Smoke Alarm Presence and Performance in U.S. Home Fires

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Abstract

The vast majority of U.S. homes have smoke alarms. However, in 2003-2006, smoke alarms were present and sounded in only 47% of reported home fires and 37% of home fire deaths. Smoke alarms were present but failed to operate in 9% of the reported fires and 23% of the deaths. When the fire was considered large enough to operate the alarm, 91% of hardwired alarms operated compared to only 75% of those powered by batteries only.

In this paper, findings from the Consumer Product Safety Commission's 2004-2005 Residential Fire Survey provide a contextual framework for the 2003-2006 national estimates of smoke alarm performance in home fires reported to local fire departments. Circumstances of the fire, the detection equipment, and occupant characteristics must be considered when evaluating smoke alarm performance. Compared to deaths resulting from fires in which no smoke alarm operated or was present, victims of fatal fires with working smoke alarms were:

- More likely to have been in the room or area of origin and even more likely to have been in the area of origin and involved in ignition;
- Less likely to have been sleeping when fatally injured;
- More likely to have been fighting the fire themselves or have been unable to act; and
- More likely to have been at least 65 years old,

Introduction

The fire protection community is continually working to reduce the losses associated with fire by improving technology and strengthening fire codes. To determine the benefit of a proposed change, it is necessary to have an accurate understanding of the equipment currently in place and how well it performs in real-life situations.

Many factors influence the outcome of a fire. These include occupant characteristics, the nature and location of the fire, the type of fire protection present, and the extent of coverage. Fire detection's greatest success is not warning of a raging blaze. Rather, smoke alarms are most useful when they provide a warning of a very small fire or alert occupants to a situation, such as a burner left on or water that has boiled away, that could turn into a fire if corrective action is not promptly taken. Any fair examination of smoke alarm performance must include fires that stayed small.

No statistics are available on the frequency in which smoke alarms alerted occupants to a situation that would likely have turned into a fire without the smoke alarm's warning. However, we know that the vast majority of household fires are handled without fire department assistance.

This paper will provide an overview of smoke alarm coverage in the U.S. population and how smoke alarms perform in fires handled without the fire department and in those to which fire departments responded. It will also compare the characteristics and circumstances of fire deaths resulting from fires in which smoke alarms operated, were present but failed to operate, and were not present at all. The death rate per 1000 reported fires for different combinations of fire protection is also discussed. More detailed information is available in the author's 2009 report, *Smoke Alarms in U.S. Home Fires*.

Smoke Alarms in the General Population

In 2009, the U.S. Consumer Product Safety Commission (CPSC) released the findings of its 2004-2005 survey of households who experienced both reported and unreported fires.¹ They estimate that an average of 7.4 million home fires occur per year. Ninety-seven percent of these fires were not attended by the fire department (unreported). The CPSC also compared households that had fires with those that did not. Because the number of households that experienced fires is such a small percentage of all households, percentages for all households and households without fires are generally within 0.1 percentage points of each other.

No smoke alarms at all were found in 7% of the households that had fires compared to 3% of households with no fires. Table 1 shows that 84% of households without fires had smoke alarms on every floor. This was true for 82% of households with fires. Thirty-one percent households of without fires had smoke alarms in all bedrooms, but this was true for only 22% of households that had fires. Nineteen percent of households without fires had interconnected smoke alarms compared to 13% of the fire households. Seventy percent of all households with smoke alarms had alarms only powered by batteries.

The CPSC also identified demographic differences associated with the presence of smoke alarms in all bedrooms. When someone in the home was at least 65 years old, 21% of the households had smoke alarms in all bedrooms. The percentage increased to 33% when all of the occupants were under 65. Thirty-five percent of households with someone under 18 had this level of protection compared to 27% of homes in which everyone was at least 18. Twenty-six percent of the homes with at least one smoker had smoke alarms in all bedrooms. This increased to 33% when no smokers were present. Only 24% of non-urban dwellers had smoke alarms in all bedrooms compared to 32% of urban households.

In the 2007 *American Housing Survey* (AHS), 67% of the respondents who reported having smoke alarms said their alarms were powered by batteries only, 24% said their alarms were powered by electricity and batteries, and 9% by electricity only. For many years, NFPA 72, *National Fire Alarm Code*, has required smoke alarms in new construction to be hardwired with

¹ Michael A. Greene and Craig Andres. 2004-2005 National Sample Survey of Unreported Residential Fires. U.S. Consumer Product Safety Commission, July 2009, pp. 73-91.

battery backup. Yet the AHS found that in 37% of homes less than five years old that had working smoke alarms, the smoke alarms were powered by battery only.²

Smoke alarm performance in unreported fires

The CPSC study also provided details on how fires were discovered in fires that were not attended by the fire service (unreported fires).³ Even when smoke alarms sounded, people often see, hear or smell the fire before the alarm sounds. In some cases, a smoke alarm is heard at about the same time one of the other cues is noticed. The statistics about smoke alarm performance in unreported fires shown in Tables 2 and 3 exclude fires in which no one was home. Figure 1 provides a framework for discussing the data in these tables. When calculating performance or effectiveness, percentages can be based on all fires with someone home, fires in which someone was home and at least one smoke alarm was present, fires with these conditions in which enough smoke reached the alarm, in which the alarm actually sounded, or on fires in which the alarm actually alerted occupants. This figure illustrates the relationships only and is not to scale.

