HOME SMOKE ALARMS –
THE DATA AS CONTEXT FOR DECISION

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Abstract

Considerable attention has been devoted to how home smoke alarms could be more effective at preventing fire deaths. The death rate per 100 reported home fires is half as high in homes with working smoke alarms compared to homes without this protection. This paper summarizes what is known about the performance and effectiveness of home smoke alarms and of victim characteristics in home fires with and without operating smoke alarms based on statistical analysis of actual fire experience data. Special studies on other factors affecting smoke alarm performance, audibility, and nuisance alarms are also discussed. The paper also identifies several questions that cannot, at present, be conclusively addressed.

1. INTRODUCTION

Many researchers focus on various aspects of smoke alarm functioning such as the effectiveness of different types of sensors, particularly ionization and photoelectric, smoke alarm audibility under different conditions, nuisance alarms, and the prevalence of smoke alarms in different populations. Code developers and authorities work to provide prudent and reasonable guidance and requirements in the face of often incomplete information. In attempting to improve one aspect of performance, other aspects may be overlooked. Data about smoke alarm presence, their functioning, reasons for failure, and the victims in actual fires provide a necessary backdrop to determine how great the impact of different changes might be. When smoke alarms do not operate, they typically have been disabled due to nuisance alarms. Studies have identified audibility as a concern for a number of populations, including older adults, children, and those impaired by drugs or alcohol, and in a variety of environmental conditions, including households with high levels of ambient noise or closed doors.

This paper includes national estimates of smoke alarm performance and victim characteristics in reported U.S. fires. Findings from the literature are also discussed. Several questions are noted that cannot be answered with existing data. Many, particularly the exact timing of events (when in the fire development a smoke alarm sounded, when a smoldering fire transitioned to flaming, and when the fire became lethal) are unlikely to be answerable.

2. METHODOLOGY

The national fire experience statistics in this analysis are estimates derived from Version 5.0 of the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) [1] and the National Fire Protection Association's (NFPA's) annual survey of U.S. fire departments. NFIRS is a voluntary system by which participating fire departments report detailed factors about the fires to which they respond. NFIRS collects information on where and when each fire occurred. It also collects detailed information on fire causes, presence and operation of

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automatic detection equipment, and victim characteristics. Roughly two-thirds of U.S. fire departments participate, although not all of these departments provide data every year. Using NFIRS data alone would underestimate the extent of the fire problem.

Version 5.0 of NFIRS introduced new codes, coding rules and definitions. The share of NFIRS data originally collected in NFIRS 5.0 has also been increasing since its introduction in 1999. Data originally collected in older versions is converted to NFIRS 5.0 prior to its release in the national NFIRS database. Because of the differences between NFIRS 5.0 and earlier versions, conversion is not exact. Consequently, it is advisable to use only data originally collected in NFIRS 5.0 for most analyses.

National estimates of specific fire problems are obtained by comparing the results from NFIRS 5.0 with the results of NFPA's annual sample-based fire department experience survey. This survey collects summary data only and lacks detail. NFPA's survey is sent to all local fire departments protecting population of 50,000 or more and a random sample, stratified by population, of the smaller departments. In most years, the sample size is sufficient to result in completed surveys returned from roughly 10% of the nation's fire departments. Survey results are used to estimate the total number of reported U.S. fires and associated losses by broad occupancy class and general incident type. Percentages of specific fire circumstances and causes from NFIRS 5.0 are applied to the projected totals from the NFPA survey. This approach is based on the national estimates methodology described by Hall and Harwood [2] with modifications to account for the fact that NFIRS data not collected originally according to NFIRS 5.0 rules and definitions has been omitted from the analysis. All of the estimates derived from NFIRS are based on coded data provided by the fire service.

