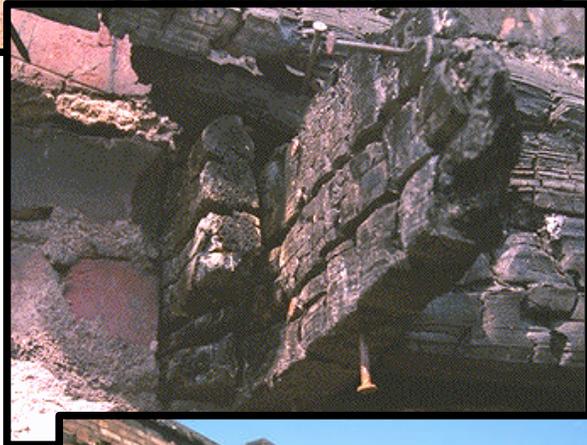


Fire Investigation Summary

Fire Fighter Fatalities



**Marks, Mississippi
August 29, 1998**

A fire that began outside in the rear of a block of buildings resulted in the deaths of two fire fighters.

The failure to establish a comprehensive Incident Management System that includes ongoing incident size-up, risk management, establishment of an accountability system, and the provision of sufficient resources can result in fire fighter injuries or fatalities.



**National Fire Protection Association
Fire Investigations Department**

At approximately 12:58 a.m. on Saturday, August 29, 1998, a fire was reported at the rear of the florist shop on Main Street in Marks, Mississippi. The fire reportedly began in a pile of cardboard and other combustible materials outside the rear of the florist shop. The fire then spread through the open eaves of a storage building behind the florist shop. The 20-ft × 30-ft. (6.1-m × 9.1-m) storage building was used to store floral packing and display materials and also contained a 6-ft × 6-ft. (1.8-m × 1.8-m) cooler unit. The building was connected to the main florist shop through a steel frame door. The florist shop was located in the middle of a block of buildings that contained a restaurant, a liquor store, dry cleaners, and a lounge. The block of buildings was approximately 140ft-(42.6 m) in length and 60 ft (18.3 m) deep.

Upon arrival of the first fire units, at 1:05 a.m. smoke and flame were showing from the eave line of the storage building. The fire department gained access to the storage building and began to extinguish the fire within the building. An additional hoseline was deployed to protect a youth club building located 15 ft (4.6 m) south of the fire building. The Marks fire chief requested mutual aid from the Lambert Fire Department at 1:09 a.m.

With the fire in the storage building extinguished, salvage and overhaul was begun in the storage building and the adjoining florist shop. When the Marks fire chief entered the florist shop with the owner at about 1:25 a.m., he reported light smoke in the building. Further investigation revealed smoke showing from the attic space of the florist shop. The chief then returned to the rear of the shop and ordered two Marks fire fighters

to access the roof and check on conditions to determine if ventilation would be necessary.

The two Marks fire fighters placed a ground ladder at the rear of the liquor store and began to climb to the roof. One fire fighter was equipped with breathing apparatus and the other was not. As they reached the roof, smoke conditions worsened, and the fire fighter without breathing apparatus returned to the ground to find breathing apparatus to don. The fire fighter remaining on the roof then proceeded to walk over to the area of the florist shop. When he stepped from the roof of the restaurant onto the roof at the rear of the florist shop, at approximately 1:40 a.m., the weakened roof structure collapsed and he fell into the store, landing in the southeast storage room in the shop. No one on the fire ground witnessed his falling through the roof. His location was unknown to the others on the fireground.

At the front of the florist shop, with smoke conditions worsening, a hoseline was stretched from the Lambert engine that had been positioned at the front of the restaurant. Two fire fighters (one from Marks and the other from Lambert) donned breathing apparatus and prepared to enter the front of the shop at about 1:55 a.m. The Marks fire fighter had also participated in the attack on the fire in the storage building and was on his third air cylinder. Within seconds of the two fire fighters' entry into the building, witnesses on the outside reported seeing the hoseline "jump." Immediately following this, the Lambert fire fighter stumbled out of the door and onto the sidewalk, stating that the fire fighter from Marks was still in the building. Fire fighters outside the shop, including

the fire fighter who had just exited, entered the building and began searching for the Marks fire fighter lost near the front of the shop. Numerous attempts were made to locate the fire fighter. Rescue efforts were hampered due to a lack of full air cylinders at the scene. A police officer had been dispatched to travel approximately 20 miles (32.2 km) to Batesville to refill the cylinders already depleted. The hoseline that was used was located. The fire fighter, however, was not with the line. During the rescue attempts, the Marks fire chief was injured by broken glass in an effort to ventilate the florist shop.

Additional mutual aid was requested from the Batesville Fire Department at 2:03 a.m. Upon arrival of Batesville units at 2:25 a.m., fire fighters from Batesville began to assist in the search for the lost Marks fire fighter in the front of the florist shop. The injured Marks fire chief turned command of the scene over to the Batesville chief while he sought medical attention for his injuries. At this point, additional mutual aid was requested from surrounding communities to assist in the search for the missing fire fighter and for help in extinguishing the fire.

Batesville fire fighters located the missing Marks fire fighter during the second search of the store, after 3:00 a.m. His body was found under a pile of debris within 24ft (7.3 m) of the front entrance.

During the search efforts, the fire spread to the adjoining establishments. When the body of the fire fighter lost in the front of the florist shop was located and removed, the focus was again turned to extinguishment of the fire. At this point, it was determined that another fire

fighter was missing, the Marks fire fighter who had gone to the roof in the rear of the block to ventilate. It was thought that he might be in the rear of the florist shop. Efforts were put forth to extinguish the fire in that and adjoining areas so that another search effort could be mounted.

The fire was under control at about 5:30 a.m., and the second missing fire fighter's body was found in a rear storage room of the florist shop around 6:00 a.m.

On the basis of the fire investigation and analysis, the NFPA has determined that the following significant factors directly contributed to the deaths of the two fire fighters:

- **Lack of a fireground accountability system**
- **Ineffective use of an established incident management system (IMS)**
- **Failure to equip fire fighters with personal alert safety systems (PASS)**
- **Lack of knowledge of the construction features of the building and how these features would affect the spread of fire in the concealed spaces, including the attic**
- **Insufficient resources (personnel and equipment such as self-contained breathing apparatus [SCBA] and spare cylinders) to mount interior fire suppression and rescue activities.**
- **Absence of an established Rapid Intervention Crew (RIC) and the lack of a standard operating procedure requiring a RIC**

Written by Robert Duval, Senior Fire Investigator
NFPA Fire Investigations Department

Fire Investigation Summary

Fire Fighter Fatalities

Marks, Mississippi August 29, 1998

The National Fire Protection Association's Fire Investigations Department documents some of the most significant fires and incidents throughout the world. The objective of these investigations is to determine what lessons can be learned from these incidents. The information is then made available to the fire safety community to be used in developing future codes and standards. A complete listing of reports is available, either upon request or can be viewed on our web page.

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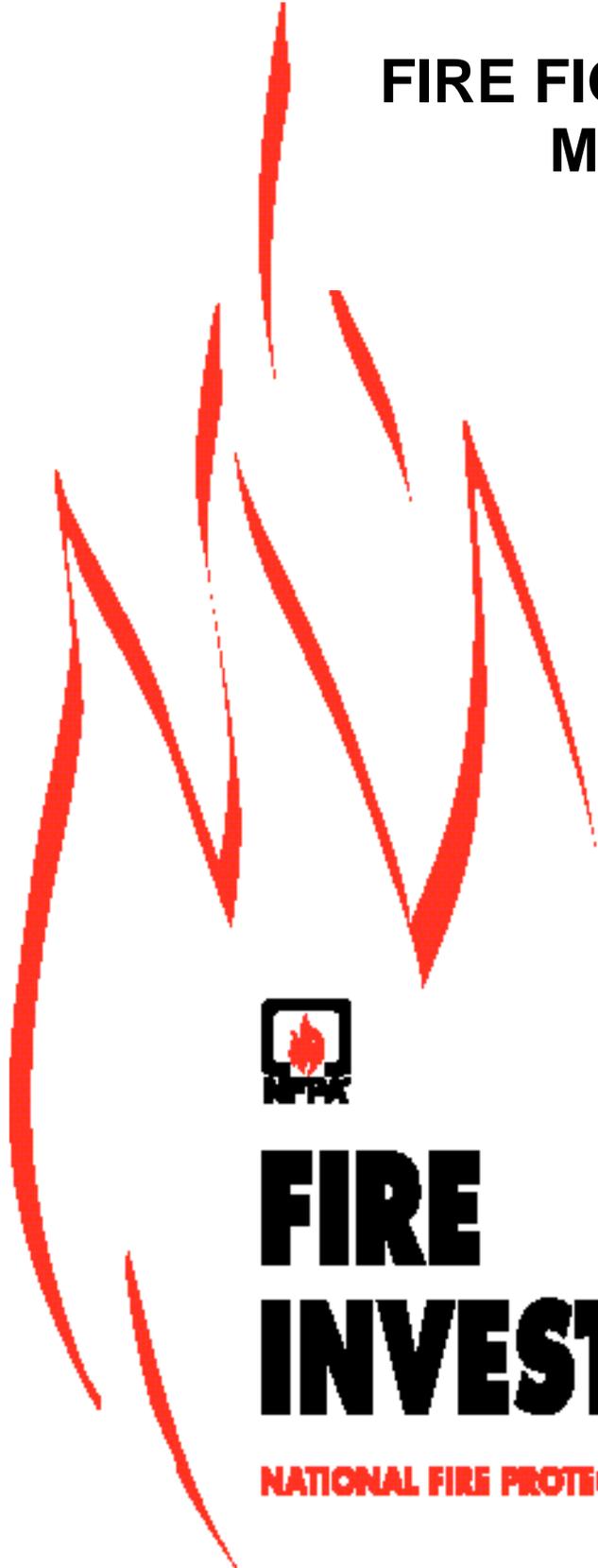
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**FIRE FIGHTER FATALITIES
MARKS, MISSISSIPPI
AUGUST 29, 1998**



**FIRE
INVESTIGATIONS**

NATIONAL FIRE PROTECTION ASSOCIATION

Fire Fighter Fatalities

Marks, Mississippi
August 29, 1998

Two Fatalities

Prepared by

Robert F. Duval

Senior Fire Investigator
National Fire Protection Association

ABSTRACT

At approximately 12:58 a.m. on Saturday, August 29, 1998 a fire was reported to the rear at the florist shop on Main Street in Marks, Mississippi. The fire reportedly began in a pile of cardboard and other combustible materials in the rear of the florist shop. The fire then spread through the open eaves of a storage building behind the florist shop. The 20-ft × 30-ft. (6.1-m × 9.1-m) storage building was used to store floral packing and display materials and also contained a 6-ft × 6-ft. (1.8-m × 1.8-m) cooler unit. The building was connected to the main florist shop through a steel frame door. The florist shop was located in the middle of a block of buildings that contained a restaurant, a liquor store, a dry cleaner, and a lounge. The block of buildings was approximately 140 ft (42.6 m) in length and 60 ft (18.3 m) deep.

Upon arrival of the first fire units, at 1:05 a.m., smoke and flame were showing from the eave line of the storage building. The fire department gained access to the storage building and began to extinguish the fire, within the building. An additional hoseline was deployed to protect a youth club building located 15 ft (4.6 m) south of the fire building. The Marks fire chief requested mutual aid from the Lambert Fire Department at 1:09 a.m.

With the fire in the storage building extinguished, salvage and overhaul was begun in the storage building and the adjoining florist shop. When the Marks fire chief entered the florist shop with the owner at about 1:25 a.m., he reported light smoke in the building. Further investigation revealed smoke showing from the attic space of the florist shop. The chief then returned to the rear of the shop and ordered two Marks fire fighters to access the roof and check on conditions to determine if ventilation would be necessary.

The two Marks fire fighters placed a ground ladder at the rear of the liquor store and began to climb to the roof. One fire fighter was equipped with breathing apparatus, and the other was not. As they reached the roof, smoke conditions worsened, and the fire fighter without breathing apparatus returned to the ground to find breathing apparatus to don. The fire fighter remaining on the roof then proceeded to walk over to the area of the florist shop. When he stepped from the roof of the restaurant onto the roof at the rear of the florist shop, at approximately 1:40 a.m., the weakened roof structure collapsed and he fell into the store, landing in the southeast storage room in the shop. No one on the fire ground witnessed his falling through the roof. His location was unknown to the others on the fireground.

At the front of the florist shop, with smoke conditions worsening, a hoseline was stretched from the Lambert engine that had been positioned in the front of the restaurant. Two fire fighters (one from Marks and the other from Lambert) donned breathing apparatus and prepared to enter the front of the shop at about 1:55 a.m. The Marks fire fighter had also participated in the attack on the fire in the storage building and was on his third air cylinder. Within seconds of the two fire fighters'

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entry into the building, witnesses on the outside reported seeing the hoseline “jump.” Immediately following this, the Lambert fire fighter stumbled out of the door and onto the sidewalk, stating that the fire fighter from Marks was still in the building. Fire fighters outside the shop, including the fire fighter who had just exited, entered the building and began searching for the Marks fire fighter lost at the front of the shop.

Numerous attempts were made to locate the fire fighter. Rescue efforts were hampered due to a lack of full air cylinders at the scene. A police officer had been dispatched to travel approximately 20 miles (32.2 km) to Batesville to refill the cylinders already depleted. The hose line that was used was located. The fire fighter, however, was not with the line. During the rescue attempts, the Marks fire chief was injured by broken glass in an effort to ventilate the florist shop.

Additional mutual aid was requested from the Batesville Fire Department at 2:03 a.m. Upon arrival of Batesville units at 2:25 a.m., fire fighters from Batesville began to assist in the search for the lost fire fighter in the front of the florist shop. The injured Marks fire chief turned command of the scene over to the Batesville chief while he sought medical attention for his injuries. At this point, additional mutual aid was requested from surrounding communities to assist in the search for the missing fire fighter and for help in the extinguishing of the fire.

Batesville fire fighters located the missing Marks fire fighter during the second search of the store, after 3:00 a.m. His body was found under a pile of debris within 24ft (7.3 m) of the front entrance.

During the search efforts, the fire spread to the adjoining establishments. When the body of the fire fighter lost in the front of the florist shop was located and removed, the focus was again turned to extinguishment of the fire. At this point, it was determined that another fire fighter was missing, the Marks fire fighter who had gone to the roof in the rear of the block to ventilate. It was thought that he might be in the rear of the florist shop. Efforts were put forth to extinguish the fire in that and adjoining areas so that another search effort could be mounted.