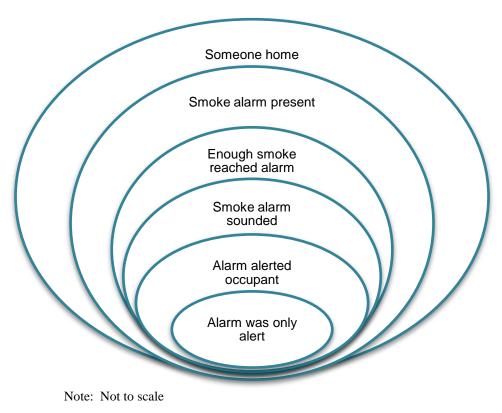


Figure 1. Measuring Smoke Alarm Performance

² U.S. Census Bureau, Current Housing Reports, Series H150/07, American Housing Survey for the United States, 2007, U.S. Government Printing Office, Washington, DC. 20401, 2008. Table 2-4.
 ³ Michael A. Greene and Craig Andres. 2004-2005 National Sample Survey of Unreported Residential Fires. U.S. Consumer Product Safety

Commission, July 2009, pp. 150-180

Table 2 shows that when smoke alarms were present and someone was home, the alarms sounded in 35% of the unreported fires. In 39% of the fires in which the devices sounded, the alarms alerted the occupants. This includes incidents in which other cues, such as the smell of smoke, were noticed at the same time the alarm was heard. In 32% of the fires with sounding smoke alarms, the smoke alarm provided the only alert to the fire prior to the fire's discovery. CPSC's statistics about fire discovery were based on a shorter recall period than were their estimates of smoke alarm presence. Discovery statistics were based on fires, not households. Households that had more than one fire may be less likely to have smoke alarms.

The second row in Table 2 shows that when at least one smoke alarm was present but alarms were not present on all floors, smoke alarms operated in only 9% of the fires. The percentage increased to 38% when alarms were present on all floors, 37% when present in all bedrooms, and 53% when smoke alarms were interconnected. When smoke alarms did not sound in unreported fires, it was usually because not enough smoke reached the smoke alarm.

The last row in Table 2 shows that, in total, when smoke alarms and occupants were present, the alarms alerted occupants to 14% of the fires. This encompasses the fires in which the smoke alarms did not operate for any reason, including incidents in which not enough smoke reached the alarm to activate it. When smoke alarms were interconnected, they alerted the occupants in 26% of the fires. When the alarms were not interconnected, smoke alarms alerted occupants in only 12% of the fires. When smoke alarms were present in the home but not present on all floors, they alerted occupants in only 4% of the fires.

Limiting the scope to fires in which someone was home, smoke alarms were present, and enough smoke was said to reach the alarm, smoke alarms sounded in 83% of the fires.

Seventy percent of the unreported fires in CPSC's survey started in the kitchen, 7% in the living room, and 7% started in the bedroom. Table 3 shows that smoke alarms sounded in 41% of the kitchen fires in homes in which smoke alarms were present, in 25% of the living room fires, and 22% of the bedroom fires. When smoke alarms sounded, they alerted someone in 40% of the kitchen fires, only 1% of the living room fires, and in 69% of the bedroom fires. When smoke alarms sounded, they provided the *only* alert in 33% of the kitchen fires, only 1% of the living room fires.

Table 3 also shows that smoke alarms were more likely to sound in fires involving stoves or ranges (47%) than lighting or wiring (8%). Smoke alarms sounded in 30% of the fires started by lighters, cigarettes, or matches; 23% of fires started by candles; and 23% of fires started by heating or cooling equipment. When smoke alarms sounded, they provided the only alert in 81% of the stove or range fires, 3% of the heating or cooling fires, 32% of the candle fires, and 29% of the lighter, cigarette, or match fires.

Smoke Alarms in Reported Fires

Methodology

Estimates regarding the presence and operational status of smoke alarms in home fires reported to U.S. fire departments during 2003-2006 were derived from the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System⁴ (NFIRS 5.0) and NFPA's annual fire department survey. The analysis used the basic approach described by Hall and Harwood in their 1989 article in *Fire Technology⁵* with modifications to accommodate the changes introduced in NFIRS 5.0. Homes include one-and two-family homes, manufactured homes, and apartments, regardless of ownership type. The terminology used to describe the detection equipment and circumstances found in reported fires is based on the NFIRS 5.0 coding choices used by fire officers to complete their incident reports.

NFIRS 5.0 includes a category of structure fires collectively referred to as "confined fires," identified by incident type 113-118. These include cooking fires confined to the vessel of origin, confined chimney or flue fires, trash fires that did not extend to other contents or the structure, confined fuel burner or boiler fires, confined commercial compactor fires, and confined incinerator fires. For these incidents, the only detection question required in NFIRS 5.0 asks simply if the detection equipment alerted or did not alert occupants. Structure fires without these incident types (incident types 110-123, excluding 113-118) are collectively referred to as "non-confined fires." Confined and non-confined fires were analyzed separately.

