Fire Investigation Summary

# Residential Fire

## Keokuk, Iowa
## December 22, 1999

**A fire in a multiple family dwelling resulted in the deaths of three fire fighters and three children.**

**The fire began on the first floor and spread rapidly, sending smoke and hot gases to the second floor trapping an adult and four children. The adult and one child were able to escape through a second floor window.**

**While in the process of rescuing the children still trapped, three fire fighters were caught in the rapid build-up of heat and flame and perished.**

NFPA®

**National Fire Protection Association**
**Fire Investigations Department**

At approximately 8:24 a.m. on Wednesday, December 22, 1999, a fire was reported in a multifamily dwelling in Keokuk, Iowa. Several neighbors phoned the Keokuk 911 center to report smoke coming from a residence, and that a woman was outside screaming that there were children trapped inside.

At the time the fire was reported, the on-duty force from the Keokuk Fire Department (an assistant chief, a lieutenant, and three fire fighters) was completing operations at a motor vehicle accident at a major intersection, two miles northwest of the fire scene. The dispatcher notified the units of the fire and the report of people trapped. Both units at the accident (Rescue 3 and Aerial 2) responded from the scene of the motor vehicle accident. During the response, additional calls were made to the 911 Center reporting heavy smoke coming from the house.

One member of the on-duty force of five fire fighters was committed in assisting the EMS crew on the ambulance and was en route to the Keokuk hospital at the time of the report of the house fire.

The chief of the department became aware of the incident as he entered his office at the fire station. The chief responded from the fire station and went to the hospital to pick up the fire fighter that was with the ambulance crew.

Upon arrival at 8:28 a.m., the units found heavy smoke showing from a two-story multifamily dwelling on the northeast corner of a four-way intersection. A water supply was established from a hydrant one-block southwest of the scene. Rescue 3, a 1500-gpm engine, laid a 5 in. diameter supply line from the hydrant while the lieutenant stayed at the hydrant to connect the line and activate the hydrant. Aerial 2, with a 50-ft ladder and a 2000-gpm pump, continued to the scene.

The assistant chief requested six fire fighters be called back to duty as he arrived at the house in Aerial 2. As the two truck operators set up the apparatus, the assistant chief reportedly spoke to the female resident of the burning apartment. She reported that three of her children were still inside the apartment and that she tried but could not get them out. (She was able to exit the house via a second-floor window with her 4-year-old son, with the assistance of neighbors.) The assistant chief completed donning his protective clothing, including SCBA and entered the right side apartment door.

The chief arrived not long after the assistant chief entered the building. The chief ordered the two apparatus operators into the building to assist the assistant chief with the search for the children. Shortly thereafter, a fire fighter passed a 22-month-old male out the front door of the apartment to a police officer, who began CPR. The officer with the infant was then taken to a police car and transported to the hospital, six blocks west of the scene. A second child, an unresponsive 22-month-old female, was then passed out the door to the fire chief. With no EMS units yet on the scene, the chief chose to take the infant to the hospital in another police car, with a police captain driving. The fire chief conducted CPR on the infant during the one-minute ride to the hospital emergency room. He quickly handed the infant over to the emergency room staff and returned to the fire scene.

In the meantime, the fire fighter that arrived with the fire chief stretched a 1-1/2 inch hoseline to the front door of the fire apartment and returned to don her SCBA. When the hoseline was charged, she noticed that the hoseline had burned through while at the entrance to the apartment. The fire fighter reported that the first level of the apartment was engulfed in flames visible from her vantage point at Aerial 2.

The location and condition of the fire fighters and the remaining child in the burning apartment was not known. The burned length of hose was removed, and the nozzle reconnected to the line as it was charged again. The fire fighter played a hose stream into the burning apartment. She was only able to advance 6-8 ft into the apartment before being driven back by the intense heat.

The first two of the "call-back" fire fighters arrived in Engine 6 (reserve unit). They were teamed with the lieutenant that was at the hydrant and had now walked the one block to the scene. The three were ordered to search the adjoining apartment for a resident that supposedly was still inside. The search was completed with nothing found. (The occupant was at a local restaurant.)

Efforts continued to contact the three fire fighters that were in the fire apartment. As additional call-back fire fighters arrived in Aerial 1 (100 ft aerial unit with a 1500 gpm pump), they were ordered to begin to search for the missing fire fighters in the original fire apartment. As the fire was knocked back and a search could begin, fire fighters quickly found one fire fighter in the first floor room to the right of the main entrance corridor. He had perished.

The assistant chief's body was then found at the top of the stairs, not far from the body of the remaining child, a seven-year-old girl. The third fire fighter was found in the master bedroom to the right of the top of the stairs. All had perished.

The remaining fire was extinguished at approximately 1:30 p.m. Overhaul was conducted until 3:30 p.m. and at that point units were placed back in service.

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

- Lack of a proper building/incident size-up (Risk vs. Benefit Analysis)
- Lack of an established Incident Management System
- Lack of an Accountability System
- Insufficient resources (such as personnel and equipment ) to mount interior fire suppression and rescue activities
- Absence of an established Rapid Intervention Crew (RIC) and a lack of a standard operating procedure requiring a RIC.

On the basis of the fire investigation and analysis, the NFPA has determined that the following significant factor may have contributed to the deaths of the three children:

- Lack of functioning smoke detectors within the apartment to provide early warning of a fire.

**Written by Robert F. Duval – Senior Fire Investigator - NFPA**

# Fire Investigation Summary

# Residential Fire

## Keokuk, Iowa

## December 22, 1999

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# RESIDENTIAL FIRE
# KEOKUK, IOWA
# DECEMBER 22, 1999

NFPA

# FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

# Residential Fire

# Keokuk, Iowa
# December 22, 1999

# 6 Fatalities

Prepared by

**Robert F. Duval**
Senior Fire Investigator
National Fire Protection Association

# ABSTRACT

At approximately 8:24 a.m. on Wednesday, December 22, 1999, a fire was reported in a multi-family dwelling in Keokuk, Iowa. Several neighbors phoned the Keokuk 911 center to report smoke coming from a residence, and that a woman was outside screaming that there were children trapped inside.

At the time the fire was reported, the on-duty force from the Keokuk Fire Department (an assistant chief, a lieutenant, and three fire fighters) was completing operations at a motor vehicle accident at a major intersection, two miles northwest of the fire scene. The dispatcher notified the units of the fire and the report of people trapped. Both units at the accident (Rescue 3 and Aerial 2) responded from the scene of the motor vehicle accident. During the response, additional calls were made to the 911 Center reporting heavy smoke coming from the house.

One member of the on-duty force of five fire fighters was committed in assisting the EMS crew on the ambulance and was en route to the Keokuk hospital at the time of the report of the house fire.

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The chief of the department became aware of the incident as he entered his office at the fire station. The chief responded from the fire station and went to the hospital to pick up the fire fighter that was with the ambulance crew.

Upon arrival at 8:28 a.m., the units found heavy smoke showing from a two-story multi-family dwelling on the northeast corner of a four-way intersection. A water supply was established from a hydrant one-block southwest of the scene. Rescue 3 (R3), a 1500-gpm engine, laid a 5 in. diameter supply line from the hydrant while the lieutenant stayed at the hydrant to connect the line and activate the hydrant. Aerial 2 (A2), with a 50-ft ladder and a 2000-gpm pump, continued to the scene.

The assistant chief requested six fire fighters be called back to duty as he arrived at the house in Aerial 2. As the two truck operators set up the apparatus, the assistant chief reportedly spoke to the female resident of the burning apartment. She reported that three of her children were still inside the apartment and that she tried but could not get them out. (She was able to exit the house via a second-floor window with her 4-year-old son, with the assistance of neighbors.) The assistant chief completed donning his protective clothing, including SCBA, and entered the right side apartment door.

The chief arrived not long after the assistant chief entered the building. The chief ordered the two apparatus operators into the building to assist the assistant chief with the search for the children. Shortly thereafter, a fire fighter passed a 22-month-old male out the front door of the apartment to a police officer, who began CPR. The officer with the infant was then taken to a police car and transported to the hospital, six blocks west of the scene. A second child, an unresponsive 22-month-old female,

was then passed out the door to the fire chief. With no EMS units yet on the scene, the chief chose to take the infant to the hospital in another police car, with a police captain driving. The fire chief conducted CPR on the infant during the one-minute ride to the hospital emergency room. He quickly handed the infant over to the emergency room staff and returned to the fire scene.

In the meantime, the fire fighter that arrived with the fire chief stretched a 1 ½-in. hoseline to the front door of the fire apartment and returned to don her SCBA. When the hoseline was charged, she noticed that the hoseline had burned through while at the entrance to the apartment. The fire fighter reported that the first level of the apartment was engulfed in flames, visible from her vantage point at Aerial 2.

The location and condition of the fire fighters and the remaining child in the burning apartment was not known. The burned length of hose was removed, and the nozzle reconnected to the line as it was charged again. The fire fighter played a hose stream into the burning apartment. She was only able to advance 6-8 ft into the apartment before being driven back by the intense heat.

The first two of the "call-back" fire fighters arrived in Engine 6 (E6 - reserve unit). They were teamed with the lieutenant that was at the hydrant and had now walked the one block to the scene. The three were ordered to search the adjoining apartment for a resident that supposedly was still inside. The search was completed with nothing found. (The occupant was at a local restaurant.)

Efforts continued to contact the three fire fighters that were in the fire apartment. As additional call-back, fire fighters arrived in Aerial 1 ([A1] 100 ft aerial unit with a 1500 gpm pump); they were ordered to begin to search for the missing fire fighters in the original fire apartment. As the fire was knocked back and a search could begin, fire fighters quickly found one fire fighter in the first floor room to the right of the main entrance corridor. He had perished.

The assistant chief's body was then found at the top of the stairs, not far from the body of the remaining child, a seven-year-old girl. The third fire fighter was found in the master bedroom to the right of the top of the stairs. All had perished.

The remaining fire was extinguished at approximately 1:30 p.m. Overhaul was conducted until 3:30 p.m. and at that point units were placed back in service.

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

- Lack of a proper building/incident size-up (Risk vs. Benefit Analysis)
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# CONTENTS

# I. INTRODUCTION

The NFPA investigated the Keokuk, Iowa, fire fighter and civilian fatalities in order to document and analyze significant factors that contributed to the six 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 Keokuk, Iowa, fire the day it occurred. NFPA Senior Fire Investigator Robert Duval traveled to Iowa to meet with the chief, fire officers, and fire fighters from the Keokuk Fire Department, and investigators from the State of Iowa Fire Marshal's Office 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 Keokuk 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 Keokuk 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 Keokuk, Iowa, 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: Keokuk, Iowa Fire Department, Office of the State of Iowa Fire Marshal and State Fire Marshal Roy Marshall, and the members of the National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation team.

# II. BACKGROUND

## The Building

The building in which the fire occurred was constructed in approximately 1910. The building's construction consisted of wood frame with plaster and lath-type interior partition walls and ceilings. The building was constructed with a "balloon-frame," with open spaces between interior and exterior walls that spanned from the attic to the basement levels. The building's exterior consisted of wood clapboard siding.

The building was arranged with two stories and an attic. The building had been converted for use as apartments before 1972. It was divided into three apartments. The left side of the building was arranged into two separate apartments (upstairs/downstairs). The right-side apartment (fire apartment) was arranged as one unit encompassing both levels.

The apartment where the fire occurred was arranged as follows (see Figure Nos. 1 and 2).

First Floor:

- Living Room (191 sq ft)
- Dining Area (191 sq ft)
- Kitchen (153 sq ft)
- Bathroom (30 sq ft)
- Closet (34 sq ft)
- Entrance foyer
  with corridor and stairwell to second floor (146 sq ft)

Total – 745 sq ft

Second Floor:

- Master Bedroom (290 sq ft)
- Boy's Bedroom (190 sq ft)
- Girl's Bedroom (98 sq ft)
- Bathroom (47 sq ft)
- Corridor (116 sq ft)

Total – 741sq ft

A central staircase was located immediately inside the front entrance to the fire apartment. This staircase opened into an open corridor on the second floor. This corridor connected the three bedrooms on the second level.

Ceiling heights on the first floor were 8 ft 11 in. in all rooms except the kitchen, where a suspended ceiling was measured at 7 ft 6 in. Ceiling heights on the second floor were uniform at 7 ft 11 in.

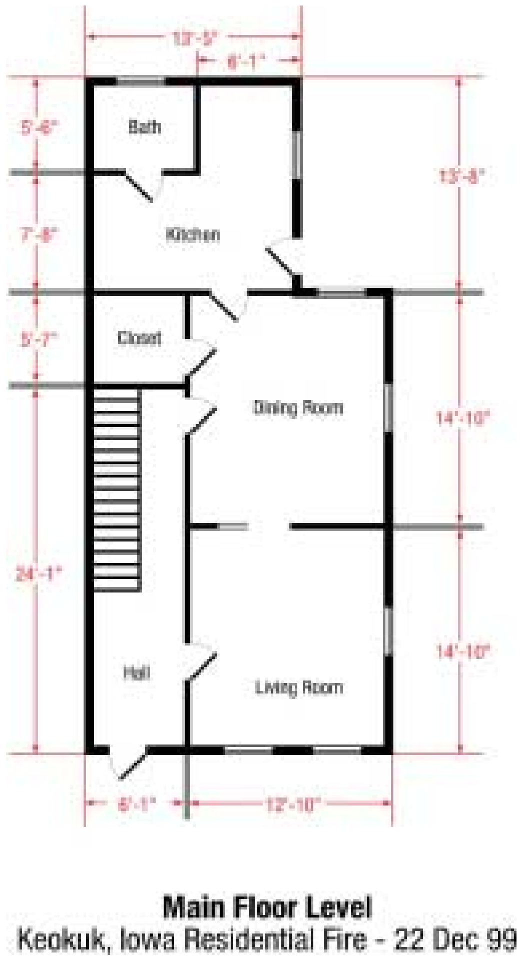
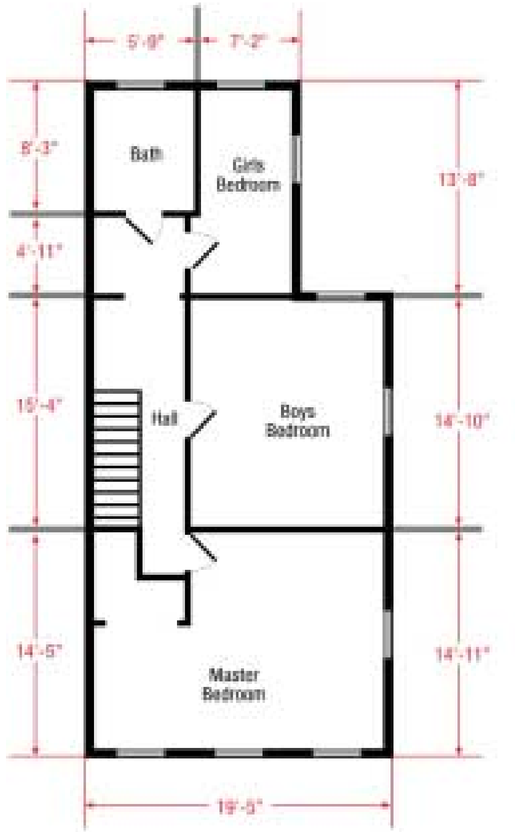



**Figure No. 1 Main Floor Level of Fire Apartment**




**Second Floor Level**
Keokuk, Iowa Residential Fire - 22 Dec 99

**Figure No. 2 Second Floor Level of Fire Apartment**

Wall coverings on the first floor consisted of wallpaper over gypsum board in the kitchen, paneling over plaster in the corridor and gypsum board over plaster in the dining room and living room.

Wall coverings on the second floor consisted of paneling over plaster in the upstairs corridor, the master and boys' bedrooms, and gypsum board over plaster in the girls' bedroom and upstairs bathroom.

Floor coverings throughout the apartment consisted of wood flooring in the dining and living rooms, carpeting over wood flooring in the first and second floor corridors, and the master bedroom, linoleum over wood flooring in the kitchen and upstairs bathroom floors. The floor coverings in the boys' and girls' bedrooms and the first floor bathroom could not be determined.

The ceiling materials consisted of fiberboard tiles over plaster in the first and second floor corridors, the living room, the boys' and girls' bedrooms, and the master bedroom. The ceiling in the dining room was determined to be plaster over wood laths.

The first floor window adjacent to the entrance to the fire apartment was boarded up with plywood at a time prior to the fire.

Four natural gas furnaces located in the basement heated the building. The gas meter was located in the north corner of the building exterior.

Electrical service was provided via overhead transmission lines through individual meters located on the northeast exterior wall of the building.

The kitchen of the fire apartment contained typical appliances and furniture. The stove was a four-burner electric unit.

## The Fire Department

The Keokuk Fire Department serves a population of 13,500 citizens in a 10-square mile response district. The population reportedly increases to approximately 25,000 during the day due to the number of industrial and commercial establishments located in the district.

The fire department employs 18 full-time career fire fighters and the chief. The fire fighting force is divided into three groups of six. Each group consists of an assistant chief, a lieutenant, and four fire fighters. Each group works a 24-hour on/ 48-hour off schedule. The chief is available for responses during the 8 a.m.– 4 p.m. timeframe and will respond to significant incidents during off-hours.

For incidents requiring personnel in addition to the on-duty force of six, the dispatcher conducts "callbacks." The incident commander determines the number of fire fighters to be called back for a given incident. These notifications are conducted by phone.

The fire department is dispatched by a joint police/fire dispatch center located in the public safety building.

The department operates a fleet of two frontline and three reserve units. Normally each of the frontline units is staffed with an officer and two fire fighters.

<u>Frontline Apparatus:</u>

| | |
|---|---|
| Aerial 2 | 50 ft ladder<br>2000-gpm pump<br>500-gal tank |

| | |
|---|---|
| Rescue Pumper 3 | 1500-gpm pump<br>500-gal tank |

<u>Reserve Apparatus:</u>

| | |
|---|---|
| Aerial 1 | 100 ft. ladder<br>1500-gpm pump<br>200-gal tank |
| Engine 6 | 1000-gpm pump<br>500-gal tank |
| Attack 1 | 300-gpm pump<br>250-gal tank |

A private ambulance contractor provides emergency medical services. The fire department provides "first-responder" service on all medical related incidents.

The fire department responds to an average of 800 incidents each year.

Fire fighter training is conducted both in-house by State of Iowa certified instructors and outside at training classes and state sponsored academies. Fire fighters must complete a training course in Fire Fighter I (NFPA 1001, *Standard for Fire Fighter Professional Qualifications*) skills within 18 months after being hired. All fire fighters are certified to the Medical First Responder-Defibrillation level.

Additional regularly scheduled training is conducted in-house by State of Iowa certified instructors on staff.

The fire department issues NFPA 1971, *Standard on Protective Ensemble for Structural Fire Fighting*, compliant personal protective clothing (PPE), including coat, trousers, boots, gloves, helmet, and hood to each fire fighter. Each fire fighter is also issued a Personal Alert Safety System (PASS device). This NFPA 1982, *Standard on Personal Alert Safety Systems (PASS)*, compliant equipment is secured to each fire fighter's coat. The self-contained breathing apparatus (NFPA 1981 – *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, compliant) utilized on the first responding apparatus are all equipped with integrated PASS devices.

## Weather

The weather on the morning of the fire was partly cloudy with a temperature of 21° F (-6° C). Winds were from the SSE at 6 mph (9.6 kph). The relative humidity was 71 percent. There was a light dusting of snow on the ground from a previous snowfall.

# III. THE FIRE

## Fire Department Operations

At approximately 7:30 a.m. on Wednesday December 22, 1999, the Keokuk Fire Department was dispatched to a serious injury traffic accident at a major intersection just north of the center of town. Both units, Aerial 2 and Rescue 3, responded to the accident with the on-duty force of five fire fighters (an assistant chief, a lieutenant, and three fire fighters). (The shift was staffed with five fire fighters instead of the usual six due to one fire fighter's scheduled vacation.)

As the units were preparing to depart from the scene of the accident at approximately 8: 24 a.m., the dispatch center notified the units of a reported structure fire with the possibility of children trapped inside. The two units with four fire fighters began the response to the given address. The fifth fire fighter was assisting the EMS crew on-board the ambulance with a critically injured victim of the traffic accident.

The Keokuk 911 Center, located in the public safety (police/fire) station, was receiving several calls reporting a house fire. Witnesses reported seeing a woman on the porch roof screaming for help. The woman and a 4-year-old male child were assisted to the ground by neighbors. The woman told the neighbors that three of her children were still inside the house, and that she couldn't get to them. This information was passed on to the responding units.

While en route, the assistant chief, on board Aerial 2, and the lieutenant on board Rescue 3, consulted their water supply books and agreed upon a hydrant one block south of the address. As Aerial 2 neared the scene, the assistant chief requested that the dispatcher call back six fire fighters. This transmission was acknowledged.

The fire chief was just entering his office at the fire station at approximately 8:24 a.m., and heard the radio transmissions reporting a fire with children trapped. He went to the dispatch room and confirmed the address, and began to respond. He decided to respond first to the hospital to pick up the fire fighter who had assisted the EMS crew, and was now waiting to be picked up at the emergency room of the hospital.