In this analysis, the term "home" encompasses one- and two-family dwellings, including manufactured homes, and apartments. Apartments include tenements, flats, townhouses, and properties of similar configuration, regardless of ownership. The total number of structure fires in homes (NFIRS 5.0 property use codes 419 and 429), including one- and two-family dwellings (property use 419) and apartments (property use 429), was calculated by multiplying percentage of structure fires in these properties in NFIRS 5.0 by the projected total number of structure fires derived from the NFPA survey.

In NFIRS 5.0, a smoke alarm or fire detection device is considered present if it is in the area of the fire or if occupants were alerted by a detection device in a confined fire

NFIRS 5.0 introduced incident type codes (incident type 113-118) for certain confined structure fires, referred to as "confined fires," including cooking fires confined to the cooking vessel, chimney fires that were confined to the chimney, confined fuel burner fires, confined incinerator and compactor fires, and contained or confined trash fires without damage to the structure or contents in response to firefighter complaints about repeatedly documenting the same details for common minor incidents. Very limited causal and detection information is required about these incidents. The only required detection element for these confined fires asks if detection equipment alerted 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.

Building fires, fires in structures other than buildings, and fires in mobile property used as fixed structures not captured in these specific confined fire categories (incident type 110-129, except 113-118) are grouped into a category called "non-confined structure fires" although it is possible for other fire scenarios in the non-confined group to result in damage confined to the object of origin. Queries were done separately for confined and non-confined structure fires, and for one- and two-family dwellings, and apartments. Unknown data (except for unknown occupancy) was allocated proportionally among known data.

National fire statistics in this analysis are based on fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. In the tables, 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. Unknown data, with the exception of property use, were allocated proportionally.

3. CURRENT STATUS OF SMOKE ALARMS IN HOMES

From 1977 to 1984, the use of home smoke alarms skyrocketed [3,4,5]. Most of these smoke alarms were single-station, battery-operated, ionization-type devices. From 1984 through 1993, the growth in usage was much less rapid but still fairly steady [6]. Usage grew more slowly from 1993 through 2004 [7]. As of 2004, 96% of all homes surveyed by telephone, or 24 of every 25 homes, reported having at least one smoke alarm. These findings are based on telephone surveys. Data from the 2000 U.S. Census show that 2.4% of U.S homes had no telephones [8].

Ninety-four percent of the fire detection devices found in reported non-confined home structure fires in 2000-2004 were designed to be triggered by smoke. These fires accounted for 95% of the associated deaths. Three percent were combination units designed to operate in response to smoke or heat. Only 1% were definitely not designed to detect smoke but were designed only to detect heat. Because home smoke alarms are so prevalent, 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. For simplicity's sake, the term "smoke alarm" is used in this analysis to include all types of fire warning equipment used in homes, including those involving detection of smoke, heat or sprinkler water flow.

During the same period, almost half of the reported home fires occurred in properties in which smoke alarms were either not present or not working. Smoke alarms operated in roughly half (49%) of the reported home fires and in 34% of home fire deaths. Table 1 shows that fires with operating smoke alarms include 26% of fires in which smoke alarms alerted occupants in confined structure fires and 23% in which smoke alarms operated in non-confined fires.

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The category of "no operating smoke alarm" includes

a) non-confined fires in which no smoke alarms present at all;
b) non-confined fires in which smoke alarms were present but did not operate; and
c) confined fires in which a smoke alarm did not alert occupants.

Non-confined fires in which smoke alarms were present but failed to operate accounted for 7% of reported home fires and 22% of home fire deaths. Non-confined fires with no smoke alarms present accounted for 24% of the fires and 43% of the deaths. Confined fires in which smoke alarms did not alert occupants accounted for 15% of the reported home fires and less that 1% of the deaths.