Property damage has not been adjusted for inflation. Smoke alarm presence or absence was reported in 69% of non-confined fires and 2% of confined fires. Fires with unknown or unreported data were allocated proportionally in calculations of national estimates. Sums may not equal totals due to rounding errors.

Presence and operation in reported fires

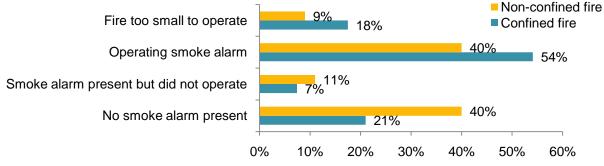
Smoke alarms or system-based smoke detectors were the fire alarm type reported in 92% of the home fires in which the fire alarm type was identified. An additional 5% used a combination of smoke and heat detection. In 2%, more than one type of detection equipment was present. Because home smoke alarms are so prevalent, the term "smoke alarm" is used as an all encompassing phrase throughout this analysis when describing early fire warning devices or systems in the home.

Table 4 shows that in 2003-2006, smoke alarms were present and operated in almost half (47%) of all reported fires, including 84,200 non-confined fires and 92,200 confined fires. Figure 2 shows that smoke alarms were more likely to be present and more likely to operate in confined fires than in non-confined fires.

⁴ U.S. Fire Administration National Fire Data Center. *National Fire Incident Reporting System 5.0 Complete Reference Guide*. January 2008, online at <u>http://www.nfirs.fema.gov/documentation/reference/</u>.

⁵ John R. Hall, Jr., and Beatrice Harwood, "The National Estimates Approach to U.S. Fire Statistics," *Fire Technology*, Volume 25, Number 2, May 1989, pp.99-113.

Figure 2. Confined and Non-Confined Reported Home Structure Fires By Smoke Alarm Performance: 2003-2006



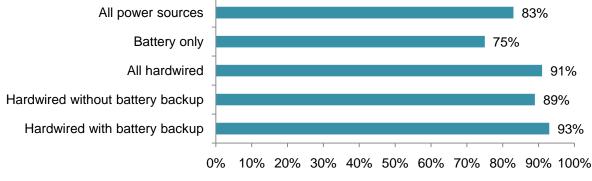
Source: NFIRS 5.0 and NFPA survey.

In 2003-2006, 41% of the reported home fires occurred in properties with either no smoke alarms at all or no working smoke alarms. Almost two-thirds of home fire deaths resulted from fires without the protection of a working smoke alarm. No smoke alarms were present at all in 40% of the home fire deaths. Alarms were present but did not operate in 23% of the fatalities. Operating smoke alarms were present in 37% of the home fire deaths. In 1% of the deaths, the fire was too small to trigger the smoke alarm.

When smoke alarms were present, they were battery-powered in 56% of the reported home fires and two-thirds (69%) of the home fire deaths. In 50% of the confined home fires and 63% of the non-confined home fires with smoke alarms, the alarms were powered by batteries only. Hardwired smoke alarms were found in 39% of the reported home fires and 25% of the fatal fire injuries that occurred when smoke alarms were present. Hardwired alarms include those with and without battery backup.

Figure 3 shows that when smoke alarms were present and the fire was large enough to trigger the device, smoke alarm, in total, operated in 83% of the fires. Battery-powered smoke alarms had the smallest percentage operating (75%), and hardwired alarms with battery backup (93%) the highest. For all power sources, higher percentages of smoke alarms operated in confined fires than in non-confined fires.

Figure 3. Smoke Alarm Operation in Reported Home Fires Considered Large Enough to Activate Alarm by Power Source: 2003-2006



Source: NFIRS 5.0 and NFPA survey.

When smoke alarms did not sound in non-confined fires considered large enough to activate them, three-quarters (77%) of the smoke alarms used batteries only as a power source. Figure 4 shows power source issues were the leading reason smoke alarms failed to operate in non-confined home fires. In 62% of the fires in which battery-powered smoke alarms failed to sound, the batteries were missing or disconnected. Dead or discharged batteries accounted for 26% of the battery-powered smoke alarm swith no battery backup failed to operate, the power had failed, been shut off, or disconnected in 62% of the fires. This scenario can include both deliberate disabling of the smoke alarm swith battery backup failed to operate, 31% of the failures were due to hardwired power failure, shut off, or disconnect; 23% were due to missing or disconnected batteries; and 3% were due to dead or discharged batteries.

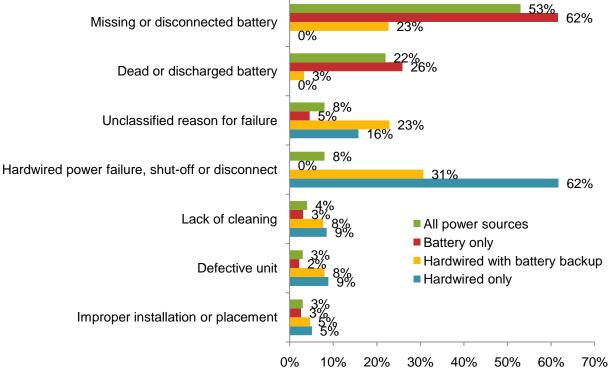


Figure 4. Reason Smoke Alarm Failed to Operate In Reported Non-Confined Home Structure Fires: 2003-2006

Source: NFIRS 5.0 and NFPA survey.

