

An Overview of Fire Detection Performance in Reported U.S. Fires

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Abstract

Almost all households in the U.S. have at least one smoke alarm, yet in 2000-2004, no smoke alarms were present or none operated in almost half (46%) of the reported home fires. (Homes include one- and two-family dwellings, apartments, and manufactured housing.) During the same period, 43% of all home fire deaths resulted from fires in homes with no smoke alarms, while 22% resulted from homes in which smoke alarms were present but did not operate. The death rate per 100 reported fires was twice as high in homes without working smoke alarms as it was in home fires with this protection. If all homes had working smoke alarms, an estimated 890 lives could be saved annually, or just under one-third the annual fire death toll. Fatalities resulting from home fires with working smoke alarms were more likely to have been in the area of origin, to have tried to fight the fire themselves, or to have been at least 65 years old.

Two-thirds of the smoke alarms in reported non-confined home fires were powered solely by batteries. The rest split evenly between hardwired only and hardwired with battery backup. More than half (54%) of the smoke alarm failures were due to missing or disconnected batteries; 19% were due to dead batteries. Nuisance alarms were the leading cause of disabled alarms. Hardwired devices accounted for 29% of the smoke alarms in non-confined fires but problems with the hardwired power source caused only 7% of the smoke alarm failures.

These estimates are based on data from the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's (NFPA's) annual fire department experience survey. This paper is a summary of NFPA's April 2007 report, *U.S. Experience with Smoke Alarms and Other fire Detection/Alarm Equipment* by the same author.

Keywords: fire statistics, home fires, residential fires, smoke alarms, smoke detectors

Methodology

In this analysis of fire detection performance in reported U.S. fires, national estimates of specific circumstances are derived from the detailed data collected by Version 5.0 of U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) used together with data from the National Fire Protection's (NFPA's) annual fire department experience survey. The total number of structure fires in homes (property use 410-429), including one- and two-family dwellings (property use 410-419) and apartments (property use 420-429) was calculated by taking the percentage of these incidents

collected in NFIRS 5.0 compared to fires in other properties. This percentage was then multiplied by NFPA's projected estimates of total structure fires during the time period.

Queries were done separately for confined and non-confined fires, and for one- and two-family dwellings, and apartments. Tables showing non-confined home fires are based on sum calculations done for these two occupancies. Unknown data (except for unknown occupancy) was allocated proportionally among known data. This approach was also used with data for non-home occupancies.

More detection detail is collected in NFIRS 5.0.

NFIRS 5.0 provides more detail about fire detection equipment and performance with six separate fields addressing presence in fire area, detection type in terms of what is detected, power supply, operation, effectiveness of operating equipment in alerting occupants, and reason for failure to operate. Two fields, extent of smoke damage, used in the past to determine whether the equipment could reasonably have been expected to operate, and method of alarm to fire department, have been dropped. In addition, earlier versions of NFIRS distinguished between detection equipment in or not in the area of origin as opposed to in or not in the fire area. A smoke alarm outside of the area of origin may operate after the fire spread.

Analyzing detection data is considerably more complicated than it was in the past. Detailed information on smoke alarm presence and operation is not required for confined or contained structure fires (incident type 113-118), including confined: cooking fires, chimney fires, fuel burner or boiler fires, incinerator fires, commercial compactor fires and contained trash or rubbish fires in a structure that did not damage the structure or its contents. The only required detection field for these incidents asks if the detector alerted occupants without indicating if either the equipment or occupants were present. Confined or contained home fires accounted for 41% of the home structure fires reported in NFIRS Version 5.0 in 2000-2004. Because the confined or contained fires are almost all minor, the pool of data with details on smoke alarm presence, operation, and effectiveness contains a larger share of more serious fires than in the past.

Smoke Alarms in Reported U.S Home Fires

Nearly all fire detection units in the home are designed to respond to smoke.

Ninety-four percent of the fire detection devices found in non-confined home structure fires reported in 2000-2004 were designed to be triggered by smoke. Three percent were combination units, designed to operate in response to smoke or heat. (NFIRS does not make a distinction between ionization and photoelectric smoke alarms.) Because home smoke alarms are so dominant, the term "smoke alarm" is used as an all encompassing phrase throughout this report when describing early fire warning devices or systems in the home. In 2004, 96% of all households surveyed (by telephone) reported having at least one smoke alarm.¹

¹ Harris Interactive. *2004 Fire Prevention Week Survey* (done for NFPA), online at <http://www.nfpa.org/assets/images/Public%20Education/FPWsurvey.pdf>.

Table 1.
Smoke Alarm Status in Homes
2000-2004 Annual Averages

| Smoke Alarm Status | Fires | | Civilian Deaths | | Death Rate per 100 Fires | Civilian Injuries | | Injury Rate per 100 Fires | Direct Property Damage (in Millions) | |
|--|----------------|---------------|-----------------|---------------|--------------------------|-------------------|---------------|---------------------------|--------------------------------------|---------------|
| Smoke alarm operated in non-confined fire | 85,700 | (23%) | 1,020 | (34%) | 1.19 | 6,180 | (43%) | 7.22 | \$3,080 | (56%) |
| Smoke alarm alerted occupants in confined fire | 99,000 | (26%) | 0 | (0%) | 0.00 | 940 | (7%) | 0.94 | \$0 | (0%) |
| <i>Subtotal - Operating smoke alarm</i> | 184,700 | (49%) | 1,020 | (34%) | 0.55 | 7,120 | (49%) | 3.85 | \$3,080 | (56%) |
| Smoke alarm present but failed to operate in non-confined fire | 26,300 | (7%) | 660 | (22%) | 2.51 | 2,370 | (16%) | 9.02 | \$700 | (13%) |
| No smoke alarm present in non-confined fire | 90,400 | (24%) | 1,270 | (43%) | 1.40 | 3,750 | (26%) | 4.15 | \$1,620 | (30%) |
| Smoke alarm did not alert occupants in confined fire | 54,600 | (15%) | 10 | (0%) | 0.01 | 760 | (5%) | 1.40 | \$0 | (0%) |
| <i>Subtotal - No operating smoke alarm</i> | 171,300 | (46%) | 1,930 | (65%) | 1.13 | 6,890 | (48%) | 4.02 | \$2,320 | (42%) |
| Fire too small to operate in non-confined fire | 19,100 | (5%) | 20 | (1%) | 0.08 | 380 | (3%) | 2.01 | \$100 | (2%) |
| Total | 375,200 | (100%) | 2,970 | (100%) | 0.79 | 14,390 | (100%) | 3.84 | \$5,500 | (100%) |