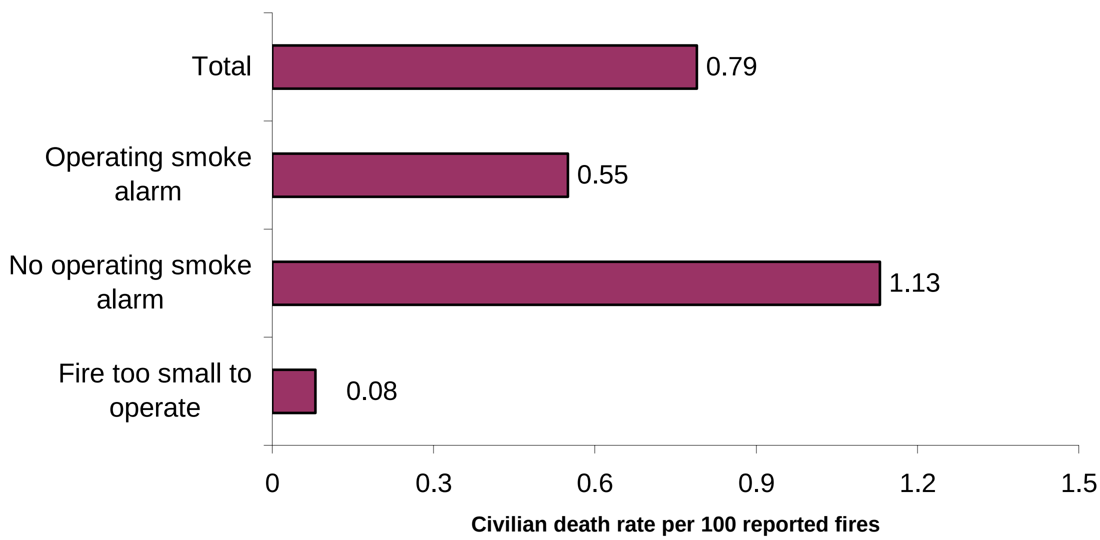

Figure 1. 2000-2004 Civilian Death Rate in Home Fires by Smoke Alarm Status

Figure 1 shows the death rate per 100 reported home structure fires by smoke alarm status. These rates, and the numbers of fires and deaths in each condition used to calculate these rates, are also shown in Table 1. In 2000-2004, the death rate was twice as high when no operating smoke alarm was present (1.13) compared to reported home fires with operating smoke alarms (0.55). In other words, a working smoke alarm in a reported home reduces the risk of death by half.

This is not the same as saying the chance of survival doubles. Assuming a potential for one death per fire, 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. The chances of surviving a reported home fire when working smoke alarms are present are 99.45% (100 minus 0.55) vs. 98.87% (100 minus 1.13) in home fires with no working smoke alarms. The first number is barely higher than the second and certainly not double the second number.

Table 1 showed that during the five-year period of 2000-2004, an estimated average of 375,200 home structure fires were reported per year. These fires caused an 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 working 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 no working smoke alarms 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.

Two-thirds of the smoke alarms in U.S. non-confined homes structure fires with this equipment were powered by batteries only. These fires resulted in 73% of the associated deaths. The 15% percent of incidents with hardwired smoke alarms with battery backup resulted in 10% of the deaths. The 14% of reported fires with smoke alarms that were hardwired only resulted in 12% of the deaths. Figure 2 shows the extent of flame damage and power source in non-confined home structure fires with working smoke alarms. 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. Hardwired smoke alarms are more likely to be interconnected and to sound throughout the home when one is activated.