It appears that the fire service had a harder time identifying causes of failures in hardwired smoke alarms. As noted in the methodology section, unknown data were allocated proportionally in the statistics presented. The reason for failure was originally undetermined for half of all hardwired alarms, but only one-quarter of the battery-powered alarms. The percentage of unclassified reasons was three to five times as high for hardwired smoke alarms as for battery-powered alarms.

Home fire deaths and smoke alarm performance

Figure 5 shows that in 2003-2006, the death rate per 1,000 reported home structure fires was twice as high when no working smoke alarm was present (that is, either no smoke alarm was present or an alarm was present but did not operate) compared to the rate with working smoke alarms (11.6 vs. 5.9). In other words, having a working smoke alarm cuts the chances of dying in a reported fire in half.

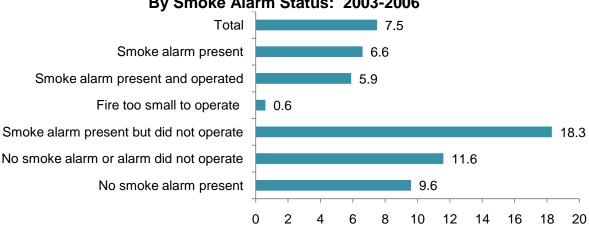


Figure 5. Death Rate per 1,000 Reported Home Structure Fires By Smoke Alarm Status: 2003-2006

To increase the benefit of smoke alarms, it is necessary to understand the circumstances and demographics of the 37% of victims killed by home fires in which smoke alarms operated. Table 4 showed that an average of 10 people died in confined fires per year and another 30 deaths per year resulted from fires that were too small to activate the alarm. These deaths are not included in the discussion that follows.

Table 5 shows that in 79% of the non-confined home fires with operating smoke alarms, the occupants were alerted and responded. Sixty-nine percent of the deaths resulted from these incidents. The 3% of non-confined home fires in which smoke alarms sounded and occupants were alerted but failed to respond accounted for 21% of the deaths caused by home fires with sounding smoke alarms. It is unclear whether the smoke alarm provided the first notification of the fire, whether there was a delay in alerting, or whether some occupants responded while others did not. Also, another 9% of the home fire deaths resulted from 3% of fires in which smoke alarms operated but did not alert the occupants. It is possible that the individuals were intimately involved with ignition and already knew about the fire or that the individuals never heard the alarm.

Table 6 shows that in fatal fires in which smoke alarms operated, almost half (47%) of the victims were involved in ignition and in the area of origin at the time of the incident. An additional 16% of the victims with operating smoke alarms were in the area of origin but not involved. Only 30% of the victims in which smoke alarms were present but did not operate, and 35% in which no smoke alarms were present, were in the area of origin and involved in ignition. Only 38% of the victims of fires with operating smoke alarms were outside the area of origin when the fire began. Fifty-six percent of the victims of fires in which smoke alarms were present.

Source: NFIRS 5.0 and NFPA survey.

but failed to operate, and 49% of the victims with no smoke alarms at all were outside the area of origin.

According to U.S. Census data, only 12% of the resident population was at least 65 years of age in 2003-2006. Although older adults face the highest risk of dying in fires, regardless of smoke alarm performance, the percentage of victims who were 65 or older was higher in fatal fires with operating smoke alarms than in fires with no working alarms. Figure 6 shows that 34% of the victims of fatal home fires with working smoke alarms were 65 years of age or older, compared to only 21% of the victims in fires in which the alarms did not operate and 25% in which no smoke alarms were present.

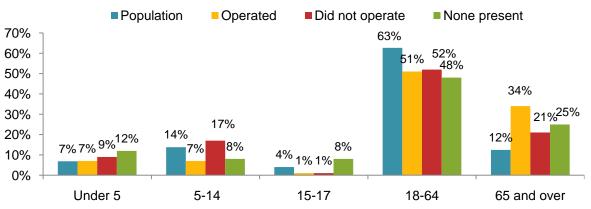


Figure 6. Fatal Home Fire Victims by Age and Smoke Alarm Status, 2003-2006

Source: NFIRS 5.0 and NFPA survey and U.S Census data.

Compared to victims of fires in which no smoke alarms were present or in which the y were present and failed to operate, when smoke alarms were present and operating, the victims were more likely to be engaged in fire control (6%) or unable to take action to save themselves (14%) and less likely to be sleeping (30%). Table 7 shows that when no alarms were present, only 2% of the victims were fighting the fire, 8% were unable to act, and 41% were sleeping. When smoke alarms were present but did not operate, 3% of the victims were trying to fight the fire, 8% were unable to act, and 45% were sleeping.