* For confined fires, fire departments are asked only if the detection equipment alerted or did not alert occupants. If the detection equipment was coded as “alerted occupants,” it was assumed that a smoke alarm was present and operated. When this equipment did not alert occupants, it was assumed to have not operated or not have been present. Because a fire may be discovered before a smoke alarm operates, a smoke alarm may operate in the absence of occupants, or a confined fire may have been too small to activate detection equipment, “smoke alarm alerted occupants in confined fire” should be considered a lower bound of operating smoke alarms in these incidents while “smoke alarms did not alert occupants in confined fire” should be considered the upper bound of possible confined fires with no or no working smoke alarms.

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These national estimates are projections based on the detailed information collected in Version 5.0 of NFIRS. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Fires are rounded to the nearest hundred, civilian deaths and injuries are rounded to the nearest ten, and direct property damage is rounded to the nearest million dollars. Property damage has not been adjusted for inflation. Sums may not equal totals due to rounding errors. Fires in which smoke alarm presence or performance was unknown or not reported were allocated proportionally among fires with known data.

Source: NFIRS and NFPA survey.

65% of home fire deaths occurred in properties without working smoke alarms. For confined fires, fire departments are asked only if the detection equipment alerted or did not alert occupants. If the detection equipment was coded as “alerted occupants,” for this analysis, it was assumed that a smoke alarm was present and operated. When this equipment did not alert occupants, it was assumed to have not operated or not have been present. This approach was used to create Table 1 and Figure 1.

Figure 1.

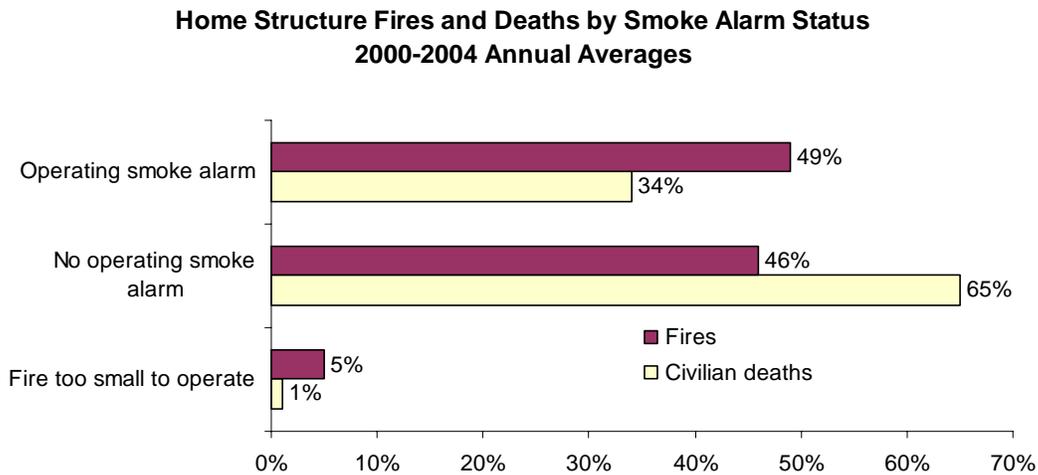
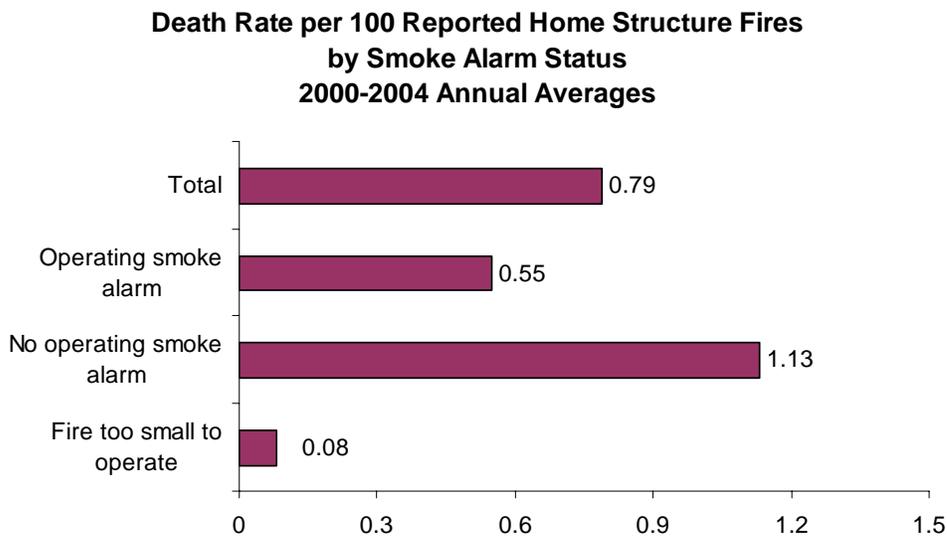


Figure 2 shows that the death rate per 100 reported home fires was 51% lower in reported home fires in which a smoke alarm operated than in reported fires with no working smoke alarms. This understates the impact of smoke alarms that alert people to situations before fire service intervention is required.

Figure 2.