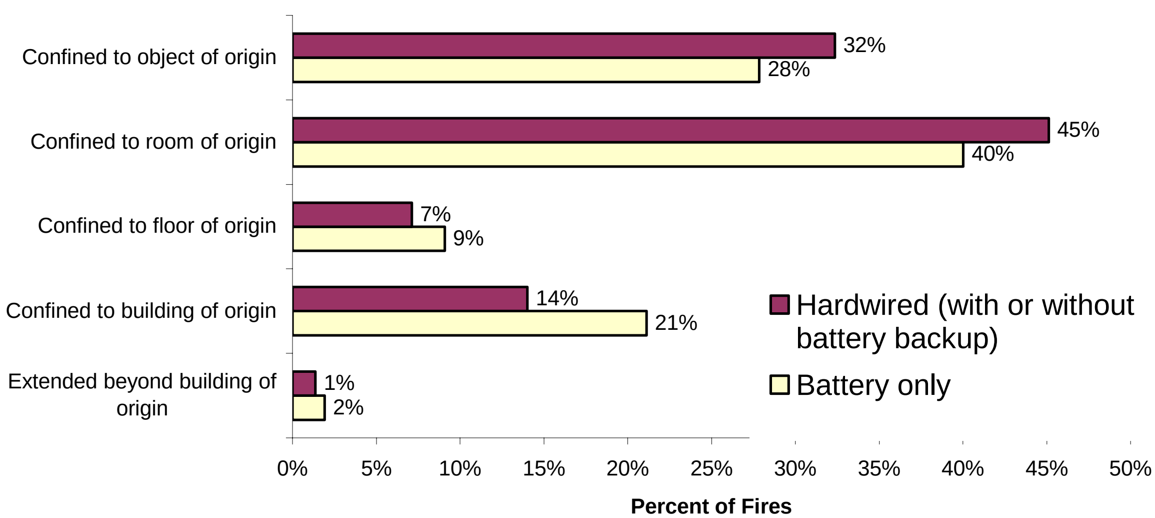

Figure 2. 2000 -2004 Extent of Flame Damage by Working Smoke Alarm Power Source

4. FACTORS LIMITING SMOKE ALARM EFFECTIVENESS

Smoke alarms only provide a warning. For the warning to be useful, it must be heard. Those hearing it must be able to take appropriate action. Escape may be impossible if alternate exits are blocked, if an individual is intimate with ignition, or if someone cannot or does not move quickly out of danger.

Tables 2-4 provide information about the victims of 2000-2004 non-confined fatal home fires (excluding fires that were considered too small to trigger the alarm) by smoke alarm status. Table 2 shows the victim's general location at the time of fatal injury. Sixty-one percent of the victims with operating smoke alarms were in the area of origin when injured compared to 53% with none present and 43% with smoke alarms that did not operate. People who are intimate with ignition may be severely injured before the fire has grown large enough to activate a smoke alarm.

Table 3 shows the victim's activity at time of fatal injury. Eight percent of the victims of fires in which smoke alarms operated were trying to fight the fire themselves when fatally injured, compared to only 3% when no smoke alarms were present and none in fires in which the smoke alarms did not operate.

Table 4 shows the human factors that contributed to the fatal injury. Physical disability was a factor contributing to the injury of 10% of the victims with operating smoke alarms but only 6% of the victims with non-operating smoke alarms and 5% with no smoke alarms at all. Possible mental disability was a factor contributing to the injury of 5% of the victims with operating smoke alarms but only 2% of the victims with non-operating smoke alarms and 3% with no smoke alarms at all. Multiple entries are allowed for human factors, meaning that for some victims, more than one of these factors may apply.

4.1 Many homes with smoke alarms do not have smoke alarms on every level
The National Smoke Detector Project found that 26% of the households surveyed had less than one alarm per floor.[9] Additional households may have had too few smoke alarms to protect widely separated sleeping areas on the same floor. Researchers estimated that 43% of the households had less than one *working* smoke alarm per floor.

A 2000 study of 691 homes in rural Iowa found that 86% had at least one smoke alarm. The study also 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.[10] Basements were the least likely level to have smoke alarms. Overall, only 22% of the homes were fully protected by smoke alarms according to these guidelines. Homes that were poorly maintained, damaged, or cluttered were less likely to have the full smoke alarm protection of working smoke alarms correctly installed on every level of the home.