The fire in the rear of the block was under control at about 5:30 a.m., and the second missing fire fighter’s body was found in a rear storage room of the florist shop around 6:00 a.m.

On the basis of the fire investigation and analysis, the NFPA has determined that the following significant factors directly contributed to the deaths of the two fire fighters:

- Lack of a fireground accountability system
- Ineffective use of an established incident management system (IMS)

- Failure to equip fire fighters with personal alert safety systems (PASS)
- Lack of knowledge of the construction features of the building and how these features would affect the spread of fire in the concealed spaces, including the attic
- Insufficient resources (such as personnel and equipment self-contained breathing apparatus [SCBA] and spare cylinders) to mount interior fire suppression and rescue activities.
- Absence of an established Rapid Intervention Crew (RIC) and the lack of a standard operating procedure requiring a RIC.

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I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated the Marks, Mississippi, fire fighter fatalities in order to document and analyze significant factors that contributed to two fatalities.

The study was conducted by NFPA as part of an ongoing program to investigate technically significant incidents. NFPA's Fire Investigations Department documents and analyzes incident details so that it can report lessons learned for life and property loss purposes.

NFPA became aware of the Marks, Mississippi, fire the day after it occurred. NFPA Fire Investigator Robert Duval traveled to Mississippi to meet with investigators from the State of Mississippi Fire Marshal's Office, fire officers and fire fighters from the participating departments, and representatives from the Mississippi State Fire Academy to view the scene, interview participants and perform an on-site study of the incident. The information gathered during the on-site activities and subsequent analysis of that information are the basis for this report. Entry to the fire scene was made through the cooperation of the Mississippi State Fire Marshal's Office and the Marks, Mississippi, Fire Department.

This report is another of NFPA's studies of fires having particularly important educational or technical interest. All information and details regarding the fire safety conditions are based on the best available data and observations made during the on-site data collection phase and on any additional information provided during the report development process. It is not NFPA's intention that this report pass judgment on or fix liability for the loss of life and property resulting from the Marks fire. Rather, NFPA intends that its report presents the findings of NFPA data collection and analysis effort while highlighting factors that contributed to the loss of life and property.

Current codes and standards were used as criteria for this analysis so that conditions at the scene of the fire could be compared with state-of-the-art fire protection practices. It is recognized, however, that these codes and standards may not have been in effect during the construction and operation of the buildings. NFPA has not analyzed the buildings in Marks, Mississippi, regarding their compliance with local codes and standards in existence when the buildings were constructed and during their operation.

The cooperation of the following agencies is greatly appreciated: Mississippi State Fire Marshal's Office, the Marks and Batesville, Mississippi Fire Departments, and the Mississippi State Fire Academy.

II. BACKGROUND

The Building

The building destroyed in the fire was constructed in numerous phases over many years. The original structure was built around 1907. Several additions and renovations were made to the original structure in subsequent years. The building contained no basement. Diagram No. 1 shows the layout of the block of buildings at the time of the fire.

The block of buildings where this incident occurred was Type V (000) construction, according to NFPA 220, Standard on Types of Building Construction, 1995 edition (see Note).

The main exterior walls of the structure were constructed of brick. The walls of the additions to the rear of the building were constructed with concrete block. The main interior partitions in the florist shop were constructed of brick and were the remnants of a party wall that also served as a firewall. Partitions in the other establishments were constructed of gypsum board or plaster on wood framing.

Much of the interior and the roofing system of the structure were destroyed in the fire and no building plans were available to investigators for the verification of certain building dimensions and construction details.

The roof structure consisted of 2 × 10-in. as well as 2 × 4-in. joists supported by brick bearing walls. The roof was a single slope arrangement, creating an approximately 6-ft (1.8 m) space in the front of the attic, reduced to an approximately 2-ft (0.6 m) space in the rear. The roof covering consisted of several layers of asphalt paper and mopped tar over plywood sheathing.

Originally, the structure contained firewalls with parapets. The walls were constructed of brick and mortar and were located between each major section of the building (lounge, cleaners, florist, restaurant, and liquor store). The parapets rose above the roofline approximately 2–3 ft. (0.6–0.9 m). The roof support rafters were installed in slots in these walls. The joists were not connected to the brick walls. The ends of the joists were only fit into the slots in the party walls. Photo No. 1 shows this construction feature.

Note: A Type V (000) structure will have a 0-hour fire rating for the exterior walls (first digit); a 0-hour rating for the structural frame or columns and girders supporting loads for more than one story (second digit); a 0-hour rating for the story assembly (third digit) – NFPA 220

It appears that, at one time, the section of the building housing the florist shop had been two separate establishments since there was a firewall located in the center of the shop. Among other penetrations, this wall contained two passageways 4ft (1.2 m) wide and 8ft (2.4 m) high, without doors. This arrangement allowed occupants to travel from one side of the store to the other from both the front and rear of the store.



Photo No. 1: Roof joist ends at brick wall in florist shop (NFPA)

All of the firewalls had been breached in several locations. The walls between each establishment had been penetrated for the installation of vents and piping. As a result of the numerous penetrations, none of these walls could be considered true firewalls.

The building had a height of approximately 16–18 ft (4.9–5.5 m) at the front and 12–14 ft (3.6–4.3 m) in the rear. The ceiling height in the florist shop was about 10 ft (3 m). The ceiling in the shop consisted of tin panels (2 × 2 ft) on wood frame over a plaster ceiling above. The ceilings in the other establishments consisted of a combination of plaster and gypsum board on a wood frame (rafters) as well as tin panels on wood frame.

The square footage of each establishment is as follows: (See Diagram No. 1 and Photo No. 2)

- Florist – 2,800 sq ft (260 sq m) [including the storage room in the rear]
- Dry Cleaners – 2,400 sq ft (223 sq m.)
- Lounge – 1,800 sq ft (167sq m)
- Restaurant – 860 sq ft (80 sq m)
- Liquor store – 450 sq ft (42 sq m)

Total– 8,310 sq ft (772 sq m)

appeared to be a single door to enter this room. A room of similar dimensions was located adjacent to this room, in the rear of the eastern section of the store. There was a door that connected the two rooms. The eastern room also had a single door to access the sales floor. The eastern room contained miscellaneous storage as well as the electrical service panels for the store.

The 630-sq ft (58.5 sq-m) storage building in the rear of the store was constructed immediately adjacent to the south wall of the florist shop. The building walls were constructed of concrete block, and the roof structure was corrugated metal on lightweight wood truss framework. The peak of the storage building's roof was nearly level with the rear edge of the florist shop's roof. The storage building contained a cooler unit to store floral arrangements. The remainder of the building contained tables for creating floral arrangements, as well as supplies such as baskets, wrapping papers, and other decorative materials.

The storage building was accessible through two doorways, an exterior door located on the west side of the building, and a door on the north side of the building that opened into the eastern storage room in the rear of the shop. The exterior door was secured with a gate and a padlock, while the interior door was secured with a deadbolt lock on the door.

The interior of the cleaners contained storage of clothing on racks and shelves to 8 ft (2.4 m). Much of the dry cleaning and pressing equipment was located in a 540-sq ft (50.2 sq-m) addition in the rear of the store.

The interior of the lounge contained a restaurant and bar operation, along with small groupings of tables and chairs arranged randomly.

The restaurant was a diner-type operation, with a counter and small tables. The kitchen was located in the rear and consisted of a grill and other appliances. There was a rear access door for the restaurant for staff and deliveries. The liquor store contained a cashier's counter and merchandise storage.

Fire Department

The Marks Fire Department is an all-volunteer unit comprised of 21 members providing emergency service to a population of approximately 1,700 residents. The department maintains a single station and covers a response area of 100 sq miles (259 sq km). The department operates three engines and a rescue/utility unit. The department responds to an average of 70 calls annually.

The department conducts in-house training monthly. The Mississippi State Fire Academy also provides in-service training on request.

The Marks Police Department dispatches for the fire department. A single dispatcher handles both the fire and police dispatching duties.

Weather

The temperature at the time of the fire was 77 °F (25°C) with broken cloud cover. The relative humidity was 94 percent. The wind was 7 mph (11.3 km/h) from the northwest.

III. THE FIRE

Fire Department Operations

The fire was discovered at 12:58 a.m. by a passing ambulance technician who notified the police dispatch by radio of smoke showing from the rear of the florist shop on Main Street. The Marks Fire Department was notified by the dispatch center at the same time.

The Marks fire chief began to drive to the station, from his home. He then heard Marks Engine 12 (1,500 gpm /1,000 gal. tank) responding on the radio. He then proceeded to the scene. Upon his arrival at the scene about 1:05 a.m., he reported smoke and flame showing from the concrete block storage building in the rear of the florist shop. He ordered Engine 12 to access the rear of the store via an alley on the west side of the block. As the engine arrived, fire fighters reported that the fire appeared to be burning beneath the corrugated metal roof structure of the building.

The police department had notified the owner of the florist shop of the fire immediately after the fire department was notified. The owner arrived at approximately 1:09 a.m. Using a key, the owner attempted to provide access to the storage building for the fire department. He was successful in unlocking the gate over the door; but he could not open the metal door to get into the building, breaking the key off in the lock. The fire department had to force entry through the door, gaining access at 1:12 a.m. Before access was gained, water was applied by two 1-3/4-in. handlines from outside the building, through eave openings, in an effort to control the fire. Water was also applied, via a deluge gun on Engine 12, to an adjoining structure (a youth center) located 10–15 ft (3– 4.6 m) south of the storage building.

Marks Engine 9 (500 gpm–front mounted pump / 900 gal tank) arrived at 1:09 a.m. and connected to a hydrant at the intersection of the alley and Main Street, in front of the liquor store. Fire fighters laid a 2-1/2 in. supply line into the alley to provide a water supply for Engine 12.

The Marks fire chief requested assistance from the Lambert Fire Department at 1:09 a.m.

Two fire fighters advanced a 1-3/4-in. hoseline into the storage building and began to extinguish the fire at 1:12 a.m. The fire reportedly involved the roof support structure of lightweight wood trusses as well as some contents of the building. The fire was extinguished within ten minutes, and overhaul began immediately. As the fire was being extinguished, the Marks fire chief accompanied the owner of the florist shop into the store to retrieve some records and to check on conditions in the store.

The chief entered the florist shop and proceeded to the rear of the store. He found an access door in the southwest corner of the store that provided access to the storage building where the fire was presumed to have started. The door was secured and could not be opened without a key.

As the chief walked to the front of the store, he noticed smoke issuing from the outside vents in the attic of the florist shop. Each of the shops in the block had a ventilation grate on the front wall to allow air movement in the attic spaces. The chief then returned to the rear of the block and ordered two fire fighters to prepare to ventilate the florist shop roof. The two fire fighters took a 14-ft. straight ladder from Engine 12 and placed it against the back wall of the restaurant. One fire fighter then donned self-contained breathing apparatus (SCBA).

The two fire fighters climbed onto the roof of the restaurant at about 1:35 a.m. The fire fighter with the SCBA stepped onto the roof first. The other fire fighter handed him an axe and had to exit the roof because of the increasing smoke condition. This second fire fighter left the roof to search for another SCBA unit. (At this point he was given another assignment and proceeded to the front of the building.)



The fire fighter remaining on the roof then proceeded to walk over to the area of the florist shop. When he stepped from the roof of the restaurant onto the roof at the rear of the florist shop, at approximately 1:40 a.m., the weakened roof structure collapsed and he fell into the store, landing in the southeast storage room in the shop. No one on the fire ground witnessed his falling through the roof. His location was unknown to the others on the fireground.

Photo No. 3: Area of origin at rear of florist shop. Parapet in center of photo divides the florist shop and is near where the fire fighter fell through weakened roof structure. (NFPA)

Meanwhile, Engine 4 from the Lambert Fire Department had arrived and was positioned at the front of the restaurant, after connecting to a hydrant on Martin Luther King Drive and laying 800-ft. (243.8 m) of 2-1/2-in supply line. A 1-3/4-in. handline was deployed from Engine 4 and was placed at the front door of the florist shop.

As the smoke conditions within the florist shop worsened, two fire fighters – one from Marks and the other from Lambert – prepared to enter the front door of the

store. The Marks fire fighter had been involved in the extinguishment of the fire in the storage building and was now operating on his third SCBA air cylinder, without a rest period. The two firefighters donned their breathing apparatus and entered the front door of the florist shop. Witnesses state that the two then exited almost immediately. The Marks fire fighter's face shield had broken. He borrowed another helmet from a Lambert fire fighter and the two re-entered the shop.

The county fire coordinator, a Lambert assistant chief, was located near Lambert Engine 4 in front of the florist shop. The coordinator indicated that after the two fire fighters re-entered the building, he saw the hoseline "jump," and moments later the Lambert fire fighter stumbled from the building, appearing dazed. The Lambert fire fighter indicated that the Marks fire fighter was still in the building.



Photo No. 4: Front of florist shop. (Note attic vents above canopy) (NFPA)

The Lambert fire fighter entered the building again in search of the Marks fire fighter. The Lambert assistant chief donned breathing apparatus and followed the fire fighter into the florist shop. Photo No. 4 shows the front entrance of the florist shop.

The Lambert chief, who had also witnessed the hoseline jump, called additional personnel to the front of the building to assist in the search. The assistant chief began searching for the Lambert fire fighter within a few feet of the entrance to the shop. Within minutes he indicated that he heard a "low-air" alarm sounding nearby. He reached toward the sound, grabbed the sleeve of the Lambert fire fighter's coat, and assisted him in leaving the building. The two exited the building at approximately 2:00 a.m.

At approximately 1:40 a.m., a Marks police officer was sent to Batesville with several empty breathing air cylinders to refill them at the Batesville fire station. At 2:03 a.m., as the police officer was arriving at the Batesville station, the Batesville department was requested to the scene in Marks. Batesville was requested to provide

additional manpower to assist in the search for the missing fire fighter and to provide additional breathing apparatus and spare SCBA cylinders. (Spare cylinders were in short supply at the scene by the time entry was made into the florist shop at 1:45 a.m.)

While the Batesville department was responding, efforts were made to rescue the Marks fire fighter in the florist shop. Several fire fighters attempted to enter the shop, only to be pushed back by the worsening conditions in the store. During the rescue attempts, the windows of the shop were removed in an effort to ventilate the building. During the removal of the windows, the Marks chief suffered a severe laceration to his arm.

Batesville units arrived at 2:25 a.m. Batesville Engine 6 laid a 5-in. supply line [400ft (121.9 m)] from a hydrant on Main Street (across the railroad tracks). A 1-3/4 in hose line was deployed from Engine 6 into the florist shop. The Marks chief transferred command to the Batesville chief so he could seek medical treatment for the laceration on his arm.