Because a fire may be discovered before a smoke alarm operates, a smoke alarm may operate in the absence of occupants, or a confined fire may have been too small to

activate detection equipment, “smoke alarm alerted occupants in confined fire” should be considered a lower bound of operating smoke alarms while “smoke alarms did not alert occupants in confined fire” should be considered the upper bound of possible fires with no or no working smoke alarms. Smoke alarms operated in roughly half (49%) of the reported home fires, no smoke alarm operated in 46%, and 5% of the fires were too small to operate the alarm. No operating smoke alarms includes both fires with none present and fires in which present smoke alarms failed to operate. One-third of the home fire deaths resulted from fires in which a smoke alarm operated.

890 lives per year could be saved if working smoke alarms were present in every home.

During the five-year period of 2000-2004, 375,200 home structure fires, on average, were reported per year. These fires caused an estimated annual average of 2,970 civilian deaths at a rate of 0.79 deaths per 100 reported home fires. Using average death rates per 100 reported fires for home fires with (0.55) and without (1.13) working smoke alarms, the predicted number of home fire deaths would be 2,070 if every home had a smoke alarm, and 4,230 if no smoke alarms were present at all. Relative to the current death toll, then, 890 lives would be saved with working smoke alarms in every home. An additional 1,260 lives would be lost if none were present. Because there is evidence that working smoke alarms often act so early that they convert what would have been a reported fire into a very small, unreported fire, the potential savings from universal working smoke alarms could be even larger.

In 80% of the non-confined home fires with operating smoke alarms, the occupants were alerted and responded. The 2% of non-confined home fires in which smoke alarms sounded and occupants were alerted but failed to respond accounted for 20% of the deaths caused by home fires with sounding smoke alarms. It is unclear if the smoke alarm provided the first notification of the fire. An operating smoke alarm failed to alert occupants in 3% of these structure fires; these fires caused 7% of the home fire deaths. In 15% of these incidents, no occupants were present; no fatalities resulted from these fires.

More than half of the smoke alarm failures were due to missing or disconnected batteries.

Sixty-seven percent of the smoke alarms present in non-confined home structure fires were powered by battery only. In 54% of the fires in which smoke alarms (*all* power sources) were present but failed to operate, batteries were missing or had been disconnected. In 19%, batteries were dead or discharged. Fourteen percent of the smoke alarms were hardwired without battery backup. However, only 7% of the smoke alarm failures were due to hardwired power disconnection, power failure or shutoff. Lack of cleaning was blamed for 4% of the failures, defective units for 3%, improper installation or placement for another 3%, and an unclassified reason was cited in 10% of these fires.

Fires were less likely to spread beyond the room of origin when smoke alarms were hard-wired.

Flame damage was confined to the room of origin in 68% of the non-confined home structure fires in which working smoke alarms were powered by batteries compared to 77% of such fires with hardwired smoke alarms, including those with and without battery

backup. Although the reasons for this difference cannot be gleaned from this data, it is likely that hardwired smoke alarms are interconnected. They also may be installed to provide wider coverage. Either could result in earlier detection, and hence, smaller fires.

Apartments were more likely to have working smoke alarms than one- or two-family dwellings.

The smoke alarm profile differed sharply between one- or two-family homes (including manufactured homes) and apartments. The category of apartments also includes condominiums, townhouses, and row houses. These property classifications are based on the type of structure, not the type of ownership. Table 2 shows that forty-four percent of the reported fires in one- or two-family homes had working smoke alarms. Only 31% of the fire deaths in these properties resulted from fires with this protection. Table 3 shows that 66% of the reported apartment fires had working smoke alarms. Fifty-seven percent of the apartment fire deaths resulted from these fires.

When smoke alarms operated, 55% of the victims of fatal fires in one- and two-family dwellings were in the general area of origin, but a much larger 76% of the apartment victims were that close to the fire. This suggests that there were proportionally more people in apartments who were so close to the fire that they needed more time to escape than a working smoke alarm could provide. Even so, apartments had a fire death rate of 0.36 per 100 fires for reported fires with working smoke alarms, compared to the 0.65 death rate for such fires in one- and two-family dwellings.

It is unclear whether the smoke alarms that were reported to have operated (or not operated) in apartment fires were in the unit of origin, in a common area, or in another unit. It is possible for building residents to be alerted by a smoke detection system in a common hallway to a fire that began in an apartment with a disabled smoke alarm. Similarly, a smoke alarm in one unit may alert occupants outside the unit of origin. A difference may also exist in the types of fires that are reported. Forty-seven percent of the apartment fires reported in Version 5.0 were confined fires with smoke alarms alerting occupants. These incidents accounted for 20% of the reported fires in one- and two-family dwellings. Forty-seven percent of the smoke alarms in non-confined apartment structure fires were powered by batteries only compared to 72% in one- and two-family dwellings.

More civilians are injured fighting the fire themselves in fires with working smoke alarms.

There is little difference in injury rates per 100 fires when working smoke alarms are present compared to fires without this protection. Someone alerted to a fire by a smoke alarm may find a fire small enough that they consider fighting it themselves. Forty percent of the reported non-fatal civilian fire injuries that occurred in homes with operating smoke alarms occurred when the civilian was engaging in fire control activities, compared to 30% of the civilian fire injuries reported in home fires with either no smoke alarms or no working smoke alarms. Eight percent of the people who were fatally injured in home structure fires with working smoke alarms were trying to fight the fire themselves compared to only 3% who died trying to fight the fire when no smoke alarms were present.