4.2 Sound and waking effectiveness
Table 3 shows that 37% of the people who died in fires with working smoke alarms were sleeping when fatally injured. The CPSC studied the sound effectiveness of residential smoke alarms. [11] They noted that the smoke alarms that are currently available are effective at waking adults who are not under the influence of alcohol or drugs or who are not sleep deprived. However, the devices may not reliably wake older adults with hearing loss. The home layout

and smoke alarm locations can influence whether the warning will be heard; earlier warning is provided by interconnected smoke alarms.

A 2005 study by CPSC found that a closed lightweight door reduced the volume of a smoke alarm signal from another room by 10 to 20 dB. The signal was weakened by roughly 20 dB each level it traveled. The layout of the home also mattered. The authors concluded that single-station smoke alarms in homes with two or three floors may not be adequate to alert unimpaired adults in all parts of the home [12].

In her review of the literature on sleep and waking to fire alarms,[13] Dorothy Bruck concluded that louder signals are needed when significant background noise is present and that arousal thresholds vary significantly from individual to individual. Sleep deprived adults are less likely to wake to a smoke alarm, as are young children and people under the influence of alcohol, marijuana or sleep inducing medication. The higher frequency hearing loss that often accompanies aging reduces the probability that older adults will wake to a smoke alarm.

Bruck et al also studied the effectiveness of pre-recording of the mother's voice, a female actor's voice, a standard Australian smoke alarm with a high pitch signal of roughly 4000 Hz, and a lower-pitch (dominant tones of 500Hz, 1500 Hz, and 2500 Hz) temporal three (T-3) signal in waking sleeping children ages 6-10 [14]. The voice alarms and the T-3 lower pitch signal were more effective than the high-pitched, standard signal, suggesting that lower frequency may be the most important component in effectiveness.

In their study on the effects of alcohol on waking to fire alarm signals among young adults, Ball and Bruck found that a female voice and the T-3 lower pitch signal were both more effective than the high-pitched Australian standard alarm [15]. However, even a blood alcohol concentration of .05 significantly reduced the likelihood of waking to any of the auditory signals. With blood alcohol levels of .08, the waking was even less frequent, but the decrease was much less than was seen between the sober and the .05 BAC. Individual responses varied widely.

A Fire Protection Research Foundation study on optimizing the smoke alarm signal to reduce fire deaths in older adults played four different auditory signals of increasing volume to 42 older adults (ages 65-85) when they were in deep sleep.[16] The four signals included a high-frequency T-3 signal used in current U.S. smoke alarms, a mixed signal T-3, a male voice, and a 500 Hz tone in the T-3 pattern. Researchers found that these subjects woke to the mixed frequency T-3 signal at a lower volume than the other three signals. Researchers also assessed the abilities of individuals woken by a smoke alarm. Physical functioning showed a decrement of roughly 10-17% across the first five minutes after waking but no important effects were found on cognitive functioning.

5. NON-WORKING SMOKE ALARMS AND NUISANCE ALARMS

As noted earlier, 22% of home fire deaths resulted from the 7% of home fires in which smoke alarms were present but failed to operate. Table 5 shows that in 54% of the non-confined home structure fires and 75% of the home fire deaths in which smoke alarms were present but failed to operate, smoke alarm batteries were missing or had been disconnected. In 19% of these fires and

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7% of these deaths, batteries were dead or discharged. In 7% of the non-confined home fires and deaths with non-working smoke alarms, failures were due to hardwired power source problems.

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 [17]. 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.

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.

5.1 Nuisance activations by type of smoke alarm

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.

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 other similar villages.[18] Home area averaged roughly 1,000 square feet or less. 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. 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."

As part of their research into the performance of smoke alarms in today's homes, the National Institute of Standards and Technology (NIST) conducted tests on a variety of scenarios associated with nuisance alarms. In these tests, they found that ionization smoke alarms had a tendency to activate in response to aerosols produced during some normal cooking. They recommended that such smoke alarms be placed as far as possible from cooking equipment but still in the protected area [19].