A search crew from the Batesville Fire Department was established and entered the shop to search for the missing Marks fire fighter. The fire fighter was not found on this initial search. A second search with fire fighters from Marks, Lambert, and Batesville located the body of the missing fire fighter at approximately 3:00 a.m.

The location of the body was documented and photos were taken as the body was removed. The fire fighter's body was located approximately 24 ft from the front door, it was no longer in contact with the hose line. The body was found beneath debris from the ceiling and some display merchandise. The fire fighter's SCBA mask was found removed from his face and from the regulator assembly, and his air cylinder was empty at the time he was discovered

As the fire fighter's body was removed from the shop, the fire was intensifying in the dry cleaner shop adjacent to the florist. All personnel were removed from the building and an exterior attack was established. Diagram No. 2 shows fire ground operations and the approximate fatality locations.

At approximately 4:00 a.m., it was determined that another fire fighter was unaccounted for, the Marks fire fighter who had been sent to ventilate the roof of the florist shop earlier. A roll call was taken on the scene, and this fire fighter was not accounted for. Personnel were sent to his home and the home of a friend nearby to see if he had shown up at either location in the time since he was last seen. Both searches prove negative. A check was also made at the local hospital to see if he had sought treatment. The hospital had no record of the fire fighter being treated.

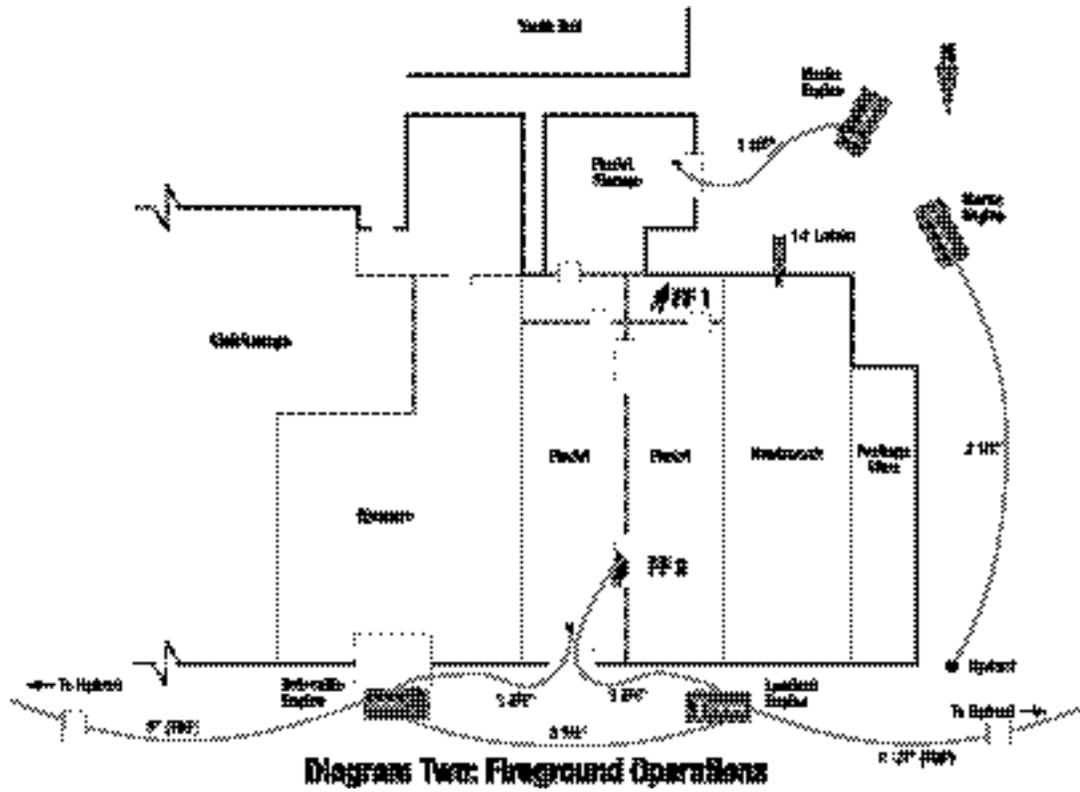


Photo No. 5: Rear storage room in florist shop where the body of second fire fighter was found. Photo taken facing rear wall (south). To the right is the party wall with the restaurant. (NFPA)

In the meantime, the search focused on his last known location, the rear of the florist shop. Efforts were made to extinguish the fire in this area to allow for a search of the back of the shop. Access was eventually made to the rear areas within the shop and a search was conducted in both storage rooms. The missing fire fighter's body was found in the southeast corner of the rear of the storage room at approximately 6:00 a.m. His body was located beneath debris from the roof structure and materials stored in the storage room. When the fire fighter was found, his air cylinder was empty. There are conflicting reports on the placement of his mask. The location of the body was documented and photos were taken prior to the removal of the body. Photo No. 5 shows the area where the fire fighter body was found.

The fire was brought under control between 5:00 a.m. and 5:30 a.m. Units remained on the scene through the day, wetting down the debris and conducting overhaul operations.

IV. TIME LINE

Note: All times are estimated. Time frame obtained through interviews with participants.

Time	Elapsed Time	Activity
8/29/98		
00:58	0	Fire is discovered at the rear of the florist shop on Main Street. Fire Department notified.
1:05	7 minutes	Marks Engine 12 responding. Chief arrives and reports flames and smoke showing from the rear of the florist shop.
1:09	11 minutes	Handlines are deployed from Engine 12 to storage building in rear of florist shop. Marks Engine 9 arrives, establishes water supply. Florist shop owner arrives.
1:09	11 minutes	Lambert FD requested by Marks chief
1:12	14 minutes	Attack is made on fire within storage building.
1:20	22 minutes	Fire is knocked down in storage building. Overhaul commences. Smoke becomes visible from attic space of florist shop.
1:22	24 minutes	Marks chief enters florist shop with owner, and encounters a light smoke condition.
1:25	27 minutes	Lambert Engine 4 arrives, and connects to a hydrant on Martin Luther King Drive, and lays a supply line to the front of the restaurant. Smoke condition within florist shop is reported to be worsening.
1:30	32 minutes	Marks chief orders vertical ventilation in florist shop.

Time	Elapsed Time	Activity
1:30	32 minutes	Two Marks fire fighters prepare to access the roof of the building from the rear, near the restaurant.
1:33-1:37	35-39 minutes	Two fire fighters access the roof at the rear of the florist shop. One fire fighter (without SCBA) has to exit, due to smoke condition.
1:40	42 minutes	Second fire fighter continues toward florist shop roof. Fire fighter falls through roof at the rear of the florist shop, into storeroom in southeast corner.
1:42	44 minutes	Hoseline is deployed to the front door of the florist shop from Lambert Engine 4.
1:45	47 minutes	Two firefighters (Marks and Lambert) prepare to enter the front of the florist shop.
1:50	52 minutes	Two fire fighters enter the front door of the florist shop with hoseline.
1:52	54 minutes	Both fire fighters exit the front door. Face shield on Marks fire fighters helmet is broken. Marks fire fighter obtains another helmet and prepares to re-enter the florist shop.
1:54	56 minutes	Both fire fighters enter the florist shop a second time.
1:56	58 minutes	Personnel outside see the hoseline in the florist shop "jump." The Lambert fire fighter stumbles out of the door and states that the Marks fire fighter is still inside.
1:58	60 minutes	The Lambert fire fighter re-enters the building to search for the Marks fire fighter. He is joined by a Lambert fire officer, who pulls him out when his low-air alarm begins to sound.

Time	Elapsed Time	Activity
2:03	1 hour 5 minutes	Batesville FD and an ambulance requested to the scene. Search efforts continue in the florist shop for the missing Marks fire fighter. Marks chief is injured by broken glass during rescue efforts.
2:25	1 hour 27 minutes	Batesville FD arrives on scene
2:30	1 hour 32 minutes	Batesville establishes a crew and searches the florist shop (first search negative). Command is transferred to Batesville chief as Marks chief receives medical attention.
3:00 – 4:00	2 hours 2 minutes – 3 hours 2 minutes	Missing fire fighter is located in front of the florist shop. Location is documented and the body removed.
4:00	3 hours 2 minutes	Fire continues to spread into adjoining occupancies. Discovery is made that another fire fighter is missing (Marks fire fighter performing ventilation).
4:00	3 hours 2 minutes	Another search is initiated for second missing fire fighter. Fire is fought simultaneously as search is begun.
5:00	4 hours 2 minutes	Fire is declared under control
6:00-6:30	5 hours 2 minutes – 5 hours 32 minutes	Body of second fire fighter is found in the rear of the florist shop. Location documented and the body is removed.

V. ANALYSIS

Origin and Cause

The Mississippi State Fire Marshal's Office has determined that the fire was incendiary in nature. The fire began in a pile of cardboard and other combustibles outside the rear of the florist shop. The fire spread to the storage building through the open eave structure and wood frame roof support system. The fire also spread into the attic space of the florist shop through the roof eave overhang above where the fire began.

A youth was convicted of manslaughter in setting the fire and was sentenced to 10 years probation.

Fire Spread and Growth

Once the fire entered the combustible attic space, it spread laterally east and west through the open attic space. The former brick firewalls, in place between each establishment, contained several penetrations. The fire then spread from the florist shop into the two adjoining spaces (dry cleaners and restaurant). The fire spread unchecked and out of sight for several minutes before smoke began to emanate from the attic ventilation grates on the north side of the building. This smoke was the first sign that the fire had entered the attic space and was spreading rapidly. The partially open attic space provided an avenue of fire travel from one end of the block to the other. (Photo No. 6 shows the attic space above the restaurant.)



Photo No. 6: View showing attic space at front (north) of restaurant. The blackened bricks indicate the attic area (NFPA)

With the fire spreading in the attic spaces, the roof support joists were weakened and eventually collapsed, first under the weight of the fire fighter on the roof and then under their own weight and the weight of the suspended ceiling installations in each

establishment. The manner in which the joists were installed in the brick walls, without attachments, allowed the roof structure to collapse without bringing down the masonry walls as well.

Fire Department Operations

Risk Management

Risk management plays an important role in managing a fireground operation. The Incident Commander must weigh the risk to the fire fighters against the objective and the benefits to be achieved.

Risk management during emergency operations is addressed in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program* (1997 edition) Section 6-2.

6-2 Risk Management During Emergency Operations.

6-2.1*

The incident commander shall integrate risk management into the regular functions of incident command.

A-6-2.1 The incident commander has an ultimate responsibility for the safety of all fire department members operating at an incident and for any and all other persons whose safety is affected by fire department operations. Risk management provides a basis for the following:

- (a) Standard evaluation of the situation
- (b) Strategic decision-making
- (c) Tactical planning
- (d) Plan evaluation and revision
- (e) Operational command and control

6-2.1.1*

The concept of risk management shall be utilized on the basis of the following principles:

- (a) Activities that present a significant risk to the safety of members shall be limited to situations where there is a potential to save endangered lives.
- (b) Activities that are routinely employed to protect property shall be recognized as inherent risks to the safety of members, and actions shall be taken to reduce or avoid these risks.
- (c) No risk to the safety of members shall be acceptable when there is no possibility to save lives or property.

A-6-2.1.1 The risk to fire department members is the most important factor considered by the incident commander in determining the strategy that will

be employed in each situation. The management of risk levels involves all of the following factors:

- (a) Routine evaluation of risk in all situations
- (b) Well-defined strategic options
- (c) Standard operating procedures
- (d) Effective training
- (e) Full protective clothing ensemble and equipment
- (f) Effective incident management and communications
- (g) Safety procedures and safety officers
- (h) Back-up crews for rapid intervention
- (i) Adequate resources
- (j) Rest and rehabilitation
- (k) Regular evaluation of changing conditions
- (l) Experience based on previous incidents and critiques

6-2.1.2* The incident commander shall evaluate the risk to members with respect to the purpose and potential results of their actions in each situation. In situations where the risk to fire department members is excessive, as defined by 6-2.1.1 of this section, activities shall be limited to defensive operations.

A-6-2.1.2 The acceptable level of risk is directly related to the potential to save lives or property. Where there is no potential to save lives, the risk to fire department members must be evaluated in proportion to the ability to save property of value. When there is no ability to save lives or property, there is no justification to expose fire department members to any avoidable risk, and defensive fire suppression operations are the appropriate strategy.

Incident Management System

A key component of a comprehensive risk management plan on the fireground is the implementation of an incident management system (IMS). With a well-established system of incident management in place the Incident Commander can receive information on conditions and activity in each area of the building and can then make decisions based on that information. In the case of this incident, the Marks chief was constantly trying to monitor conditions in both the front and rear of the building. He also made a trip inside the building with the owner at one point. The chief's movements were a case of "you cannot be everywhere at the same time." An Incident Commander has to establish a system and allow sector commanders to relay important information back to the Command Post.

NFPA 1561, *Standard on Fire Department Incident Management System* (1995 edition), establishes minimum requirements for the development and implementation of an incident management system. Incident management systems, as designed, grow with the complexity of the incident. For smaller incidents, during which a limited

number of units are operating, the Incident Commander can directly oversee each unit without difficulty. However, as the incident becomes more complex, the incident commander must delegate control of tasks or portions of the scene to other commanders so that the “span of control” is not exceeded. The span of control is the number of units reporting directly to a command officer. (A span of control of between 3 and 7 is considered desirable.)

Some of the key points that the establishment of an incident management system assists in controlling include: size-up of the incident, communications, interagency coordination, and accountability of personnel operating on the fireground.

Size -up

A thorough size-up of a building can reveal hidden dangers such as concealed spaces, lightweight or deteriorated construction, or suddenly changing conditions that can trap fire fighters. In this incident a fire had been burning in the concealed attic space for several minutes before it was discovered. The fire burning in this space eventually weakened the roof support joists, causing them to collapse.

The NFPA Fire Investigation Unit has investigated other fire fighter fatality incidents at which similar situations have occurred. In Branford, Connecticut, in November, 1996, a fire in a carpet showroom and warehouse burned into an attic space above the head of fire fighting crews that had entered to locate the fire. Over the course of several minutes, while the crews were still attempting to locate the fire, portions of the roof system collapsed, trapping fire fighters in the building. One fire fighter was killed and six others were injured. In Chesapeake, Virginia, on March 18, 1996, a fire in an auto parts store spread from a hot water heater in the rear into the store and entered the concealed space above the suspended ceiling. The fire spread rapidly within the space above the ceiling consuming the lightweight wood truss members, and causing the roof to collapse, trapping and killing two fire fighters before they could escape. (Abstracts of both of these NPFA reports are located in the Appendix of this report.)

The danger posed by not knowing details of the building construction and layout before and during the fire attack has been demonstrated time and time again.