Table 2.
Smoke Alarm Status
in One- and Two-Family Dwelling Fires
2000-2004 Annual Averages

| Smoke Alarm Status | Fires | | Civilian Deaths | Death Rate per 100 Fires | Civilian Injuries | Injury Rate per 100 Fires | Direct Property Damage (in Millions) |
|---|----------------|---------------|---------------------|--------------------------|----------------------|---------------------------|--------------------------------------|
| Smoke alarm operated in non-confined fire | 67,700 | (24%) | 790 (31%) | 1.17 | 4,180 (40%) | 6.17 | \$2,451 (54%) |
| Smoke alarm alerted occupants in confined fire* | 54,900 | (20%) | 0 (0%) | 0.00 | 500 (5%) | 0.91 | \$0 (0%) |
| <i>Subtotal - Operating smoke alarm</i> | 122,700 | (44%) | 800 (31%) | 0.65 | 4,680 (45%) | 3.82 | \$2,451 (54%) |
| Smoke alarm present but failed to operate in non-confined fire* | 21,600 | (8%) | 560 (22%) | 2.61 | 1,790 (17%) | 8.28 | \$582 (13%) |
| No smoke alarm present in non-confined fire | 80,200 | (29%) | 1,210 (47%) | 1.50 | 3,290 (31%) | 4.09 | \$1,450 (32%) |
| Smoke alarm did not alert occupants in confined fire | 40,300 | (14%) | 10 (0%) | 0.01 | 480 (5%) | 1.20 | \$0 (0%) |
| <i>Subtotal - No operating smoke alarm</i> | 142,200 | (51%) | 1,770 (69%) | 1.25 | 5,560 (53%) | 3.91 | \$2,032 (44%) |
| Fire too small to operate in non-confined fire | 15,600 | (6%) | 10 (0%) | 0.04 | 260 (2%) | 1.66 | \$84 (2%) |
| Total | 280,500 | (100%) | 2,580 (100%) | 0.92 | 10,500 (100%) | 3.74 | \$4,567 (100%) |

* For confined fires, fire departments are asked only if the detection equipment alerted or did not alert occupants. If the detection equipment was coded as “alerted occupants,” it was assumed that a smoke alarm was present and operated. When this equipment did not alert occupants, it was assumed to have not operated or not have been present. Because a fire may be discovered before a smoke alarm operates, a smoke alarm may operate in the absence of occupants, or a confined fire may have been too small to activate detection equipment, “smoke alarm alerted occupants in confined fire” should be considered a lower bound of operating smoke alarms in these incidents while “smoke alarms did not alert occupants in confined fire” should be considered the upper bound of possible confined fires with no or no working smoke alarms.

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These national estimates are projections based on the detailed information collected in Version 5.0 of NFIRS. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Fires are rounded to the nearest hundred, civilian deaths and injuries are rounded to the nearest ten, and direct property damage is rounded to the nearest million dollars. Property damage has not been adjusted for inflation. Sums may not equal totals due to rounding errors. Fires in which smoke alarm presence or performance was unknown or not reported were allocated proportionally among fires with known data.

Source: NFIRS and NFPA survey.

Table 3.
Smoke Alarm Status in Apartment Fires
2000-2004 Annual Averages

| Smoke Alarm Status | Fires | | Civilian Deaths | | Death Rate per 100 Fires | Civilian Injuries | | Injury Rate per 100 Fires | Direct Property Damage (in Millions) | |
|--|---------------|---------------|-----------------|---------------|--------------------------|-------------------|---------------|---------------------------|--------------------------------------|---------------|
| Smoke alarm operated in non-confined fire | 18,000 | (19%) | 220 | (57%) | 1.25 | 2,000 | (51%) | 11.15 | \$630 | (67%) |
| Smoke alarm alerted occupants in confined fire* | 44,100 | (47%) | 0 | (0%) | 0.00 | 430 | (11%) | 0.98 | \$0 | (0%) |
| <i>Subtotal - Operating smoke alarm</i> | 62,100 | (66%) | 230 | (57%) | 0.36 | 2,440 | (63%) | 3.93 | \$630 | (67%) |
| Smoke alarm present but failed to operate in non-confined fire | 4,800 | (5%) | 100 | (25%) | 2.04 | 590 | (15%) | 12.36 | \$120 | (13%) |
| No smoke alarm present in non-confined fire* | 10,200 | (11%) | 60 | (15%) | 0.60 | 470 | (12%) | 4.57 | \$170 | (19%) |
| Smoke alarm did not alert occupants in confined fire | 14,200 | (15%) | 0 | (0%) | 0.00 | 280 | (7%) | 1.94 | \$0 | (0%) |
| <i>Subtotal - No operating smoke alarm</i> | 29,200 | (31%) | 160 | (40%) | 0.54 | 1,330 | (34%) | 4.56 | \$290 | (31%) |
| Fire too small to operate in non-confined fire | 3,500 | (4%) | 10 | (2%) | 0.27 | 120 | (3%) | 3.59 | \$20 | (2%) |
| Total | 94,700 | (100%) | 390 | (100%) | 0.41 | 3,890 | (100%) | 4.11 | \$940 | (100%) |

* For confined fires, fire departments are asked only if the detection equipment alerted or did not alert occupants. If the detection equipment was coded as “alerted occupants,” it was assumed that a smoke alarm was present and operated. When this equipment did not alert occupants, it was assumed to have not operated or not have been present. Because a fire may be discovered before a smoke alarm operates, a smoke alarm may operate in the absence of occupants, or a confined fire may have been too small to activate detection equipment, “smoke alarm alerted occupants in confined fire” should be considered a lower bound of operating smoke alarms in these incidents while “smoke alarms did not alert occupants in confined fire” should be considered the upper bound of possible confined fires with no or no working smoke alarms.

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These national estimates are projections based on the detailed information collected in Version 5.0 of NFIRS. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Fires are rounded to the nearest hundred, civilian deaths and injuries are rounded to the nearest ten, and direct property damage is rounded to the nearest million dollars. Property damage has not been adjusted for inflation. Sums may not equal totals due to rounding errors. Fires in which smoke alarm presence or performance was unknown or not reported were allocated proportionally among fires with known data.