The first two units arrived at the scene at approximately 8:28 a.m.

Keokuk Fire Department standard operating policy is for Aerial 2 to proceed to the fire building and set up in an appropriate location, while Rescue 3 establishes a water supply and completes a forward lay with 5 in. diameter supply hose and supplies Aerial 2. The officer on Rescue 3 (lieutenant) secures the hydrant and establishes the hose connection.

Rescue 3 stopped at the hydrant one block south of the fire building, and the lieutenant began to set up the hydrant as the apparatus continued to the scene. Aerial 2 stopped in the center of the intersection, west of the building, and the assistant chief exited the apparatus while the operator began to tie in the supply line to the pump. The operator of Rescue 3 assisted him (see Figure No. 3).

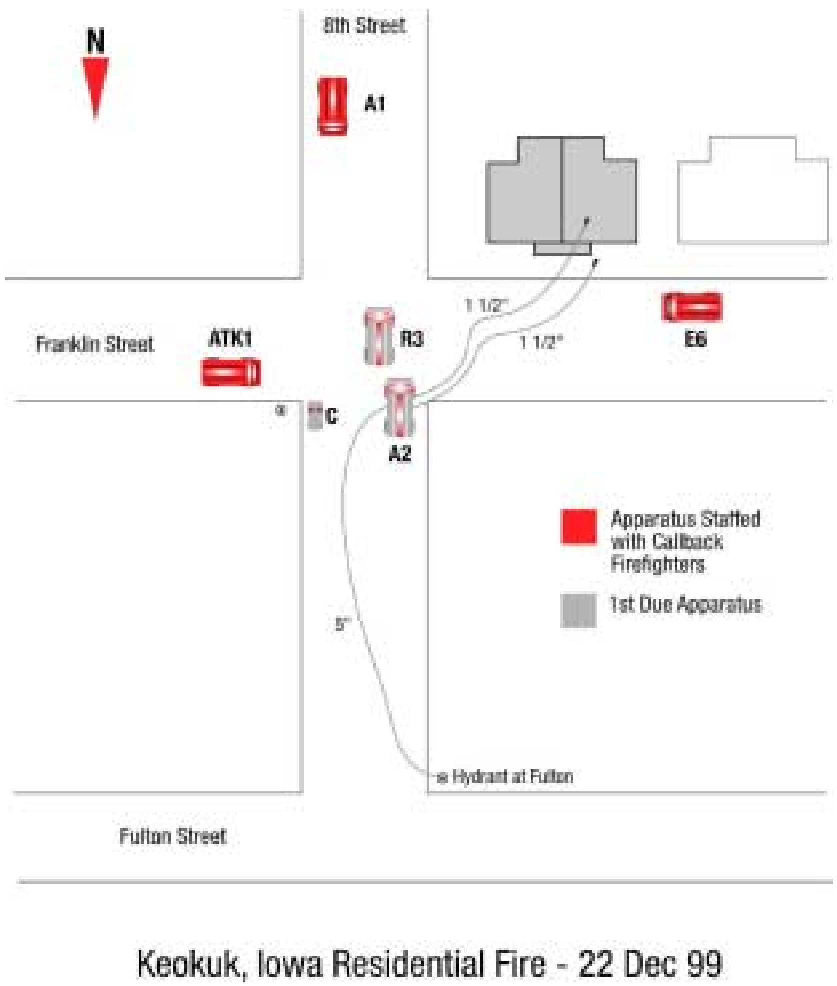



**Figure No. 3  Fire Department Operations**

The assistant chief reportedly spoke to the woman who had fled the building and she reported that three children were still inside. The assistant chief completed donning his personal protective equipment (PPE), including self-contained breathing apparatus (SCBA), and entered the building.

NOTE: All SCBA used by the on-duty personnel were equipped with integrated Personal Alert Safety Systems (PASS devices). (The department was in the process of phasing in the units with the integrated PASS devices. The SCBA on the reserve apparatus did not contain the integrated devices.) All personnel were issued a stand-alone PASS device as well. These units were attached to the member's turnout coats.

The chief arrived on scene with the other fire fighter approximately one minute after the arrival of the apparatus.

The lieutenant reported having minor difficulty operating the hydrant. Once he was able to operate the hydrant, he began to head toward the scene.

Upon his arrival, the chief noted the assistant chief had entered the building. The chief ordered the two apparatus operators to enter the building as well, to assist the assistant chief in the search for the children. The fire fighter who arrived with the chief advanced a pre-connected 1½ in. diameter hose line from Aerial 2 to the front door of the fire apartment. The line was charged and she then returned to the unit to don a SCBA.

Police officers began to arrive at the scene and establish a perimeter around the building. A police officer who arrived at the same time as the apparatus attempted to enter the building to assist in the search, but was turned away due to the smoke.

At approximately this time, the first child was removed from the building. The child, a 22-month-old male, was handed to a reserve police officer near the front steps of the apartment. The officer began to perform CPR on the infant as he was transported by a police unit to the Keokuk Hospital, six blocks west of the scene.

Within seconds, a second child, a 22 month-old female, was brought to the front of the building. The fire chief was standing on the front steps and was handed the infant. He immediately looked for EMS personnel, but found that there were no personnel available. He began CPR on the infant on the front lawn of the house. A police captain came up to the fire chief and offered a ride to the hospital. The fire chief was transported to the hospital at 8:35 a.m. They arrived at the hospital at 8:36 a.m.

The fire fighter who had arrived with the chief was donning her SCBA at Aerial 2 and reported seeing heavy flames in the lower level of the fire apartment. At this point, the hoseline that had been advanced to the doorway had burned through and was spraying water on the front steps of the apartment. Realizing that the first line had burst, she advanced a second pre-connected 1½ in. diameter hoseline from Aerial 2 to the doorway and began to apply water into the burning apartment.

The lieutenant then arrived from the hydrant and noticed a heavy fire condition in the right-side apartment and the water spraying at the front door of the house. At this time, the fire fighter at the front door shouted back that she was out of water. The lieutenant went to the pump panel on Aerial 2 and noticed that the intake valve had not been opened and that the tank water had run out. He opened the intake valve and re-established the water supply with hydrant water.

The fire chief arrived back at the scene at approximately 8:38 a.m. He noted that the burnt hoseline was spraying water near the front door. He shut the valve controlling the burnt hoseline. The burnt section of hose was removed and the nozzle placed on the next section of hose.  He noted the fire fighter applying water in the front door of the apartment with the second pre-connected hoseline and that the fire condition had increased since he had left moments before.

The chief made a request for a general call-back of all available off-duty fire fighters.

Engine 6 arrived with the first of the call-back personnel at 8:40 a.m.

At approximately 8:40 a.m. the fire chief received a report of another missing occupant.  This was the occupant of the upstairs apartment opposite the fire apartment.  His vehicle was spotted near the scene, but he was unaccounted for.  The chief ordered the two fire fighters that arrived on Engine 6 and the lieutenant from Rescue 3 to enter the adjoining apartment and conduct a search for the missing victim (see Photo No. 1).

**Photo No. 1  Fireground activity approximately 16 minutes after alarm. E6 crew and Lieutenant from R3 prepare to search adjoining apartment. Photo used with permission: C. Iutzi, Daily Gate City Newspaper**

The chief returned to the front door of the fire apartment and attempted to raise the assistant chief.   After numerous attempts to raise him, the chief began to question personnel on the scene if they have seen the assistant chief elsewhere on the fire ground.

While conducting the search of the adjoining apartment, the team of three fire fighters called the chief to request ventilation of the building, due to the extreme smoke conditions at the upper levels of the apartment.

**Photo No. 2 Outside ventilation being conducted in the rear of the fire building.**
**Photo used with permission: C. Iutzi, Daily Gate City Newspaper**

Ventilation was conducted by two reserve police officers at the rear windows of the both the fire apartment and the left side, first floor apartment, but not in the upstairs apartment that the three fire fighters were searching (see Photo No. 2).

Aerial 1 arrived on scene with four fighter fighters at approximately 8:50 a.m. As they approached the scene from the north, they reported seeing the ventilation activities taking place in the rear of the building. They also reported seeing a large amount of fire in the northeast corner (rear) of the building, traveling up the outside the building.

Additional fire fighters were also being transported from the public safety building in police units and personnel vehicles. As these fire fighters sought assignments from the fire chief, it had become apparent that the initial team of three fire fighters that had entered the fire apartment was unaccounted for. The chief assigned teams of fire fighters to begin to search for the missing fire fighters in the right-side apartment.

Fire fighters began to advance a hoseline further into the fire apartment. As they proceeded several feet into the living room, they discovered the body of the first missing fire fighter. (It was originally thought that this was the body of the assistant chief. It was later identified as the operator of Aerial 2.) The fire in the living and dining rooms was partially extinguished so that the body could be removed. The body was removed and transported to the hospital at approximately 9:00 a.m. (see Figure No. 4).

**Photo No. 3  View of the rear of the fire building upon arrival of Aerial 1, approximately 24 minutes after the alarm.**
**Photo used with permission:  C. Iutzi Daily Gate City Newspaper**

At this point the chief transferred command to another assistant chief and left the scene to begin to notify the victims families.  The chief also sent the remaining members of the on-duty shift back to the fire station to refill SCBA cylinders.

The search for the remaining two fire fighters continued on the second floor of the fire apartment.  Fire fighters found the body of the assistant chief at the top of the stairs in the corridor.  Immediately adjacent to the assistant chief's body was that of a seven-year-old female.  These bodies were removed and transported to the hospital at approximately 10:30 a.m. (see Figure No. 5).

The body of the third fire fighter was located in the center of the master bedroom. The chief was notified of the discovery of the victims as he was notifying family members.  The body were removed and transported to the hospital at approximately 11:00 a.m. (see Figure No. 5).

The remaining fires were extinguished at approximately 1:30 p.m. Overhaul operations were conducted until 3:30 p.m. when the fire was declared under control and units were returned to service.

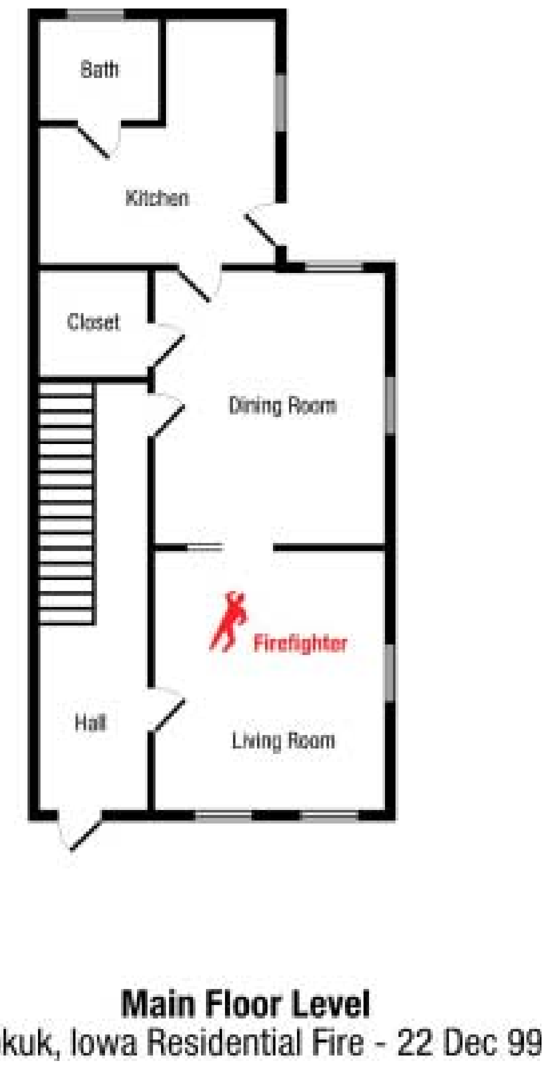



**Figure No. 4 – Location of Fire Fatality, First Floor**

## Casualties

Three fire fighters perished in this fire. The assistant chief was a 48-year-old male with 25 years experience with the fire department. The operator of Aerial 2 was a 39-year-old male and was a four-year member of the fire department. The Rescue 3 operator was a 29-year-old male who had been with the fire department for six years.

According to autopsy results, the assistant chief and operator of Aerial 2 died of smoke inhalation, burns, and exposure to extreme heat. Both had carboxyhemoglobin levels above 25 percent. (The normal level for a non-smoker is <1.5 percent. A toxic level is considered above 20 percent.) The autopsy results show that the Rescue 3 operator died of burns and exposure to extreme heat.

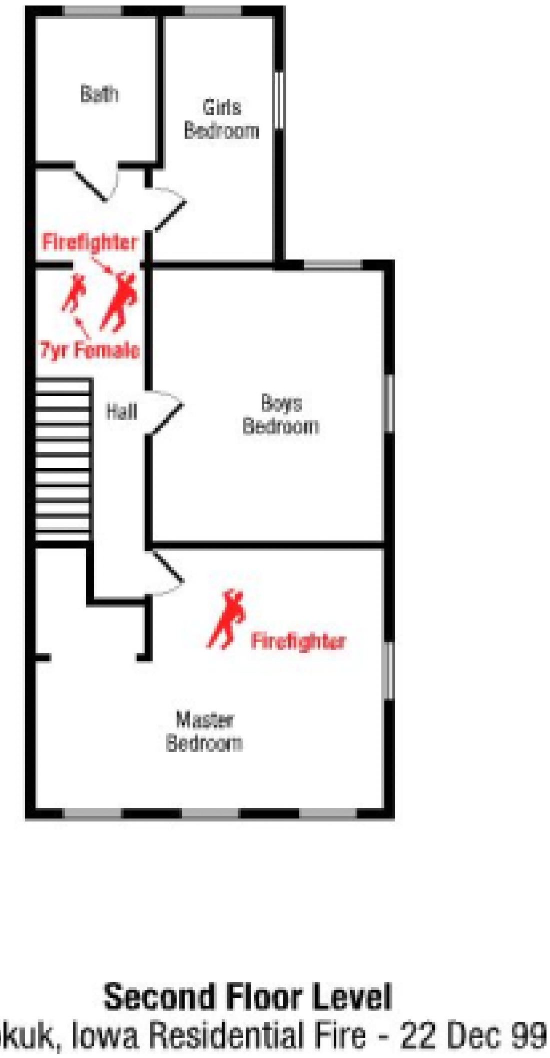



**Figure No. 5 – Locations of Fire Fatalities, Second Floor**

The SCBA facepieces were reportedly in place on all three fire fighters, when they were found but their air supplies were depleted.

Three children also perished in this fire, a seven-year-old female, and a set of 22-month-old twins, male and female.

There were no other fire fighter injuries associated with this incident. The mother and 4 year-old male that were able to escape the building were both hospitalized with smoke inhalation.

## Damage

The building was extensively damaged in this fire. The right-side apartment and all the contents were destroyed in the fire. The fire spread through the first floor of the apartment and up the stairwell onto the second floor and into the attic space. The most severe damage was located in the rear (north) section of the fire apartment, including the kitchen on the first floor and the children's bedrooms on the second floor. The fire burned through the interior partitions and vented to the outside of the building on the northeast corner of the building, outside the kitchen of the fire apartment (see Photo Nos. 4 and 5).

The two adjoining apartments suffered smoke and water damage throughout. The fire did extend into both apartments in limited areas. Much of the contents of both apartments suffered only from smoke and water damage.


**Above: Photo No. 4 View of interior stairwell from front door. (NFPA photo)**

**Left: Photo No. 5 Building exterior showing fire extension from kitchen upward to children's bedrooms (NFPA photo)**

## IV. TIME LINE

| Time<br>(Elapsed Time) | Activity<br>[From Keokuk FD/PD recorded phone and radio transmissions and transcripts] |
|---|---|
| **12/22/99** | |
| 8:24am<br>(0 minutes) | 911 calls reporting structure fire with children trapped. |
| | |
| 8:24 (0) | FD units informed of fire while clearing from motor vehicle accident. |
| | |
| 8:25 (1) | Rescue 3 and Aerial 2 respond from scene of accident (short one fire fighter). |
| | |
| 8:26 (2) | Chief responds from Public Safety Building to hospital to pick up fire fighter that had gone with EMS from accident scene. |
| | |
| 8:28 (4) | Assistant chief requests six fire fighters be called back.<br>FD units arrive on scene. |
| | |
| 8:30 (6) | Fire Chief arrives on scene (estimated time). |
| | |
| 8:32 (8) | PD unit requests an ambulance sent to the scene. |
| | |
| 8:34 (10) | PD unit to hospital with infant (CPR in progress). |
| | |
| 8:35 (11) | PD unit w/ Fire Chief to hospital with infant<br>(CPR in progress). |
| | |
| 8:36 (12) | Fire Chief arrives at hospital Emergency Room. |
| | |
| 8:38 (14) | Police units returning to scene (with Fire Chief). |
| | |
| 8:38 (14) | Engine 6 (with two call-back FFs) en route to fire. |
| | |
| 8:40 (16) | Engine 6 arrives at fire scene. |
| | |
| 8:44 (20) | Second ambulance requested to scene by PD. |
| | |
| 8:48 (22) | Aerial 1 responding with four FFs. |
| | |
| 8:50 (24) | Aerial 1 arrives (estimated time). |

| **Time**<br>**(Elapsed Time)** | **Activity** |
|---|---|
| | |
| 8:57 (31) | Three FFs are picked up at station and brought to scene. |
| | |
| 9:00 (34) | Body of first FF located (estimated time). |
| | |
| 9:07 (41) | Coroner and Fire Marshal requested to scene. |
| | |
| **10:30 – 11:00**<br>(2 hours and 6 min – 2 hours and 35 min) | Bodies of the two remaining FFs and the remaining child are located (estimated time). |
| | |
| 1:30<br>(5 hours and 6 min) | Fire extinguished. Overhaul operations continue. |
| | |
| 3:30 p.m.<br>(7 hours and 6 min) | All FD units are in quarters. |
| | |

# V. ANALYSIS

## Origin and Cause

The Iowa State Fire Marshal's Office has determined that the fire's origin was in the kitchen of the fire apartment. It was discovered that the four-year-old male woke before his mother and went to the kitchen, where he apparently turned on a burner on the stove. The burner ignited some plastic items on top of the burner. The fire spread from the stovetop to adjoining combustibles.

When the young child reported the fire to his mother, who was in the master bedroom, she reported that it was too hot to enter the corridor to access the children's bedrooms at the other end of the corridor. She returned to bedroom, opened the window over the small porch in the front of the house, and placed the boy on the porch roof and re-entered to again attempt to reach the bedrooms. She was again unable to reach the bedrooms through the smoke and heat coming up the stairwell and the fire below the bedrooms in the kitchen. She escaped onto the porch roof and began screaming for help.

## Fire Spread and Growth

The fire that started on the stove in the kitchen in the rear of the apartment spread through the kitchen and into the adjoining dining room. The fire also began burning into the partitions of the kitchen and through to the exterior of the building. Flame spread was observed on the exterior of the building in the northeast corner, outside the kitchen. The open partitions ("balloon-frame") also allowed the fire to travel upward in the partition and into the rear (girls') bedroom.

The fire continued to spread toward the front of the apartment, through the living room, and toward the open staircase to the second floor. Simultaneously, the fire was spreading into the rear bedrooms from below.

The first responding fire fighters reported only a smoke condition at the front of the building and in the stairwell upon their arrival. They also reported a significant amount of smoke on the upper levels of the building (venting from the eaves and other openings on the upper portions of the building).

As the first several minutes passed the fire fighter who had placed the hose line at the front door, reported that when she turned back to the building, while donning her SCBA, there was a large amount of fire visible in the front door of the fire apartment. It was at this point that the first hoseline was burnt through, near the doorway. At that point the fire had spread throughout the entire first floor level of the fire apartment.

## Fire Department Operations

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

- Lack of a proper building/incident size-up (Risk vs. Benefit Analysis)
- Lack of an established Incident Management System
- Lack of an Accountability System
- Insufficient resources (such as personnel and equipment) to mount interior fire suppression and rescue activities
- Absence of an established Rapid Intervention Crew (RIC) and a lack of a standard operating procedure requiring a RIC

**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 on the fireground begins with the receipt of the alarm and continues until the incident is under control. The risks posed by the incident itself or by the actions taken by the responders to the incident must constantly be compared to the benefit to be derived by the actions taken. The information that the incident commander or any other responder uses to make a risk vs. benefit analysis must be complete and up-to-date. Conditions on a fireground change rapidly. What might have appeared to be safe situation moments ago can turn deadly in seconds, giving the responders little or no time to react.

Being able to recognize signs of impending problems, such as collapse, backdraft, and flashover, comes with training and experience. Recognizing that a dangerous situation exists or is about to get worse can allow a fire fighter or incident commander the time to react and remove themselves or other responders from danger.

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

> **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 the 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.

**Size–up**

A tool to assist the incident commander as well as every fire fighter is a proper size-up. Like risk management, the incident size-up also begins with the alarm and continues until units are released. Size-up is used to analyze risk and to gather information during the risk vs. benefit analysis. During a structural fire the overall situation is sized-up as well as the structure or structures involved in the incident.

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 for several minutes in the rear areas of the apartment building, hidden from the fire fighters on their approach. Only heavy smoke was showing from the sides of the building visible to the fire fighters as they arrived.