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5.2 Type of smoke alarm and battery by operational status

A U.K. study examined the percentage of working smoke alarms by type installed in local authority inner city housing [20]. Eleven to twelve percent of the smoke alarms found in the homes at the beginning of the study were working. Five different types of smoke alarms were installed as part of this study. When the households were visited 15 months later, 93% still had smoke alarms installed. Fifty-four percent had a working smoke alarm. The alarm installed for the study was working in 51% of the homes. In homes with at least one smoker, 38% of the photoelectric (called optical in the study) alarms and 48% of the ionization alarms were working. Based only on the smoke alarms installed as part of this study, 15 months after installation,

- 56% of the ionization alarms with zinc batteries and no pause buttons operated;
- 47% of the ionization alarms with zinc batteries and pause buttons operated;
- 66% of the ionization alarms with lithium batteries and pause buttons operated;
- 56% of the photoelectric alarms with lithium batteries operated; and
- 36% of the photoelectric alarms with zinc batteries operated.

The batteries were dead in 6% of the photoelectric alarms with zinc batteries. This was a larger share than was seen in any other type. Reports of low battery signals and battery changing among smoke alarms with zinc batteries were higher for alarms with photoelectric sensors (19% low battery signals and 26% battery changing) and those with ionization sensors and pause buttons (22% low battery signal and 25% battery changing), than they were for zinc battery ionization alarms without pause buttons (8% low battery signal and 13% battery changing). In a multivariate analysis that controlled for the type of battery, sensor and presence of a smoker, pause buttons were found to have a negative effect.

5.3 Smoke alarm activation to developing hazard

Some of the nuisance activations, particularly from cooking, fall into a gray area. A sounding smoke alarm may remind a cook who has left the kitchen area of food on the stove requiring immediate attention. While not yet a fire, the potential exists if corrective action is not taken. If such action is taken, the situation can often be quickly resolved without fire department involvement. Only 12% of the cooking fires experienced by people interviewed in the English Housing Survey were reported to the fire department. This was the lowest share of any of the fire causes studied [21].

6. THE IONIZATION VS. PHOTOELECTRIC DEBATE

The National Institute of Standards and Technology (NIST) conducted tests on different types of smoke and heat alarms under conditions found in today's households. These tests were designed to assess the performance of the different technologies and the effectiveness of current code requirements under different conditions, particularly those found in today's fatal fires. Although fire growth is faster today than in the past, both photoelectric and ionization smoke alarms provided warning early enough to provide the necessary escape time in most scenarios with ionization reacting more quickly to flaming fires and photoelectric operating faster to smoldering fires.[22] However, some concerns have been separately raised about whether ionization smoke alarms actually do operate early enough in smoldering fires and whether photoelectric do operate early enough in flaming fires. A special task group has been formed to assist the technical

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committee for *NFPA 72®, National Fire Alarm Code®*, in evaluating the need for code changes addressing the type of sensor used in smoke alarms.

7. REMAINING QUESTIONS

Unfortunately, NFIRS does not directly identify fires that began with a smoldering fire or provide any information on how long a fire smoldered. It does not distinguish between photoelectric and ionization smoke alarms, nor, in NFIRS 5.0, is the proximity of the smoke alarm to the area of origin captured. Details on the location of the smoke alarm in relation to occupants and whether the occupants heard it are also lacking. (Information is captured on whether the smoke alarm alerted occupants, but a home environment may have multiple occupants and people may be alerted before a smoke alarm sounds.) NFIRS does not collect data on whether smoke alarms were present on every level. Information from actual fires is not available on when in the fire sequence smoke alarms operated or when in the sequence conditions became lethal. Nor is adequate information available regarding the growth of the fire in relation to available exits, or whether the residents had developed and practiced an escape plan. The absence of this information makes it more difficult to estimate the likely impact of any specific change.

. 8. CONCLUSIONS

When working smoke alarms are present, the death rate per 100 reported home fires is half that of properties without this protection.