Source: NFIRS and NFPA survey.

U.K. data show that smoke alarms result in quicker fire discovery.

The United Kingdom tracks the interval between the time of ignition and the time of discovery.² In 64% of the home fires in which the alarm was raised by the smoke alarm were discovered within five minutes of ignition. The fire was confined to the item of origin in 68% of these incidents.

Only 51% of the fires in which no smoke alarms were present or in which they did not raise the alarm were discovered within five minutes. Forty-six percent of these fires were confined to the object of origin. This suggests that occupants of homes with working smoke alarms will be alerted to fires earlier and that fires in these homes are less likely to have the opportunity to spread.

Many homes do not have an adequate number of smoke alarms.

A study of homes in rural Iowa found that smoke alarms were not installed according to NFPA guidelines in 57% of the homes with smoke alarms. In 85% of these cases (48% of the homes with at least one smoke alarm), a smoke alarm had not been installed on every level. Basements were the least likely level to have smoke alarms.³ The National Smoke Detector Project found that 26% of the households surveyed had fewer than one alarm per floor. The National Smoke Detector Project also estimated that 43% of the households had fewer than one *working* smoke alarm per floor.⁴

Fire Detection in Non-Home Occupancies

Wider variety of detection equipment is found in non-home occupancies.

Three-fifths (61%) of the fire detection devices found in reported non-confined, non-home fires were intended to be triggered only by smoke, as compared to 94% found in homes. Thirteen percent of the fires occurred in properties with more than one type of detection, another 13% had combination units designed to be triggered by heat or smoke, 7% of the properties had water flow alarms associated with sprinklers, and 5% would be triggered by heat. The type of detection varies considerably by occupancy although smoke dominates in every type examined. The fire detection equipment was meant to be triggered by smoke only in just 27% of the non-confined structure fires in the category of industrial, utility, defense, agriculture, mining and manufacturing properties, and in 38% of such fires in warehouses. Sprinklers with waterflow alarms accounted for roughly one-quarter of the fire detection equipment found in these two property class categories. Unfortunately, NFIRS does not collect information about whether the detection equipment was part of a full system.

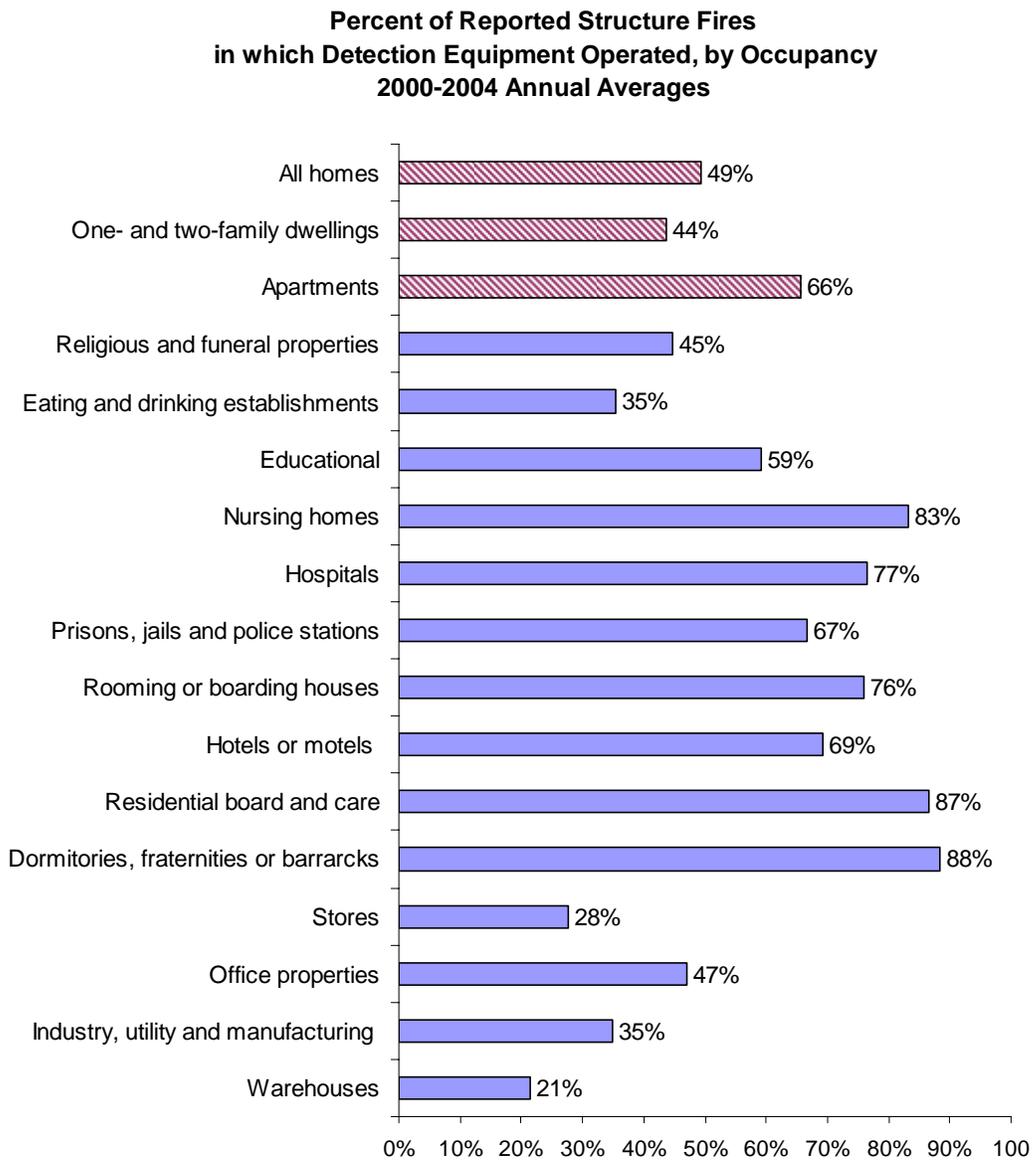
² Office of the Deputy Prime Minister, *Fire Statistics, United Kingdom, 2004*, London, 2006, p. 40, online at http://www.communities.gov.uk/pub/670/FireStatisticsUnitedKingdom2004PDF1193Kb_id1163670.pdf.