Human factors that contributed to the fatal fire injury are discussed in more detail in the full report. Physical disability contributed to the fatal fire injury in 17% of the deaths resulting from fires in which smoke alarms operated. Such a disability was a factor in only 10% of the deaths when no smoke alarms were present and 9% of the fatalities when smoke alarms were present but failed to operate. When physical disability was a factor contributing to the fatal injury, smoke alarms operated in fires associated with 54% of the deaths.⁶

Table 8 shows the leading items first ignited in non-confined home fire deaths by smoke alarm status. The percentage of deaths resulting from fires starting with items likely to be very close to the victims, such as mattresses or bedding, and clothing, was higher when smoke alarms operated than when no alarms were present.

⁶ Marty Ahrens. *Physical Disability as a Factor in Home fire Deaths,* Quincy, MA: NFPA, 2009, p. 5.

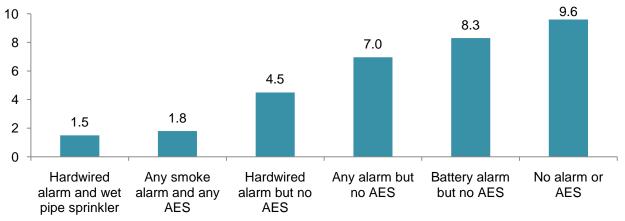
During 2002-2005 two-thirds (66%) of the victims of home fires in which smoking materials ignited upholstered furniture and 55% of the victims of all home fires that began with upholstered furniture, were in the area of fire origin when fatally injured.⁷ During the same period, 86% of the victims of home mattress and bedding fires started by smoking materials and 75% of all victims of home fires beginning with mattresses and bedding were in the area of origin.⁸ Victims who are very close to where the fire started will have less time to escape and may be injured before fire protection can operate.

The death rate per 100 reported non-confined home fires for these items by smoke alarm status is also shown in Table 8. While the death rates for some items, particularly cooking materials and rubbish, would be much lower if confined fires were included,⁹ some points stand out. When upholstered furniture was the item first ignited, the death rate was 7.6 per 100 non-confined fires when smoke alarms operated and 9.1 when no smoke alarms were present at all and 12.8 per 100 fires when smoke alarms were present but failed to operate.

Increasing levels of fire protection

CPSC's *Residential Fire Survey* showed that interconnected smoke alarms were more likely to alert occupants to an unreported fire than were smoke alarms that were not interconnected. NFIRS does not indicate whether smoke alarms are interconnected or provide data on extent of coverage. It does provide information about power source. As mentioned earlier, in 56% of the reported home fires in 2003-2006 and 69% of the associated deaths, smoke alarms were powered by batteries only. Figure 7 shows that the death rate per 1,000 reported fires steadily declines with greater levels of fire protection. The death rate is lowest in homes with wet pipe sprinklers and hardwired smoke alarms. These rates are based on presence only. Operation was not considered.

Figure 7. Fire Death Rate per 1,000 Reported Home Structure Fires by Presence of Smoke Alarms and Automatic Extinguishing Systems (AES) 2003-2006



Source: NFIRS 5.0 and NFPA survey

⁷ Marty Ahrens. *Home Fires that Began with Upholstered Furniture*, Quincy, MA: NFPA, 2008, p. 12.

⁸ Marty Ahrens. Home Fires that Began with Mattresses and Bedding, Quincy, MA: NFPA, 2008, p. 12.

⁹ See discussion of confined fires on page 6.

Compared to reported home fires with no smoke alarms or automatic extinguishing systems/equipment (AES) at all, the death rate per 1,000 reported fires is

- 14% lower when battery-powered smoke alarms are present but AES are not;
- 27% lower when smoke alarms with any power source are present but AES are not;
- 53% lower when hardwired smoke alarms are present but AES are not;
- 81% lower when smoke alarms with any power source and any AES are present; and
- 84% lower when hardwired smoke alarms and wet pipe sprinklers are present.

Discussion

When smoke alarms operate in fires reported to the fire department, the death rate per 1,000 fires is half the rate of fires that lack this protection, either because smoke alarms failed to operate or because none were present. Even so, 37% of all fire deaths resulted from fires in which smoke alarms operated. When evaluating the effectiveness of existing technologies and codes or considering the benefits of possible refinements, it is necessary to have an accurate understanding of how existing technology is actually used. Often the technology that is in place lags considerably behind the code requirements. Although hardwired smoke alarms have been required in new construction for decades, more than one-third of the homes that were under five years old in the AHS had smoke alarms powered by batteries only. This suggests that this requirement is not universally in place or enforced.

The 2007 edition of NFPA 72 required interconnected smoke alarms in all homes, including existing ones, and the installation of smoke alarms in all bedrooms. Although CPSC's 2004-2005 was conducted before these provisions took effect, with only 19% of all households having interconnected smoke alarms at that time, and the two-thirds of households in the 2007 AHS with smoke alarms powered by batteries only, it is clear that most homes do not yet have the benefit of interconnected smoke alarms. CPSC found that interconnected smoke alarms were more likely to sound and to alert occupants in unreported fires.