The first arriving fire fighters were immediately drawn to the rescue of the three trapped children and never had the opportunity to complete a size-up of the entire building.

The danger posed by not knowing the extent to which a fire is burning within a building that fire fighters will be operating in during rescue or fire attack has been demonstrated numerous times in the past, often with tragic circumstances.

**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. With an IMS in place, the transfer of command can be made efficiently upon arrival and briefing of incoming officers. In the case of this incident, the initial incident commander (the assistant chief) was committed in the rescue effort and unable to brief the chief upon his arrival.

When he arrived on the scene, the chief operated with little or no information on the location and activities of the fire fighters inside the building. The chief then became involved in the rescue and was unable to further monitor conditions and fireground activities until his return from the hospital emergency room. In the chief's absence, there was no effective fireground command.

Communication is a major component in the IMS. This communication can be "face-to-face" or via radio or other means. There was little or no communication from the first arriving units, once the rescue effort began. The Keokuk Fire Department issues personal radios to the lieutenants, assistant chiefs and the chief. Extra radios are maintained in the cab of the two front line units for use by fire fighters. Of the first arriving personnel, only the assistant chief and the lieutenant were carrying radios. Once the assistant chief and the two fire fighters entered the building to conduct the search and rescue operation, there were no radio transmissions from the assistant chief. This further hampered attempts to locate the search team before and after they were incapacitated.

NFPA 1561, *Standard on Emergency Services Incident Management System* (2000 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 three and seven is considered desirable.)

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

**Accountability**

A key 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 by function and location. 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, group or sector commands should 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 Section 6-3 of NFPA 1500, *Standard on Fire Department Occupational Health and Safety* (1997 edition) and Section 2-6 of NFPA 1561, *Standard on Emergency Services Incident Management System* (2000 edition).

The Keokuk Fire Department normally operates with six personnel per shift (group). Each shift is under the command of an assistant chief. A lieutenant is also assigned to each shift. The remaining personnel are fire fighters. The Keokuk Fire Department does not have a formal accountability system.

In this case, the initial incident commander, the assistant chief, was immediately committed to the rescue of the three children. By the time the chief arrived there was no accounting for the location of the assistant chief within the building. The chief sent the two remaining fire fighters at the scene (the lieutenant was still at the hydrant) into the building to locate the assistant chief and to assist in the rescue. When the chief left the scene with one of the rescued children, there was no accounting for the location of the three fire fighters still inside the building. Upon the chief's return a few minutes later, the three still could not be accounted for.

An established accountability system includes a method to track all of the fire fighters operating at an incident and their location and function. In the event of a collapse, explosion or other significant event the fire fighters can be rapidly located, and rescued if necessary.

**Resources**

Adequate resources are necessary for a safe and efficient fireground operation. These resources can include personnel, apparatus, and equipment. When a fire attack or a rescue attempt 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.

NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program* (1997 edition) addresses the allocation of resources in the initial moments of a fireground operation in the following sections:

> **6-4 Members Operating at Emergency Incidents.**
>
> **6-4.1***
> The fire department shall provide an adequate number of personnel to safely conduct emergency scene operations. Operations shall be limited to those that can be safely performed by the personnel available at the scene. No member or members shall commence or perform any fire-fighting function or evolution that is not within the established safety criteria of the organizational statement as specified in 2-1.2 of this standard.
>
> **A-6-4.1** The limitation of emergency scene operations to those that can be safely conducted by the number of personnel on the scene is intended to reduce the risk of fire fighter death or injury due to understaffing. While

members can be assigned and arrive at the scene of an incident in many different ways, it is strongly recommended that interior fire-fighting operations not be conducted without an adequate number of qualified fire fighters operating in companies under the supervision of company officers.

It is recommended that a minimum acceptable fire company staffing level should be four members responding on, or arriving with, each engine and each ladder company responding to any type of fire. The minimum acceptable staffing level for companies responding in high-risk areas should be five members responding or arriving with each engine company and six members responding or arriving with each ladder company. These recommendations are based on experience derived from actual fires and in-depth fire simulations, and are the result of critical and objective evaluation of fire company effectiveness. These studies indicate significant reductions in performance and safety where crews have fewer members than the above recommendations. Overall, five member crews were found to provide a more coordinated approach for search and Rescue and fire suppression tasks.

During actual emergencies, the effectiveness of companies can become critical to the safety and health of fire fighters. Potentially fatal work environments can be created very rapidly in many fire situations. The training and skills of companies can make a difference in the need for additional personnel and in reducing the exposure to safety and health risks to fire fighters where a situation exceeds their capabilities.

**6-4.2**
When inexperienced members are working at an incident, direct supervision shall be provided by more experienced officers or members. This requirement shall not reduce the training requirements contained in Chapter 3 of this standard.

**6-4.3***
Members operating in hazardous areas at emergency incidents shall operate in teams of two or more. Team members operating in hazardous areas shall be in communication with each other through visual, audible, or physical means or safety guide rope, in order to coordinate their activities. Team members shall be in close proximity to each other to provide assistance in case of emergency.

**A-6-4.3** For additional information see 29 CFR 1910.134 and U.S. Department of Labor, Occupational Safety and Health Administration, Memorandum for Regional Administration and State Designees, "Response to IDLH or Potential IDLH Atmospheres" *[Commonly referred to as the Two-in/Two-out Rule]*.

**6-4.4***
In the initial stages of an incident where only one team is operating in the hazardous area at a working structural fire, a minimum of four individuals is required, consisting of two individuals working as a team in the hazard area and two individuals present outside this hazard area for assistance or rescue at emergency operations where entry into the danger area is required. The standby members shall be responsible for maintaining a constant awareness of the number and identity of members operating in the hazardous area, their location and function, and time of entry. The standby members shall remain in radio, visual, voice, or signal line communications with the team.

**A-6-4.4** The assembling of four members for the initial fire attack can be accomplished in many ways. The fire department should determine the manner in which they plan to assemble members in their response plan. The four members assembled for initial fire-fighting operations can include an officer, chief officer, or any combination of members arriving separately at the incident.

Members that arrive on the scene of a working structural fire prior to the assembling of four persons can initiate exterior actions in preparation for an interior attack. These can include, but are not limited to, actions such as the establishment of a water supply, the shutting off of utilities, the placement of ladders, the laying of the attack line to the entrance of the structure, or exposure protection.

If members are going to initiate actions that would involve entering of a structure because of an imminent life-threatening situation where immediate action can prevent the loss of life or serious injury, and four members are not yet on the scene, the members should carefully evaluate the level of risk that they would be exposed to by taking such actions. If it is determined that the situation warrants such action, incoming companies should be notified so that they will be prepared to provide necessary support and backup upon arrival.

**6-4.4.1** The "initial stages" of an incident shall encompass the tasks undertaken by the first arriving company with only one team assigned or operating in the hazardous area.

**6-4.4.2*** One standby member shall be permitted to perform other duties outside of the hazardous area, such as apparatus operator, incident commander, or technician or aide, provided constant communication is maintained between the standby member and the members of the team. The assignment of any personnel, including the incident commander, the safety officer, or operators of fire apparatus, shall not be permitted as standby personnel if by abandoning their critical task(s) to assist or, if necessary, perform rescue, they clearly jeopardize the safety and health of any fire fighter working at the incident. No one shall be permitted to serve as a standby member of the fire-fighting team when the other activities in which he/she is engaged inhibit his/her ability to assist in or perform rescue, if necessary, or are of such importance that they cannot be abandoned without placing other fire fighters in danger.

**A-6-4.4.2** The following examples show how a department might deploy a team of four members initially at the scene of a structure fire, regardless of how the team members are assembled:
(a) The team leader and one fire fighter could advance a fire-fighting hoseline into the IDLH [Immediately Dangerous to Life and Health] atmosphere, and one fire fighter and the pump operator become the stand-by members.
(b) The team leader could designate the pump operator to be the incident commander. The team leader and one fire fighter enter the IDLH atmosphere, and one fire fighter and pump operator remain outside as the standby members.
(c) Two fire fighters could advance the hoseline in the IDLH atmosphere, and the team leader and pump operator remain outside as stand-by members.

**6-4.4.3** The standby member shall be provided with at least the appropriate full protective clothing, protective equipment, and SCBA as required in Chapter 5 of this standard. The full protective clothing, protective equipment, and SCBA shall be immediately accessible for use by the outside team if the need for rescue activities inside the hazard area is necessary. The standby members shall don full protective clothing, protective equipment, and SCBA prior to entering the hazard area.

**6-4.4.4** When only a single team is operating in the hazardous area in the initial stages of the incident, this standby member shall be permitted to assist, or if necessary, perform, rescue for members of his/her team, providing abandoning his/her task does not jeopardize the safety or health of the team. Once a second team is assigned or operating in the hazardous area, the incident shall no longer be considered in the "initial stage," and at least one rapid intervention crew shall be required.

**6-4.4.5** Initial attack operations shall be organized to ensure that, if upon arrival at the emergency scene, initial attack personnel find an imminent life-threatening situation where immediate action could prevent the loss of life or serious injury, such action shall be permitted with less than four personnel when conducted in accordance with Section 6-2 of this standard. No exception shall be permitted when there is no possibility to save lives. Any such actions taken in accordance with this section shall be thoroughly investigated by the fire department with a written report submitted to the fire chief.

At this incident, three of the initial responders were involved in a rescue operation immediately upon arrival, leaving no fire fighters to provide a standby team. Within minutes of the arrival of the chief and the additional fire fighter, a standby team was available.  However, this standby team had no idea where the initial entry team was within the building.  There was no communication with the entry team.

**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 commander usually assigned a company or companies or put together a team from personnel on the scene to complete the rescue.  NFPA 1500 introduced a section on Rapid Intervention for Rescue of Members in the 1992 edition. The formation and implementation of Rapid Invention 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 (or Search) 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 (a standby team referred to above), 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 Section 6-5 of NFPA 1500. The use of RICs during the incident is covered in NPFA 1521, *Standard for Fire Department Safety Officer* (1997 edition), and NFPA 1561.

A formal RIC was not established during the operations in Keokuk. Available members conducted search attempts for the missing fire fighters as they arrived as call-back resources.  The department has no formal operating procedure for the establishment of a RIC during fireground operations.

## Smoke Detectors

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

- Lack of functioning smoke detectors within the apartment to provide early warning of a fire

A report on the use and performance of fire alarm systems by NFPA Fire Analysis and Research Division titled “U.S. Experience with Smoke Alarms and other Fire Alarms” (January 2000) states that half of the home fire deaths occur in the 6 percent of homes with no smoke alarms.

The following is from “The U.S. Experience with Smoke Alarms and other Fire Alarms” (January 2000):

> As of 1997, 15 of every 16 (94%) U.S. homes had at least one smoke alarm. However, 1997 fire data shows that 38% of the home fires reported to U.S. fire departments and 51% of the homes fire deaths still occurred in the now small share of homes with no smoke alarms. In three of every ten reported fires in smoke alarm-equipped homes the device did not work. Smoke alarms did not sound in half of the fire deaths that resulted from fires in homes equipped with these devices. Thus, more than two-fifths of the home fires and only one in four home fire deaths occurred in homes in which smoke alarms sounded.[1]

Witnesses and responders reported that there were no audible signals heard from smoke detectors within the fire apartment. After the fire, investigators could only find the plastic case from a smoke detector on the second floor within the fire apartment. There was no evidence of a battery in the device. If the apartment was equipped with smoke detectors, it appears that they did not activate during this incident, and therefore, did not give the family adequate advance warning of the fire, or allow them additional time for escape.

The leading cause of smoke alarm failure is dead, missing, or disconnected batteries. Occupants will remove the batteries from the devices because of nuisance alarms, from cooking, dust, steam, and so forth. They will also fail to replace a dead battery or leave the battery out of the device after removing it, leaving the smoke alarm disabled and useless, and leaving the occupants with a false sense of security. Batteries in these devices should be tested at least monthly and replaced annually.

If a fire occurs in a home with a smoke alarm, the risk of death is slightly more than half that of a fire in a home without a smoke alarm.

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[1] Marty Ahrens, “The U.S. Experience with Smoke Alarms and other Fire Alarms,” Quincy, MA: NFPA Fire Analysis and Research Division, January 2000, i.

NFPA 72, *National Fire Alarm Code*® (1999 edition) outlines the installation of smoke detectors within family living units. *Chapter 8, Fire Warning Equipment for Dwelling Units* contains minimum requirements for the selection, installation, operation, and maintenance of fire warning equipment for use within family living units. These requirements include the type of equipment, the location, installation, and power supply for the equipment as well as maintenance and testing and performance of the devices and systems.

Paragraph 8-1.4.1.6 of NFPA 72 calls for the location of smoke detectors in all sleeping rooms, outside of each separate sleeping area in the immediate vicinity of the bedrooms, and on each additional story of the family living unit, including basements. (in accordance with 7-6.2.10 of NFPA 101®). (See Figure Nos. 6 and 7.)

Experience has shown that all hostile fires in family living units generate smoke to some degree. This is also true with respect to heat buildup from fires. However, the results of full-scale experiments conducted over the past several years in the U.S., using typical fires in family living units, indicate that detectable quantities of smoke precede detectable levels of heat in nearly all cases. In addition, slowly developing, smoldering fires can produce smoke and toxic gases without a significant increase in the room's temperature. Again, the results of experiments indicate that detectable quantities of smoke precede the development of hazardous atmospheres in nearly all cases.[2]

Household fires at night or while occupants are sleeping are especially dangerous. Fire products and gases can overcome the residents before they have an opportunity to act and escape. Most fire casualties are victims of smoke inhalation-type injuries rather than burns.

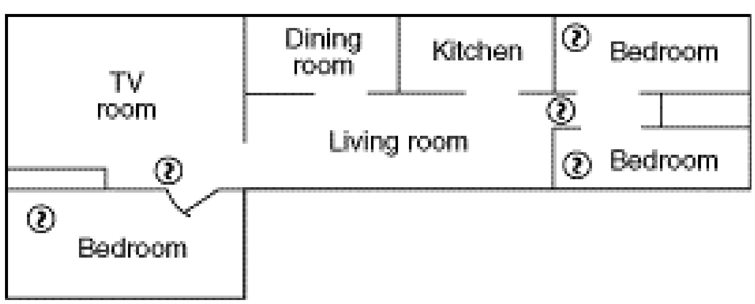


**Figure No. 6 In family living units with more than one sleeping area, a smoke detector should be provided to protect each sleeping area in addition to detectors required in bedrooms. (Figure A-8-1.2.1(b) from NFPA 72)**

[2] NFPA 72, National Fire Alarm Code® (1999) A-2-2.1.1.

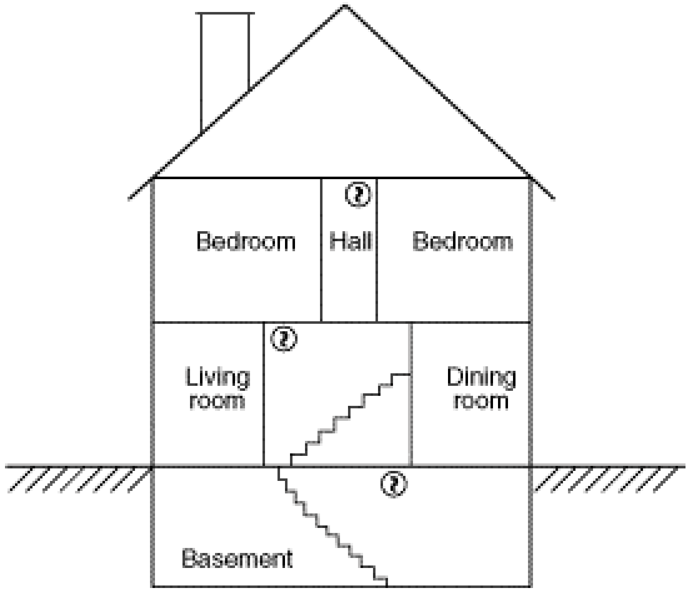


**Figure No. 7  A smoke detector should be located on each story. (Figure A-8-1.2.1(c) from NFPA 72)**

For the above reasons, the required protection in NFPA 72 utilizes smoke detectors as the primary life safety equipment for providing a reasonable level of protection against fire.

# VI. SUMMARY

An accidental fire started by a child playing with a stove resulted in the deaths of three children and the three fire fighters attempting to save the children. Had functioning smoke detectors been present in the apartment, this incident most likely would have had a different outcome. Perhaps the mother and four children would have been waiting on the front lawn of the home when the fire department arrived to extinguish what would have turned out to be a kitchen fire.

Without the benefit of a functioning smoke detector, the family was not given any early warning of the fire, which spread rapidly both inside and outside of the home, quickly cutting off escape from the second floor, forcing the mother to escape via a bedroom window and a porch roof. She was able to escape with one child before smoke and hot gases cut off her path to the rear bedrooms where the younger children slept.

With the extreme life hazard that initial units were confronted with, the incident commander did not complete a full size-up. Because of minimal staffing that responded with the first two units, all available personnel were committed to the rescue of the children, and no one was available to determine the location and extent of the fire.

The initial moments of a fire department operation at a structural fire are often hectic. If you add rescue or search for trapped occupants to the equation, the situation can quickly deteriorate if some form of incident management (IMS) and personnel accountability is not established. It is important for the incident commander to be able to account for all personnel on the fireground, and be able to locate them should conditions require that personnel be removed from the building (i.e., backdraft, flashover, collapse).

In this case, the initial incident commander was involved in the search for the trapped occupants from the beginning of the incident. This left the chief, who arrived minutes after the first units, with little or no information on the fire fighters' locations and status. Then the fire chief became involved in the operation by transporting one of the rescue children to the hospital, due to a lack of personnel and an ambulance on the scene. This left no incident commander on the scene for several minutes and further complicated the accountability issues.

A Rapid Intervention Crew (RIC) has become an essential part of fire ground operations. Whenever fire fighters are operating in a hazardous location (i.e., structural fire fighting), a stand-by crew should be established in the initial moments until a fully staffed RIC can be equipped and put into place. With the limited personnel that responded in the first minutes of this incident, even a stand-by crew of two could not be established, due to the rescue operations and removal of the children from the building.

In another incident investigated by NFPA, which occurred in Marks, Mississippi, on August 29, 1998, some of these same factors came into play. In that incident, lack of accountability, an incident management system and a Rapid Intervention Crew, as well as limited fireground resources resulted in the deaths of two fire fighters. (See Appendix for a report summary of this incident.)

The several factors outlined in this report such as the lack of functioning smoke detectors, minimal fire department resources at the time of arrival, lack of established accountability and incident management systems, and a lack of a Rapid Intervention Crew played an integral part in the tragic outcome of this fire.

Incident commanders need to be aware of the hazards present at each fire scene. They need to implement methods to account for the personnel operating on the fireground, and have the resources to rescue those operating in hazardous locations. By establishing a management system to manage the incident in an effective manner, the incident commander is putting a system in place to monitor the hazards, account for the personnel, and provide sufficient resources to battle the fire and provide for rescue of personnel when needed.

# VII. NFPA DOCUMENTS

| | |
|---|---|
| **NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program (1997 edition)*** | 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 Emergency Service Incident Management System (2000 edition)*** | This standard establishes minimum performance requirements for an incident management system based on concerns for the safety and health of fire department personnel.<br>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 provided for a uniform approach to incident management while providing for some variations to meet local requirements. |
| **NFPA 1404, *Standard for a Fire Department Self-Contained Breathing Apparatus Program (1996 edition)*** | 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 101® *Life Safety Code®* *(2000 edition)*** | This Code addresses life safety from fire. Its provisions will also aid life safety in similar emergencies.<br>The Code addresses those construction, protection, and occupancy features necessary to minimize danger to life from fire, including smoke, fumes, or panic. The Code identifies the minimum criteria for the design of egress facilities so as to permit prompt escape of occupants from buildings or, where desirable, into safe areas within buildings.<br><br>The Code recognizes that life safety is more than a matter of egress and, accordingly, deals with other considerations that are essential to life safety.<br><br>The Code does not attempt to address all those general fire prevention or building construction features that are normally a function of fire prevention and building codes. |
| **NFPA 72 *National Fire Alarm Code® (1999 edition)*** | The purpose of this code is to define the means of signal initiation, transmission, notification, and annunciation; the levels of performance; and the reliability of the various types of fire alarm systems. This code defines the features associated with these systems and also provides the information necessary to modify or upgrade an existing system to meet the requirements of a particular system classification. |

# APPENDIX

## Fire Fighter Fatalities
## Commercial Building
## Marks, Mississippi
## August 29, 1998

## Summary

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 (6.1m – 9.1m) storage building was used to store floral packing and display materials and also contained a 6-ft – 6ft (1.8m – 1.8m) 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 cleaners, 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 15ft (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 fireground 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 the 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 24 ft (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, 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

## Fire Fighter Fatality
## Floor Covering Showroom/Warehouse
## Branford, Connecticut
## November 28, 1996

## Summary

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 and 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 re-entered 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 he was last seen by the officer. The cause of the fire fighter's death was listed as smoke inhalation.