³ C. Peek-Asa, V. Allareddy, J. Yan, C. Taylor, J. Lundell, and C. Zwerling. "When One is Not Enough: Prevalence and Characteristics of Homes Not Adequately Protected by Smoke Alarms," *Injury Prevention*, 2005;11:364-368, online at <http://ip.bmj.com/cgi/reprint/11/6/364>.

⁴ Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 24.

Almost two-thirds (64%) of the fire detection devices found in non-home non-confined structure fires were hardwired, with 40% hardwired only and 24% hardwired with battery backup. Only one-fifth (20%) were powered by batteries only. This contrasts with the non-confined home fires in which 58% of home smoke alarms were powered by batteries only. Figure 3 shows that working fire detection equipment was less likely to be found in fires in homes (particularly in one- and two-family dwellings) than in fires in many other occupancy classes, particularly health care properties such as nursing homes and hospitals, and the more regulated residential occupancies, such as dormitories and fraternity houses, residential board and care facilities, and rooming and boarding houses.

Figure 3.



The three property classes with the largest share of fires with working detection equipment are: 1), dormitories, fraternities or sororities, 2) residential board and care, and

3) nursing homes. Confined fires in which detection equipment alerted occupants accounted for 71%, 69%, and 54% of the reported structure fires in these properties, respectively. Properties in which people were expected to be awake and mobile were less likely to have fire detection equipment.

Reasons for fire detection equipment failures in non-home occupancies are different from those in homes.

Another difference regarding fire detection equipment outside the home is seen in the reasons for detection equipment failure. Missing or disconnected batteries caused 54% of the smoke alarm failures in home fires; this was true in only 30% of the failures of fire detection equipment in non-home properties. Seventeen percent of non-home fire detection failures were due to problems with hardwired power, compared to 11% of the home smoke alarm failures.

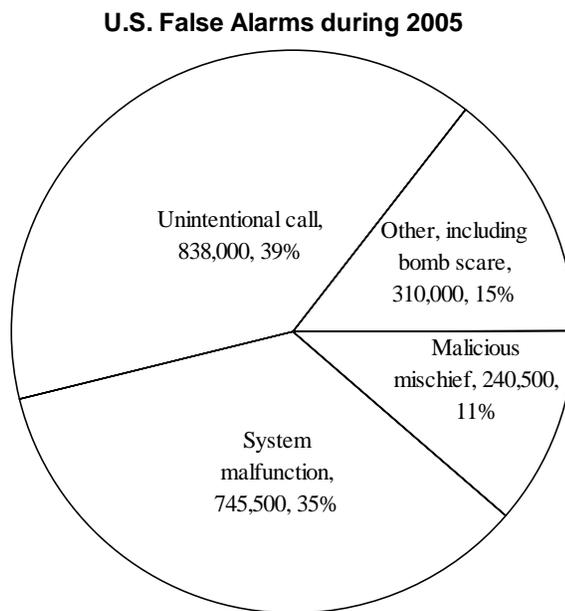
The different types of equipment can have different failure modes. With the smaller number of non-confined fires with non-working detection equipment in these occupancies, the numbers did not support a more detailed breakdown of failure modes by occupancy.

False Alarms and Nuisance Activations

Nine percent of U.S. fire department calls were false alarms.

In 2005, U.S. fire departments responded to 2,134,000 false alarms, excluding good intent calls and smoke scares. Nine percent of all fire department responses were to false calls; only 7% were to fires.⁵

Figure 4.



⁵ Michael J. Karter, Jr., *Fire Loss in the United States during 2005*, Quincy, MA: NFPA, 2006, available from http://www.nfpa.org/assets/files/PDF/OS_fireloss.pdf.

False alarms and nuisance activations (in all occupancy types, not just homes) are problems to both the fire service and to building occupants. False alarms tie up fire department resources. Nuisance activations interrupt other activities and may lead people to ignore the early warning of a smoke alarm. They are the leading reason for deliberately disabling smoke alarms.

System malfunctions and unintentional calls each accounted for roughly one-third of false alarms to fire departments

Figure 4 shows that 35 percent of the false calls reported in to US fire departments in 2005 were due to system malfunctions. Thirty-nine percent of the false calls were unintentional calls, including incidents in which smoke alarms operated as designed, but the operation was unwelcome and unneeded, such as activations while broiling or frying.

False alarms are also a problem outside the U.S.

Other countries are having similar problems. In New Zealand, false alarms (excluding good intent calls) accounted for 29% of the fire department's responses during fiscal year 2005-2006.⁶ An older study of New Zealand's false calls found that about half of all false alarms came from fire alarm systems. Fifty-one percent of New Zealand's false alarms were caused by 8% of the alarm systems.⁷ The Australasian Fire Authorities Council has created a business plan to address this issue that identifies strategies for partnerships with stakeholders, including owners and occupants, the fire service, building designers, fire alarm industry, and the code community.⁸ In the United Kingdom, false alarms (including malicious and good intent false alarms) accounted for about half of the fire call responses in 2004, with 64% of false alarms and one-third of all fire calls being false calls "due to apparatus."⁹

Special survey found actual fires caused roughly 3% of the fire department responses to residential fire alarm activations.