Figure 3 showed that hardwired smoke alarms (with or without battery backup) operated in 91% of fires considered large enough to activate the alarm while smoke alarms powered by batteries only operated in just 75% of the fires. While hardwired smoke alarms are not necessarily interconnected, hardwired alarms are much more likely to be interconnected than are those powered only by batteries. To be effective in providing a warning, the smoke alarm's signal must be noticed. Only 84% of the homes in CPSC's survey had smoke alarms on every floor.

In a 2005 study, Arthur Lee wrote 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. Closed doors were also found to reduce the volume of the signal.¹⁰ Dorothy Bruck and her colleagues found

¹⁰ Arthur Lee. *The Audibility of Smoke Alarms in Residential Homes*, Bethesda, MD: U.S. Consumer Product Safety Commission, September 2005, revised January 2007, online at <u>http://www.cpsc.gov/LIBRARY/FOIA/FOIA05/os/audibility.pdf</u>.

that several factors influence the effectiveness of smoke alarms in waking people. These include the nature of the smoke alarm signal, individual arousal thresholds, the presence of background noise, sleep deprivation, hearing loss, childhood or youth, alcohol, medication and drugs^{11,12,13},^{14,},^{15 16} CPSC's residential survey found that a number of high-risk groups, including older adults and households with smokers were somewhat less likely than average to have smoke alarms in all bedrooms. Households that had fires had less smoke alarm protection than other households. Even so, the vast majority of high-risk households and households with fires did have at least some smoke alarm protection.

Several differences were seen when smoke alarm performance was compared in fires that resulted in death. Compared to victims of fires with no working smoke alarms, victims of fires with working smoke alarms were less likely to be sleeping and more likely to have been fighting the fire, at least 65 years old, or unable to act when fatally injured. Physical disability was more likely to be a factor when smoke alarms operated. Victims with operating smoke alarms were also more likely to have been in the room or area of origin and even more likely to have been in the area of origin *and* involved in ignition than victims without working alarms.

Figure 7 showed that the lowest death rates per 1,000 reported fires were found in fires with wet pipe sprinklers and hard-wired smoke alarms. A few limitations should be noted. The rates shown in Figure 7 are based solely on data from fires reported to local fire departments. It is quite possible that people who are more concerned about safety have installed more complete fire protection or that homes with the best fire protection are owned by healthier and lower risk individuals. While it is impossible to state that all of the differences in fire death experience are due to the presence or absence of different types of fire protection, it is clear that the equipment does play a major role.

NFPA strongly believes that the highest level of home fire safety can be obtained when hardwired, interconnected smoke alarms are combined with residential fire sprinklers. NIST researchers compared the performance of sprinkler actuating elements with other detection

http://www.nfpa.org/assets/files//PDF/Research/alcohol&alarmsreport.pdf.

¹¹ Dorothy Bruck, "The Who, What, Where and Why of Waking to Fire Alarms: A Review, "Fire *Safety Journal*, Volume 36 (2001), pages 623-639.

¹² Dorothy Bruck, Sharnie Reid, Jefoon Kouzma, and Michelle Ball, "The Effectiveness of Different Alarms in Waking Sleeping Children," *Proceedings of the 3rd International Symposium on Human Behavior in Fire 2004*, London, England, Interscience Communications Limited 2004, pp. 279-289.

¹³ Michelle Ball and Dorothy Bruck, "The Effect of Alcohol upon Response to Fire Alarm Signals in Sleeping Adults," *Proceedings of the 3rd International Symposium on Human Behavior in Fire 2004*, London, England, Interscience Communications Limited 2004, pp. 291-301.

¹⁴ Dorothy Bruck, Ian Thomas, and Michelle Ball. *Optimizing Fire Alarm Notification for High Risk Groups Research Project: Waking Effectiveness of Alarms (Auditory, Visual and Tactile) for the Alcohol Impaired*, Quincy, MA: The Fire Protection Research Foundation, June 2007, pp. 7-8, online at

¹⁵ Dorothy Bruck, Ian Thomas and Ada Kritikos. *Reducing Fire Deaths in Older Adults: Optimizing the Smoke Alarm Signal Research Project: Investigation of Auditory Arousal with Different Alarm Signals in Sleeping Older Adults.* Quincy, MA: The Fire Protection Research Foundation, May 2006, pp. 7-9, online at http://www.nfpa.org/assets/files//PDF/Research/Investigation of Auditory Arousal.pdf.

¹⁶ Dorothy Bruck and Ian Thomas. *Optimizing Fire Alarm Notification for High Risk Groups Research Project: Waking Effectiveness of Alarms (Auditory, Visual and Tactile) for Adults Who Are Hard of Hearing, Quincy, MA: The* Fire Protection Research Foundation, June 2007, pp. 7-8, online at http://www.nfpa.org/assets/files//PDF/Research/hardofhearing&alarms.pdf.

technologies in their 21st century study of home smoke alarm performance.¹⁷ Sprinklers activated after the smoke alarms in all the scenarios tested. While smoke alarms cannot control or extinguish a fire, the early alert is important even when sprinklers are present.

Additional information may be found in the author's full report, *Smoke Alarms in U.S. Home Fires*, published by NFPA in 2009.