Accountability

A component of an established incident management system (IMS) is an accountability system. Such a system provides a means to track and account for all personnel operating at the incident. An Accountability System allows for a rapid “head count” in the event of an emergency (e.g., collapse or explosion) or at a predetermined interval during the incident. Division or sector commands can also track the personnel assigned in an area and the functions they are performing. There are several accountability systems in use in the fire service today. The type of system instituted by an individual department should fit the operational procedures

of the department. A system that functions well in a large urban department will not necessarily work for a small rural volunteer department. Some accountability systems include the use of tactical worksheets, riding lists, identification tags, or bar-code systems.

All personnel operating at the emergency incident are responsible for their participation in the accountability system. The incident commander is responsible for the overall personnel accountability at each incident.

The establishment and use of accountability systems is addressed in NFPA 1500, Section 6-3, and NFPA 1561, Section 2-6.

At this incident, the fire fighter who went to the roof to ventilate and fell through the weakened roof structure was unaccounted for an extended period. Had an accountability system been in place, the fact that he was missing and his location might have been discovered much sooner.

Personal Alert Safety System (PASS)

The personal alert safety system (PASS) has become another important component of fire fighter's protective equipment. A PASS device is to be used every time a fire fighter enters a hazardous environment or situation. The device is intended to sound an audible alarm if the fire fighter becomes incapacitated or is in need of assistance. The sound of an activated PASS device warns all others on the fireground of a fire fighter in distress and assists the rescuers in locating the missing or trapped fire fighter. In many cases PASS devices are not activated by fire fighters prior to entering the hazardous area. The fire fighters then may be unable to activate the unit manually once they become trapped.

PASS devices come in two basic types: integrated, which is an integral part of the breathing apparatus and is automatically activated when the air cylinder is opened, and stand-alone, which has to be activated initially by the fire fighter. Fire fighters who become trapped or lost, or are otherwise in distress can activate both units manually. The units will also sound if a fire fighter is motionless for 30 seconds.

The design, performance and certification requirements and test methods for PASS devices are covered in NFPA 1982, *Standard on Personal Alert Safety Systems (PASS)* (1998 edition). The use of PASS devices is discussed in NFPA 1500, Section 5-8.

The Marks Fire Department did not have any PASS devices in use on the night of the incident.

Rapid Intervention for Rescue

The concept of Rapid Intervention for fire fighters in distress is a fairly new concept in its current form. In the past, there may not have been a formally established team of fire fighters assigned to standby and await a potential rescue situation involving a trapped fire fighter or fire fighters. If a fire fighter became trapped or was missing, the Incident Command usually assigned a company or companies or put together a team from personnel on the scene to complete the rescue. NFPA1500 introduced a section on Rapid Intervention for Rescue of Members in the 1992 edition. The formation and implementation of Rapid Intervention Crews (RIC) is becoming a common practice in the fire service. The function is referred to alternatively as Rapid Intervention Teams (RIT) or Fire Fighter Assistance Safety Teams (FAST), but the goal is the same: the location and rescue of trapped or incapacitated fire fighters.

As soon as fire fighters are committed to a hazardous situation (e.g., interior fire fighting), an RIC should be established. Initially, this crew can consist of two fire fighters, but the crew should be expanded according to the complexity and the size of the incident. One or more crews can be deployed based on the Incident Commander's evaluation of the situation.

The necessary equipment should be staged for use by the RIC. Such equipment includes forcible entry tools, lights, extra SCBA, hand tools, ropes and associated hardware, medical equipment and extra protective equipment. Specialized equipment may be needed, depending on the situation encountered.

The RIC should be utilized only for rapid intervention duties and not for other fireground tasks. If the RIC is deployed for tasks other than fire fighter rescue, another RIC should be formed to take the place of the initial group.

The establishment of Rapid Intervention Crews is addressed in NFPA 1500 Section 6-5. The use of RICs during the incident is covered in NFPA 1521, *Standard for Fire Department Safety Officer* (1997 edition) and NFPA 1561.

A formal RIC was not established during the operations in Marks. Available members assisted in the rescue attempts prior to the arrival of the Batesville Fire Department. An established RIC was then implemented and proceeded to search first for the missing fire fighter in the front of the florist shop and then for the fire fighter who had fallen through the roof.

Resources

Adequate resources are necessary for a safe and efficient fireground operation. These resources can include personnel, apparatus, and equipment. When a fire attack is conducted, sufficient standby personnel and equipment are needed to provide support for the operation.

To properly manage risk at an emergency incident the incident commander must have sufficient resources at his/her disposal. These resources can be put to use immediately or staged at a predetermined location and made available when needed.

The staging of resources allows the incident commander to manage the assets in the following ways:¹

- Gathers personnel and equipment in an accessible location until they can be deployed
- Provides a location for personnel responding without apparatus to report
- Provides a pool of readily available resources, thereby reducing response time
- Reduces freelancing by personnel and enhances scene safety

At the Marks incident, breathing air for the SCBA units in use at the scene ran out prior to the rescue attempts in the front portion of the florist shop. Additional air was obtained by requesting additional fire departments and by transporting empty air cylinders to the Batesville fire station approximately 20 miles away.

A formal staging area was not established. Personnel and apparatus reported directly to the scene at this incident.

On the basis of the fire investigation and analysis, NFPA has determined that the following significant factors directly contributed to the deaths of the two fire fighters:

- Lack of a fireground accountability system
- Ineffective use of an established incident management system (IMS)
- Failure to equip fire fighters with PASS Devices
- Lack of knowledge of the construction features of the building and how these features would effect the spread of fire in the concealed spaces, including the attic.
- Insufficient resources (personnel and equipment, SCBA and spare cylinders) to mount interior fire suppression and rescue activities.
- Absence of an established Rapid Intervention Crew (RIC) and the lack of a standard operating procedure requiring a RIC.

¹ Foley, Stephen N., ed. 1998. Fire Department Occupational Health and Safety Standards Handbook. Quincy, MA: National Fire Protection Association, p 175.

VI. SUMMARY

What began as a small fire in a storage building ended tragically.

The fireground is by nature a fast-paced and at times, a chaotic place. Care must be taken to control the pace and put procedures in place to control the chaos. Implementation of an Incident Management System (IMS), and a personnel accountability system are two ways to ensure firefighter safety and help control fireground activities.

An Incident Management System allows for the control of all aspects of the fireground and all of the activities therein. Each task or geographic area is under the control of a fire officer or fire fighter. All personnel in that area or assisting with that task are under the direct supervision of the officer or fire fighter. All information about the fire attack and supporting functions is directed toward the incident commander so that the commander can make decisions based on that information. This system allows for coordination of all aspects of the fire attack and associated operations.

In conjunction with the use of an IMS, a personnel accountability system allows for efficient tracking of fire fighters while on the fire ground. A quick “head count” taken at regular intervals and after a dangerous condition arises (e.g., collapse or explosion), allows for the accounting of all personnel on the fire ground. Missing personnel can be identified promptly and a search can be undertaken.

The use of personal alert safety systems (PASS) devices offers a means to locate a missing or trapped fire fighter and provides a fire fighter with a way to signal that they are in distress, amidst the noise of the fireground.

The provision of a Rapid Intervention Crew (RIC) will offer a means to locate and rescue lost, trapped, or incapacitated fire fighters. This crew can initially be two fire fighters and can grow with the size and complexity of the incident. This crew should be dedicated only to the task of rapid intervention and should not be used for other fireground tasks.

Sufficient resources should be available to the Incident Commander during the incident. These resources include personnel as well as equipment. An adequate number of personnel allows for the completion of multiple tasks simultaneously and allows for sufficient standby personnel to be in place to relieve fire fighters and provide for a RIC. An adequate amount of equipment should include apparatus and associated equipment, as well as spare self-contained breathing apparatus (SCBA) cylinders or a means to re-fill depleted cylinders rapidly.

The attack and extinguishment of a fire must be a coordinated effort on numerous fronts. Incident management must provide risk management, adequate supervision, accountability, and resources; and fire fighting personnel must operate in a safe and efficient manner, taking into account the risks encountered and the benefits to be achieved.

VII. NFPA DOCUMENTS

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program	The purpose of this standard is to specify the minimum requirements for an occupational safety and health program for a fire department and to specify safety guidelines for those members involved in rescue, fire suppression, emergency medical services, hazardous materials operations, special operations, and related activities.
NFPA 1561, Standard on Fire Department Incident Management System	<p>This standard establishes minimum performance requirements for an incident management system based on concerns for the safety and health of fire department personnel.</p> <p>Many of the requirements of this standard could be satisfied by adopting a “model” system (such as the Incident Command system) that is intended to provide for a uniform approach to incident management while providing for some variations to meet local requirements.</p>
NFPA 1404, Standard for a Fire Department Self-Contained Breathing Apparatus Program	This standard contains minimum requirements for a fire service respiratory protection program. These requirements are applicable to organizations providing fire suppression, fire training, rescue and respiratory protection equipment training, and other emergency services including public, military, and private fire departments and fire brigades.

NFPA 1982, Standard on Personal Alert Safety Systems (PASS)	This standard specifies minimum design, performance, and certification requirements and test methods for all Personal Alert Safety Systems (PASS) to be used by fire fighters and other emergency services personnel who engage in rescue, fire fighting, and other hazardous duties.

APPENDIX - Abstracts of Fire Fighter Fatalities Reports

Carpet Store Fire One Fire Fighter Fatality Branford, CT November 28, 1996

At approximately 4:30 p.m. on Thursday, November 28, 1996, a fire occurred in a Branford, Connecticut, carpet store and warehouse. The fire started in the store's office area, damaged the ceiling assembly, and ignited the building's wood roof trusses. Seven fire fighters were making the initial attack when the roof collapsed. Five of seven fighters were able to find their way out of the building. The sixth fire fighter was unconscious and had to be rescued, and the seventh died before he could escape.

The building was 60 ft (18.3 m) wide and 120 ft (36.5 m) long. It had wood-frame exterior bearing walls in one section and masonry block exterior bearing walls in all other areas. Lightweight wood trusses carried the store's roof over a clear span of 60 ft (18.3 m). The building did not have any fire detection or suppression systems.

The Branford fire fighters responded to a report of smoke coming from the roof of a carpet store and found light smoke showing near the roof eaves at the front of the building, upon arrival. On the basis of the observed conditions, the fire officers believed that the fire was located somewhere in the showroom area. Six fire fighters advanced two hoselines to the front of the building. Another Branford fire fighter entered the building without the knowledge of the Incident Commander or the officer in charge of interior operations bringing the total number of fire fighters in the building to seven.

The fire fighters found fire in a corner of a showroom and attempted to extinguish that fire. At approximately the same time, the incident commander, who was outside of the building, and the interior officer realized that there was fire above the fire fighters. The interior officer ordered everyone out of the building and the incident commander radioed the interior crews, also ordering them out. Before the fire fighters could leave the building, the roof collapsed. This was approximately 17 minutes after the fire fighters arrived on the scene.

Four fire fighters escaped out of the front of the building, and the officer and two fire fighters were trapped toward the center of the building. These fire fighters freed themselves from the debris and began spraying the burning rubble with a hoseline. The officer then told the two fire fighters that they would have to move to the rear of the building where two overhead doors were located. The officer and one fire fighter began moving toward the rear of the building and became separated from the other fire fighter.

Before reaching the door, the fire fighter who was with the officer ran out of air and collapsed. Unable to help the fire fighter, the officer continued on, found a door and left the building. Once outside, the officer could not get assistance from other fire fighters, so he reentered the building. The fire officer found the collapsed fire fighter even though the fire fighter had not turned on his PASS (Personal Alert Safety System) device. The officer dragged the fire fighter out of the building.

Once the incident commander learned that six fire fighters had escaped, he believed that everyone was out because he was not aware that a seventh fire fighter had entered the building. After a brief discussion of the events that had occurred, the officers determined that one fire fighter had in fact not escaped. The missing fire fighter was found approximately 20 ft (6 m) from the position where the officer last saw him. The cause of the fire fighter's death was listed as smoke inhalation.

On the basis of its investigation and analysis, the NFPA determined that the following factors contributed to the loss of the Branford fire fighter:

- Fire officers and fire fighters unaware that the roof of the Branford carpet store was constructed with lightweight wood trusses
- The ineffective use of an incident management system and no formal fire fighter accountability system
- The absence of a Rapid Intervention Crew (RIC)
- The lack of automatic sprinkler protection

**Automotive Parts Store
Two Fire Fighter Fatalities
Chesapeake, VA
March 18, 1996**

At approximately 11:30 a.m. on Monday, March 18, 1996, fire fighters in Chesapeake, Virginia, responded to a fire in an auto parts store. No fire was visible from the exterior of the building when the fire fighters arrived.

Two fire fighters entered the building and located a small fire at the rear of the store. The fire fighters extinguished the fire and began checking for fire extension. Approximately 20 minutes after their arrival, the roof of the building collapsed and the two fire fighters were trapped inside. The fire fighters both died of burns, with smoke inhalation being a contributory factor.

The building involved was approximately 12 years old. Two of the building's exterior bearing walls were constructed with unprotected steel frames and two were constructed with masonry block. Lightweight wood trusses with a clear span of 50 ft (15.2 m) supported the store's roof. Because the facility was an auto parts store, it contained a wide variety of combustible and noncombustible materials, flammable auto paints (liquid and aerosol), and other flammable and combustible liquids. Most packaging materials and some shelving materials were also combustible.

The fire occurred when a utility worker damaged the electrical service drop conductors on the outside of the store. Electrical arcing inside the store ignited fires that quickly involved the wood trusses supporting the roof and ignited a fire in the area of an electric hot water heater. Though some of the fire was visible to anyone in the occupied area of the building, much of the fire was hidden in the concealed space above the store's ceiling, and the fire was able to spread in that area.

The fire fighters that died in this fire probably did not know that the building was constructed with lightweight wood roof trusses. Approximately seven minutes after they had arrived on the scene, the crew inside the building radioed their battalion chief to report that they had found the fire. They asked for a second crew to come into the building and requested a pike pole. Approximately 13 minutes after this transmission, the roof collapsed, intensifying the fire and trapping the fire fighters inside the building. The trapped fire fighters radioed for assistance, but, for an undetermined reason, the incident commander did not understand the transmission. Two other chief officers who were responding to the scene did hear the transmission and relayed the information to the on-scene commander. By the time the on-scene commander realized that fire fighters were possibly trapped inside the building, the fire had become too intense to attempt rescue operations.