On the basis of its investigation and analysis, 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

## Fire Fighter Fatalities
## Automobile Parts Store
## Chesapeake, Virginia
## March 18, 1996

## Summary

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 who 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

## Seattle, Washington
## Food Warehouse
## Fire Fighter Fatalities
## January 5, 1995

## Summary

A fire in a Seattle 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 in. by 4 in. 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

In the years since this incident, 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.

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# U.S. EXPERIENCE WITH SMOKE ALARMS AND OTHER FIRE ALARMS

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**January 2000**

# U.S. EXPERIENCE WITH SMOKE ALARMS AND OTHER FIRE ALARMS

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January 2000

# Executive Summary

**Half of the home fire deaths occur in the 6% of homes with no smoke alarms.**

As of 1997, 15 of every 16 (94%) U.S. homes had at least one smoke alarm. However, 1997 fire data show that 38% of the home fires reported to U.S. fire departments and 51% of the home fire deaths still occurred in the now small share of homes with no smoke alarms. In three of every ten reported fires in smoke alarm-equipped homes, the devices didn't work. Smoke alarms did not sound in half of the fire deaths that resulted from fires in homes equipped with these devices. Thus, more than two-fifths of the home fires and only one in four home fire deaths occurred in homes in which smoke alarms sounded.

Homes with smoke alarms (whether or not the alarms were operational) typically have a death rate that is about 40-50% less than the rate for homes without alarms.

In 1992, the U.S. Consumer Product Safety Commission sent surveyors to people's homes to find out how common smoke alarms were and what portion of these devices were working in the general population's homes. In one of every five homes that had at least one smoke alarm installed, not a single one was working. This is a smaller share than what is seen in homes with reported fires, but it is still too high. When homes without smoke alarms are added to homes with only non-working alarms, we see that one-quarter of U.S. households do not have the protection of even one working smoke alarm.

Although households without smoke alarms are slightly more likely to be poor, non-white or headed by an adult over 65 years old, the principal common feature is a much greater tendency to have reported fires. Households with smoke alarms can discover and control a larger share of the fires they have without involving the fire department. This influences the statistics. The usual socioeconomic factors correlated with fire risk are less useful as predictors of smoke alarm usage.

**Smoke alarm failures usually result from dead, missing or disconnected batteries.**

When smoke alarms don't work, it is usually because the batteries are dead, disconnected or missing. People are most likely to remove or disconnect batteries because of nuisance activations. People need to test the alarm every month to make sure the batteries are still working and to replace the battery every year.

Fortunately, the percentage of smoke alarms that are non-working has leveled off, so the percentage of households with at least one working smoke alarm has followed an upward trend in most years. This is encouraging.

Strategies to ensure that smoke alarms continue to work after installation have not been evaluated in the field, but wired-in (or hard-wired) systems do not need new batteries (except for back-up in power outages), do not permit removal of their primary power sources for use elsewhere, and are statistically much less susceptible to power source interruptions. At present, most homes have battery-powered smoke alarms, which are not interconnected. A single station smoke alarm may not be heard on other floors or in other rooms.

**Follow these tips.**

NFPA's Learn Not to Burn® Foundation's Technical Advisory Council issued these recommendations in 1989 and 1991 for the testing and maintenance of smoke alarms:

- Install new batteries in all smoke alarms once a year on the day you change your clock from daylight to standard time or when the alarm chirps to warn that the battery is dying.
- Replace all batteries immediately upon moving into a new home.
- Test units monthly, in accordance with NFPA 72, *National Fire Alarm Code.* Test the units using the test button or an approved smoke substitute, and clean the units, both in accordance with the manufacturers' instructions. Do not use an open-flame device for testing because of the danger the flame could pose.

The households with smoke alarms that don’t work now outnumber the households with no alarms by a substantial margin. Any program to ensure adequate protection must include smoke alarm maintenance. Although most homes have at least one smoke alarm, many homes do not have a unit on every floor. Also, many people forget that a smoke alarm’s sole function is to sound the warning. People need to develop and practice escape plans so that if the alarm sounds, they can get out quickly. Because smoke alarms alert occupants to fires that are still relatively small, some people attempt to fight these fires themselves. Unfortunately, some of these attempts are unsuccessful, either due to rapid fire spread or inappropriate methods of fire control. Meanwhile, precious escape time is lost.

Detection and alarm systems are also needed in many occupancies other than homes. Public assembly properties, store and office properties, and storage properties stand out as occupancies where the majority of fires occur in places without smoke or heat alarms and more than one-fifth of the units present are estimated to be non-operational when fire occurs.

# Table of Contents

## Introduction

This report discusses the use and performance of fire alarm systems in all types of buildings. Fire incident data collected by the National Fire Incident Reporting System (NFIRS) do not indicate whether alarms are smoke alarms, heat alarms, or other types of alarms, let alone what type of smoke alarm (e.g., ionization vs. photoelectric.) It is known that nearly all fire alarms in homes are smoke alarms. For clarity's sake, the term 'smoke alarm' is used to include all types of fire alarms, including those that detect heat or sprinkler water flow.

**'Smoke alarms' are more than 'smoke detectors.'**
The terminology used in this report has changed slightly to conform to industry practices. Most homes have what we now call 'smoke alarms.' These units detect the presence of smoke and sound the alarm. Some multi-family complexes and non-residential structures have smoke detectors that are components of an alarm system. The detection unit itself does not sound the alarm. Instead, the signal is transmitted to the control unit that then sounds the alarm throughout the premises. Older studies of smoke detectors usually studied devices that would now be called 'smoke alarms.'

**NFPA 72 provides guidelines for fire alarm system usage.**
NFPA 72, *National Fire Alarm Code*,® was developed by NFPA technical committees on:

- Fundamentals of Fire Alarm Systems;
- Household Fire Warning Equipment;
- Initiating Devices for Fire Alarm Systems;
- Supervising Station Fire Alarm Systems; and
- Testing and Maintenance of Fire Alarm Systems.

The Technical Correlating Committee of the National Fire Alarm Code released NFPA 72.

Technical committees are comprised of members from manufacturing, enforcing authorities, system installers and maintainers, users, research and testing organizations, insurance companies, labor, consumers and others. The codes are updated through our regular three-year cycle, and members of the public may submit recommendations for change or comment on the proposed changes. Reports on Proposals (ROP) and Reports on Comments (ROC) are published and available to the public during this process. NFPA members vote to accept or reject the proposed changes at the Fall or Annual Meetings, and Appeals are handled by the Standards Council.

## Who Has Home Smoke Alarms?

**15 out of 16 homes have at least one smoke alarm.**
From 1975 to 1984, the use of home smoke alarms skyrocketed. Most of these smoke alarms were single-station, battery-operated, ionization-type devices. With this rapid growth in usage and the clear evidence from actual fire stories and fire statistics showing the life-saving effectiveness of these alarms, the home smoke alarm became the fire safety success story of the decade. From 1984 through 1993, the growth in usage was much less rapid but fairly steady. Usage seemed to grow much more slowly from 1993 through 1997. As of 1997, at least one smoke alarm can be found in 15 of every 16 homes. The growth in smoke alarm usage is shown in Figure 1.

**A disproportionate share of the home fires occur in homes with no smoke alarms.**
Figure 1 also shows that the percentage of *fires* occurring in homes with smoke alarms is still much lower than the percentage of *homes* with smoke alarms.

Two principal factors could explain why there are, proportionally, so many more smoke alarms in homes in general than in homes with reported fires. First, households that have fires tend, for a variety of reasons, to be the kind of households that would be less likely to buy or own smoke alarms. Second, smoke alarms discover some fires so early that the occupants can control the fires without involving or notifying the fire department.

There is no way to develop a conclusive analysis of the relative importance of these two factors with existing data bases, but some exploratory analysis given in Appendix A suggests that the second factor (early detection and control of the situation by the occupant) is more important.

The population groups that face the highest fire risk have increased their smoke alarm usage along with the rest of the country. All national surveys that have examined smoke alarm usage by major population group have found that smoke alarm usage for all population groups is far higher than smoke alarm usage in homes that have reported fires. Table 1 shows this.

A 1998 article, 'Residential Smoke Alarms and Fire Escape Plans,' prepared by the National Center for Injury Prevention and Control, at the Centers for Disease Control and Prevention (CDC), summarized data from the fire module of the Injury Control and Risk Survey. The 1994 telephone survey obtained over 5,200 usable responses. Ninety-one percent (91%) of the households reported that at least one smoke alarm was installed in their home. This is slightly lower than the 93%

reported for that year by *Prevention Magazine*, our primary source for consistent data.

Table 2 summarizes the responses to two questions:

1. Do you have any smoke detectors installed in your home? and

2. Have any members of your household ever discussed an escape plan in case of fire?*

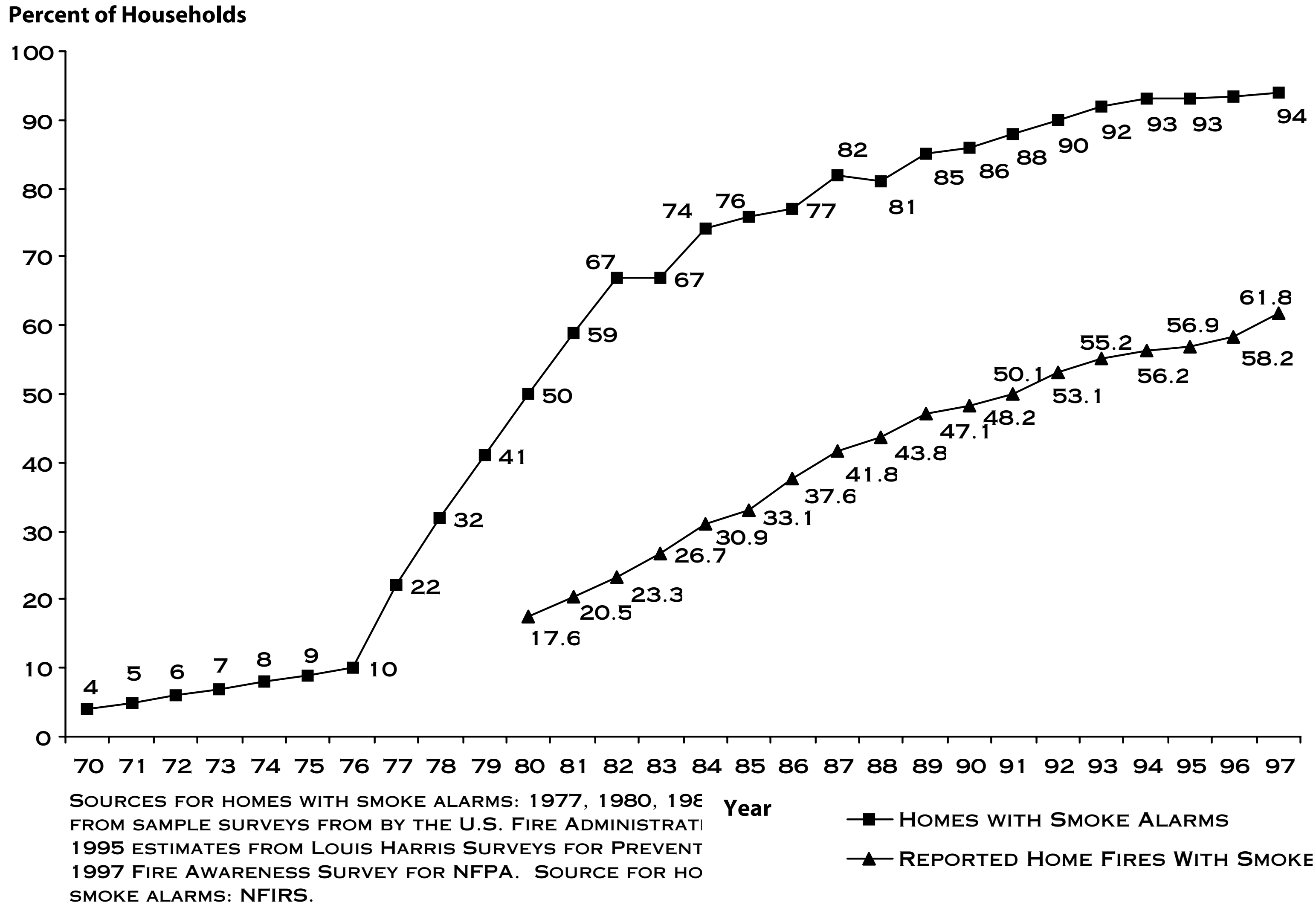
In a study examining reported fires in Minnesota during 1997, no smoke alarms were present in 35% of the home fires reported in counties of less than 50,000, compared to 18% of the home fires in the eleven more densely populated counties and 23% for the state overall.** According to national studies of all households (not just those having fires), rural households were less likely to have smoke alarms than the overall population. (See Tables 1 and 2.)

To some degree, households that are poor or have other risk-related characteristics are still less likely than others to have smoke alarms, as Tables 1 and 2 show. But the gap is not nearly enough to explain the high concentration of fires in homes without smoke alarms. Apparently, the households that still do not have these devices are more risk-prone but in ways that do not correlate strongly or neatly with the socioeconomic characteristics – poverty, race, age, etc. – that usually correlate with the risk of having a reported fire or having a fatal fire.

* Pauline A. Harvey, Jeffrey J. Sacks, George W. Ryan, and Patricia F. Bender, "Residential Smoke Alarms and Fire Escape Plans," *Public Health Reports*, Rockville, MD: Public Health Service, September/October 1998, Volume 113, page 459-464.

** *Fire in Rural Minnesota – 1997;* Minnesota Department of Safety, State Fire Marshal Division.

**Figure 1. Growth in Home Smoke Alarm Usage, 1970-1997**



## Table 1. Smoke Alarm Usage by Major Population Group in 1982, 1989 and 1991

| Group | Percentage of Group Having Home Smoke Alarms | | |
|---|---|---|---|
| | 1982 | 1989 | 1991 |
| Total population | 67% | 85% | 88% |
| Apartments | 63% | | |
| Rural households | 62% | | 83%* |
| Households headed by person over 65 years of age | 62% | | 83% |
| Households headed by person who did not complete high school | 61% | 72% | 83% |
| Households in the South | 60% | 80% | 85% |
| Households not headed by married couple | 56% | | |
| Households with incomes below $7,500 per year | 55% | 79% | 84% |
| Non-white households | 53% | | 86%** |
| Smokers | | | 87% |
| Heavy drinkers | | | 83% |
| People who ever use drugs | | | 83% |
| Homes with fires | 23% | 47% | 50% |

* Outside SMSA but not necessarily rural.

** Black households specifically.

Sources: 1982 figures from Figure 1 (homes with fires) and John R. Hall, Jr. and Sid Groeneman, "Two Homes in Three Have Detectors," *Fire Service Today*, February 1983, pp. 18-20; 1989 and 1991 figures from The Prevention Index '90 and '92, *Prevention Magazine*, 33 East Minor Street, Emmaus, PA 19098, 1990 and '92. Some figures available for 1982 were not available for 1989. Some additional materials on these demographics for 1991 were provided to NFPA by *Prevention Magazine.*

**Table 2.**
**Presence of Smoke Alarm and Plans for Fire Escape by Household Characteristics Injury Control and Risk Survey 1994**

| Characteristic | Percent Reporting Installed Smoke Alarms | Percent Reporting Fire Escape Plans |
|---|---|---|
| Total | 91.1% | 59.8% |
| Household income[a] | | |
| Below poverty level | 82.3% | 51.5% |
| Above poverty level | 92.8% | 60.5% |
| Metropolitan Statistical Area[b] | | |
| Urban | 92.9% | 59.3% |
| Rural | 85.8% | 61.0% |
| Type of home[a] | | |
| Five or more apartments | 95.6% | 50.1% |
| Manufactured housing | 90.3% | 66.6% |
| Attached home | 91.0% | 54.6% |
| Detached home | 90.2% | 62.2% |
| Year home built[c] | | |
| Before 1950 | 89.5% | 62.2% |
| 1950-1959 | 90.5% | 56.4% |
| 1960-1979 | 90.0% | 60.1% |
| 1980 or later | 96.7% | 63.3% |
| Census region[b] | | |
| Northeast | 93.1% | 59.5% |
| North Central | 93.8% | 59.7% |
| South | 88.8% | 58.8% |
| West | 90.0% | 61.6% |
| Highest educational level in household[a] | | |
| Less than high school | 78.3% | 47.9% |
| High school graduate | 88.9% | 58.5% |
| Some college | 92.6% | 59.6% |
| College graduate | 93.6% | 59.6% |
| Home ownership[d] | | |
| Rented | 89.6% | 51.3% |
| Owned | 91.9% | 63.6% |

[a]Statistically significant at $P < 0.001$ for smoke alarms and fire escape plans.
[b]Statistically significant at $P < 0.001$ for smoke alarms only.
[b]Statistically significant at $P < 0.001$ for smoke alarms and $P < 0.05$ for fire escape plans.
[d]Statistically significant at $P < 0.05$ for smoke alarms and $P < 0.001$ for fire escape plans.

Source: Pauline A. Harvey, Jeffrey J. Sacks, George W. Ryan, and Patricia F. Bender, "Residential Smoke Alarms and Fire Escape Plans," *Public Health Reports*, Rockville, MD: Public Health Service, September/October 1998, Volume 113, page 462.

## How Does Home Smoke Alarm Presence Affect the Fire Outcome?

**If a home fire occurs, smoke alarms reduce the risk of death by 40-50%.**

If a fire occurs in a home with a smoke alarm, the risk of death is slightly more than half that of a fire in a home without a smoke alarm. Table 3 shows that smoke alarms cut the risk of dying if a home fire occurs by 40-50%. Table 3 also shows that the estimated impact of smoke alarms on death rates fluctuates somewhat from year to year.

In other words, having a smoke alarm cuts your chances of dying, if you have a fire, nearly in half. This is not the same as saying your chances of surviving double. Table 3 shows that, on average, 1.06 civilian deaths occurred per 100 home fires with no smoke alarm and that 0.58 deaths occurred per 100 fires with a smoke alarm; 0.58 is 45% less than 1.06. A 100% chance of dying would mean that every fire is fatal, or, roughly, 100 deaths per 100 fires. Fortunately, that is not the case. Your chances of surviving a home fire when smoke alarms are present are 99.42% (100 minus 0.58) vs. 98.94% (100 minus 1.06) in home fires with no smoke alarms. The first number is barely higher than the second and certainly not double the second number.

Table 3 understates the power and value of home smoke alarms. First, the death rates for homes with a smoke alarm include fires in homes with non-operational alarms or incomplete coverage. Households should do even better if they follow NFPA recommendations for installation and maintenance and develop and practice escape plans so they are ready to use the extra warning time effectively. Second, the figures in Table 3 are based on reported fires only, but as noted, smoke alarms discover some fires while they are still small enough to be extinguished by occupants without involving the fire department.

Appendix A suggests smoke alarms may cut the number of fires reported to fire departments by 75-80%, relative to the number that would have been reported had there been no smoke alarms. Still, the analysis of this issue is very uncertain because the limitations of available data require an indirect analysis and some estimation of the likely range for values that cannot be directly measured.

**Smoke alarm death risk reduction is greatest in 1- & 2-family dwellings.**
A ten-year analysis that separates single-family dwellings, duplexes, and manufactured homes from apartments, townhouses, and condominiums identifies a surprisingly large difference in the statistical estimate of the life-saving effectiveness of home smoke alarms. In dwellings, duplexes, and manufactured homes, smoke alarms are estimated to reduce the risk of dying if fire occurs by 51%, while in apartments, townhouses, and condominiums, the estimated reduction is only 16%, based on 1988-1997 fires.

The next section of this report will show that, according to our best estimates, the problem of non-operational smoke alarms is of about equal size in the two types of homes, so apparently that is not the explanation. Apartments might have fewer or longer escape routes, more cases of incomplete coverage (e.g., common areas only) or more success in preventing fires from growing large enough to report. None of these hypotheses can be tested with available data.

It is also possible that, on average, apartment fires are more dangerous, that more apartment victims are unable to act on an early warning, or that more apartment victims ignore the sounding smoke alarms. The latter could occur, for example, if occupants were more likely to assume that any smoke alarm activation is a nuisance activation from outside their unit.

Few of the explanations we can test with data, however, show more than slight differences between dwellings and apartments. Table 4 is an overview of characteristics of fatal victims and their fatal fires, in apartments and in dwellings, duplexes, and manufactured homes, with and without smoke alarms reported present. Many of the differences in Table 4 are small. Also, some groups of characteristics seem to be measuring the same or similar phenomena but show inconsistent patterns in doing so.

**Apartment fire victims were more likely to be in the room of fire origin.**
The most striking difference has to do with the victim's proximity to the fire. When alarms are present, 41% of the victims of fatal fires in dwellings, duplexes, and manufactured homes are in the room of fire origin at ignition, but 52% of the apartment victims are that close to the fire. This suggests that there are proportionally more people in apartments who are so close to the fire that they may not have time to escape, even with the warning from a working smoke alarm. Other NFPA analyses have shown that 35% of the fatal apartment fire victims died from fires that originated in bedrooms, compared to 26% of the fatal fire victims in dwellings, duplexes, or

manufactured homes.* This may help fill in the details on how apartment victims come to be closer to the fire in so many cases.