¹⁷ Richard W. Bukowski, Richard D. Peacock, Jason D. Averill, Thomas G. Cleary, Neslon P. Bryner, William D. Walton, Paul A. Reneke, and Erica D. Kuligowski, NIST Technical Note 1455, *Performance of Home Smoke Alarms: Analysis of the Response of Several Available Technologies in Residential Fire Settings*, Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology, 2008 revision, pp. xxiii-xxvi, and 248-249, available at http://smokealarm.nist.gov/.

Table 1.Smoke Alarm Coverage and Power Source in Homes with and without FiresIn CPSC's 2004/2005 Residential Fire Survey

Coverage and Power Source	Households with fires	Households without fires	All Households
No alarm	7%	3%	3%
Alarms on all floors	82%	84%	84%
In all bedrooms	22%	31%	31%
Interconnected alarms	13%	19%	19%
Battery-powered	72%	70%	70%
House current	10%	13%	13%
House current with battery backup	18%	17%	17%

Source: Greene and Andres, 2009.

Table 2.Smoke Alarm Coverage and Performance in Unreported Fires when Someone Was HomeIn CPSC's 2004/2005 Residential Fire Survey

Performance	All Unreported Fires	Inter- Connected	Not Inter- Connected	All Bedrooms	Not All Bedrooms	All Floors	Not All Floors
Were present	89%	100%	87%	99%	85%	100%	48%
Alarm sounded, based on	l						
those present	35%	53%	32%	37%	34%	38%	9%
Alarms that alerted, based	d						
on those sounded	39%	49%	37%	45%	37%	39%	46%
Alarms provided the only	7						
alert, based on those							
sounded	32%	49%	28%	35%	31%	32%	46%
Alerted occupants based							
on those present	14%	26%	12%	16%	13%	15%	4%

Source: Greene and Andres, 2009.

Table 3.Smoke Alarm Performance in Unreported Fires when Someone Was HomeIn CPSC's 2004/2005 Residential Fire Survey, by Fire Area and Cause

Performance	Kitchen	Living Room	Bedroom		Lighting or Wiring	Heating o Cooling		Lighter, Cigarette, or Match
Were present	90%	99%	87%	87%	84%	98%	100%	96%
Alarm sounded, based o								
those present	41%	25%	22%	47%	8%	23%	23%	30%
Alarms that alerted, base								• • • •
on those sounded	40%	1%	69%	38%	81%	23%	35%	29%
Alarms provided the onl	y							
alert, based on those	220/	1.07	(00)	220/	010/	20/	220/	200/
sounded	33%	1%	69%	33%	81%	3%	32%	29%

Source: Greene and Andres, 2009.

Table 4.Home Structure Fires by Smoke Alarm Performance2003-2006 Annual Averages

	г.			ilian	Direct Civilian Property Damage				
Detection Performance		res	Deaths		Injuries		(in Millions)		
Smoke alarm operated in non-confined fire	84,200	(22%)	1,030	(36%)	5,910	(45%)	\$3,575	(58%)	
Smoke alarm operated in confined fire	92,200	(24%)	10	(0%)	940	(7%)	\$0	(0%)	
Subtotal – Operating smoke alarm	176,400	(47%)	1,040	(37%)	6,860	(52%)	\$3,575	(58%)	
Smoke alarm present but did not operate in non-confined fire Smoke alarm present but did not operate in	22,600	(6%)	640	(23%)	2,060	(16%)	\$714	(12%)	
confined fire	12,600	(3%)	0	(0%)	190	(1%)	\$4	(0%)	
Subtotal – Smoke alarm present but did not operate	35,200	(9%)	640	(23%)	2,250	(17%)	\$718	(12%)	
Fire too small to operate in non-confined fire	18,600	(5%)	30	(1%)	420	(3%)	\$114	(2%)	
Fire too small to operate in confined fire	29,900	(8%)	0	(0%)	190	(1%)	\$6	(0%)	
Subtotal – Fire too small to operate alarm	48,500	(13%)	30	(1%)	610	(5%)	\$120	(2%)	
Subtotal – Smoke alarm present	260,100	(69%)	1,710	(60%)	9,720	(74%)	\$4,413	(72%)	
No smoke alarm present in non-confined fire No smoke alarm present in confined fire <i>Subtotal – No smoke alarm</i>	82,600 35,800 118,500	(22%) (9%) (<i>31%</i>)	1,140 0 1,140	(40%) (0%) (40%)	3,040 330 <i>3,380</i>	(23%) (3%) (26%)	\$1,695 \$9 \$ <i>1,704</i>	(28%) (0%) (28%)	
Subtotal – No working smoke alarm present	153,700	(41%)	1,780	(62%)	5,630	(43%)	\$2,422	(40%)	
Total	378,600	(100%)	2,850	(100%)	13,100	(100%)	\$6,117	(100%)	

Note: Sums may not equal totals due to rounding errors. Source: NFIRS 5.0 and NFPA survey.