On the basis of NFPA's investigation and analysis of this fire, the following factors contributed significantly to the loss of the two Chesapeake fire fighters:

- The presence of lightweight wood roof trusses
- Fire officers and fire fighters unaware that the roof of the Chesapeake auto parts store was constructed with lightweight wood trusses
- The lack of a fire attack strategy that could minimize the risk to fire fighters while suppressing a fire involving lightweight wood trusses
- The lack of automatic sprinklers

**Warehouse
Four Fire Fighter Fatalities
Seattle, WA
January 5, 1995**

A fire in a Seattle, Washington, warehouse on January 5, 1995, resulted in the deaths of four members of the Seattle Fire Department. All four died when the floor between the upper and lower levels of the building collapsed. The fire, which was determined to have been set intentionally, began in the building's lower level directly below the area in which fire crews were conducting interior fire operations.

The building in which the fire occurred was originally constructed in 1909 with a structural support system of heavy timber. Over the years, however, the warehouse had been modified a number of times. One of these modifications was a cripple wall constructed of material estimated to be 2 inches by 4 inches in dimension, that had been installed to support the joists of the floor assembly between the upper and lower levels. Unfortunately, this cripple wall was more susceptible to fire than the building's other structural support mechanisms and when it failed it caused the floor to fail, creating the opening into which the four fire fighters fell.

As a result of NFPA's on-site investigation, which began the day after the collapse, and subsequent interviews, the following were identified as contributing factors in this incident:

- Confusion about the physical layout of the building, as well as the location of crews working in, above, and around the structure
- Lack of awareness on the fireground of the location of the fire and the various crews in relation to the fire
- Insufficient progress reports transmitted over the fireground frequency
- Lack of awareness of the length of time the building had been on fire and the passage of time after fire department notification
- Failure to take into account the fact that the building was a known arson target when formulating the fireground strategy
- Insufficient information to develop a risk/benefit evaluation of fireground operations.

Over the past five years, the Seattle Fire Department has aggressively sought to enhance fire fighter safety by: instituting a personnel accountability system that has become the model for many other fire departments around the country and by equipping personnel with protective equipment that meets current standards and portable radios that allow them to transmit an automatic, coded distress call to the dispatch center. Despite these precautions, four fire fighters lost their lives. As this incident so tragically illustrates, a great many dangers must still be accounted for during fire fighting operations.

**LP-Gas BLEVE
Two Fire Fighter Fatalities
Albert City, IA
April 9, 1998**

At approximately 11:10 p.m. on Thursday, April 9, 1998, a fire was reported at a large turkey farm near Albert City, Iowa. The fire began when an all-terrain vehicle (ATV) driven by teenagers struck two pipelines carrying liquid propane from an 18,000-gal (68 m³) capacity LP-Gas tank to two vaporizer units, creating a leak. The ensuing cloud of vapor was ignited by a nearby ignition source. The teens were able to escape the area prior to ignition and went to a nearby farmhouse to phone 911.

The tank was located between three buildings: an office and storage building 60 ft (18 m) to the west, a large turkey coop 100 ft (30.5 m) to the east, and another storage building 90 ft (27.4 m) to the north. The buildings were of wood-frame construction with a combination of metal and wood exterior siding. A gravel road was located approximately 65 ft (19.8 m) south of the tank. The propane fuel was utilized in heater units located in the farm buildings.

The fire department arrived at approximately 11:21 p.m. The initial report given upon arrival stated that there was fire involving the LP-Gas tank and that the tank was venting from the relief vents at the top of the vessel. Fire was noted to be below the tank, as well.

The fire department began to set up operations to protect the exposed buildings with hoselines. Because there was no water supply in the area, a tanker shuttle operation was implemented, with a portable tank left at the scene. The department's tanker unit returned to town to refill after transferring its load of water to the portable tank. The remaining two engines and a rescue unit were set up on the northern side of the tank and began operations.

Two fire fighters advanced a hoseline from the engine set up northwest of the LP-Gas tank. They positioned themselves at the west corner of the storage building immediately north of the tank. The fire chief joined them to monitor conditions from that vantage point. This group was approximately 100 ft (30.5 m) from the tank.

Two additional fire fighters advanced a hose line from the engine staged northeast of the LP-Gas tank between the building north of the tank and the large coop east of the tank. These men were approximately 90 feet (27.4 m) north of the tank.

The gas venting from the pressure relief valves on the tank created a loud noise similar to a jet engine, making communications on the fireground difficult. The fire chief indicated that the plan was to allow the tank to burn itself out and to protect exposures.

As this plan was being implemented, at approximately 11:28 p.m., a large explosion occurred, sending large sections of the tank flying in four different directions. The largest portion of the tank, a piece 24 ft (7.3 m) long, was hurled over 300 ft (91.4 m) into the large coop east of the tank. Another piece was propelled directly north, narrowly missing the two fire fighters positioned north of the tank. This piece went through the north building and was stopped by a silo more than 150 ft (45.7 m) from the tank's original location. The force of this piece passing by the two fire fighters carried one of the men into the building and up against the far wall. He crawled out of the wreckage and rejoined the others.

The third large piece was thrown northwest from the tank's location and struck the two fire fighters operating the hoseline at the west corner of the north building. The impact killed the two men instantly. This piece narrowly missed the fire chief as he stood near the two men who were killed. However, he was badly burned by the blast.

Other pieces of the tank were scattered in the open field across the road from the tank. Some traveled almost 250 ft (76.2 m) from the site of the blast. A piece of one of the vent pipes was found embedded over 3 ft deep into a gravel driveway over 200 ft (61 m) west of the tank's original location.

The fire was extinguished by the blast, leaving only several small hot spots that were promptly extinguished by fire fighters.

The fire chief, five fire fighters, and a sheriff's deputy were injured in the blast. Three of the injured fire fighters and the chief were badly burned. The remaining two fire fighters and the deputy were treated and released from area hospitals.

On the basis of the fire investigation and analysis, NFPA has determined that the following significant factors directly contributed to the explosion and the fire fighter deaths:

- The lack of protection around the LP-Gas tank installation and associated equipment, which allowed the ATV to strike the vaporizer piping
- The impingement of flame on the propane tank (in the vapor space), causing the tank shell to weaken and fail
- The close proximity of fire department operations to the LP-Gas tank while the tank was being exposed to direct flame contact
- The lack of an adequate and reliable water supply in close proximity to the site to allow for hose streams to be rapidly placed in service to cool the LP-Gas tank that was being impinged upon by flames from the broken pipes
- The decision, given the lack of an adequate water supply, to protect the exposed buildings and not to relocate all personnel to a safe location

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Fire Loss in the United States During 1998

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September 1999

Overview of 1998 U.S. Fire Experience

Number of Fires

- 1,755,500 fires were attended by public fire departments, a moderate decrease of 2.2% from the year before.
- 517,500 fires occurred in structures, a decrease of 6.3%.
- 381,500 fires or 74% of all structure fires occurred in residential properties.
- 381,000 fires occurred in vehicles, a decrease of 4.0% from the year before.
- 857,000 fires occurred in outside properties, a slight increase of 1.3%.
- The South with 7.8 had the highest fire incident rate per thousand population.
- What do these fire frequencies above mean? Every 18 seconds, a fire department responds to a fire somewhere in the nation. A fire occurs in a structure at the rate of one every 61 seconds, and in particular a residential fire occurs every 83 seconds. Fires occur in vehicles at the rate of 1 every 82 seconds, and there's a fire in an outside property every 37 seconds.

Civilian Fire Deaths

- 4,035 civilian fire deaths occurred in 1998, a very slight decrease of 0.4%.
- 3,220 fire deaths occurred in the home in 1998, a decrease of 4.2%.
- About 80% of all fire deaths occurred in the home.
- The South with 18.4 civilian deaths per million population had the highest regional rate.
- Nationwide, there was a fire death every 130 minutes.

Civilian Fire Injuries

- 23,100 civilians were injured in 1998, a slight decrease of 2.7% from the year before. This estimate for civilian injuries is on the low side, due to under reporting of civilian injuries to the fire service.
- 17,175 or 74.3% of all civilian injuries occurred in residential properties, while 2,250 or 9.7% occurred in nonresidential structure fires.
- The Northeast (115.1) and the Northcentral (98.8) had the highest regional rates per million population.
- Nationwide, there was a civilian fire injury every 23 minutes.

Property Damage

- An estimated \$8,629,000,000 in property damage occurred as a result of fire in 1998, a slight increase of 1.2%.
- \$6,717,000,000 or 78% of all property damage occurred in structure fires.
- \$4,391,000,000 or 65% of all structure property loss occurred in residential properties.
- The South with \$38.4 had the highest property loss (reflects wildfires in Florida that resulted in \$390 million loss) followed by the Northcentral (\$31.5) and the Northeast (\$31.4).

Incendiary and Suspicious Fires

- An estimated 76,000 structure fires were deliberately set or suspected of having been deliberately set, a decrease of 3.2% from a year ago, and 14.7% of all structure fires.
- Incendiary or suspicious fires in structures resulted in 470 civilian deaths, an increase of 5.6% from 1997.
Incendiary or suspicious structure fires also resulted in \$1,249,000,000 in property damage, the lowest figure in 20 years. This represents 18.6% of all structure property loss.
- 45,000 vehicle fires of incendiary or suspicious origin occurred, a decrease of 3.2%, and caused \$215,000,000 in property damage, virtually no change from a year ago.

Fires

In 1998, public fire departments responded to 1,755,500 fires in the United States, according to estimates based on data the NFPA received from fire departments responding to its 1998 National Fire Experience Survey (see Tables 1 and 2). This represents a significant decrease of 2.2% from a year ago.

There were an estimated 517,500 structure fires in 1998, a decrease of 6.3% from a year ago. For the 1977-98 period, the number of structure fires were at their peak in 1977 when 1,098,000 structure fires occurred (see Figure 1). The number of structure fires then decreased quite steadily particularly in the 1980s to 688,000 fires by the end of 1989 for an overall decrease of 37.3% from 1977. Since 1989, structure fires have decreased 24.5% to 517,500 by the end of 1998.

Fire incident rates by size of community were examined for the 1994-98 period. (See Figure 2). The smallest communities (under 2,500 population) had the highest rate with 12.8 fires per thousand population. This rate was 96% higher than the national average.

Of the 1998 structure fires, 381,500 were residential fires, accounting for 73.7% of all structure fires, and a moderate decrease of 6.2% from last year (see Table 3). Of the residential fires, an estimated 283,000 occurred in one- and two-family dwellings, accounting for 54.7% of structure fires, and a decrease of 6.4% from a year ago. Another 86,500 fires occurred in apartments, accounting for 16.7% of all structure fires.

The number of nonresidential structure fires by property type changed little in 1998 except for special structures (e.g., vacant buildings, and buildings under construction) which decreased a significant 23.5% to 26,000.

In 1998, fires outside of structure with value (e.g., timber, crops, outside storage) increased 9.7% to 62,000, while the number of rubbish fires including dumpsters decreased 7.3% to 229,000.

For the 1977-98 period, the number of outside fires were at their high in 1977 when 1,658,500 outside fires occurred. The number of outside fires decreased steadily the next six years to 1,011,000 in 1983 for a considerable decrease of 39.0% from 1977. Outside fires changed little for the rest of the 1980s except for 1988 when 1,214,000 occurred. Outside fires reached 910,500 in 1993, stayed near the 1,000,000 level the next three years, and then dropped 13.7% in 1997, and then increased slightly to 857,000 in 1998.

Table 1
Estimates of 1998 Fires, Civilian Deaths, Civilian Injuries
and Property Loss in the United States

	Estimate	Range¹	Percent Change Fro 1997
Number of Fires	1,755,500	1,719,500 to 1,791,500	-2.2
Number of Civilian Deaths	4,035	3,625 to 4,445	-0.4
Number of Civilian Injuries	23,100	21,800 to 24,400	-2.7
Property Loss ²	\$8,629,000,000	\$8,403,000,000 to 8,855,000,000	+1.2

The estimates are based on data reported to the NFPA by fire departments that responded to the 1998 National Fire Experience Survey.

¹ These are 95 percent confidence intervals.

² This includes overall direct property loss to contents, structures, vehicles, machinery, vegetation, and anything else involved in a fire. It does not include indirect losses. No adjustment was made for inflation in the year-to-year comparison.

Table 2
Estimates of 1998 Fires and
Property Loss by Property Use

Type of Fire	Number of Fires		Property Loss ¹	
	Estimate	Percent Change from 1997	Estimate	Percent Change from 1997
Fires in Structures	517,500	-6.3**	\$6,717,000,000	-5.2*
Fires in Highway Vehicles	358,500	-4.9	1,129,000,000	+4.2
Fires in Other Vehicles ²	22,500	+12.5	208,000,000	+12.4
Fires Outside of structures with value involved but no vehicle (outside storage, crops, timber, etc.)	62,000	+9.7	497,000,000	+402.0 ³
Fires in Brush, Grass Wildland (excluding crops and timber) with no value or loss involved	424,000	+2.0	—	—
Fires in Rubbish including dumpsters (outside of structures), with no value or loss involved	229,000	-7.3	—	—
All Other Fires	142,000	+11.8	78,000,000	+11.4
Total	1,755,500	-2.2	\$8,629,000,000	+1.2

The estimates are based on data reported to the NFPA by fire departments that responded to the 1998 National Fire Experience Survey.

¹ This includes overall direct property loss to contents, structure, a vehicle, machinery, vegetation or anything else involved in a fire. It does not include indirect losses, e.g., business interruption or temporary shelter costs. No adjustment was made for inflation in the year-to-year comparison.

² This includes trains, boats, ships, aircraft, farm vehicles and construction vehicles.

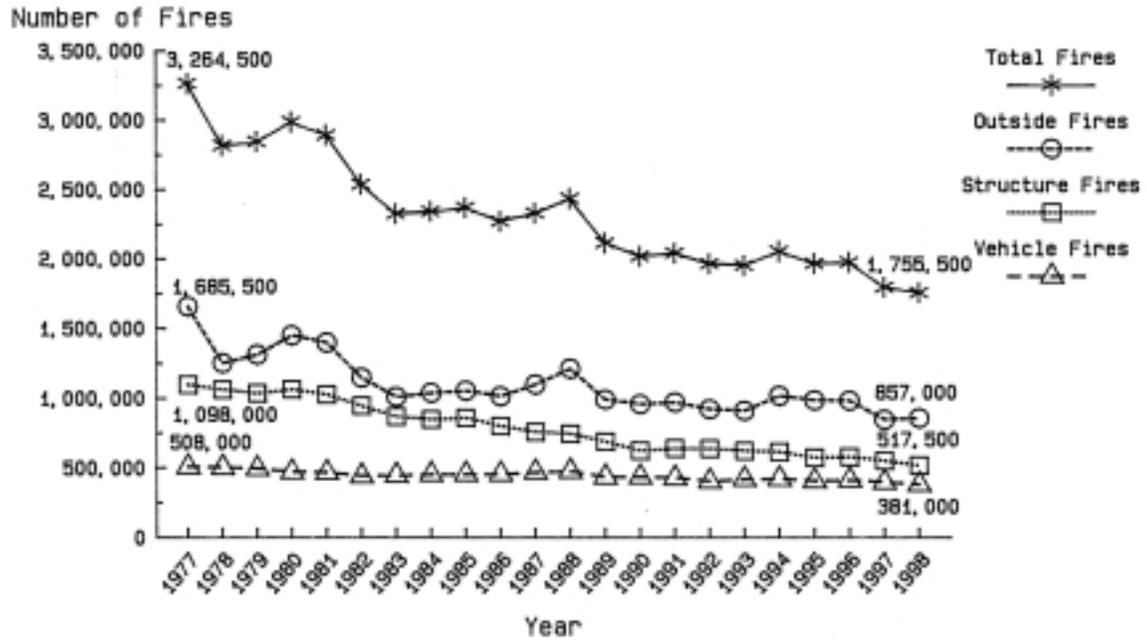
³ This increase reflects wildfires in Florida that resulted in \$390 million loss in timber.