**U.K. study shows fires discovered by smoke alarms tend to be discovered earlier.**

An analysis of smoke alarm performance in the United Kingdom found several points that resemble the U.S. experience. They also have some data that are not collected here.

- In 1998, the death rate in U.K. home fires when the fire was discovered by a smoke alarm was 56% lower than when it was not discovered by a smoke alarm.

- Seventy-one percent (71%) of the home fires that were discovered by smoke alarms were discovered within five

* Marty Ahrens, *The U.S. Fire Problem Overview Report*, Quincy, MA: NFPA Fire Analysis and Research Division, May 1999, page 62.

minutes of ignition. In 77% of the alarm-discovered fires, flame damage was confined to the object of origin.

- When home fires were not discovered by smoke alarms, only 51% were discovered within five minutes of ignition. Flame damage was confined to the object of origin in only 46% of these fires.*

* Lorraine Watson and Jonathan Gamble, *Home Office Statistical Bulletin: Fire Statistics –- United Kingdom 1998*, London, U.K., Research, Development and Statistics Directorate, September 8, 1999, Issue 15/99, p 29.

**Table 3.**
**Life-Saving Effectiveness of Home Smoke Alarms**
**1980-1997**

**Deaths per 100 Fires**

| Year | Alarm Present | No Alarm Present | How Much Lower is the Death Rate with Alarm Present? |
|---|---|---|---|
| 1980 | 0.54 | 1.00 | 46% |
| 1981 | 0.53 | 0.92 | 42% |
| 1982 | 0.43 | 0.90 | 52% |
| 1983 | 0.55 | 0.90 | 39% |
| 1984 | 0.43 | 0.84 | 49% |
| 1985 | 0.62 | 1.02 | 39% |
| 1986 | 0.55 | 1.07 | 49% |
| 1987 | 0.59 | 0.99 | 40% |
| 1988 | 0.66 | 1.16 | 43% |
| 1989 | 0.65 | 1.06 | 39% |
| 1990 | 0.61 | 1.14 | 46% |
| 1991 | 0.53 | 0.84 | 37% |
| 1992 | 0.57 | 1.03 | 45% |
| 1993 | 0.50 | 1.03 | 51% |
| 1994 | 0.51 | 1.04 | 50% |
| 1995 | 0.60 | 1.13 | 47% |
| 1996 | 0.60 | 1.18 | 49% |
| 1997 | 0.56 | 0.97 | 42% |
| Average 1988-1997 | 0.58 | 1.06 | 46% |

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Source: National estimates based on NFIRS and NFPA survey.

**Table 4.**
**Characteristics of Fatal Victims in**
**Home Fires, With and Without Smoke Alarms Present**
**1988-1997**

| | One- and Two-Family Dwellings | | Apartments | |
|---|---|---|---|---|
| **Characteristic** | **Alarm Present** | **No Alarms** | **Alarm Present** | **No Alarms** |
| Victim in room of fire origin at ignition | 40.9% | 39.4% | 52.3% | 46.1% |
| Fire spread flames beyond room of origin | 74.8% | 84.2% | 65.3% | 77.9% |
| Fire spread smoke beyond room of origin | 94.1% | 93.4% | 93.3% | 91.3% |
| Victim physically or mentally handicapped, or impaired, or too young or old to react | 29.4% | 27.8% | 31.0% | 29.0% |
| Victim age 65 or older | 25.8% | 26.7% | 25.0% | 14.3% |
| Victim age 5 or younger | 22.4% | 20.6% | 19.6% | 27.7% |
| Victim unable to act or irrational | 20.3% | 18.9% | 21.1% | 19.4% |
| Victim attempting fire control or rescue | 6.5% | 6.1% | 5.3% | 4.3% |
| Victim incapacitated before fire | 14.0% | 13.8% | 13.2% | 10.6% |
| Fire between victim and exit | 20.9% | 19.0% | 21.3% | 28.9% |
| Victim's clothing on fire | 6.6% | 5.1% | 8.5% | 3.7% |
| Victim blocked by locked door or illegal gates or locks | 2.1% | 3.6% | 2.3% | 2.8% |

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Victims with characteristic unknown have been proportionally allocated.

Source: National estimates based on NFIRS and NFPA survey.

## What Percentage of Home Smoke Alarms Are Working?

**In homes with smoke alarms, 20% had none that worked.**
Published studies of the operational status of alarms have focused almost exclusively on home smoke alarms. There are two different kinds of studies – studies of smoke alarm performance in fires and studies of smoke alarm operational status in homes in general. Table 5 summarizes the findings of all published studies known to the author. One of the best was done for the National Smoke Detector Project. This study showed that in one-fifth (20%) of the homes (regardless of fire experience) that had at least one smoke alarm, none were working.

Another way to estimate the fraction of working smoke alarms is to estimate what percentage of home fires are reported to have an operational smoke alarm. (This cannot be done directly from the reported data but requires some adjustments, which are described in Appendix B.) Table 6 shows the results.

**A lower percentage of homes with fires had working smoke alarms.**
Since homes with reported fires are much less likely to have smoke alarms than homes in general, it is likely that smoke-alarm-equipped homes with fires might be more likely than smoke-alarm-equipped homes without fires to have allowed their smoke alarms to become non-operational. If having a fire is correlated with a lesser concern for fire safety, this lack of concern might be expected to produce a lower rate of smoke alarm usage and a higher rate of non-operational smoke alarms where these alarms were present.

Eighty percent (80%) of the homes surveyed by the National Smoke Detector Project in 1992 had at least one working alarm. This is substantially better than the percentages of smoke-alarm-equipped dwelling and apartment fires with working alarms. As Table 6 shows, these percentages have hovered around 70% since 1986.

**When present, similar percentages of working smoke alarms are seen in fires in one- and two-family homes and in apartments.**
Note that Table 6 also indicates that the percentage of operational smoke alarms (compared to the number of smoke alarms present) is roughly the same for apartments as for single-family dwellings, duplexes, and manufactured homes. (Where they differ, the percentages for apartments are usually better. However, the difference was only significant in 1985.)

This may seem surprising to urban fire experts accustomed to seeing disproportionate levels of smoke alarm system problems in poor multi-family housing. However, in the U.S. as a whole, poverty and other household characteristics that one might expect to be correlated with poor smoke alarm maintenance are found in rural dwellings and manufactured homes as often as in urban multi-family housing. (Note that we do not know that smoke alarm operational status is correlated to poverty, but most measures of fire frequency and usage of fire protection equipment are.) In addition, apartments tend to be more stringently regulated than one- and two-family homes.

**The percentage of homes with working smoke alarms is still growing.**

Figures 2 and 3 each show three trend lines for homes with reported fires. Figure 2 shows the trends in one- and two-family dwellings and manufactured housing while Figure 2 shows the trends in apartments.

The top, dotted line shows the percentage as a fraction of homes with working smoke alarms compared to homes with smoke alarms present. The solid line shows the percentage of fires in homes with smoke alarms, whether working or not. The lowest, dashed line is the product of the two – the percentage of home fires that occurred in homes with a working smoke alarm.

In 1985, the decline in operationality actually overtook the rise in smoke alarm presence in fires in dwellings, resulting in a net decrease in the percentage of dwelling fires occurring in dwellings with operational smoke alarms. Since then, the trend has reversed again. Each year, a larger percentage of the fires occur in homes with working smoke alarms.

**Only 16% of fire deaths in one- and two-family homes occurred in fires with sounding smoke alarms.**

Tables 7, 8 and 9 show the percent of fire deaths that occurred in: homes with smoke alarms; homes with smoke alarms present that operated; and homes with an operating smoke alarm. The third category combines the first two. The columns in Tables 7 and 8 are like the trend lines in Figures 2 and 3, but for deaths, not fires. Predictably, the presence and the operationality of smoke alarms are lower in fatal home fires than in home fires in general.

During the ten year period from 1988 through 1997,

- Only 16% of the fire deaths in one- and two-family homes or manufactured housing occurred in structures with a working smoke alarm;

- 32% of the apartment fire deaths occurred in properties with this protection; and
- 20% of the total home fire deaths resulted from fires with operational smoke alarms.

**3/4 of all homes have at least one working smoke alarm.**

If 94% of homes now have smoke alarms and 20% of those have non-operational smoke alarms, then 6% of homes have no smoke alarms at all (100% minus 94%) and another 19% of homes have smoke alarms that do not work (20% of 94%). Therefore, three of every four homes (75%) have at least one working smoke alarm (100% minus 6% minus 19%). Although the homes without these devices still have nearly half of the fires, restoring operational status to the non-working smoke alarms could have a major impact and should be considered a priority, along with installing smoke alarms in the remaining homes that do not have them.

**About 30% of smoke alarms in homes with fires in past ten years have been non-operational.**

Table 6 indicated the problem of non-operational smoke alarms in homes with fires has leveled off with about 30% non-operational. It is encouraging to see that the erosion of smoke alarm protection appears to have stopped, but a situation in which nearly one-third of smoke alarms are not working when they are needed is not acceptable.

**Table 5.**
**Percentage of Home Smoke Alarms Operational - Results of Several Studies**

| | | |
|---|---|---|
| 1. | Twelve communities* (principally Montgomery County, MD), 1978-1979 | 92% |
| 2. | Santa Barbara, CA, 1983** | 64% |
| 3. | Oregon, 1984** | 75% |
| 4. | Unreported fires study (fires with smoke spread beyond room of origin), 1984*** | 68% |
| 5. | DeKalb County, GA, 1985**** | 70% |
| 6. | Inference from two national studies, 1985***** | 83% |
| 7. | National Smoke Detector Project Survey, 1992****** | 80% |

* Raymond E. Hawkins, *An Evaluation of Residential Smoke Detectors Under Field Conditions: Final Phase*, Washington: International Association of Fire Chiefs Foundation, March 1983, p. xiii.

** Leon Cooper, "Why We Need to Test Smoke Detectors," *Fire Journal*, November 1986, pp. 43-45.

*** Audits & Surveys, Inc., *1984 National Simple Survey of Unreported Residential Fires*, Final Technical Report, Contract C-83-1239, for the U.S. Consumer Product Safety Commission, June 13, 1985.

**** Centers for Disease Control, U.S. Department of Health and Human Services, *Morbidity and Mortality Weekly Report*, July 18, 1986.

***** The Prevention Index '87, *Prevention Magazine*, 33 East Minor Street, Emmaus, Pennsylvania 18098, 1987 and R. E. Hoffman, "Tracking 1990 Objectives for Injury Prevention With 1985 NHIS Findings," *Public Health Report* #101, November-December 1986, pp. 581-586. The former estimated 76% of homes had at least one alarm in 1985, and the latter estimated 63.3% of homes had at least one functioning alarm in 1985, which would mean an 83% rate of operationality.

****** Charles L. Smith, *Smoke Detector Operability Survey - Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. ii.

## Table 6.
## Estimated Percentage of Fire-Involved Homes With Smoke Alarms Which Were Operational 1980-1997

| Year | Single-Family Dwellings, Duplexes and Manufactured Homes | Apartments |
|---|---|---|
| 1980 | 75.7% | 76.0% |
| 1981 | 72.5% | 73.9% |
| 1982 | 71.5% | 71.1% |
| 1983 | 68.3% | 70.5% |
| 1984 | 67.4% | 67.9% |
| 1985 | 62.5% | 69.7% |
| 1986 | 68.0% | 69.4% |
| 1987 | 68.0% | 70.4% |
| 1988 | 67.1% | 68.9% |
| 1989 | 68.1% | 69.3% |
| 1990 | 68.2% | 68.0% |
| 1991 | 67.5% | 69.4% |
| 1992 | 67.5% | 69.6% |
| 1993 | 69.1% | 70.4% |
| 1994 | 69.8% | 70.8% |
| 1995 | 69.5% | 70.9% |
| 1996 | 69.9% | 71.7% |
| 1997 | 70.1% | 71.1% |

Note: Homes are all structures that households may occupy, other than properties such as hotels, boarding homes, dormitories, or barracks, where households share some building services. The dwelling category encompasses one- and two-family homes, including manufactured homes, while apartments include all other homes, i.e., buildings containing three or more housing units.

These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on estimates of fires where alarms activated within set of fires deemed large enough to activate an operational smoke alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or unclassified or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin.

Source: National estimates based on NFIRS and NFPA survey.

**Figure 2. Smoke Alarms in Dwelling Fires, 1980-1997**

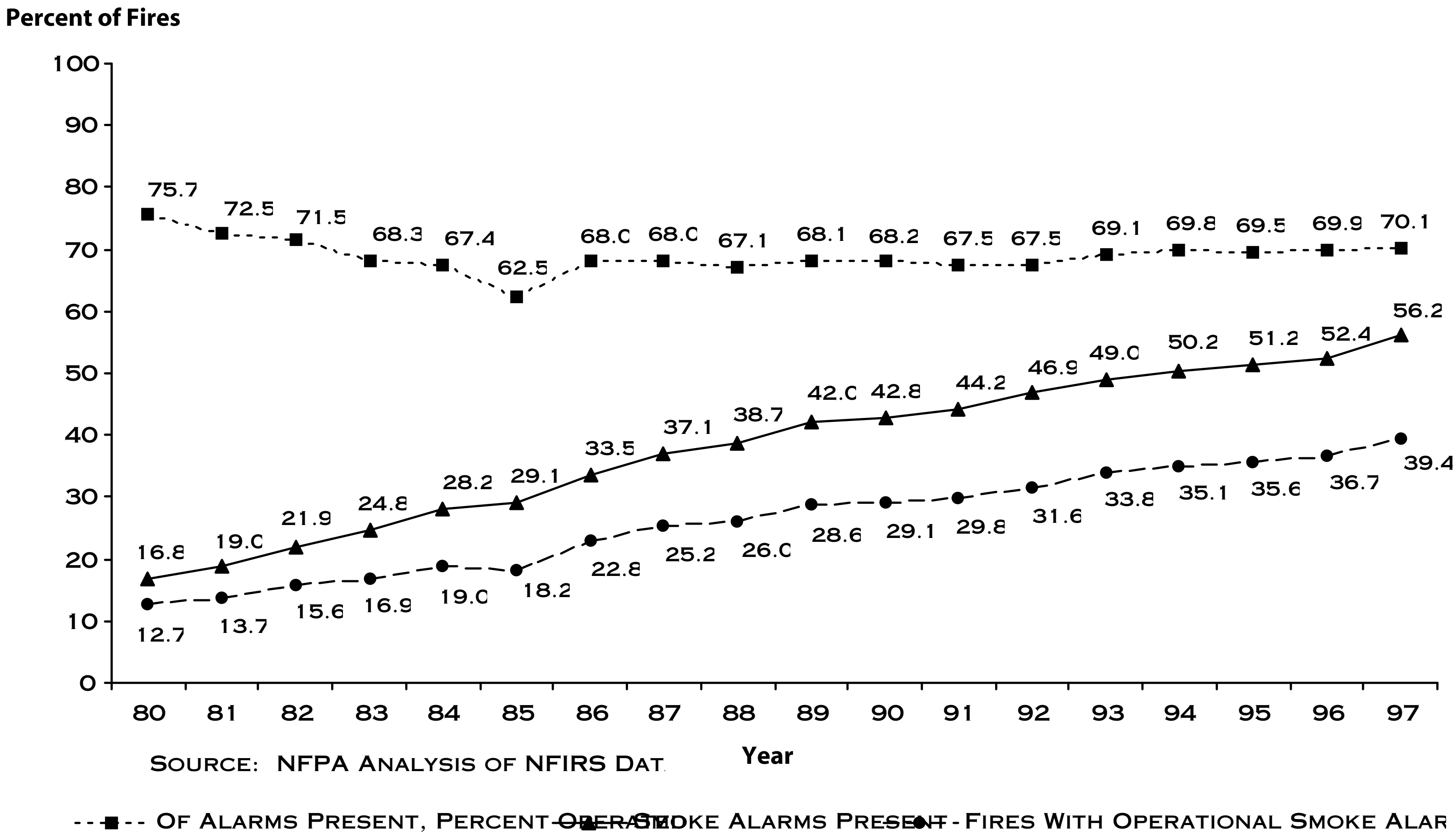


**Figure 3. Smoke Alarms in Apartment Fires, 1980-1997**

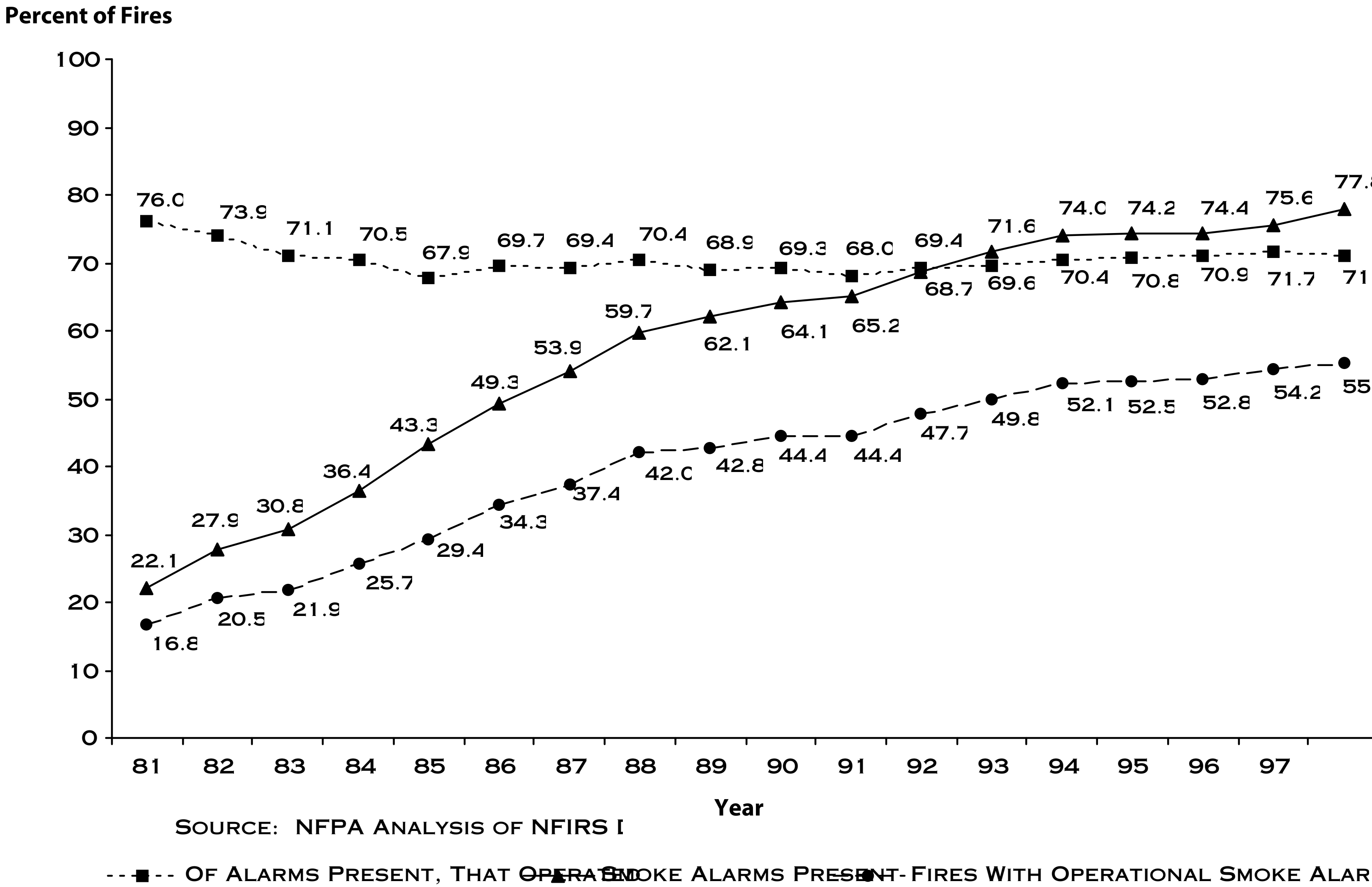


**Table 7.**
**Fire Deaths in One- and Two-Family Dwellings and Manufactured Housing by Smoke Alarm Presence and Operationality**
**1980-1997**

**Percent of Dwelling Fire Deaths in Dwellings with Alarms where**

| Year | Smoke Alarms Were Present | Present Smoke Alarms Operated | Smoke Alarms Were Present and Operated |
|---|---|---|---|
| 1980 | 7.4% | 64.0% | 4.7% |
| 1981 | 12.0% | 66.6% | 8.0% |
| 1982 | 10.3% | 61.9% | 6.4% |
| 1983 | 15.0% | 67.3% | 10.1% |
| 1984 | 13.3% | 43.7% | 5.8% |
| 1985 | 18.0% | 49.2% | 8.9% |
| 1986 | 18.0% | 52.2% | 9.4% |
| 1987 | 22.9% | 46.8% | 10.7% |
| 1988 | 24.1% | 54.5% | 13.1% |
| 1989 | 25.3% | 49.5% | 12.5% |
| 1990 | 26.3% | 53.7% | 14.1% |
| 1991 | 31.7% | 51.9% | 16.5% |
| 1992 | 30.0% | 48.7% | 14.6% |
| 1993 | 30.3% | 57.8% | 17.5% |
| 1994 | 30.9% | 43.6% | 13.5% |
| 1995 | 37.3% | 54.4% | 20.3% |
| 1996 | 32.4% | 49.8% | 16.1% |
| 1997 | 41.8% | 46.8% | 19.6% |
| Average 1980-1997 | 21.5% | 52.6% | 11.4% |
| Average 1988-1997 | 30.5% | 51.0% | 15.5% |

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on estimates of fires where alarms activated within set of fires deemed large enough to activate an operational smoke alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or unclassified or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin.

