------|---|
| <p>Side D (Engine 95)</p> <p>Large volume of flame from the A/D Corner (Engine 95-2)</p> <p>Engine 95's 1-3/4" (45 mm) line is unable to progress against the volume of fire in the involved unit.</p> | <p>0621</p> | <p><i>Engine 95 deployed a 1-3/4" (45 mm) line to the door on Side A and 2-1/2" (64 mm) line to the A/D corner</i></p> <p> Engine 95-2 arrived</p> <p><i>Engine 95-2 began forward lay from hydrant on Craig Street west of Garden Avenue.</i></p> |
| <p>Large volume of flame and smoke from Side D and flame from the A/D Corner (Engine 85).</p> <p>Application of water from Engine 95's hoselines had limited effect on the fire (Engine 95).</p> <p>Moderate volume of smoke in Exposure B, limited optical density (thickness), ceiling light in the living room is on and visible from the exterior of the building (Engine 95 Officer).</p> | <p>0622</p> | <p> Engine 85 arrived.</p> <p><i>Command assigns Engine 85 to primary search of Exposure B and rescue of the trapped occupant.</i></p> <p><i>Window on Side A, Floor 1 of Exposure B vented by the Officer of Engine 95 Search Team (Lieutenant King & Firefighter Holmes) perform a 360° walk-around prior to making entry.</i></p> |
| <p>Light smoke and low temperature on Floor 1 of Exposure B (Lt. King)</p> | <p>0623</p> | <p><i>Hydrant on Craig Street frozen. A crew from Engine 95-2 seeks an alternate water supply on Garden Avenue (past the fire building)</i></p> |
| <p>Light smoke and low temperature on Floor 1 of Exposure B (Lt. King)</p> | <p>0624</p> | <p><i>Engine 85 provides tank water to Engine 95 using a 5" (127 mm) line. Search Team (Lieutenant King and Firefighter Holmes) from Engine 85 enters through a window on Side A Floor 1 of Exposure B.</i></p> <p><i>Engine 95 provides a 1-3/4" (45 mm) line to the Search Team.</i></p> |
| <p>Light smoke and low temperature on Floor 1 of Exposure B (Lt. King)</p> | <p>0625</p> | <p><i>Search Team knocks down fire extension into exposure B and conducts primary search of Floor 1 Exposure B.</i></p> <p><i>Engine 85 places a blower at the door on Side A (not started)</i></p> |
| <p>Flames from the roof (Engine 85-2)</p> | <p>0626</p> | <p> Engine 85-2 arrived.</p> |

| Fire Behavior Indicators & Conditions | Time | Response & Fireground Operations |
|---|------|--|
| | | <p><i>Engine 95-2 provides tank water to Engine 85 through a 4" (102 mm) line. Engine 85 is supplying Engine 95.</i></p> |
| | 0628 | <p><i>Crew from Engine 95-2 finds hydrant on Garden Avenue south of the fire building is also frozen.</i></p> <p><i>Engine 85-2 supplies Engine 85 with tank water through a 4" (102 mm) line.</i></p> |
| <p>Flames showing from A/D corner. Large volume of dark smoke showing from Exposure B (Engine 77)</p> | 0629 | <p> Engine 77 arrived.</p> |
| | 0630 | <p><i>Crew from Engine 95-2 begins to hand stretch 3" hose to a hydrant on Craig Street east of Garden Avenue.</i></p> |
| | 0631 | <p> Rescue 87 arrived and assigned as the Rapid Intervention Team (RIT).</p> |
| | 0632 | |
| | 0633 | <p><i>Rescue 87 supplies Engine 85 with tank water.</i></p> |
| | 0634 | <p><i>Search team moves to Floor 2 Exposure B via the interior stairs and began a left hand search.</i></p> |
| <p>Relatively low temperature on Floor 2 Exposure B, plastic window insulation not melted. Black smoke banking down (Engine 95 Officer). However, the depth of the hot gas layer was not specified.</p> | 0635 | <p><i>Ladder placed to a window on Floor 2 Side A of Exposure B and window vented by the Engine 95 Officer (see Figure 1) as the search team moved to Floor 2.</i></p> <p><i>Engine 85 deploys a ladder to a window on Floor 2 Side B (see Figure 1)</i></p> |
| | 0536 | <p><i>Engine 95-2 deploys a 1-3/4" handline (location not specified).</i></p> |
| <p>Flames extend quickly from the involved</p> | 0637 | <p><i>Loss of pressure in handlines</i></p> |