Peter Finley of the Vineland, New Jersey Fire Department won a 2002 outstanding research award for his analysis of the verification and response dilemma with residential fire alarm systems¹⁰ In his survey of fire departments protecting populations of 47,000 to 67,000, he found that three-quarters of the departments did not permit this verification of residential alarms. Eighty-nine percent did not consider smoke from cooking or burnt food to be a false alarm. Smoke from candles or a fireplace was not considered a false alarm by 70%. Forty-five percent issued fines, penalties or citations to repeat false alarm

⁶ New Zealand Fire Service Statistics. *Emergency Incident Statistics: 1 July 2005 – 30 June 2006*, online at http://www.fire.org.nz/facts_stats/statistics.htm.

⁷ New Zealand Fire Service – "False Alarms Costs," from http://www.fire.org.nz/facts_stats/faA_slse_alarm/false.htm.

⁸ Australasian Fire Authorities Council *Unwanted False Alarms Reduction Committee Business Plan 2005 - 2010*. October 2005, online at

⁹ Office of the Deputy Prime Minister. *Fire Statistics -- United Kingdom 2004*, London, U.K., February, 2006, available at http://www.communities.gov.uk/pub/670/FireStatisticsUnitedKingdom2004PDF1193Kb_id1163670.pdf.

¹⁰ Peter J. Finley, Jr., *Residential Fire Alarm Systems: The Verification and Response Dilemma*, Executive Analysis of Fire Service Operations in Emergency Management, an applied research project submitted to the National Fire Academy as part of the Executive Fire Officer Program, from http://www.usfa.fema.gov/pdf/efop/tr_02pf.pdf, pp. 27-40.

offenders. Responding departments indicated that, on average, actual fires caused 2.8% of the residential fire alarm activations, 26.5% were caused by smoke from cooking or burnt food, 3.7% were triggered by steam from a shower, 4.1% were triggered by smoke from fireplaces, candles, etc., 23.8% were other accidental activations, and 31.2%, on average, were system malfunctions.

Most households tried to prevent fire department response to non-emergency activations.

Finley also surveyed Vineland households with residential fire alarm activations in the previous year. Eighty-four percent said they had tried to stop the fire department from responding.

Unwanted activations far outnumber actual fires.

Nuisance activations of single-station smoke alarms or of systems that do not require automatic notification of the fire department may not result in fire department responses, but they can lead to alarm disabling or a failure to take a sounding alarm seriously. The few studies of field experience with unwanted alarms have consistently shown 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.¹¹

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.¹² 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.

When smoke alarm batteries were missing, their removal was usually due to annoyance over alarm activations from cooking.

As noted earlier, batteries were removed or disconnected far more frequently than was AC power. In CPSC's National Smoke Detector Project, 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.¹³ 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

¹¹ 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.

¹² Remote Detection and Alarm for Residences - The Woodlands System, Washington: U.S. Fire Administration, May 1980.

¹³ Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 12.

problem. Alarming to steam or humidity was cited about one-fourth to one-third as often as either of the two leading problems.¹⁴

More than one-third of New Zealand households in a smoke alarm installation program had problems with nuisance alarms.

Thirty-eight percent of the New Zealand households in a smoke alarm installation program reported problems with nuisance alarms. Thirty-six percent of the households reported that cooking had set off a nuisance alarm, 15% reported that steam activated the smoke alarm, and seven percent blamed faulty smoke alarms. (Multiple factors could be mentioned.)¹⁵

Steam was leading trigger mentioned for nuisance alarms in SAFE KIDS project.

In the six months between installation and follow-up testing in a SAFE KIDS Smoke alarm installation program of smoke alarms in 541 homes in 10 low-income communities, 124 smoke alarms had sounded due to something other than a fire. Moisture from the shower was cited as the reason for 39% of the activations, malfunctions in 8%, cooking smoke in 5%, cigarette smoke in 2%, and “other” in 46%. Two-thirds said they ventilated the home during these activations.¹⁶

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.¹⁷

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 the National Smoke Detector Project, 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.¹⁸

An Alaskan study, published in 2000, installed photoelectric smoke alarms in 58 homes in two rural Eskimo Inupiat villages and ionization smoke alarms in 65 homes in two

¹⁴ Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 22.

¹⁵ Mavis Duncanson, Katherine Lawrence, Jean Simpson and Alistair Woodward, *Follow-up Survey of Auaahi Whakatupato Smoke Alarm Installation Project in the Eastern Bay of Plenty*, New Zealand Fire Service Commission Research Report Number Seven, University of Otago, August 2000, from http://www.fire.org.nz/research/reports/reports/report_7.htm.

¹⁶ Angela Mickalide and Ana Validzic. “Smoke Alarm Maintenance in Low-Income Families,” *American Journal of Public Health*, October 1999, Vol. 89, No. 10, pp. 1584-1585, online at <http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1508809&blobtype=pdf>.

¹⁷ Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, p. 23.

¹⁸ 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.

other similar villages.¹⁹ Home area averaged roughly 1,000 square feet or less. A baseline survey before the program found functional smoke alarms in only 38% of the homes in what would be the ionization group and 22% of the homes in the future photoelectric group. Follow-up visits were made six months after the alarms were installed. At that time, 81% of the ionization homes had working smoke alarms compared to 96% of the homes with photoelectric devices. Ninety-two percent of the ionization homes and 11% of the photoelectric homes had experienced at least one false alarm. Ninety-three percent of the 69 ionization false alarms were due to cooking as were four of the six (67%) of the photoelectric false alarms. Eighty-one percent of the ionization cooking false alarms were related to frying. Heating equipment triggered five (8%) of the ionization false alarms and two (one-third) of the photoelectric false alarms. The authors noted that false alarms seemed to be more common in homes that were smaller, that used wood fuel for heat and in which the smoke alarms were located near the cooking areas. The authors conclude that “Photoelectric alarms may be the preferred choice for dwellings with limited living space and frequent false alarms.”

NFPA 72 has location requirements for smoke alarms.