Source: National estimates based on NFIRS and NFPA survey.

## Table 8.
## Fire Deaths in Apartments,
## by Smoke Alarm Presence and Operationality
## 1980-1997

**Percent of Apartment Fire Deaths in Apartments with Alarms where**

| Year | Smoke Alarms Were Present | Present Smoke Alarms Operated | Smoke Alarms Were Present and Operated |
|---|---|---|---|
| 1980 | 24.2% | 86.2% | 20.8% |
| 1981 | 17.5% | 59.6% | 10.4% |
| 1982 | 24.6% | 78.5% | 19.3% |
| 1983 | 33.0% | 54.0% | 17.8% |
| 1984 | 41.5% | 60.8% | 25.2% |
| 1985 | 44.0% | 60.0% | 26.4% |
| 1986 | 48.4% | 69.0% | 33.4% |
| 1987 | 58.5% | 72.2% | 42.3% |
| 1988 | 56.9% | 69.2% | 39.4% |
| 1989 | 64.9% | 58.3% | 37.8% |
| 1990 | 60.1% | 61.6% | 37.0% |
| 1991 | 67.7% | 66.4% | 44.9% |
| 1992 | 70.3% | 56.0% | 39.4% |
| 1993 | 70.1% | 45.6% | 32.0% |
| 1994 | 71.9% | 61.5% | 44.3% |
| 1995 | 72.7% | 50.8% | 37.0% |
| 1996 | 69.7% | 61.1% | 42.6% |
| 1997 | 72.7% | 50.5% | 36.7% |
| 1980-1997 Average | 51.5% | 61.2% | 31.5% |
| 1988-1997 Average | 67.0% | 58.1% | 39.0% |

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on estimates of fires where alarms activated within set of fires deemed large enough to activate an operational smoke alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or unclassified or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin.
Source: National estimates based on NFIRS and NFPA survey.

**Table 9.**
**Home Fire Deaths,**
**by Smoke Alarm Presence and Operationality**
**1980-1997**

| | Percent of Home Fire Deaths in Homes with Alarms where | | |
|---|---|---|---|
| **Year** | **Smoke Alarms Were Present** | **Present Smoke Alarms Operated** | **Smoke Alarms Were Present and Operated** |
| 1980 | 10.2% | 73.2% | 7.5% |
| 1981 | 12.9% | 64.9% | 8.4% |
| 1982 | 12.7% | 67.4% | 8.6% |
| 1983 | 18.3% | 63.0% | 11.5% |
| 1984 | 18.6% | 50.8% | 9.5% |
| 1985 | 23.1% | 53.2% | 12.3% |
| 1986 | 23.4% | 58.4% | 13.6% |
| 1987 | 30.0% | 56.6% | 17.0% |
| 1988 | 30.6% | 59.8% | 18.3% |
| 1989 | 35.1% | 53.6% | 18.8% |
| 1990 | 33.3% | 56.7% | 18.9% |
| 1991 | 38.8% | 57.0% | 22.1% |
| 1992 | 38.2% | 51.6% | 19.7% |
| 1993 | 37.5% | 53.6% | 20.1% |
| 1994 | 38.9% | 49.9% | 19.4% |
| 1995 | 44.3% | 53.3% | 23.6% |
| 1996 | 38.9% | 53.3% | 20.7% |
| 1997 | 48.6% | 48.0% | 23.3% |
| Average 1980-1997 | 27.4% | 52.6% | 11.4% |
| Average 1988-1997 | 37.9% | 53.6% | 20.3% |

Note: Homes include one-and two-family dwellings, manufactured housing and apartments.

Percentages are based on estimates of fires where alarms activated within set of fires deemed large enough to activate an operational smoke alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or unclassified or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin. These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Source: National estimates based on NFIRS and NFPA survey.

## Why Are So Many Smoke Alarms Non-Operational?

**Most non-operational smoke alarms had dead or missing batteries.**
Three different studies asked why so many smoke alarms were not working. In all three studies, the main problem was dead or missing batteries.

In his 1983 study for the International Association of Fire Chiefs Foundation, Raymond Hawkins looked at 314 fires in which smoke alarms failed to sound despite sufficient smoke to cause activation. He found that:

- Dead batteries, missing batteries and other power source problems accounted for 69% of the incidents;
- 12% of the alarms were incorrectly installed; and
- 11% were installed in an incorrect location.

The installation errors included smoke alarms that were installed in dead air space, too low on a wall, too close to an air return or without a cover. To summarize, human factors, such as lack of knowledge or maintenance, or failure to read and follow manufacturers' instructions, were blamed for more than nine of every ten smoke alarm failures.*

**CPSC's National Smoke Detector Project tested smoke alarms in homes.**
The U.S. Consumer Product Safety Commission's (CPSC's) National Smoke Detector Project surveyed smoke alarm operability in 1992 by sending field investigators into people's home to ask a series of questions and to test all the alarms in their homes. This project surveyed the general population, not just people who had fires. Installation issues were not considered in this study. The report was released in 1993. About 88% of the households screened had at least one installed smoke alarm; 41% of households with these devices reported having more than one.** In 20% of the households surveyed with at least one smoke alarm present, none were operational. However, *46% of the respondents in households in which no smoke alarms functioned thought that all of them were working.****

About 20% of the tested devices did not have functioning power sources. Among the power source problems noted (some alarms had more than one problem) were these:

- 11% of the tested alarms were missing batteries;
- 5% had dead batteries;
- 3% had disconnected batteries;
- and 1% had been disconnected from the A/C power source.

Although 72% of the alarms were powered by batteries only, they accounted for 93% of the alarms with power source problems.*

* Raymond E. Hawkins, *An Evaluation of Residential Smoke Detectors under Actual Field Conditions – Final Phase,* Washington: International Association of Fire Chiefs Foundation, March 1983, p. 17.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, pp. 3-4.

*** Charles L. Smith, *Smoke Detector Operability Survey–- Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, pp. 14-15.

**Apartments and homes built since 1980 were more likely to have hard-wired smoke alarms.**
The use of battery-powered vs. A/C-powered smoke alarms follows some patterns that would be expected in light of recent codes and regulations. Overall, 72% of the devices involved battery power only (compared to 23% hard-wired A/C, 2% plug-in A/C, and 2% A/C with battery backup).** Seventy-six percent (76%) of the single-family dwellings (excluding manufactured homes) had battery-only smoke alarms; 62% of the apartments had battery-only devices.***

Codes such as NFPA's *Life Safety Code*® have, for several years, required hard-wired smoke alarms in new construction. Since 1976, new manufactured homes have been required to have hard-wired A/C-powered smoke alarms; only 38% of the manufactured homes (all ages) surveyed had battery-only smoke alarms.**** Eighty-one percent (81%) of the homes (including apartments and manufactured homes) built *before* 1980 had battery-only devices; only 31% of the homes built in 1980 or later had smoke alarms powered only by batteries.*****

**CPSC also studied smoke alarms in homes that had fires.**
The CPSC also conducted a study of smoke detector failures in homes with fires. Fifteen cities collected data in 1992 and 1993, and when possible, collected the smoke alarm unit if it did not sound after power was connected and the unit sprayed with aerosol smoke. The devices were also collected if the unit did not respond to the test button, if it had been disconnected due to a problem, if it had a dead battery and the occupant could not recall hearing the warning chirp, and if an AC-powered detector could not be tested but failed during the fire.******

* Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 18.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 6.

*** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 7.

**** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 7.

***** Charles L. Smith, *Smoke Detector Operability Survey — Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 9.

******* Linda E. Smith, *Fire Incident Study: National Smoke Detector Project*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, pp. 4-5.

The smoke alarm was disconnected from its power source in 59% of the cases when a smoke alarm was present, should have sounded, but failed to so. Missing batteries were the most frequent problem, followed by disconnected batteries and then disconnected AC power. Because smoke alarms were examined after fires, the fire may have caused some of the conditions found. In some cases, multiple problems were found. Fifteen percent of the smoke alarms were deformed by heat, 13% were missing covers; 8% were clogged with dirt, and 5% showed signs of insect infestation. Nineteen percent of the smoke alarms, including devices that were connected and disconnected at the time of the fire, did not sound when powered.*

Half of the smoke alarms that failed to sound in field tests did sound when tested in the laboratory. It was suggested that horn corrosion may have been a factor, and that contact continuity may have been restored during removal, packing and transporting. One-quarter sounded after repairs were made. Fire-damaged and corroded components were replaced.**

Disconnected smoke alarms were collected and tested when the occupants reported that the alarms had been disconnected because of problems. Nuisance alarms were the most common complaint. These devices were found to be more sensitive than devices collected for other reasons and devices tested in the *Smoke Detector Operability Study*. Foreign objects such as dust, dirt or insects can increase sensitivity, as can fire products. Because the sensitivity levels before the fires are unknown, conclusions are limited.***

* Linda E. Smith, *Fire Incident Study: National Smoke Detector Project*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, p. 13-14.

** Julie I. Shapiro, *Fire Incident Study Sample Analysis*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, pp. 9-10.

*** Julie I. Shapiro, *Fire Incident Study Sample Analysis*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, p. 12.

## Unwanted Activations and Missing or Disconnected Batteries

**Batteries were most often removed because of annoying alarm activations from cooking.**
When batteries were removed or disconnected from alarms, the leading reason was unwanted activations. Removal for this reason was eight times as frequent as removal to use the batteries in another product.* The leading problems cited for smoke alarms with dead batteries or missing or disconnected power sources were: 1) alarming to cooking fumes and 2) alarming continuously when powered. (Some of the latter may have been the device chirping to indicate a low battery.) These two were cited with roughly equal frequency. Sounding too often for unspecified reasons was the next most frequently cited unwanted alarm problem. Alarming to steam or humidity was cited about one-fourth to one-third as often as either of the two leading problems.**

**1/3 of alarms cited for nuisance activations were located incorrectly.**
Nuisance alarm problems often can be addressed by moving the device to a different location or by switching from ionization-type to photoelectric-type devices. One-third of the devices studied for nuisance alarms in the National Smoke Detector Project were reportedly in locations that made nuisance alarms more likely, often *less than five feet* from a potential source of smoke, steam, or moisture sufficient to produce nuisance alarms.***

**Ionization devices had a disproportionate share of nuisance alarms.**
Cooking smoke tends to contain more of the smaller particles (less than one micron) that activate an ionization-type device rather than the larger particles that activate a photoelectric-type device. In this study, 97% of the devices tested for involvement in nuisance alarms were ionization-type devices, although they comprised only 87% of all devices in the study.****

Reducing the sensitivity of smoke alarms can reduce the likelihood of nuisance alarms. The National Smoke Detector Project referenced one dormitory study that found that devices involved in nuisance alarms were more sensitive, on average, than those that were not.***** However, the project report cautioned that reduced sensitivity could adversely affect a smoke alarm's ability to provide timely warning of a real fire.

* Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 12.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 22.

*** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 23.

**** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, pp. 20-21.

***** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, pp. 20-21.

The few studies of field experience with unwanted alarms have shown consistently that smoke detection and alarm systems produce far more nuisance activations than real alarms.  A study of Veterans Administration hospitals found 15.8 unwanted activations for every real alarm, or one unwanted activation for every six devices per year.*  An earlier study of home smoke detection as units in an Automatic Remote Residential Alarm System (ARRAS) in The Woodlands, TX, found 27.0 unwanted activations for every real alarm, or unwanted activations in six of every seven homes each year.** While both studies identified a number of steps that could be taken to sharply reduce the rate of unwanted activations, the current rate is so high that neither study expects unwanted activations can be made less frequent than real smoke activations.  Thus, nuisance activations may continue to induce owners to deactivate their smoke alarms.

In a survey conducted for the NFPA, 39% of the respondents with smoke alarms reported that one had sounded at least once in the past twelve months.***  Two scenarios were responsible for 90% of the sounding smoke alarms – cooking fumes or heat triggered 73% of the alarms and 16% of the respondents reported the low battery chirping.****

All respondents who reported that an alarm had sounded were asked for their first thought after they heard it:

- 40% said that food had burned (again);
- 11% were annoyed at what they assumed to be a nuisance alarm;
- 10% were not concerned because they knew what caused it;
- 9% wondered how to turn off the alarm;
- 8% figured the alarm had a low battery;
- *only 7% thought there was a fire and they should get out;*
- 4% didn't recognize it as a smoke alarm and wondered what it was;
- 3% noted that the smoke alarm works;
- 2% thought they should have used an exhaust fan; and
- 7% reported other responses.*****

These responses show that most people do not automatically assume a sounding smoke alarm is an emergency situation.  In some cases, they know what caused the alarm and know that they are safe.  However, lives have been lost when real alarms were mistakenly considered false.  Unwanted activations can generate a dangerous sense of complacency.

* Peter M. Dubivsky and Richard W. Bukowski, *False Alarm Study of Smoke Detectors in Department of Veterans Affairs Medical Centers (VAMCS)*, NISTIR 89-4077, Gaithersburg, MD:  National Institute of Standards and Technology, May 1989, p. 45.

** *Remote Detection and Alarm for Residences - The Woodlands System*, Washington:  U.S. Fire Administration, May 1980.

*** *1997 Fire Awareness/Escape Planning Study* for National Fire Protection Association, Quincy, MA., August 1997, Table 3.

**** *1997 Fire Awareness/Escape Planning Study* for National Fire Protection Association, Quincy, MA., August 1997, Table 4.

***** *1997 Fire Awareness/Escape Planning Study* for National Fire Protection Association, Quincy, MA., August 1997, Table 5.

## Impact of Aging Smoke Alarms

Smoke alarms are appliances, just like toasters, stereos and furnaces. Unlike other appliances, these devices function quietly in the background. Its alarm, in response to a real smoke situation or to testing, is the only evidence that it works. A stereo that does not play will not lead to tragedy, but a worn-out smoke alarm, failing to sound in a fire, could.

**Replace smoke alarms every ten years.**
Roughly half of the smoke alarms collected as inoperable and studied in the National Smoke Detector Project were more than 10 years old, hence older than the currently recommended replacement age.* Problems of smoke alarm age include “sensitivity drift,” which refers to a shift in the range of visibility obscuration or particulate density that will activate the smoke alarm. Such a shift can mean either an increase in nuisance activations (if sensitivity increases) or a decreased ability to react promptly to real fires (if sensitivity decreases). (One study has done "projections of potential alarm-component failure related to smoke alarm age, based on analogy with other electronic devices."**)

* Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, p. 23.

** Joan L. Gancarski and Tom Timoney, *Research Report on Home Smoke Detector Effectiveness,* Quincy, MA: National Fire Protection Association, 1984.

## What Else Does a Household with a Smoke Alarm Need for Adequate Protection?

**Smoke alarms should be tested monthly.**
Most smoke alarm owners do not test or maintain their smoke alarms as often as they should. In 1982, 60% said they did not test as often as once a month, and 16% said they never tested.*

The National Smoke Detector Project found somewhat more encouraging news, as a majority of respondents who stated their testing frequency – and nearly half overall – had tested their alarms within the past month. The value of testing was borne out in other parts of the study.

Of those surveyed, 78% believed all their alarms worked, in the majority of cases because they had tested the alarm(s). Eighty-eight percent (88%) of this group were correct; testing showed they did indeed have working smoke alarms. Another 11% of those surveyed did not know whether theirs were working, and of those, only 61% proved to have working smoke alarms when testing was done. The final 11% of those surveyed believed at least one smoke alarm was not working, usually because they knew the battery was dead or missing or the power source was disconnected. Of this 11%, only 40% proved to have working smoke alarms when testing was done – and it is surprising the percentage was that high.**

**Develop and practice home escape plans to use when alarm sounds.**
Buying, installing, testing and maintaining home smoke alarms is essential protection from fire, but it is not enough. A smoke alarm merely sounds the warning. Many households have not developed the escape plans that would allow them to use the extra warning time smoke alarms provide to best advantage. One 1985 study found 59% of the population had developed an escape plan.*** But a 1980 survey found that the majority (56%) of households with escape plans had never practiced them.**** If these two figures can be used together, then only one-third of U.S. households have developed escape plans *and* practiced them, so there is still considerable room for improvement.

* John R. Hall, Jr. and Sid Groeneman, "Two Homes in Three Have Detectors," *Fire Service Today*, February 1983, pp. 18-20.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 15.

*** The Prevention Index '85, *Prevention Magazine*, 33 East Minor Street, PA 18098, 1987.

**** Elrick and Lavidge, Inc., *A Detector in Every Other Home: Full Report,* Washington: U.S. Fire Administration, November 1980.

The results were even more disturbing in the CDC study "Residential Smoke Alarms and Fire Escape Plans." In this 1994 study, 60% of the respondents had designed or at least talked about a fire escape plan at least once. The adequacy of the plans was not evaluated. Table 2 shows that the poor, people with less than a high school education and people who rent their homes were less likely to have discussed any kind of an escape plan. Only 17% of the households with plans reported practicing them. Only 10% of the households included in this survey, had actually developed and practiced a home escape plan.*

In a 1997 study sponsored by the NFPA, 53% of the households surveyed said they had escape plans, a somewhat smaller percentage than the CDC found. The majority of the plans were limited to planned routes and exits; this study did not evaluate the realism of the plans. Only 21% of the households with a plan had ever practiced it. This means that only 16% of the households surveyed by the NFPA had an escape plan they had practiced.

To reduce this gap in preparedness, the NFPA has made "*Fire Drills: The Great Escape*" the theme of Fire Prevention Week for 1998-2000. At 6:00 p.m. on October 7, 1998, the first-ever unified North American fire drill was held. Families around the U.S. and Canada practiced leaving their homes and going to their meeting places. The second was held at 7:00 p.m. on October 6, 1999.

**Many homes need more than one smoke alarm.**

Many homes need more than one smoke alarm for code-compliant complete protection, so even if a home has one working smoke alarm, there may be room for improvement. The National Smoke Detector Project found that 26% of the households surveyed had less than one alarm per floor, which indicates too few smoke alarms for code compliance. Additional households may have had too few smoke alarms to protect widely separated sleeping areas on the same floor. Closed doors that delay the spread of smoke may also delay smoke alarm response. The National Smoke Detector Project also estimated that 43% of the households had less than one *working* smoke alarm per floor.**

**Sometimes, people notice the fire first or no one hears the alarm.**

The Home Office of the United Kingdom has also looked at smoke alarm performance. A table in the *Home Office Statistical Bulletin: Summary Fire*

*Statistics – United Kingdom 1998* on fires in homes with smoke alarms shows reasons for fires in which the devices operated but did not alert anyone. These situations remind us that smoke alarms merely provide information. In some cases, people are already aware of the problem; in others, no one receives the information. The leading reasons are given below:

- In 48% of these fires, a person raised the alarm before the system operated (Someone in the same room may notice a fire immediately.);
- In 22% of these dwelling fires, no one was in earshot; and
- The occupants failed to respond in 12% of these fires.*

* Pauline A. Harvey, Jeffrey J. Sacks, George W. Ryan, and Patricia F. Bender, "Residential Smoke Alarms and Fire Escape Plans," *Public Health Reports,* September/October 1998, Rockville, MD., Volume 113, page 459-464.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 24.

**A single-station alarm may not be heard in other parts of the home.** An alarm sounding on one floor of a home may not alert a resident on another floor. The NFPA *Life Safety Code*® requires smoke alarms to be powered by the house electrical service in all *new* housing and (by performance requirements) indirectly requires that smoke alarms be interconnected within the dwelling unit. When the alarms are interconnected, all sound when one is activated. Since single-station, battery-operated units still predominate in most *existing* homes, the possibility of wider use of wired-in smoke alarms is another opportunity for further improvement in home smoke alarm protection.

The National Smoke Detector Project found that 6% of households with smoke alarms had them connected to a central alarm system.** This is even more protection than interconnected alarms alone provide.

The use of smoke alarms in apartments has grown much faster than smoke alarm use in detached dwellings, at least as far as homes that have fires are concerned. This may be partially explained by state and local laws that regulate multi-family homes more stringently than dwellings. Smoke alarms are more likely to be required in apartments than in single-family homes.***

* Lorraine Watson and Jonathan Gamble, *Home Office Statistical Bulletin: Fire Statistics – United Kingdom 1998*, London, U.K., Research, Development and Statistics Directorate, September 8, 1999, Issue 15/99, pp. 31-32.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 3.

*** The latest survey to show this was in Paul G. LeCoque and King Harris, "State by State... An Update of Residential Smoke Detector Legislation," *Fire Journal*, January/February 1990, pp. 40-47.