In 2000-2004, an average of 1,020 people per year (34% of the home structure fire fatalities) died in homes with working smoke alarms. The percentage of fires spreading beyond the room of origin is lower in fires with hardwired smoke alarms than battery-operated devices. Because battery-operated devices are less likely to be interconnected, an activated battery-operated smoke alarm may be further from the area of origin and/or occupants, resulting in delay in automatic detection and/or notification. Victims of fatal fires with working smoke alarms were more likely to have been in the area of fire origin (61%) and possibly severely injured very early in the fire development, to have had a physical or mental disability (10% and 5%, respectively), or to have tried to fight the fire themselves (8%) than are victims of fires without working smoking alarms.

Special studies have found that many homes with smoke alarms do not have alarms on every level. Ambient noise can diminish a smoke alarm's waking effectiveness, as can closed doors. The high-frequency hearing loss associated with aging can reduce the probability that older adults will be roused by a typical smoke alarm. The typical signal is also less effective at waking children. Drugs, alcohol and medication can reduce the likelihood that a sleeping individual will be roused by a conventional smoke alarm.

Some portion of the 34% of fire deaths resulting from fires with working smoke alarms may be reduced by changes in smoke alarm design and placement practices. Sensor changes may affect when a fire is discovered, signal changes may increase the likelihood that the alarm will be heard, and requirements for smoke alarms in bedrooms and interconnectivity increases the likelihood that occupants will be alerted to fire in another part of the home. None of these

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changes will affect the availability of exits or the ability of people to physically remove themselves from danger.

Twenty-two percent of the home fire deaths resulted from fires in which smoke alarms were present but failed to operate. Although nuisance activations, the leading reason for disabled smoke alarms, are produced by both ionization and photoelectric smoke alarms, studies suggest nuisance alarms are more common with ionization devices. In many cases, the smoke alarm was placed too close to cooking equipment or other potential alarm trigger.

Forty-three percent of home fire deaths in 2000-2004 occurred in properties with no smoke alarms at all. At a recent meeting on fire and fall prevention, attendees expressed concern that more stringent smoke alarm requirements and accompanying costs and liability issues could make it more difficult for smoke alarm installation programs to get *any* protection into high-risk homes that currently have none [23].

Smoke alarms are effective. Numerous studies have suggested areas for improvement. While it is often necessary to focus on only one or two aspects at a time, it is important to remember that a home fire is a complex environment. In addition to the characteristics of the smoke alarm, the fire itself, the occupants' location, condition and behavior, and exit availability all play a role in determining the outcome.

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Table 1.
Home Structure Fires by Smoke Alarm Performance
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%)
Subtotal - Operating smoke alarm	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%)
Subtotal - No operating smoke alarm	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%)

Table 2.
Victim's Location at Time of Fatal Injury by Smoke Alarm Status
2000-2004 Annual Averages

Victim's Location	Present and Operated			Present but Did Not Operate			None Present			*Row Total*	
In area of origin	620	(61%)	*(40%)*	280	(43%)	*(18%)*	670	(53%)	*(42%)*	1,580	*(100%)*
In building, but not in area of origin	390	(38%)	*(29%)*	370	(56%)	*(27%)*	590	(47%)	*(44%)*	1,360	*(100%)*
Column total	1,020	(100%)	*(35%)*	660	(100%)	*(22%)*	1,270	(100%)	*(43%)*	2,940	*(100%)*

Table 3.
Activity at Time of Fatal Injury by Smoke Alarm by Smoke Alarm Status
2000-2004 Annual Averages