*Change was statistically significant at the .05 level.

**Change was statistically significant at the .01 level.

Figure 1

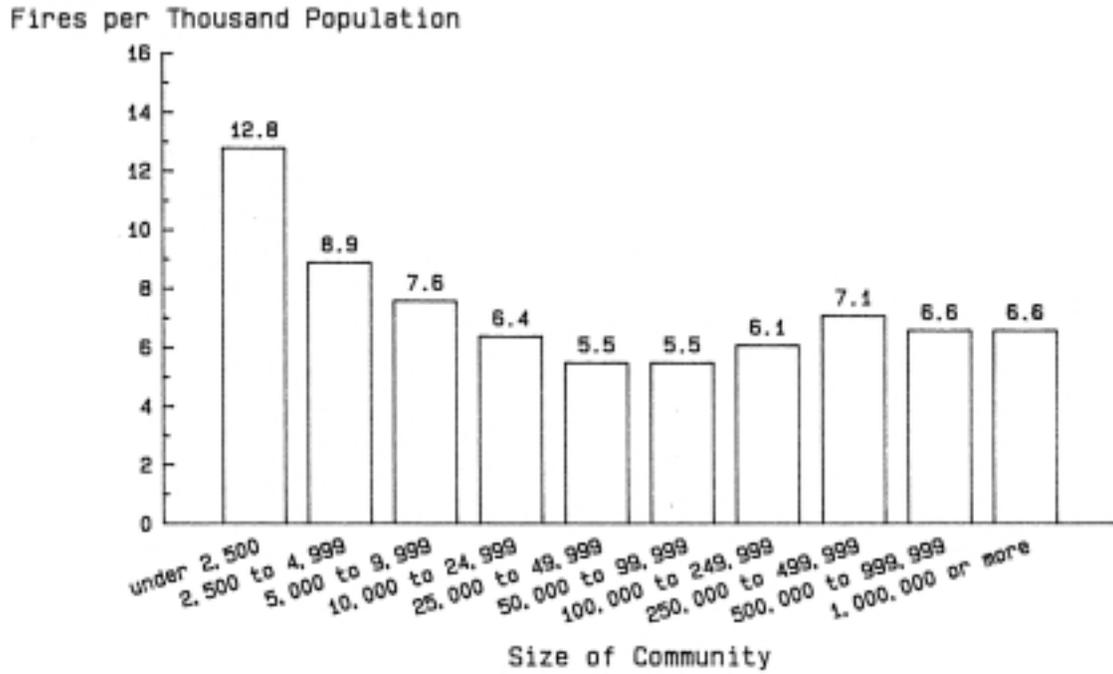
Figure 1
Estimates of Fires by Type
in the United States (1977-1998)



Source: NFPA's Annual Survey of Fire Departments for U.S. Fire Experience (1977-98)

Figure 2

Figure 2
Fires per Thousand Population
by Size of Community (1994-98)



Source: NFPA's Annual Survey of Fire Departments
for U.S. Fire Experience (1994-98)

Table 3
Estimates of 1998 Structure Fires and
Property Loss by Property Use

Property Use	Structure Fires		Property Loss ¹	
	Estimate	Percent Change from 1997	Estimate	Percent Change from 1997
Public Assembl	15,500	-3.3	\$354,000,000	+8.3
Educational	8,000	+6.7	84,000,000	+44.8
Institutional	9,000	+5.9	23,000,000	-8.0
Residential (Total)	381,500	-6.2**	4,391,000,000	-4.2
One- and Two-Family Dwellings ²	283,000	-6.4**	3,642,000,000	-2.5
Apartments	86,500	-7.0	631,000,000	-12.1
Other Residential ³	12,000	+9.1*	118,000,000	-10.6
Stores and Offices	25,500	-5.6	462,000,000	-24.5
Industry, Utility, Defense ⁴	16,000	-5.9	496,000,000	-31.4
Storage in Structures	36,000	-1.4	687,000,000	+19.1
Special Structures	26,000	-23.5	220,000,000	+22.2
Total	517,500	-6.3**	\$6,717,000,000	-5.2*

The estimates are based on data reported to the NFPA by fire departments that responded to the 1998 National Fire Experience Survey.

¹ This includes overall direct property loss to contents, structure, a vehicle, machinery, vegetation or anything else involved in a fire. It does not include indirect losses, e.g., business interruption or temporary shelter costs. No adjustment was made for inflation in the year-to-year comparison.

² This includes manufactured homes.

³ Includes hotels and motels, college dormitories, boarding houses, etc.

⁴ Incidents handled only by private fire brigades or fixed suppression systems are not included in the figures shown here.

*Change was statistically significant at the .05 level.

**Change was statistically significant at the .01 level.

Civilian Deaths

The 1,755,000 fires responded to by fire departments in the U.S. resulted in an estimated 4,035 civilian deaths based on data reported to the NFPA. This represents a very slight decrease of 0.4% or virtually no change from the year before (see Table 4). This can better be understood by examination of results by property type.

An estimated 3,250 civilians died in residential fires in 1998, a modest decrease of 4.1%. Of these residential deaths, 2,775 occurred in one- and two-family dwellings, a slight increase of 2.7% from a year ago. An estimated 445 civilians died in apartment fires, a significant decrease of 33.3% from a year ago.

In all, fires in the home (one- and two-family dwellings and apartments) resulted in 3,220 civilian deaths, a decrease of 4.2% from a year ago. Looking at trends in civilian deaths since 1977-78¹, several observations are worth noting (see Figure 3). Home fire deaths were at their peak in 1978 when 6,015 fire deaths occurred. Home fire deaths then decreased steadily during the 1979-82 period except for 1981, and decreased a substantial 20% during the period to 4,820 by the end of 1982. From 1982 to 1988, the number of home fire deaths stayed quite level in the 4,655 to 4,955 area except for 1984 when 4,075 fire deaths occurred. In the past ten years, home fire deaths moved well below the 1982-88 plateau and fell in the 3,425 to 3,720 area during 1991 to 1995 followed by a jump in 1996 when 4,035 deaths occurred, and a two year sustained decline to the 3,220 to 3,360 range in 1997 to 1998. This appears to be a new lower level for home fire deaths, but the high year in 1996 should make us cautious.

With home fire deaths accounting for 79.8% of all fire deaths, fire safety initiatives targeted at the home remain the key to any reductions in the overall fire death toll. Five major strategies are: First, more widespread public fire safety education is needed on how to prevent fires and how to avoid serious injury or death if fire occurs. Information on the common causes of fatal home fires should continue to be used in the design of fire safety education messages. Second, more people must use and maintain smoke detectors and develop and practice escape plans. Third, wider use of residential sprinklers must be aggressively pursued. Fourth, additional ways

Table 4
Estimates of 1998 Civilian Fire Deaths and Injuries by Property Use

<u>Property Use</u>	<u>Civilian Deaths</u>			<u>Civilian Injuries</u>		
	<u>Estimate</u>	<u>Percent Change From 1997</u>	<u>Percent of all Civilian Deaths</u>	<u>Estimate</u>	<u>Percent Change From 1997</u>	<u>Percent of all Civilian Injuries</u>
Residential (total)	3,250	-4.1	80.5	17,175	-3.4	74.3
One-and Two-Family Dwellings ¹	2,775	+2.7	68.8	11,800-	4.1	51.1
Apartments	445	-33.3	11.0	5,000	0	21.6
Other Residential ²	30	0	0.7	375	-21.1	1.6
Non-residential Structures ³	170	+41.7	4.2	2,250	13.5	9.7
Highway Vehicles	545	+21.1	13.5	2,050	+5.1	8.9
Other Vehicles ⁴	30	0	0.7	175	0	0.8
All Other ⁵	40	33.3	1.0	1,450	+16.0	6.3
Total	4,035	-0.4		23,100	-2.7	

Estimates are based on data reported to the NFPA by fire departments that responded to the 1998 National Fire Experience Survey. Note that most changes were not statistically significant; considerable year-to-year fluctuation is to be expected for many of these totals because of their small size.

¹ This includes manufactured homes.

² Includes hotels and motels, college dormitories, boarding houses, etc.

³ This includes public assembly, educational, institutional, store and office, industry, utility, storage, and special structure properties.

⁴ This includes trains, boats, ships, aircraft, farm vehicles, and construction vehicles.

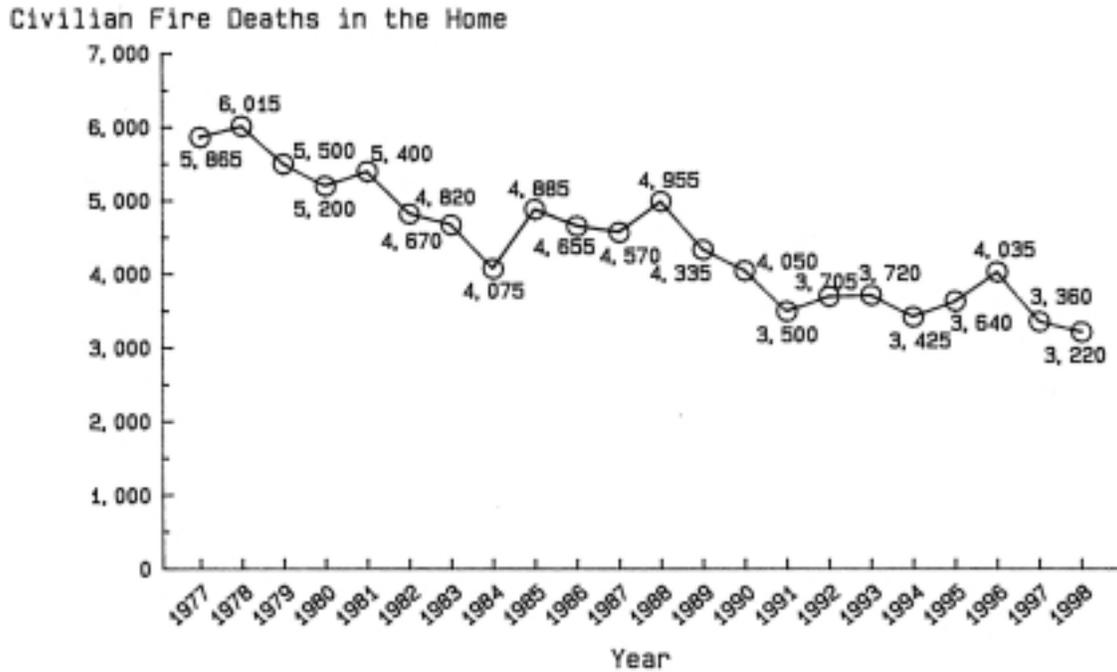
⁵ This includes outside properties with value, as well as brush, rubbish, and other outside locations.

*Statistically significant at the .05 level.

**Statistically significant at the .01 level.

Figure 3

Figure 3
Civilian Fire Deaths in the Home
in the United States (1977-98)



Source: NFPA's Annual Survey of Fire Departments for U.S. Fire Experience (1977-98)

must be sought to make home products more fire safe. The regulations requiring more child-resistant lighters are a good example, as is the recent examination of the feasibility of less fire-prone cigarettes. The wider use of upholstered furniture and mattresses that are more resistant to cigarette ignitions is an example of change that has already accomplished much and will continue to do more. Fifth, the special fire safety needs of high risk groups, e.g., the young, older adults, and the poor need to be addressed.^{2, 3}

Civilian fire death rates by size of community were examined for the 1994-98 period (see Figure 4). The smallest communities (under 2,500 population) had the highest rate. The rate for communities under 2,500 population was more than twice the national average rate.

Also in 1998, an estimated 170 civilians died in nonresidential structure fires, a significant increase of 41.7%.

An estimated 545 civilians died in highway vehicle fires, an increase of 21.2% from a year ago, while 30 civilians died in other vehicle fires, no change from a year ago.

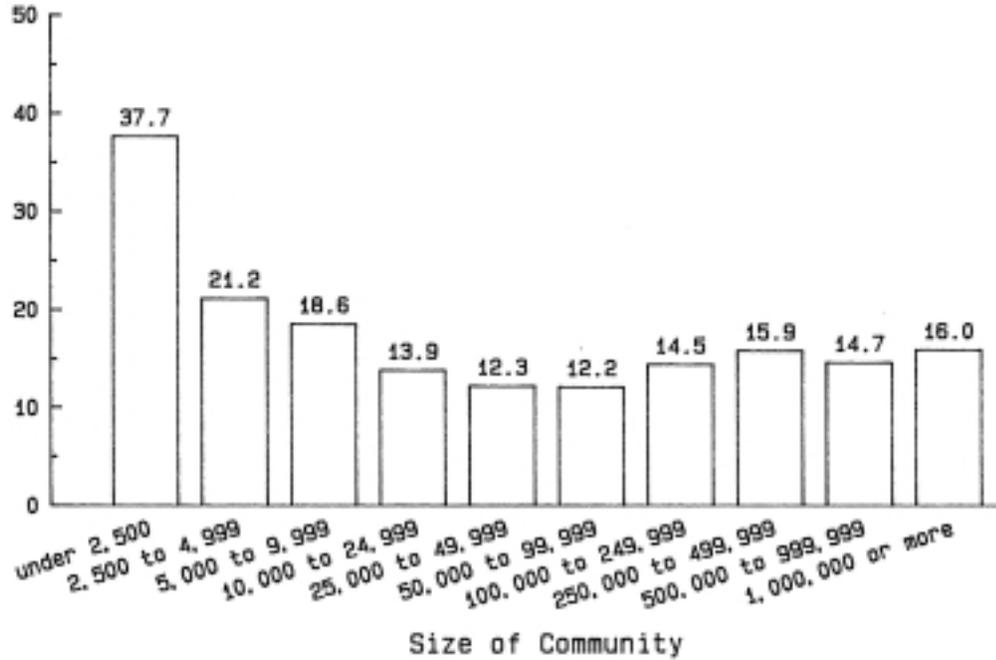
The NFPA estimates that 470 civilians or 13.7% of all civilian deaths that occurred in structure fires were of an incendiary or suspicious nature.