Table 5. Effectiveness of Operating Smoke Alarms In Non-Confined Home Structure Fires 2003-2006 Annual Averages

							Di	rect
Tffooding ag	Т	!	-	vilian				Damage
Effectiveness Alerted occupants and occupants	F	ires	De	eaths	Inju	ıries	(In MI	illions)
responded	66,800	(79%)	710	(69%)	5,150	(87%)	\$2,492	(70%)
Alerted occupants but occupants		<i>(</i> -)					****	(
failed to respond	2,500	(3%)	220	(21%)	340	(6%)	\$113	(3%)
No occupants were present	12,600	(15%)	0	(0%)	160	(3%)	\$770	(22%)
Failed to alert occupants	2,400	(3%)	100	(9%)	270	(5%)	\$200	(6%)
Total	84,200	(100%)	1,030	(100%)	5,910	(100%)	\$3,575	(100%)

Source: NFIRS 5.0 and NFPA survey.

Table 6.Victim's General Location at Time of Incident by Smoke Alarm Presence and OperationIn Non-Confined Home Structure Fire Deaths2003-2006 Annual Averages

Victim's Location		ent and crated		ent but t Operate	None Present	
In area of origin and involved	480	(47%)	190	(30%)	400	(35%)
In area of origin and not involved	160	(16%)	80	(13%)	170	(15%)
SubtotalIn area of origin	640	(62%)	280	(43%)	560	(49%)
Not in area of origin and not involved	160	(16%)	170	(27%)	280	(24%)
Not in area of origin but involved	220	(22%)	190	(29%)	290	(25%)
Subtotal –Not in area of origin	380	(38%)	360	(56%)	570	(49%)
Unclassified	0	(0%)	0	(0%)	10	(1%)
Total	1,030	(100%)	640	(100%)	1,140	(100%)

Note: Fire deaths resulting from fires too small to activate the smoke alarm are not included in these tables. Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Table 7. Activity at Time of Victim's Fatal Injury by Smoke Alarm Presence and Operation in Non-Confined Home Structure Fire Deaths Excluding Fires Too Small to Activate the Smoke Alarm 2003-2006 Annual Averages

Activity	Present and Operated			sent but ot Operate	None Present	
Escaping	310	(30%)	200	(31%)	420	(37%)
Sleeping	310	(30%)	290	(45%)	460	(41%)
Unable to act	150	(14%)	50	(8%)	90	(8%)
Unclassified activity	70	(7%)	30	(5%)	40	(4%)
Fire control	70	(6%)	20	(3%)	20	(2%)
Returning to vicinity of fire before control	50	(5%)	10	(2%)	30	(3%)
Irrational act	50	(5%)	20	(4%)	30	(2%)
Rescue attempt	20	(2%)	20	(3%)	40	(3%)
Total	1,030	(100%)	640	(100%)	1,140	(100%)

Note: Fire deaths resulting from fires too small to activate the smoke alarm are not included in this table. Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Table 8.Non-Confined Home Structure Fire DeathsBy Leading Items First Ignited and Smoke Alarm Status2003-2006 Annual Averages

	PRESENT AND OPERATED		PRESENT BUT DID NOT OPERATE			None Present			
Item First Ignited	Civi Dea		Deaths per 100 Fires	D	eaths	Deaths per 100 Fires	De	eaths	Deaths per 100 Fires
Upholstered furniture	220	(22%)	7.6	110	(18%)	12.8	310	(28%)	9.1
Mattress or bedding Flammable or combustible liquid or	180	(18%)		100	· /	6.4	150	(13%)	3.1
gas, or pipe, hose, duct or filter	90	(9%)		40	(6%)	5.6	60	(6%)	1.7
Clothing	80	(8%)		40	(6%)	3.3	40	(3%)	1.3
Unclassified furniture or utensil	60	(5%)		30	(5%)	4.7	80	(7%)	3.4
Structural member or framing	50	(4%)		40	(6%)	1.8	50	(4%)	0.6
Cooking material, including food	40	(4%)		30	(5%)	1.0	30	(3%)	0.5
Multiple items first ignited	30	(3%)	2.4	20	(3%)	4.8	40	(4%)	1.9
Electrical wire or cable insulation	30	(3%)	0.5	10	(2%)	0.6	50	(4%)	0.9
Floor covering rug, carpet, or mat	30	(3%)	1.4	50	(8%)	9.1	50	(4%)	1.7
Cabinetry	30	(2%)	0.9	10	(2%)	1.9	20	(2%)	1.1
Interior wall covering. excluding									
drapes	20	(2%)	0.7	20	(3%)	2.6	60	(6%)	1.6
Rubbish, trash, or waste	20	(2%)	1.0	20	(3%)	3.3	20	(1%)	0.6
Unclassified structural component									
or finish	20	(2%)	1.0	20	(3%)	3.2	50	(4%)	1.4
Magazine, newspaper or writing paper	20	(2%)	1.3	10	(1%)	2.0	20	(1%)	1.1
Unclassified soft goods or wearing		(=, •)		- 0	(-,)			(-,)	
apparel	20	(2%)	1.0	10	(2%)	2.3	30	(2%)	1.7

Note: Confined fires, which tend to be minor, were excluded from the calculations of deaths per 100 reported fires.

Source: NFIRS 5.0 and NFPA survey.