Activity	**Present and Operated**			**Present but Did Not Operate**			**None Present**			***Row Total***	
Sleeping	380	(37%)	*(31%)*	320	(49%)	*(27%)*	510	(40%)	*(42%)*	1,210	*(100%)*
Escaping	280	(27%)	*(31%)*	180	(27%)	*(20%)*	440	(35%)	*(49%)*	900	*(100%)*
Unable to act	130	(12%)	*(39%)*	80	(12%)	*(24%)*	120	(10%)	*(37%)*	320	*(100%)*
Fire control	80	(8%)	*(70%)*	0	(0%)	*(0%)*	30	(3%)	*(30%)*	110	*(100%)*
Irrational act	60	(5%)	*(44%)*	30	(4%)	*(21%)*	40	(4%)	*(35%)*	130	*(100%)*
Unclassified activity	40	(4%)	*(35%)*	30	(5%)	*(27%)*	40	(3%)	*(37%)*	110	*(100%)*
Rescue attempt	30	(3%)	*(30%)*	20	(3%)	*(20%)*	50	(4%)	*(50%)*	100	*(100%)*
Returning to vicinity of fire before control	30	(3%)	*(49%)*	10	(1%)	*(13%)*	30	(2%)	*(38%)*	70	*(100%)*
Total	1,020	(100%)	*(35%)*	660	(100%)	*(22%)*	1,270	(100%)	*(43%)*	2,940	*(100%)*

Table 4.
Home Fire Deaths by Human Factor Contributing to Injury* and Smoke Alarm Status
2000-2004 Annual Averages

Human Factor*	**Present and Operated**			**Present but Did Not Operate**			**None Present**			***Row Total***	
Asleep	260	(25%)	*(28%)*	290	(44%)	*(32%)*	350	(28%)	*(39%)*	900	*(100%)*
Possibly impaired by alcohol	120	(12%)	*(40%)*	60	(10%)	*(21%)*	110	(9%)	*(39%)*	300	*(100%)*
Physically disabled	110	(10%)	*(52%)*	40	(6%)	*(19%)*	60	(5%)	*(29%)*	200	*(100%)*
Possibly mentally disabled	50	(5%)	*(49%)*	10	(2%)	*(12%)*	40	(3%)	*(38%)*	100	*(100%)*
Possibly impaired by other drug or chemical	40	(4%)	*(44%)*	10	(2%)	*(18%)*	30	(3%)	*(38%)*	80	*(100%)*
Unattended or unsupervised person	30	(3%)	*(24%)*	60	(9%)	*(47%)*	40	(3%)	*(29%)*	130	*(100%)*
Unconscious	20	(2%)	*(37%)*	10	(2%)	*(18%)*	30	(2%)	*(45%)*	60	*(100%)*
Physically restrained	0	(0%)	*(30%)*	0	(0%)	*(25%)*	0	(0%)	*(44%)*	10	*(100%)*
None	230	(22%)	*(40%)*	100	(15%)	*(18%)*	250	(20%)	*(43%)*	580	*(100%)*
Not reported	320	(32%)	*(33%)*	160	(25%)	*(17%)*	490	(38%)	*(50%)*	970	*(100%)*
Total	1,020	(100%)	*(35%)*	660	(100%)	*(22%)*	1,270	(100%)	*(43%)*	2,940	*(100%)*

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Table 5.
Reason for Smoke Alarm Failure in Non-Confined Home Structure Fires
2000-2004 Annual Averages

Reason for Failure	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Missing or disconnected battery	14,300	(54%)	500	(75%)	1,640	(69%)	$380	(55%)
Dead or discharged battery	5,100	(19%)	50	(7%)	360	(15%)	$110	(16%)
Unclassified reason for failure	2,600	(10%)	20	(3%)	110	(5%)	$80	(11%)
Hardwired power failure, shut-off or disconnect	1,800	(7%)	40	(7%)	130	(5%)	$70	(10%)
Lack of cleaning	900	(4%)	30	(4%)	70	(3%)	$20	(3%)
Defective unit	800	(3%)	10	(1%)	40	(2%)	$10	(2%)
Improper installation or placement	800	(3%)	20	(3%)	40	(2%)	$20	(3%)
Total	26,300	(100%)	660	(100%)	2,370	(100%)	$700	(100%)

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