In 1998, 93 fire fighters died in the line of duty. This represents a decrease of 4.1% from the year before.⁴

Figure 4

Figure 4
Civilian Fire Deaths per Million Population
By Size of Community (1994-98)

Civilian Fire Deaths per Million People



Source: NFPA's Annual Survey of Fire Departments
for U.S. Fire Experience (1994-98)

Civilian Fire Injuries

Results based on data reported to the NFPA indicate that in addition to 4,035 civilian fire deaths, there were 23,100 civilian fire injuries in 1998. This is a moderate decrease of 2.7% from a year ago.⁵

Estimates of civilian injuries are on the low side, because many civilian injuries are not reported to the fire service. For example, many injuries occur at small fires that fire departments do not respond to, and sometime when departments do respond they may be unaware of injured persons that they did not transport to medical facilities.

The NFPA estimates that 17,175 people were injured in residential fires in 1998, a moderate decrease of 3.4%. Of these injuries, 11,800 occurred in one- and two-family dwellings, while 5,000 occurred in apartments. Overall, 74.3% of all civilian injuries occurred in residential properties.

The number of civilian injuries has changed less than the other measures of fire loss for the 1977-98 period. The number of civilian injuries has ranged from a high of 31,275 in 1983 to a low of 23,100 in 1998 for an overall decline of 26%. There was no consistent pattern going up or down until recently, when injuries fell roughly 5,000 in 1994-95 to 25,775, changed little in 1996, then dropped 8% to 23,750 in 1997, and changed little in 1998.

Property Loss

The NFPA estimates that the 1,755,500 fires responded to by the fire service caused \$8,629,000,000 in property damage in 1998. This year's estimate is a significant 1.2% decrease from the 1997 figure. The average loss per fire was \$4,915, up 3.5% from a year ago.

Fires in structures resulted in an estimated \$6,717,000,000 in property damage in 1998, a decrease of 5.2%. Average loss per structure fire was \$12,980, up a slight 1.1% from a year ago (see Figure 5). Over the 1977-98 period, the average loss per structure fire ranged from a low of \$3,757 in 1977 to a high of \$13,713 in 1996 for an increase of 265%. When property loss is adjusted for inflation, the increase in the average loss per structure fire for 1977 and 1996 decreases to 42%.

Of the property loss in 1998, an estimated \$4,391,000,000 occurred in residential properties, down 4.2% from a year ago. An estimated \$3,642,000,000 in property damage occurred in one- and two-family dwellings, down 2.5% from last year. An estimated \$631,000,000 in property damage

Figure 5

Figure 5
Average Property Loss per Structure Fire
in the United States (1977-98)



Source: NFPA's Annual Survey of Fire Departments
for U.S. Fire Experience (1977-98)

also occurred in apartments. Other property damage figures worth noting for 1998 include: \$496,000,000 in industrial properties, a significant decrease of 31.4%; \$462,000,000 in store and office properties, a significant decrease of 24.5%; \$687,000,000 in storage properties, a significant increase of 19.1%; \$220,000,000 in special structures, an increase of 22.2%; and \$497,000,000 in fires outside of structure with value, a highly significant increase of 402% (reflects wildfires that occurred in Florida that resulted in \$390,000,000 loss in timber).

It should be kept in mind that property loss totals can change dramatically from year to year because of the impact of occasional large loss fires. The NFPA provides an analysis of these large loss fires in the November/December issue of *NFPA Journal* every year.

Incendiary and Suspicious Fires

Based on data reported by fire departments in the survey, the NFPA estimates that 76,000 of the structure fires that occurred in the United States in 1998 were of an incendiary or suspicious nature (see Table 5), and the lowest since the NFPA changed its survey methodology in 1977. These incendiary and suspicious fires took the lives of 470 civilians, an increase of 5.6%.

Over the 1989-98 decade, the number of incendiary or suspicious structure fires were at their highest in 1989 when 97,000 occurred (see Figure 6). Incendiary or suspicious fires changed little during 1990-91, then decreased 13.8% during 1992-93 to 84,500 in 1993. From 1994 to 1996, incendiary or suspicious fires changed little except for 1995 when 90,500 occurred, but then decreased 11.1% during 1997-98 to 76,000 in 1998.

Incendiary and suspicious fires also resulted in \$1,249,000,000 in property damage, a decrease of 4.6% from a year ago, and the lowest total since 1979, even without adjusting for inflation.

There were 45,000 vehicle fires of incendiary or suspicious origin, a very slight decrease of 3.2%, from a year ago. These fires did an estimated \$215,000,000 in property damage, an increase of 0.5%, or virtually no change from a year ago.

In all, fires that were set or suspected of having been deliberately set accounted for 13.5% of all fires in structures and vehicles, but for 18.2% of the property loss.

Table 5
Estimate of 1998 Losses in
Incendiary and Suspicious Structure Fires

<u>Type of Fire</u>	Number of Fires		Number of Civilian Deaths		Direct Property Loss¹	
	<u>Estimate</u>	<u>Percent Change From 1997</u>	<u>Estimate</u>	<u>Percent Change From 1997</u>	<u>Estimate</u>	<u>Percent Change From 1997</u>
Structure Fires of Incendiary Origin	46,500	-10.1	355	+4.4	\$816,000,000	+1.7
Structure Fires of Suspicious Origin	29,500	+11.3	115	+9.5	433,000,000	-14.6
Total Structure Fires of Incendiary or Suspicious Origin	76,000	-3.2	470	+5.6	1,249,000,000	-4.6

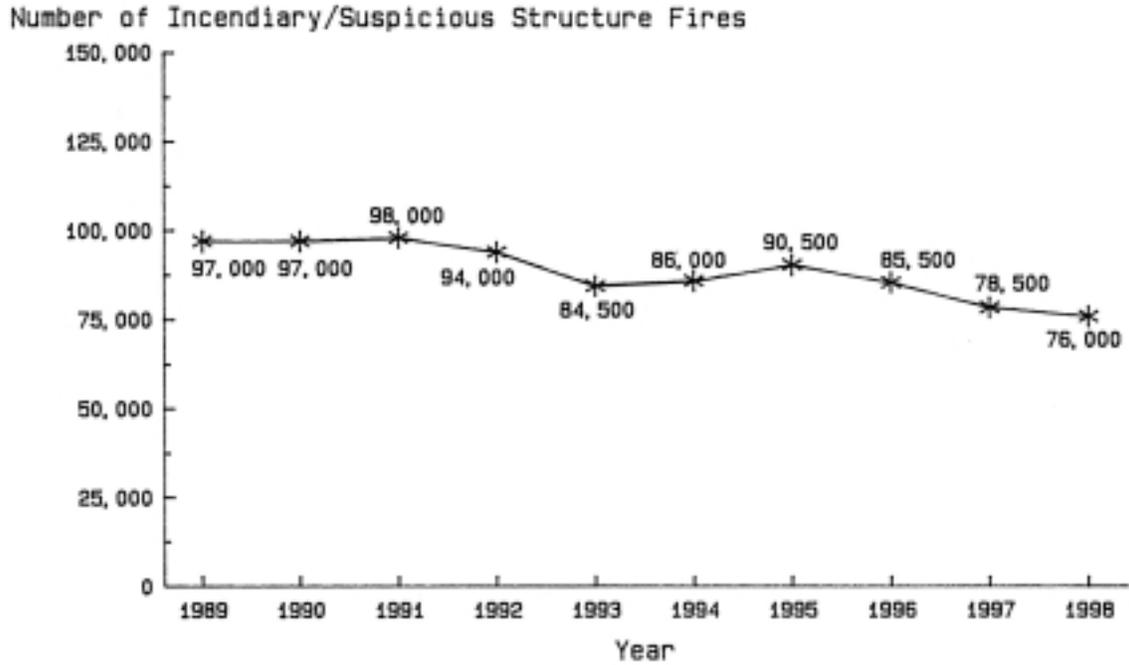
The estimates are based on data reported to the NFPA by fire departments that responded to the 1998 National Fire Experience Survey.

¹ This includes overall direct property loss to contents, structure, a vehicle, machinery, vegetation, or anything else involved in a fire. It does not include indirect losses, e.g., business interruption or temporary shelter costs. No adjustment was made for inflation in the year-to-year comparison.

*Change was statistically significant at the .05 level.

Figure 6

Figure 6. Number of Incendiary or Suspicious Structure Fires in the United States (1989-98)



Source: NFPA's Annual Survey of Fire Departments
for U.S. Fire Experience (1989-98)

Region

Fire loss rates nationwide and by region can be seen in Table 6. The South with 7.8 had the highest fire incident rate per thousand population followed by the Northeast (6.7).

The South with 18.4, again had the highest death rate per million population followed by the Northcentral (16.2).

The Northeast (115.1), and the Northcentral (98.8), had the highest injury rates per million population, while the West had the lowest rate (60.0). The South with (\$38.4) had the highest property loss per capita rate (which again reflects the wildfires in Florida) followed by the Northeast (\$31.5), and the Northcentral (\$31.4).

Fires per thousand population by region and community size are shown in Table 7. The Northeast had the highest rate for communities of 100,000 to 249,999, the Northcentral had the highest rate for communities of 250,000 to 249,999 and the South had the highest rate for the largest communities (500,000 or more), and for all community sizes less than 100,000 population.

Civilian fire deaths per million population by region and community size are shown in Table 8. The Northeast had the highest rate for the largest communities (populations of 500,000 or more), the Northcentral had the highest rates for communities of 100,000 to 499,999, the South had the highest rates for communities of 5,000 to 99,999, and the West had the highest rate for communities 2,500 to 4,999.

Civilian fire injuries per million population by region and community size are shown in Table 9. The Northcentral had the highest rate for larger communities (populations of 250,000 or more) and communities of 5,000 to 24,999, the Northeast had the highest rates for communities of 25,000 to 249,999 and communities of less than 2,500 population, and the West had the highest rate for communities of 2,500 to 4,999.

Property loss rates per person by region and community size are shown in Table 10. The Northeast had the highest rate for communities of 10,000 to 24,999, the Northcentral had the highest rate for communities of 100,000 to 24,999, the West had the highest rate for communities of 250,000 to 499,999, and the South had the highest rates for communities of 500,000 or more, communities of 25,000 to 99,999, and the smaller communities (populations of less than 10,000).

Table 6
Fire Loss Rates Nationwide and by Region, 1998

<u>Region</u>	<u>Number of Fires per Thousand Population</u>	<u>Civilian Deaths per Million Population</u>	<u>Civilian Injuries per Million Population</u>	<u>Property Loss per Capita</u>
Nationwide	6.5	14.9	85.5	\$32.0
Northeast	6.7	12.6	115.1	31.5
Northcentral	6.1	16.2	98.8	31.4
South	7.8	18.4	79.5	38.4
West	4.8	9.2	60.0	22.7

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

Table 7
1998 Fires per Thousand Population

Population of Community	All Regions	Northeast	Northcentral	South	West
500,000 or more	5.6	*	*	6.0	4.0
250,000 to 499,999	6.6	*	9.4	7.4	4.1
100,000 to 249,999	5.4	7.4	5.4	5.8	3.9
50,000 to 99,999	5.1	6.0	4.3	6.8	4.0
25,000 to 49,999	4.9	4.4	4.2	5.9	5.1
10,000 to 24,999	5.8	5.4	5.0	6.8	6.3
5,000 to 9,999	6.9	5.8	5.6	9.0	8.8
2,500 to 4,999	8.1	7.3	6.6	10.6	9.2
under 2,500	11.7	10.9	8.8	18.7	13.9

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

*Insufficient data

Table 8
1998 Civilian Fire Deaths per Million Population
by Region and Size of Community

Population of Community	All Regions	Northeast	Northcentral	South	West
500,000 or more	12.7	17.7	13.4	15.2	5.9
250,000 to 499,999	15.9	17.0	28.4	15.7	9.4
100,000 to 249,999	13.9	15.2	16.7	16.5	6.3
50,000 to 99,999	11.7	12.6	12.2	15.5	5.5
25,000 to 49,999	9.4	9.0	7.5	14.8	5.1
10,000 to 24,999	12.5	7.5	12.7	15.7	10.9
5,000 to 9,999	17.4	10.7	11.6	33.8	13.7
2,500 to 4,999	13.5	*	11.5	13.7	18.5
under 2,500	33.6	23.8	28.2	55.7	19.4

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

*Insufficient data

Table 9
1998 Civilian Fire Injuries per Million Population
by Region and Size of Community

Population of Community	All Regions	Northeast	Northcentral	South	West
500,000 or more	88.7	*	122.8	99.6	54.1
250,000 to 499,999	126.5	*	192.2	132.2	102.9
100,000 to 249,999	109.0	155.2	140.7	105.8	75.6
50,000 to 99,999	96.9	123.3	110.4	89.3	65.5
25,000 to 49,999	86.6	140.0	80.0	95.9	36.7
10,000 to 24,999	78.4	85.2	89.0	66.4	61.8
5,000 to 9,999	65.7	46.0	82.8	49.4	75.3
2,500 to 4,999	71.4	65.9	39.2	122.1	88.1
under 2,500	97.0	110.9	81.4	89.0	96.2

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

*Insufficient data

Table 10
1998 Property Loss per Person
by Region and Size of Community

Population of Community	All Regions	Northeast	Northcentral	South	West
500,000 or more	\$23.5	*	\$25.9	\$34.3	\$15.1
250,000 to 499,999	37.3	*	36.9	32.9	37.2
100,000 to 249,999	32.1	\$25.5	51.0	27.3	24.2
50,000 to 99,999	24.5	20.5	22.3	29.4	25.5
25,000 to 49,999	24.4	18.9	24.6	29.9	19.2
10,000 to 24,999	36.6	44.9	36.2	36.0	30.6
5,000 to 9,999	40.9	38.2	31.5	46.0	34.2
2,500 to 4,999	44.2	31.9	51.5	57.0	39.0
under 2,500	77.2	52.1	61.3	91.0	67.0

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

*Insufficient data

Average 1998 Fire Experience by Community Size

Average 1998 fire loss experience by size of community is presented in Table 11. Results are shown for all fires, structure fires, civilian deaths, civilian injuries, and property loss. It is not surprising that the larger the community, the higher the average fire statistic.