| Fire Behavior Indicators & Conditions | Time | Response & Fireground Operations |
|--|------|--|
| unit into Exposure B. (unspecified personnel operating on the exterior) | |  Command orders companies to abandon the building. Engine 85 sounded its air horn as an audible signal to abandon the building. Personnel Accountability Report (PAR) requested by the Accountability Officer. No contact with the Search Team. |
| Rapid deterioration of conditions in Exposure B with rapidly increasing temperature and transition to flaming combustion on Floors 1 and 2 (Lieutenant King) | 0638 |  Lieutenant King radioed for help, indicating he was trapped on Floor 2. <i>The Engine 95 officer accessed Floor 2 Side B using the ladder that had been previously placed by Engine 85 and vented a window.</i> |
| Flame and a large volume of black smoke from both units in the building. (Engine 77) | 0639 | <i>Lieutenant King broke a window and radioed that he was near a window on Side D (he may have said, B and was misheard by Command and exterior companies).</i> <i>Engine 77 proceeded to Side D and realizing that the Lieutenant was in the other unit continued to Side B.</i> |
| Large volume of black smoke, but no flames from the window on Floor 2 Side B of Exposure B(Engine 77 Officer) | | <i>The Engine 77 Officer climbed a ladder to the window on Side B and attempted to look for the trapped search crew using a TIC, but it malfunctioned. He straddled the window sill and continued to attempt contact until advised that the victims had been removed.</i> |
| Large volume of flame from windows on Floor 1 (unspecified personnel operating on the exterior) | 0640 |  Lieutenant King exited the building via the door on Side A and reported that Firefighter Holmes was trapped on Floor 2 to the left of the stairs and then collapsed. |
| Flames were burning through the floorboards on Floor 1 and Floor 2 was smoke logged (Rescue 87 Officer) | 0641 |  A firefighter from Engine 85-2 operated a 1-3/4" hoseline into the stairwell from the front door to establish fire control and RIT (Rescue 87) makes entry to Exposure B. |

| Fire Behavior Indicators & Conditions | Time | Response & Fireground Operations |
|---|------|---|
| <p>The fire progressed to a fully developed stage in all compartments within the building, followed by collapse of the exterior wall on Side D.</p> | 0642 | <p> Water Tender 77 arrived.</p> <p><i>RIT proceeded to Floor 2 and located Firefighter Holmes approximately 10'(2 m) from the top of the stairs. He was on his hands and knees, but not moving.</i></p> |
| | 0643 | <p> RIT removed Firefighter Holmes to Side A via the interior stairway.</p> |
| | 0644 | <p><i>Firefighter Holmes and Lieutenant King were transported to the hospital.</i></p> |
| | 0645 | <p><i>Command shifted the strategic mode to defense and established a water tender shuttle to augment water supply.</i></p> |

Lasting Impact

In an interview with the Sharon Pennsylvania Herald on December 10, 2008, shortly after the release of NIOSH Report 2008-06, Pine Township Engine Company Chief Christopher Holmes (Firefighter Brad Holmes brother) observed:

Memorials have been said and benefits have been held to perpetuate the memory of Holmes, but a more lasting legacy is the renewed focus firefighters have put on doing their jobs safely. Now it seems like it's strictly business... Our training has been upgraded 500 percent.

Chief Holmes's observations point to the importance of the NIOSH Firefighter Fatality Investigation and Prevention Program and the importance of studying and learning from Death in the Line of Duty reports.

Contributing Factors

Firefighter injuries and fatalities often result from a number of causal and contributing factors. NIOSH Report F2008-06 identified the following contributing factors in this incident the lead to the injury to Lieutenant King and death of Firefighter Holmes:

- Inadequate water supply. Two hydrants in the vicinity of the burning structure were frozen from the cold weather.
- The victim and injured Lieutenant did not have the protection of a charged hoseline during their search for the trapped occupant.
- Inadequate training in defensive search tactics.
- Non-use of a thermal imaging camera which may have allowed the search and rescue crew to advance more quickly through the structure.
- Ventilation was not coordinated with the interior search.
- Size-up information about the structure was not relayed to the interior search crew. The interior crew was searching in the wrong duplex for the trapped occupant and did not realize they were in a duplex.
- The incident commander was unaware of the search crew's location in the building. He did not receive any interior reports and was concentrating on resolving water supply issues.

While this list identifies a number of important causal or contributory factors, it fails to identify others!

Questions

The following questions focus on fire behavior, influence of tactical operations, and related factors involved in this incident.

1. What stage(s) of fire and burning regime do you believe existed in the involved unit when Chief 95 arrived? (Remember that Figure 1 illustrates conditions considerably later in the incident than Chief 95's arrival.)

2. What building factors are likely to influence fire development and extension in structures with this type of building construction?

13. What was the tactical rate of flow for full involvement of a single unit in this building? (The tactical rate of flow is the flow required for fire control and does not include the flow rate for backup lines.)

14. What factors may have influenced the limited effectiveness of the 1-3/4" and 2-1/2" attack lines deployed by Engine 95?

15. What tactical options might have improved the effectiveness of fire control operations given the available water supply?

16. While not fire behavior related, what water supply options might have reduced the delay in establishing a continuous water supply?

17. What additions or revisions would you make to the list of contributing factors identified in NIOSH Report F2008-06?