## Home Smoke Alarms and Civilian Fire Injuries

**Smoke alarms do not reduce the civilian injury rate.**
Smoke alarms reduce the death rate by 40-50%, but they do not have the same effect on the injury rate. Table 10 shows that the civilian injury rate per 100 reported fires is three times as high when smoke alarms are present as when they are not. The activity at time of injury provides some explanation for this seeming anomaly. Fewer than 7% of the fatalities were engaged in rescue or fire control combined. One-third of the civilian injuries occurred when the individual attempted to control the fire, and 7% of those injured were hurt when attempting rescue. In fires which were said to be small to trigger the smoke alarm, more than half of the people injured were hurt when they tried to control the fire themselves.

**Fires that were confined to room of origin injured 4/5 of civilians hurt while trying to control the fire.**
An analysis by extent of flame damage provides some useful information. Eighty percent (80%) of the civilians injured while trying to control the fire were injured in fires that were confined to the room of fire origin. Sixty-three (63%) percent of the civilians injured attempting rescue were injured in fires that extended beyond the room.

People appear to be more likely to attempt to fight a fire that seems small. However, fires can grow quickly. In some cases, inappropriate attempts to fight the fire only make it worse or persistent unsuccessful attempts may lead to injury. It seems clear that at least a portion of the population will try to control small fires themselves. Efforts should be taken to ensure that people know the safest way to do so and when not to try.

Our data do not tell us how large the fire was at the time it was discovered; we only know the extent of flame damage at the end of the incident. Consequently, we cannot discern the impact of civilian fire control attempts upon the fire's final outcome.

## Table 10. Home Smoke Alarms and Civilian Injuries during 1997

### Rates of Home Civilian Fire Injuries by Smoke Alarm Performance

| Civilian Injuries per 100 Fires when | |
|---|---|
| Smoke alarm was present | 12.7 |
| Present smoke alarm operated | 6.9 |
| Smoke alarm did not operate | 8.0 |
| Fire too small to trigger smoke alarm | 1.9 |
| No smoke alarm was present | 4.2 |
| All home fires | 4.4 |

### Portion of Injured Civilians Attempting to Control the Fire at Time of Injury, by Smoke Alarm Status and Extent of Flame Damage

| | Extent of Flame Damage | | |
|---|---|---|---|
| Smoke Alarm Status | All Damage | Confined to Room | Spread Beyond Room |
| Smoke alarm present | 37.5% | 47.2% | 18.2% |
| Smoke alarm operated | 47.4% | 45.1% | 18.0% |
| Smoke alarm did not operate | 32.3% | 42.4% | 18.1% |
| Fire too small to trigger smoke alarm | 51.9% | 53.5% | NA |
| No smoke alarm present | 30.2% | 41.2% | 16.5% |
| Total | 33.7% | 45.5% | 16.6% |

### Portion of Injured Civilians Attempting to Conduct Rescue at the Time of Injury, by Smoke Alarm Status and Extent of Flame Damage

| | Extent of Flame Damage | | |
|---|---|---|---|
| Smoke Alarm Status | All Damage | Confined to Room | Spread Beyond Room |
| Smoke alarm present | 7.1% | 4.5% | 12.2% |
| Smoke alarm operated | 7.3% | 4.9% | 11.9% |
| Smoke alarm did not operate | 9.0% | 6.4% | 12.4% |
| Fire too small to trigger smoke alarm | 2.6% | 1.4% | NA |
| No smoke alarm present | 5.9% | 3.8% | 8.6% |
| Total | 7.0% | 4.4% | 10.9% |

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. All rows labeled "Smoke alarm present," "Fire too small to trigger smoke alarm," and "No smoke alarm present" are based on fires with known smoke alarm status. The rows labeled "Smoke alarm operated" and "Smoke alarm did not operate" are based also on only the set of fires deemed large enough to trigger an operational smoke alarm, based on final extent of smoke damage. These sets of fires thus specifically exclude fires in which the extent of smoke damage was unknown or unclassified or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin. The row "Smoke alarm present" is based on all fires, regardless of extent of smoke damage. Injuries for which the activity involved was unknown have been allocated proportionally among injuries with known activity. Percentages are based on all injuries in home fires having that row characteristic (smoke alarm status) and that column characteristic (extent of flame damage). Therefore, percentages cannot be meaningfully summed across rows or columns within tables, but corresponding entries in the "fire control" and "attempted rescue" tables can be combined meaningfully.

Source: National estimates based on NFIRS and NFPA survey.

## How Operational Are Smoke or Other Fire Alarms Outside the Home?

Tables 11 and 12 use NFIRS data and the same adjustment procedure described in Appendix B to develop, for most major classes of property:
(1) percentages of fires with smoke or other fire alarms present; and
(2) percentages of fires in alarm-equipped buildings for which the alarms were operational. These figures are much less dependable than the figures for homes for several reasons. For some property classes, the numbers of fires are low enough that statistical uncertainty becomes a concern. This can cause unusually large one-year jumps or drops in estimated operationality. Also, non-residential properties are more likely to use heat alarms or to have very limited partial coverage. The analysis procedures used here will tend to underestimate the percentage of properties with operational alarms in those cases because smoke spread beyond the room of origin will no longer be a good proxy for a fire sufficient to activate an operational fire alarm.

Note, too, that some properties use automatic suppression systems (e.g., sprinklers) to detect and control fires; it is likely that these are not coded as detection systems at all. These results are still useful as exploratory analysis and to give a sense of the relative performance in different property classes.

**Smoke alarm operationality is lower in homes than in most other occupancies.**
As expected, the percentage of alarms in the home that are operational is lower than the percentage for most other property classes. Public assembly occupancies, stores and offices, and storage facilities other than dwelling garages were the only other ones at a comparably low level in 1997.

Second, properties that care for persons who are sick, very young or very old would be expected to have both high usage of alarms and high operationality. This has generally been true. Unfortunately, the situation in schools is not so good. Smoke alarms in educational occupancies were considered medium usage and medium operationality.

Third, nearly all property classes except storage facilities have shown dramatic increases over the 1980's in the percentage of fires in properties with smoke alarms *present.*

**Reasons differ for non-operational alarms in occupancies other than homes.**
Another difference regarding alarms outside the home is that the reasons for non-operationality are likely to be different. An illustration of this may be found in some of the reasons for failure given in the fires recorded in NFPA's Fire Incident Data Organization (FIDO) that cited mechanical failure of the alarm:

- Human actions that take the system out of service, such as the shut down of the alarm system as part of a renovation or maintenance activity or in response to an earlier alarm. These are the non-residential counterparts to missing batteries in home alarms.
- Mechanical problems, such as sprinkler waterflow switches sticking, although waterflow alarms should not be relied on for detection.
- Weather effects, including lightning strikes and high winds that disable the detection system or the telephone or electrical systems that support it.
- Fire effects, including burnthrough of the telephone lines that would relay alarms to supervising stations.

The human and mechanical problems can be addressed through appropriate testing, maintenance, and inspection provisions. Even some of the problems caused by weather and fire effects can be addressed if appropriate backup is provided.

Hard-wired, interconnected fire detection *systems* may be more common in non-residential structures. Often, these systems are designed to interact with other fire protection features. Consequently, more factors are involved. In their discussion of reliability analysis and prediction techniques for fire protective signaling systems, Moore and Cholin consider the reliability of a fire protection system the product of four reliability factors for: a) the equipment; b) the system design; c) the installation; and d) the going forward system maintenance.* The report includes a discussion of some of the issues involved in calculating each of these factors.

The Fire Alarm Committee of the Fire Marshal Association of Colorado was formed in response to frustration with unwanted alarms and the industry's frustration with varying codes, interpretations and practices. The committee chose to follow a six-story, sprinklered office building from plans to completion to identify some of the problems in the process. They found multiple snags, including a lack of code analysis, incomplete or missing documentation, delays in determining if the building was a high-rise, mistakes in assignment at the AHJ, made worse by consecutive vacations at the fire department (delaying identification of the error), and then the contractor contact. No forum existed for questions prior to plan submittal or during the review process. The plans were not clear about where additional protection (above what was required) was being provided. Coordination was lacking among the contractors. Approved plans were not on site, the plans did not always correspond to what was installed, and detectors were covered in plastic while construction continued.** This "real world" example illustrates some of the issues raised by Moore and Cholin.

* Wayne D. Moore and John M. Cholin, *Reliability Analysis and Prediction Techniques for Fire Protective Signaling Systems,* 1995, p. 5.

** Fire Marshal Association of Colorado, *Fire Alarm Committee Report,* September 9, 1999, unpublished report.

**Naperville, IL study found "shakedown" period and that newer technology reduced rate of unwanted activations.**

A 1996-1998 study of unwanted commercial smoke alarm activations in Naperville, Illinois compared the frequency of unwanted activations with the age and number of systems. In this study of fire department responses to unwanted alarms, 30-32% of unwanted alarms came during the “shakedown” period, i.e., from installations less than twelve months old. After this period, the newer systems produced fewer false (responses to non-smoke stimuli) alarms than the older ones.*

* Fred Conforti, "False Alarms: The Battle Isn't Over," *NFPA Journal*, July/August 1999, Volume 93, Number 4, pp. 86-89.

**Table 11. Trends in Smoke Alarm Presence by Major Property Use, 1980-1997**

| | Percentage of Structure Fires Where Smoke or Fire Alarm Was Present | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Property Use** | **1980** | **1981** | **1982** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** |
| Dwellings, Duplexes & Manufactured Housing | 16.8 | 19.0 | 21.9 | 24.8 | 28.2 | 29.1 | 33.5 | 37.1 | 38.7 | 42.0 |
| Apartments | 22.1 | 27.9 | 30.8 | 36.4 | 43.3 | 49.3 | 53.9 | 59.7 | 62.1 | 64.1 |
| Public Assembly | 11.0 | 12.4 | 14.6 | 16.0 | 18.6 | 20.7 | 23.9 | 26.7 | 29.9 | 31.9 |
| Educational | 27.7 | 31.5 | 34.4 | 40.0 | 40.6 | 46.1 | 46.2 | 51.3 | 54.6 | 56.1 |
| Care of Aged | 74.7 | 79.2 | 79.4 | 80.4 | 79.1 | 82.4 | 86.0 | 88.1 | 90.2 | 90.8 |
| Care of Young | 60.2 | 51.1 | 57.4 | 60.0 | 61.4 | 67.7 | 70.7 | 75.6 | 79.4 | 81.6 |
| Hospitals & Clinics | 67.6 | 69.4 | 73.4 | 70.4 | 74.4 | 80.3 | 85.5 | 86.0 | 86.4 | 87.0 |
| Prisons & Jails | 29.2 | 40.1 | 36.5 | 46.6 | 48.2 | 52.0 | 41.6 | 63.7 | 74.2 | 86.4 |
| Care of Mentally Handicapped | 63.2 | 62.7 | 59.0 | 63.7 | 67.5 | 71.4 | 73.9 | 82.8 | 85.4 | 89.8 |
| Hotels & Motels | 29.6 | 36.1 | 40.2 | 47.3 | 52.2 | 56.4 | 63.8 | 66.7 | 69.6 | 72.4 |
| Dormitories | 49.9 | 60.6 | 60.4 | 66.6 | 73.8 | 77.0 | 81.1 | 80.5 | 82.6 | 87.3 |
| Stores & Offices | 8.3 | 9.9 | 11.1 | 13.3 | 14.8 | 17.2 | 18.8 | 23.4 | 26.3 | 28.7 |
| Industry & Manufacturing | 14.8 | 14.9 | 16.5 | 17.1 | 18.0 | 19.9 | 20.6 | 22.5 | 23.9 | 24.7 |
| Storage (excluding dwelling garages)* | 2.9 | 2.2 | 2.7 | 3.2 | 3.3 | 3.9 | 4.2 | 5.1 | 5.3 | 5.5 |

* "Storage" facilities include tool sheds, barns, silos, and other storage buildings that are not the warehouses one might think of in connection with this category.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are estimated as number of structure fires with smoke alarm present divided by number of structure fires with alarm status known. This table does not distinguish type of alarms or completeness of coverage.

Source: NFIRS

## Table 11. Trends in Smoke Alarm Presence by Major Property Use, 1980-97 (Continued)

### Percentage of Structure Fires Where Smoke or Fire Alarm Was Present

| Property Use | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|
| Dwellings, Duplexes & Manufactured Housing | 42.8 | 44.2 | 46.9 | 49.0 | 50.2 | 51.2 | 52.4 | 56.2 |
| Apartments | 65.2 | 68.7 | 71.6 | 74.0 | 74.2 | 74.4 | 75.6 | 77.8 |
| Public Assembly | 33.2 | 34.0 | 36.3 | 36.9 | 38.3 | 40.8 | 42.8 | 45.0 |
| Educational | 59.3 | 59.4 | 63.9 | 64.8 | 63.6 | 65.9 | 64.1 | 68.9 |
| Care of Aged | 90.9 | 91.8 | 92.7 | 93.0 | 92.8 | 93.0 | 93.6 | 93.4 |
| Care of Young | 84.7 | 84.1 | 86.8 | 88.3 | 89.1 | 90.3 | 90.7 | 90.2 |
| Hospitals & Clinics | 87.3 | 87.2 | 89.1 | 88.1 | 89.9 | 89.9 | 90.6 | 91.8 |
| Prisons & Jails | 79.7 | 86.7 | 91.3 | 91.4 | 89.2 | 91.6 | 92.2 | 92.6 |
| Care of Mentally Handicapped | 92.1 | 90.0 | 93.0 | 93.3 | 92.7 | 93.8 | 93.8 | 94.0 |
| Hotels & Motels | 71.9 | 74.3 | 75.4 | 75.1 | 77.4 | 76.9 | 78.0 | 80.3 |
| Dormitories | 88.4 | 90.6 | 90.8 | 91.7 | 92.1 | 94.3 | 92.3 | 93.1 |
| Stores & Offices | 28.1 | 30.6 | 32.1 | 34.2 | 35.0 | 34.2 | 35.9 | 39.4 |
| Industry & Manufacturing | 26.8 | 27.4 | 28.8 | 30.8 | 29.8 | 32.7 | 33.3 | 34.6 |
| Storage (excluding dwelling garages)* | 6.3 | 6.2 | 6.0 | 6.2 | 5.9 | 6.1 | 6.0 | 7.3 |

*"Storage" facilities include tool sheds, barns, silos, and other storage buildings that are not the warehouses one might think of in connection with this category.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are estimated as number of structure fires with smoke alarm present divided by number of structure fires with alarm status known. This table does not distinguish type of alarms or completeness of coverage.
Source: NFIRS

## Table 12. Trends in Smoke or Fire Alarm Operationality in Fires, by Major Property Use, 1980-97

### Percentage of Operating Smoke or Fire Alarms in Structure Fires with Smoke or Fire Alarms Present

| Property Use | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dwellings, Duplexes & Manufactured Housing | 75.7 | 72.5 | 71.5 | 68.3 | 67.4 | 62.5 | 68.0 | 68.0 | 67.1 | 68.1 |
| Apartments | 76.0 | 73.9 | 71.1 | 70.5 | 67.9 | 69.7 | 69.4 | 70.4 | 68.9 | 69.3 |
| Public Assembly | 66.0 | 64.0 | 65.2 | 67.1 | 70.7 | 62.2 | 65.2 | 68.6 | 69.0 | 68.4 |
| Educational | 79.0 | 79.1 | 80.2 | 75.7 | 75.7 | 69.0 | 72.9 | 80.9 | 76.5 | 77.2 |
| Care of Aged | 79.7 | 85.4 | 84.5 | 84.7 | 86.4 | 80.0 | 84.0 | 82.1 | 86.7 | 86.6 |
| Care of Young | 94.4 | 76.4 | 77.0 | 82.2 | 79.2 | 79.0 | 88.2 | 82.1 | 84.0 | 87.5 |
| Hospitals & Clinics | 84.5 | 82.0 | 84.0 | 80.0 | 84.0 | 78.0 | 80.9 | 82.1 | 85.2 | 84.2 |
| Prisons & Jails | 81.2 | 65.7 | 91.7 | 84.2 | 85.3 | 81.2 | 81.0 | 81.9 | 84.0 | 89.1 |
| Care of Mentally Handicapped | 92.8 | 77.3 | 85.0 | 82.1 | 91.3 | 81.0 | 88.5 | 89.5 | 84.9 | 88.3 |
| Hotels & Motels | 79.2 | 77.2 | 80.0 | 78.4 | 74.1 | 77.1 | 82.2 | 77.5 | 78.4 | 77.9 |
| Dormitories | 85.9 | 82.8 | 89.0 | 86.8 | 88.9 | 82.8 | 83.5 | 88.6 | 87.8 | 82.0 |
| Stores & Offices | 69.9 | 72.2 | 73.0 | 70.0 | 72.5 | 66.2 | 73.3 | 71.0 | 71.4 | 72.8 |
| Industry & Manufacturing | 86.5 | 82.5 | 83.3 | 83.2 | 81.0 | 78.3 | 80.5 | 81.0 | 78.1 | 80.4 |
| Storage (excluding dwelling garage)* | 5.4 | 66.2 | 64.1 | 65.0 | 70.8 | 67.6 | 67.9 | 71.6 | 62.9 | 68.6 |

* "Storage" facilities include tool sheds, barns, silos, and other storage buildings that are not the warehouses one might think of in connection with this category.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are estimated from the number of structure fires where smoke alarms activated within set of structure fires deemed large enough to activate operational alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or other or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin. CAUTION: This procedure may be less dependable as a proxy for true reliability in properties that use primarily heat alarms or that tend to have very limited partial systems.

Source: NFIRS

**Table 12. Trends in Smoke or Fire Alarm Operationality in Fires, by Major Property Use, 1980-97 (Continued)**

| | Percentage of Operating Smoke or Fire Alarms in Structure Fires with Smoke or Fire Alarms Present | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Property Use** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** |
| Dwellings, Duplexes & Manufactured Housing | 68.2 | 67.5 | 67.5 | 69.1 | 69.8 | 69.5 | 69.9 | 70.1 |
| Apartments | 68.0 | 69.4 | 69.6 | 70.4 | 70.8 | 70.9 | 71.7 | 71.1 |
| Public Assembly | 67.0 | 72.0 | 68.4 | 69.2 | 71.0 | 71.8 | 73.3 | 72.8 |
| Educational | 79.6 | 80.7 | 80.4 | 75.7 | 78.4 | 79.7 | 81.1 | 76.7 |
| Care of Aged | 85.8 | 86.1 | 87.0 | 86.7 | 88.1 | 87.8 | 85.4 | 90.0 |
| Care of Young | 87.4 | 85.0 | 85.0 | 89.8 | 82.6 | 86.2 | 87.6 | 82.8 |
| Hospitals & Clinics | 87.2 | 85.4 | 86.0 | 89.4 | 87.5 | 88.3 | 90.0 | 84.9 |
| Prisons & Jails | 84.7 | 85.2 | 85.5 | 87.1 | 84.5 | 88.9 | 86.5 | 91.5 |
| Care of Mentally Handicapped | 88.9 | 87.3 | 93.5 | 90.5 | 86.7 | 85.6 | 92.0 | 90.5 |
| Hotels & Motels | 78.5 | 77.8 | 76.4 | 77.4 | 78.8 | 75.2 | 79.0 | 82.0 |
| Dormitories | 84.2 | 89.0 | 89.6 | 93.6 | 93.2 | 88.2 | 89.6 | 89.3 |
| Stores & Offices | 75.7 | 71.1 | 73.1 | 71.9 | 71.9 | 67.8 | 72.2 | 71.3 |
| Industry & Manufacturing | 79.1 | 79.9 | 80.5 | 81.6 | 80.8 | 81.6 | 82.7 | 84.9 |
| Storage (excluding dwelling garages)* | 69.9 | 68.9 | 68.3 | 67.2 | 67.9 | 68.1 | 70.9 | 73.8 |

* "Storage" facilities include tool sheds, barns, silos, and other storage buildings that are not the warehouses one might think of in connection with this category.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are estimated from the number of structure fires where smoke alarms activated within set of structure fires deemed large enough to activate operational alarm. Set excludes fires coded too small to activate smoke alarm, fires with extent of smoke unknown or other or confined to object or area of origin, and fires originating in room without smoke alarm and having extent of smoke confined to room of origin. CAUTION: This procedure may be less dependable as a proxy for true reliability in properties that use primarily heat alarm or that tend to have very limited partial systems.
Source: NFIRS

## Topics for Future Research

This analysis has examined smoke alarm performance presence and operationality in reported fires. It has also included some mention of other studies. However, there is much that we do not yet know. Technology has changed. The typical contents of a home or other structure are also different. Are assumptions based on older data still valid?

The Fire Protection Research Foundation's Research Advisory Council on Fire Detection and Alarm Futures has reviewed a number of proposals in this field.

One proposed project would test different types of residential fire alarms for responsiveness to different kinds of fires and propensity to unwanted activations. The Consumer Product Safety Commission is pursuing public/private funding for this endeavor, which has the potential to answer many questions and dispel many myths regarding comparative detector/alarm performance, most notably those questions relating to the ionization vs. photoelectric issue.

Another project would focus on tenability in terms of performance goals and occupant response. Different populations have differing abilities to escape a fire situation, based on mobility, knowledge of the structure, and other factors, even when all reactions could be considered appropriate. This is not always the case. The type of fuel and mode of burning would also play a role in tenability. This may be a necessary project for valid interpretation of the results of the first project.