Section 11.8.3.5 of the 2007 edition of NFPA 72, *National Fire Alarm Code*,[®] provides specific location requirements for smoke detectors and smoke alarms. Some of these are designed to facilitate operation; others are intended to prevent nuisance activations. Any smoke alarms installed within 20 feet of a cooking appliance must have either a means of silencing the alarm or be photoelectric. Smoke alarms should also not be located within 36 inches of the door to a bathroom with a shower or tub.

Many questions remain unanswered.

NFIRS does not capture information on the location of the smoke alarm in relation to the area of origin, whether an adequate number have been installed, the time of ignition related to the time of smoke alarm activation, or the time of the fire discovery. It also does not distinguish between photoelectric and ionization smoke alarms. Nor can NFIRS data indicate at what point a smoldering fire has become life-threatening. These statistics also do not provide any information about unreported fires. However, they do provide valuable information to researchers working on these questions.

Discussion and Recommendations

1. As of 2004, 24 of every 25 homes with telephones (96%) 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 are not enough to explain why the small number of homes without smoke alarms account for one of every four reported non-confined 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.

¹⁹ Thomas M. Fazzini, Ron Perkins, and David Grossman. “Ionization and Photoelectric Smoke Alarms in Rural Alaskan Homes,” *West J. Med*; 2000;173:89-92. online at <http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1071008&blobtype=pdf>.

2. In fires reported to fire departments, the rate of death per 100 reported fires in homes with working smoke alarms is half that of homes without this protection.
3. One-fifth of homes with smoke alarms have no smoke alarms that work. Since 96% of homes (with telephones) have smoke alarms, the 20% non-operational translates into 19% of all homes having non-operational smoke alarms. Five times as many homes have only alarms that don't work as have no smoke alarms at all.
4. Power source problems are the leading reason why non-operational home smoke alarms do not work. Missing, disconnected and dead batteries are by far the most common problems. Regular testing can identify dead batteries or non-functional alarms.
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) Hardwired smoke alarms do not require periodic replacement of the primary power source (Batteries for backup must still be replaced annually.), do not permit removal of their primary 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;
 - Using a smoke alarm with a pause (silence) button; (When pressed the button deactivates the alarm for a few minutes. The smoke alarm then reactivates automatically.); and/or
 - More frequent or effective alarm cleaning.

Manufacturers could also reduce the sensitivity of smoke alarms. However, reduced smoke alarm sensitivity may affect performance in real fires. The National Smoke Detector Project also raised concerns over the ability of consumers to clean smoke alarms effectively.²⁰ One British study suggests that photoelectric smoke alarms and pause buttons result in shorter battery life, at least for smoke alarms with zinc batteries.²¹

²⁰ Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, p. 22.

²¹ Diane Rowland, Caroub GiGuisseppi, Ian Roberts, Katherine Curtis, Helen Roberts, Laura Ginnelly, Mark, Sculpher, and Angela Wade. “Prevalence of Working Smoke Alarms in Local Authority Inner City Housing: Randomised Controlled Trial,” *BMJ* 2002; 325:998-1001, online at <http://www.bmj.com/cgi/reprint/325/7371/998>.

6. The Educational Messages Advisory Committee (EMAC) to NFPA's Public Education Division developed the following tips for the testing and maintenance of smoke alarms.

- Choose a smoke alarm that has the label of a recognized testing laboratory.
- Install a smoke alarm in every sleeping room, outside each sleeping area, and on every level of your home.
- For the best protection, interconnect all smoke alarms throughout the home. When one sounds, they all sound.
- Install a new battery in all conventional smoke alarms at least once a year. Immediately install a new battery if an alarm "chirps," warning the battery is low.
- Replace smoke alarms that use extended life (10-year) batteries when the alarm chirps or fails to respond to periodic testing. The batteries in these units cannot be replaced.
- Replace all smoke alarms when they are 10 years old.
- Test your smoke alarms at least monthly. 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.
- Special smoke alarms are made for people who are deaf or hard of hearing. These alarms use strobe (flashing) lights. The use of vibration devices may provide additional benefit in some cases.

7. Other issues 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.²²

8. 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 result in better long-term protection.²³

²² 2004 Fire Prevention Week Survey conducted for National Fire Protection Association by Harris Interactive Market Research, p. 16.

²³ Pauline Harvey, Mary Aitken, George W. Ryan, Lori A. Demeter, Jeanne Givens, Ramya Sunderaraman, Scott Goulette. "Strategies to Increase Smoke Alarm Use in High-Risk Households," *Journal of Community Health*, Vol. 29, No. 5, October 2004, pp. 375-385.

9. Smoke alarms provide the warning. They do not put out the fire or move people out of harm's way. NFPA chose *Fire Drills: The Great Escape* as the theme for Fire Prevention Week 1998-2000 so that people would know what to do when a smoke alarm indicated a fire. The 2003 theme of "*When Fire Strikes: Get out! Stay Out!*" reinforced the need to evacuate.

10. Home 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 investigate first, attempt to fight the fire themselves or get distracted before calling the fire department. A monitored system adds another level of protection. However, nuisance activations and system malfunctions in monitored systems result in hundreds of thousands of false alarms each year. Greater coordination between fire alarm companies, property owners and the fire service could perhaps result in better fire alarm placement for monitored systems. Replacing ionization devices with photoelectric alarms in areas close to cooking areas or bathrooms could also reduce nuisance activations. The early warning of a smoke alarm is invaluable, if it is heeded.

11. 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.

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

13. Wireless technology that uses radio frequency as a means to interconnect battery-powered smoke alarms is now available. Recent concerns about the ability of smoke alarms to wake sleeping children have made parents aware of their need to hear a smoke alarm in their child's room or anywhere in the home. Costs have fallen for many types of technical equipment. Should this prove true for these smoke alarms, it would offer the potential advantages of interconnectivity with less expense and installation effort than with traditional hardwired smoke alarms and allow the alarm to sound throughout the home.