Average 1998 residential fire experience by size of community is presented in Table 12. Results are shown for number of fires, civilian deaths, civilian injuries, and property loss.

Table 11
Average 1998 Fire Experience by Size of Community

Population of Community	All Fires	Structure Fires	Civilian Deaths	Civilian Injuries	Property Loss
1,000,000 or more	11,444	2,702	29.60	178.00	\$54,649,800
500,000 to 999,999	3,634	1,133	8.76	68.55	16,942,100
250,000 to 499,999	2,219	607	5.49	43.23	12,385,400
100,000 to 249,999	807	273	2.09	16.70	4,771,900
50,000 to 99,999	345	116	0.79	6.52	1,675,700
25,000 to 49,999	162	52	0.32	2.88	812,800
10,000 to 24,999	88	28	0.20	1.20	555,900
5,000 to 9,999	47	14	0.12	0.52	279,200
2,500 to 4,999	28	8	0.05	0.24	192,500
under 2,500	13	3	0.05	0.13	79,100

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

Table 12
Average 1998 Residential Fire Experience by Size of Community

Population of Community	Number of Fires	Civilian Deaths	Civilian Injuries	Property Loss
1,000,000 or more	2,005	27.88	145.66	\$20,232,000
500,000 to 999,999	881	7.30	53.45	8,574,800
250,000 to 499,999	445	4.65	29.91	5,152,900
100,000 to 249,999	201	1.84	12.78	2,086,000
50,000 to 99,999	83	0.69	4.84	823,800
25,000 to 49,999	37	0.28	2.19	427,500
10,000 to 24,999	21	0.14	0.86	276,300
5,000 to 9,999	11	0.10	0.34	136,900
2,500 to 4,999	6	0.04	0.14	106,200
under 2,500	2	0.03	0.04	41,900

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

Fire Department Responses

In all, fire departments responded to the following estimated number of fires and other incidents in 1998.

	Number	Percent Change From 1997
Fire Incidents	1,755,500	-2.2
Medical Aid Responses (Ambulance, EMS, Rescue)	10,936,000	+4.3
False Alarms	1,956,000	+7.8
Mutual Aid or Assistance Calls	707,500	+2.8
Hazardous Material Responses (Spills, Leaks, etc.)	301,000	+10.9
Other Hazardous Responses (arcing wires, bomb removal etc.)	559,000	+12.1
All Other Responses (smoke scares, lock-outs, etc.)	2,538,000	+6.2
Total Incidents	18,753,000	+4.4

A further breakdown on false responses was collected on the 1998 surveys and the results can be seen in Table 13.

Table 13
Estimates of False Alarms by Type, 1998

	Estimate	Percent Change From 1997	Percent of All False Alarms
Malicious, Mischievous False Call	309,000	+7.9	15.8
System Malfunction	851,000	+4.2	43.5
Unintentional Call	569,000	+16.1	29.1
Other False Alarms (Bomb Scares, etc.)	227,000	+2.5	11.6
Total	1,956,000	+7.8	

Source: NFPA's Survey of Fire Departments for 1998 U.S. Fire Experience.

SURVEY METHODOLOGY

Each year, based on a sample survey of fire departments across the country, the NFPA estimates the national fire problem as measured by the number of fires that public fire departments attend, and the resulting deaths, injuries and property losses that occur. This report summarizes key findings based on the NFPA Survey for 1998 Fire Experience. This section explains the major steps in conducting the 1998 survey.

Sample Selection

The NFPA currently has 26,985 public fire departments listed in its Fire Service Inventory (FSI) file. Based on desired levels of statistical precision for the survey results and the staff available to process, edit, and follow up on the individual questionnaires the NFPA determined that 3,000 fire departments were a reasonable number for the 1998 sample.

Because of the variation in fire loss results by community size, fire departments were placed in one of the following 10 strata by size of community protected:

- 1,000,000 and up
- 500,000 to 999,999
- 250,000 to 499,999
- 100,000 to 249,999
- 50,000 to 99,999
- 25,000 to 49,999
- 10,000 to 24,999
- 5,000 to 9,999
- 2,500 to 4,999
- Under 2,500

Sample sizes for the individual strata were chosen to ensure the best estimate of civilian deaths in one- and two-family dwellings, the statistic that most aptly reflects the overall severity of the fire problem. All departments that protect 100,000 people or more were included. These 309 departments in the four highest strata protect 110,014,900 people.

For the remaining six population strata, assuming response rates similar to the past two years for the four highest strata, a total sample of 2,835 was indicated. Sample sizes for individual strata were calculated using a methodology that assured optimum sample allocations⁷. Based on the average variation in civilian deaths in one- and two-family dwellings by stratum for the last two years and on the estimated number of fire

departments, appropriate relative sample weights were determined. Then the corresponding sample sizes by stratum were calculated. The sample size by stratum was then adjusted based on the response rates from the last two years' returns. A sample size of 13,400 was found to be necessary to obtain the desired total response of 3,000 fire departments. For all strata, where a sample was necessary, departments were randomly selected.

Data Collection

The 13,400 fire departments selected for the survey were sent the 1998 NFPA Fire Experience Questionnaire during the last week of January 1999. A second mailing was sent in mid-March to fire departments that had not responded to the first mailing. A total of 2,790 departments responded to the questionnaire, 2,126 to the first mailing and 664 to the second.

Table 14 shows the number of departments that responded by region and size of community. The overall response rate was 21%, although response rates were considerably higher for departments protecting larger communities than they were for departments protecting smaller communities. The 2,790 departments that did respond protect, 104,752,140 people or 39% of the total U.S. population.

After the NFPA received the surveys, technical staff members of the Fire Analysis and Research Division reviewed them for completeness and consistency. When appropriate, they followed up on questions with a telephone call.

After the edit, procedures were completed, the survey data were keyed to a computer file, where additional checks were made. The file was then ready for data analysis and estimation procedures.

Estimation Methodology

The estimation method used for the survey was ratio estimation, with stratification by community size.⁸ For each fire statistic a sample loss rate was computed for each stratum. This rate consisted of the total for that particular statistic from all fire departments reporting it, divided by the total population protected by the departments reporting the statistic. Note

Table 14
Number of Fire Departments Responding to 1998 NFPA Survey, by
Region and Community Size

Population of Community	All Regions	Northeast	Northcentral	South	West
1,000,000 or more	9	2	1	3	3
500,000 to 999,999	28	1	3	17	7
250,000 to 499,999	37	5	6	14	12
100,000 to 249,999	94	12	16	41	25
50,000 to 99,999	219	29	85	60	45
25,000 to 49,999	247	38	104	70	35
10,000 to 24,999	471	82	194	137	58
5,000 to 9,999	457	82	188	122	65
2,500 to 4,999	431	94	179	111	47
under 2,500	797	106	401	167	123
TOTAL	2,790	451	1,177	742	420

that this means that the departments used in calculating each statistic could be different, reflecting differences in unreported statistics. The sample fire loss rates by stratum were then multiplied by population weighting factors to determine the estimates of that particular fire statistic for each stratum. Finally, the stratum estimates were combined to provide the overall national estimate.

If this method of estimation is to be effective, estimates of the total number of fire departments and the total population protected in each stratum must be accurate. The NFPA makes every effort to ensure that this is the case. The population weights used for the national estimates were developed using the NFPA FSI (Fire Service Inventory) File and U.S. Census population figures.

For each estimate, a corresponding standard error was also calculated. The standard error is a measure of the error caused by the fact that estimates are based on a sampling of fire losses rather than on a complete census of the fire problem. The standard error helps in determining whether year-to-year differences are statistically significant. Differences that were found to be statistically significant were so noted in tables. Property loss estimates are particularly prone to large standard errors because they are sensitive to unusually high losses, and, as a result, large percentage differences from year to year are not always statistically significant. In 1998, for instance, property damage in special properties was estimated to be \$220,000,000. This represented an increase of 22.2% from the year before, but was found not to be statistically significant.

In addition to sampling errors, there are nonsampling errors. These include biases of the survey methodology, incomplete or inaccurate reporting of data to the NFPA, and differences in data collection methods by the fire departments responding. As an example of a nonsampling error, most of the fires included in the survey took place in highly populated residential areas, because the fire departments selected for the surveys are primarily public fire departments that protect sizable residential populations. Fires that occur in sparsely populated areas protected primarily by State and Federal Departments of Forestry are not likely to be included in the survey results.

The editors of survey data attempted to verify all reported civilian deaths in vehicle fires. They contacted most of the fire departments that reported fire-related deaths in vehicles and found that many of the deaths were indeed the results of fire. In some instances, however, impact was found to have been the cause of death. This effort can have a considerable impact on the estimates.

The results presented in this report are based on fire incidents attended by public fire departments. No adjustments were made for unreported fires and losses (e.g., fires extinguished by the occupant). Also, no adjustments were made for fires attended solely

by private fire brigades (e.g., industry and military installations), or for fires extinguished by fixed suppression systems with no fire department response.

Fire Experience of Nonrespondents

A telephone follow-up was made to a sample of nonrespondents to determine whether fire departments that did not respond to the survey experienced fire loss rates similar to those that did respond. This would help the NFPA determine whether we received questionnaires only from departments that had experienced unusually high or low fire losses.

Response rates by population strata indicate that for departments in strata that protect fewer than 25,000 people the survey response rates dropped considerably. Because of the low survey response in these strata, we decided to concentrate our follow-up effort on them.

The sample of nonrespondents selected was proportional by state and population of community to the original sample selected for the survey. As a result of these efforts, 104 fire departments were successfully contacted and answered some of the questions about their fire experience.

Table 15 compares fire loss rates for both respondents and nonrespondents. For communities 10,000 to 24,999, the nonrespondent rate was 15% higher for fires, 45% higher for civilian deaths, and 29% higher for property loss (None of these results were found to be statistically significant.)

For communities under 10,000, the respondent rate was 5% higher for number of fires, 19% higher for deaths, and 46% higher for property loss (None of these results were found to be statistically significant.)

Table 15
A Comparison of Respondents and Nonrespondents*
to the 1998 NFPA Survey by Community Size

Population of Community	Number of Fires (Per Thousand Population)				Civilian Deaths (Per Million Population)				Property Loss (Per Capita)			
	Respondents		Nonrespondents		Respondents		Nonrespondents		Respondents		Nonrespondents	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
10,000 to 24,999	446	5.8	38	6.6	468	12.52	34	8.6	345	36.60	13	28.43
under 10,000	1,650	8.0	63	7.6	1,675	20.30	63	17.0	1,217	50.64	27	34.70

*Some departments did not return the questionnaire. A sample of these nonrespondents was contacted by telephone and questioned about their 1998 fire experience.

Note: "n" refers to the number of departments reporting the statistic.

Definition of Terms

Civilian: The term “civilian” includes anyone other than a fire fighter, and covers public service personnel such as police officers, civil defense staff, non-fire service medical personnel, and utility company employees.

Death: An injury that occurred as a direct result of a fire that is fatal or becomes fatal within one year.

Fire: Any instance of uncontrolled burning. Includes combustion explosions and fires out on arrival. Excludes controlled burning (whether authorized or not), overpressure rupture without combustion, mutual aid responses, smoke scares, and hazardous responses (e.g., oil spill without fire).

Incendiary: Legal decision or physical evidence indicates that a fire was deliberately set.

Injury: Physical damage that is suffered by a person as a direct result of fire and that requires (or should require) treatment by a practitioner of medicine (physician, nurse, paramedic, EMT) within one year of the incident (regardless of whether treatment was actually received), or results in at least one day of restricted activity immediately following the incident. Examples of injuries resulting from fire are smoke inhalation, burns, wounds and punctures, fractures, heart attacks (resulting from stress under fire condition), strains and sprains.

Property Damage: Includes all forms of direct loss to contents, structure, machinery, a vehicle, vegetation or anything else involved in the fire but not indirect losses, such as business interruption or temporary shelter provisions.

Structure: An assembly of materials forming a construction for occupancy or use in such a manner as to serve a specific purpose. A building is a form of structure. Open platforms, bridges, roof assemblies over open storage or process areas, tents, air-supported, and grandstands are other forms of structures.

Suspicious: Circumstances indicate the possibility that a fire may have been deliberately set, e.g., multiple ignitions were found, or there were suspicious circumstances and no accidental or natural ignition factor could be found.

Vehicles, Highway and Other: Fires in these instances may have been associated with an accident, however, reported casualties and property loss should be the direct result of the fire only. Highway vehicles include any vehicle designed to operate normally on highways, e.g., automobiles, motorcycles, buses, trucks, trailers (not mobile homes on foundations), etc. Other vehicles include trains, boats and ships, aircraft, and farm and construction vehicles.

Acknowledgments

The NFPA gratefully thanks the many fire departments that responded to the 1998 National Fire Experience Survey for their continuing efforts for providing us in a timely manner the data so necessary to make national projections.

The survey project manager and author of the report gratefully thanks the man members of NFPA staff who worked on this year's survey including: Frank Deely, Richard Coffey, and Robert McCarthy for editing the survey forms and their follow-up calls to fire departments; and Norma Candeloro for handling the processing of survey forms and typing this report.

Footnotes

1. Note that the NFPA changed its survey methodology in 1977-78, and meaningful comparisons cannot be made with fire statistics estimated before 1977.
2. John R. Hall Jr., *Patterns of Civilian Fire Casualties in Home Fires by Age and Sex, 1992-96*, Quincy; National Fire Protection Association, Fire Analysis and Research Division.
3. Rita F. Fahy and Alison L. Miller, "How Being Poor Affects Fire Risk", *Fire Journal*, Vol. 83, No. 1 (January 1989), p. 28.
4. Arthur E. Washburn, Paul R. LeBlanc, and Rita F. Fahy, "U.S. Fire Fighter Deaths - 1998", *NFPA Journal*, Volume 94, No. 4 (July/August 1999), p.
5. In addition to civilian injuries, the NFPA estimates fire fighter injuries and publishes them annually in a separate report. See Michael J. Karter, Jr. and Paul R. LeBlanc, "U.S. Fire Fighter Injuries - 1997", *NFPA Journal*, Vol. 93, No. 11 (November/December 1998), p. 103. The 1998 fire fighter injury report will appear in the November/December 1999 issue of *NFPA Journal*.
6. As defined by the U.S. Bureau of the Census, the four regions are: Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. Northcentral: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. South: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. West: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.
7. George W. Snedecor and William G. Cochran, *Statistical Methods*, Seventh Edition (Ames, Iowa; Iowa State University Press, 1980), pp. 446-449.
8. William G. Cochran, *Sampling Techniques*, third edition (New York: John Wiley, 1977), pp. 150-161.