A third proposed project would study fire alarm system performance and overall reliability in greater detail. Although specific components of these systems have known levels of reliability, these levels are not known for systems as a whole and can only be estimated.

A proposal to determine the requirements and operating concepts for multi-functional and integrated alarm systems is also being considered. In many cases, fire detection and security systems are integrated. Multi-functional sensors, such as closed circuit television or motion detectors, could provide additional information about the nature of an emergency and the location of occupants. This study could provide industry with the information to design new projects and it could also suggest tools to allow the fire service to respond more effectively.

Another proposed project would explore how detection systems could integrate engineering models, such as fire and egress models, with real time data from sensors in the building to create a useful firefighting display that would help the fire service manage the incident.

Yet another proposed project would develop new tests for UL 268 to ascertain resistance to unwanted activations and performance in actual fire situations. As proposed, detection devices would be tested against conditions associated with normal welding, cooking, smoking and steam. This project could also have a bearing on the photoelectric vs. ionization controversy.

In a recent article in *Fire Technology,* James Milke discussed the possibility of pairing CO and $CO_2$ sensors in one detector to increase detection systems' ability to discriminate between fire and nuisance sources.*

* James A. Milke, "Monitoring Multiple Aspects of Fire Signatures for Discriminating Fire Detection," *Fire Technology*, Volume 35, Number 3, pp. 195-209.

## Recommended Practices and Sample Programs

### Additional information on recommended practices and established usage programs is available.

Readers who are interested in codes, standards and recommended practices on this topic should consult NFPA 72, *National Fire Alarm Code.®*

Other readers may be interested in programs promoting smoke alarm usage. In 1996, the Centers for Disease Control and Prevention's (CDC's) National Center for Injury Prevention and Control issued a report, compiled by Ruth Shults and Pauline Harvey, *Efforts to Increase Smoke Detector Use in U.S. Households: An Inventory of Programs.* Two national programs and 49 programs from 33 states are described in the document. To obtain a copy of the report or to obtain more information about the CDC's burn and fire prevention activities, contact:

Division of Unintentional Injury (Mail Stop K-63)
National Center for Injury Prevention and Control
Centers for Disease Control and Prevention
4770 Buford Highway, NE
Atlanta, GA 30341-3724

Two programs, described below, collected more data than usual. A formal study, the Oklahoma City project, included significant follow-up. Smoke Alarms for Elders (S.A.F.E.) in Quincy, MA, was unusual because older adults were asked if they wanted someone to check their smoke alarm, change the battery or install a smoke alarm. This program also documented the presence and operational status of the smoke alarms in the homes visited.

### Smoke alarms in Oklahoma City give-away program were sometimes not installed.

A smoke alarm program sponsored by the Oklahoma State Department of Health was described in an article "Surveillance and Prevention of Residential Fire Injuries," by Sue Mallonee, Gregory Istre, Mark Rosenberg, Malinda Reddish-Douglas, Fred Jordan, Paul Silverstein, and William Tunell.* After identifying areas of Oklahoma City with the highest rates of injuries from residential fires, a smoke alarm give-away program was developed for those areas. Smoke alarms were distributed door to door. The fire injury rate declined by 80% during the four years after the program, although this decline could not be solely attributable to the distributed devices. Educational efforts and publicity about the program probably played a role as well.

Firefighters visited a random sample of 60% of the homes that had received smoke alarms 12 months after the give-away. After one year, they found that 51% of the devices were properly installed and functioning; 6% of the smoke alarms were not installed; 2% were improperly installed; the smoke alarm or battery was not functioning in 5% of the incidents; and the batteries had been removed from 10% of the units. In 14% of the incidents, the occupant no longer had the device; and in 11%, the smoke alarm had been removed from the home when the occupant moved. (Smaller follow-ups were also done after three months and 48 months.)

In addition to demonstrating a reduction in injuries after a smoke alarm give-away, this program also demonstrated that merely giving someone an alarm does not mean that the device will be installed and installed correctly. After 12 months, one-third of the distributed alarms were either not installed, improperly installed, no longer in the occupant's possession or no longer in the structure. When possible, installation of alarms should be provided.

Although too many homes still need smoke alarms, programs focusing on smoke alarm maintenance are also needed. Often people mean to test, but never get around to it. Many elderly people are unable to safely reach a smoke alarm to test it.

*"Surveillance and Prevention of Residential Fire Injuries," by Sue Mallonee, Gregory Istre, Mark Rosenberg, Malinda Reddish-Douglas, Fred Jordan, Paul Silverstein, and William Tunell, *New England Journal of Medicine*, Waltham, MA. Volume 335, Number 1, July 4, 1996, pages 29-31.

**Volunteers for Smoke Alarms For Elders (S.A.F.E) helped protect elderly residents.**

To kick off Fire Prevention Week in 1997, the NFPA's Center for High Risk Outreach, Quincy, MA Fire Department, the Quincy Rotary Club and Beechwood on the Bay Community Center, organized Quincy's first Project S.A.F.E. (Smoke Alarm for Elders.) This program was an extension of the Elder Home Repair Program provided by Beechwood on the Bay, an intergenerational center. Funding was donated for smoke alarms and batteries. A local hardware store sold the alarms at cost and donated dowels that could be used to check the alarms. The event was advertised through local media, elder organizations, religious groups, and other venues. Volunteers were recruited from the fire department and the Rotary.

Community residents over 75 years old or suffering mobility impairments were invited to call Beechwood to schedule appointments to either have a smoke alarm installed or to have their existing alarm(s) tested. Four out of five participants lived in single-family homes.

Volunteers were instructed to install as many alarms as necessary to bring the home up to code, to test all smoke alarms, and to replace all batteries unless the resident was sure of the batteries' age. Volunteers installed at least one alarm in 81% of the homes they visited. (Local codes differ slightly from NFPA standards.)

Although this group was a self-selected segment of the city's elderly and not a random sample, several disturbing facts were discovered. No alarms were found in 18% of the 139 homes visited. Thirty-nine percent (39%) of the 267 existing alarms tested were not operational when initially tested and would not have sounded in the event of a fire. Half of the non-operational alarms had dead batteries; batteries were missing in one-quarter of the alarms; one in ten had poor connections; and 14% of the alarms were defective or obsolete (including two from 1972 with missing batteries).

Residents were given dowels and shown how to use the dowel to test the alarm themselves. They were also told that someone would come to replace the battery for them if the alarm started chirping. Handouts with basic fire and fall prevention messages were also provided.*

The event was repeated in 1998, with additional sponsorship from the Kiwanis and Lions Club. In 1998, 35% of the tested alarms were not working when initially tested. The batteries were dead in 57% of the non-working smoke alarms; 20% of the devices were old or defective; 13% were missing batteries; and batteries were disconnected in 10% of the non-working devices.**

**New *Remember When…* provides a Fire and Fall Prevention Program to use with older adults.**

NFPA's Center for High Risk Outreach is also working with the CDC on *Remember When... A Fire and Fall Prevention Program for Older Adults.* The program provides safety messages while asking older adults to remember trivia bout old songs, television shows, etc. One module provides instructions on how to conduct a program similar to the S.A.F.E. program in Quincy. While checking on smoke alarms, volunteers can identify loose rugs and other safety hazards. Some provide night-lights or bath mats. This program was completed in 1999 after three years of testing and development. Additional information can be obtained by contacting:

Sharon Gamache
Center for High Risk Outreach
National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
(617) 984-7286

Smoke alarms save lives. This report describes progress and areas needing improvement. We applaud the many individuals and organizations that work to ensure that every home is protected by smoke alarms, and that the residents have the knowledge to respond appropriately. We would also encourage groups that undertake smoke alarm campaigns to collect data on what they find initially. This data can be used to help define problems in the specific community and to refine future programs.

* *Project S.A.F.E. Smoke Alarm for Elders – Quincy, MA, October 1997,* Unpublished report by Marty Ahrens and Sharon Gamache, NFPA, Quincy, MA.

** *Quincy Project S.A.F.E – 1998 Results,* Unpublished report by Marty Ahrens. NFPA, Quincy, MA.

## Discussion and Recommendations

1. As of 1997, fifteen out of every 16 homes (94%) had at least one smoke alarm. Most high-fire-rate groups (e.g., poor households) are lagging slightly behind in smoke alarm usage, but in all these groups, the majority of households have smoke alarms. The slight differences in smoke alarm usage cannot be enough to explain why the 6% of homes without smoke alarms account for nearly half of all reported home fires. The principal reason seems to be that smoke alarm households are able to control far more of their fires without involving the fire department.

2. In fires reported to fire departments, the rate of death in homes with smoke alarms is slightly more than half that of homes without smoke alarms.

3. One-fifth of homes with smoke alarms and almost one-third of homes with smoke alarms that have reported fires have no smoke alarms that work. The latter percentage has held fairly steady since 1983. Since 94% of homes have smoke alarms, the 20% non-operational translates into 19% of all homes having non-operational smoke alarms. Three times as many homes have only alarms that don't work as have no smoke alarms at all. (The latter group still accounts for nearly half of all reported home fires.)

4. Power source problems are the leading reason why non-operational home smoke alarms do not work. Dead, disconnected and missing batteries are by far the most common problems. Regular testing could identify dead batteries. The 1992, 1994, and 1996 Fire Prevention Week themes showed continued emphasis on efforts to address this problem.

5. Strategies for dealing with power source problems have not all been evaluated in the field, but several observations seem consistent with the evidence:

(a) Wired-in alarm systems do not require periodic power source replacement, do not permit removal of their power sources for use elsewhere, and are statistically much less susceptible to power source interruption.

(b) The disconnected- or missing-battery problem is closely linked to the nuisance-activation problem. If these activations were reduced, it would also reduce the possibility that people will assume all smoke alarm activations are nuisance alarms because of the very high percentage that are. Nuisance activations can be addressed by:

- Moving an alarm further away from kitchen smoke or bathroom steam;

- Replacing ionization-type alarms with photoelectric-type alarms;
- Reducing alarm sensitivity, and/or
- More frequent or effective alarm cleaning.

However, reduced smoke alarm sensitivity may affect performance in real fires. The National Smoke Detector Project has also raised concerns over the ability of consumers to clean smoke alarms effectively.*

New technology may help address the nuisance activation problem. Smoke alarms with silencer buttons are now on the market. A silencer button can be pressed to silence the alarm for up to three minutes unless the smoke is too dense around the device. In that case, the unit will continue to sound until the smoke is no longer heavy enough to suggest a possible serious situation. (See section 2-4.5.5 of NFPA 72.)

6. NFPA's Learn Not to Burn® Foundation's Technical Advisory Council issued these recommendations in 1989 and 1991 for testing and maintenance:

- Install new batteries in all smoke alarms on the day you change your clock from daylight to standard time or when the alarm chirps, warning that the battery is dying.
- Replace all batteries immediately upon moving into a new home.
- Test units monthly, in accordance with NFPA 72, *National Fire Alarm Code* by using the alarm's test button or an approved smoke substitute, and clean the units, both in accordance with the manufacturers' instructions.
- Keep batteries in smoke alarms; never borrow them for other purposes.
- Do not use an open-flame device for testing because of the danger the flame could pose.

These messages were used as a basis for messages recommended by the communications committee of the National Smoke Detector Project.

7. Other design problems with the alarm unit itself need to be considered. The National Smoke Detector Project identified some cases of horn deterioration or corrosion leading to alarm failure but was unable to determine whether regular testing produces a "self-wiping" effect that eliminates the problem, as manufacturers maintain, because most, but not all, of the problem alarms had not been tested with the recommended frequency.**

8. Many steps related to home smoke alarm usage also need attention:

(a) Most homes that need more than one smoke alarm have at least one smoke alarm, but most do not have as many as they need for code-compliant every-level protection.

(b) Most households say they have an escape plan, but most have never rehearsed their plan.

* Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, p. 22.

** Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, pp. 18-19.

9. The U.S. fire service, fire protection professionals and the media all played a large role in placing alarms in most American homes. They could now serve an equally important role by educating the public on the number and placement of smoke alarms needed for full protection and the need to test and maintain smoke alarms. Many fire departments continue to promote home smoke alarms. Some even install alarms and replace batteries, especially for high-risk households in their communities. In some cases, recipients of smoke alarms in give-away programs do not install them. Programs with installation components may result in better long-term protection.

10. Smoke alarms provide the warning. They do not put out the fire or move people put of harm's way. NFPA chose *Fire Drills: The Great Escape* as the theme for Fire Prevention Week so that people would know what to do when a smoke alarm indicated a fire.

11. Smoke alarms have been intended primarily to protect people, not property. If no one is present to hear the alarm and the alarm is not connected to a monitoring system, no one will know that a problem exists. Even when people are present, they sometimes attempt to fight the fire themselves or get distracted before calling the fire department. A monitored system adds another level of protection.

12. A number of major property classes outside the home seem to have significant problems with non-operational alarms. We need to address this problem in detection and alarm systems in buildings other than homes.

13. As manufacturers develop new technology, some recommendations may need to be modified. For example, some smoke alarms now use lithium batteries. When these batteries fail, owners should replace the alarm, not the battery.

## Appendix A: Estimating Alarm Impact on Reporting Fires

If there is a difference between the proportion of homes having alarms and the proportion of fires occurring in homes with alarms, then there are two principal factors that could explain this: (1) Alarms may permit sufficiently early discovery of fire that the probability of reporting, given that fire occurs, is lower for homes with alarms. Let $R_r$ be the ratio given by this probability for homes without alarms divided by this probability for homes with alarms. (2) Homes that have alarms might be safer homes, less likely to have fires in the first place. Let $R_f$ be the ratio given by the probability of fire for homes without alarms divided by the probability of fire for homes with alarms.

It turns out to be much easier to estimate the product of $R_r$ and $R_f$ than it is to estimate either term by itself. Therefore, this analysis begins with the probabilistic-model formula for $R_f$ times $R_r$ shown in Table 9, which uses two figures shown in Figure 1 -- proportion of homes with alarms and proportion of reported fires in homes with alarms.

The formula in Table 10, combined with the statistics in Figure 1, indicates that $R_f$ times $R_r$ equaled 6.7 in 1982, the year for which we have the most detailed information on alarm usage by population subgroup. The product of $R_f$ times $R_r$ by itself is not particularly useful. It simply provides a way to estimate one term if the other has been estimated. The easier of the two terms to estimate directly appears to be $R_f$, the difference in basic fire risk, because this difference is highly correlated with socioeconomic characteristics, and we have statistics on differences in socioeconomic characteristics between homes with alarms and homes without alarms.

Table 1 indicates alarm usage was 55% for poor households and 67% overall. Since 15% of U.S. households were poor in 1982, this means alarm usage in non-poor households was 69%. We do not have a best source for an estimate of how much more likely fires are in poor households than in non-poor households. But consider a wide range of possibilities, from 1.5 (fires are 50% more likely in a poor household) to 5.0 (fires are five times as likely in a poor household as in a non-poor household). The corresponding range for $R_f$ is only 1.04 to 1.22 (see Table 10). The estimate of $R_f$ might go higher if alarms are more likely to be acquired by the low-risk members of high-risk groups (e.g., the more fire safety conscious of the poor households). But it is unlikely that $R_f$ would rise enough to become the principal component in the product of $R_f$ and $R_r$. It appears that $R_r$ is in the range of four to five, which would mean that 75-80% of the fires that would have grown large enough to be reported in the absence of alarms are not reported when alarms are present.

**Table 13. Formula for Impact of Alarm on Reporting of Fires, Given Differences in Basic Risk of Alarm Users and Non-Users**

A. probability (alarm | reporting, fire)

= probability (alarm, reporting, fire) / probability (reporting, fire)

B. probability (reporting, fire)

= [probability (reporting, fire, alarm)] +
[probability (reporting, fire, no alarm)]

= [probability (reporting | fire, alarm)] [probability (fire, alarm)] +
[probability (reporting | fire, no alarm)] [probability (fire, no alarm]

= [probability (reporting | fire, alarm)] [probability (fire | alarm)]
[probability (alarm)] +
[probability (reporting | fire, no alarm)] [probability (fire | no alarm)]
[probability (no alarm)]

C. Let $f_w$ = probability (fire | alarm)
$f_{wo}$ = probability (fire | no alarm)
$R_f = f_{wo}/f_w$
$r_w$ = probability (reporting | fire, alarm
$r_{wo}$ = probability (reporting | fire, no alarm)
$R_r = r_{wo}/r_w$
$p_D$ = probability (alarm)
$p_{DRF}$ = probability (alarm | reporting, fire)

D. Combining A, B, and C gives this formula:

$$p_{DRF} = [r_w\ f_w\ p_D]/[r_w\ f_w\ p_D + r_{wo}\ f_{wo}\ (1-p_D)]$$

$$= p_D/[p_D + (1-p_D)\ R_f\ R_r]$$

E. Rearranging terms yields this formula:

$$(R_f\ R_r) = [p_D\ (1-p_{DRF})]/[p_{DRF}\ (1-p_D)]$$

Figure 1 in this report gives values for $p_D$ and $p_{DRF}$ for each of these years: 1977, 1980, and 1982-96.

## Appendix B: Methodology for Estimating Alarm Operationality

Estimates of alarm performance in fires may be made using the National Fire Incident Reporting System (NFIRS), managed by the U.S. Fire Administration. Alarm performance in the fires in NFIRS is coded as follows:

1. Alarms operated and were in room of fire origin.
2. Alarms operated and were not in room of fire origin.
3. Alarms did not operate and were in room of fire origin.
4. Alarms did not operate and were not in room of fire origin.
5. Alarms were not required to operate because fire was too small.
6. No alarms were present (coded 8).
7. Alarm performance unclassified (coded 9).
8. Alarm performance unknown (coded 0).

This coding indicates whether alarms operated but not whether they were operational. If the "fire too small" code were used whenever it was appropriate, then one could estimate the percentage of alarms operational as the total of fires coded 1 or 2 divided by the total of fires coded 1, 2, 3, or 4. It is possible to check whether the "fire too small" code is being used whenever it is appropriate. If so, the estimated percentage of fires for which the alarm activated would be the same for small and large fires, because all characterizations of alarms having operated or not operated would be limited to fires deemed large enough to activate an operational alarm. This is not what the data show, however. In NFPA's analysis of 1980-83 NFIRS data on dwelling fires, we found that the estimated percentage of alarms operational was 10-15 percentage points lower for fires with extent of flame either unknown or confined to object of origin than for larger fires. There was also a much smaller three-percentage-point difference between the estimates for fires with extent of flame beyond object of origin but confined to room of origin versus fires with extent of flame beyond the room of origin.

After some additional exploratory analysis, it was decided that adjustments could and should be made to the data to produce meaningful results. It appeared that the operational status of alarms could best be estimated as the percentage of activations based on only those fires deemed large enough to activate an operational alarm. Since most of the analysis was to be done on home alarms nearly all of which are smoke alarms, it was decided to switch to smoke spread rather than flame spread as a measure of fire size. The fires that seemed large enough to produce activation were assumed to be those fires (a) with known extent of smoke, (b) not coded as too small to activate an alarm, and (c) with smoke extent beyond the area of origin if the alarm was in the room with the fire and beyond the room of origin if the alarm was outside the room of fire origin.

It is worth restating that these procedures were followed because it was assumed that most home fire alarms are in fact smoke alarms. In fact, the data base does not permit one to separate smoke alarms from other alarms and limit the analysis to them.

## Table 14. Estimating $R_f$

A. $R_f$ = probability (fire | no alarm)/probability (fire | alarm)

B. probability (fire | alarm)

= probability (fire, alarm)/probability (alarm)

C. probability (fire | no alarm)

= probability (fire, no alarm)/probability (no alarm

D. probability (alarm

= [probability (alarm | poor)][probability (poor)]
+ [probability (alarm | not poor)][probability (not poor)]

= (0.55)(0.15) + (0.69)(0.85) = 0.669 in 1982

E. probability (no alarm) = 1 - probability (alarm) = 0.331 in 1982.

F. Let f = probability (fire | not poor)
and p = probability (fire | poor)/probability (fire | not poor)

G. Assume that the probability of having a fire is affected by whether a household is poor but has no other dependence or correlation on the presence or absence of an alarm. In statistical technology, having a fire and having an alarm are independent events, within poor or non-poor households.

H. Then probability (fire, alarm)

= [probability (fire, alarm | poor)][probability (poor)]
+ [probability (fire, alarm | not poor)][probability (not poor)]

= p f (0.55)(0.15) + f (0.69)(0.85) in 1982

I. Then probability (fire, no alarm)

= [probability (fire, no alarm | poor)][probability (poor)]
+ [probability (fire, no alarm | not poor)][probability (not poor)]

= p f (0.45)(0.15) + f (0.31)(0.85) in 1982

## Table 14. Estimating $R_f$ (Continued)

J. Finally, in 1982, based on A, B, C, D, E, H, and I:

$$R_f = \frac{[p\ f\ (0.55)(0.15) + f\ (0.69)(0.85)][0.331]}{[p\ f\ (0.45)(0.15) + f\ (0.31)(0.85)][0.660]}$$

The f values cancel, and $R_f$ depends on p, as follows:

| p | $R_f$ |
|---|---|
| 1.5 | 1.04 |
| 2.0 | 1.07 |
| 3.0 | 1.13 |
| 5.0 | 1.22 |