Smoke Alarms in U.S. Home Fires

Marty Ahrens

September 2009

National Fire Protection Association
Fire Analysis and Research Division

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Abstract

Almost all households in the U.S. have at least one smoke alarm, yet in 2003-2006, smoke alarms were present in only two-thirds (69%) of all reported home fires and operated in just under half (47%) of the reported home fires. ("Homes" includes one- and two-family homes, apartments, and manufactured housing.) Forty percent of all home fire deaths resulted from fires in homes with no smoke alarms, while 23% 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 a working smoke alarm as it was in home fires with this protection. Hardwired smoke alarms are more reliable than those powered solely by batteries.

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.

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

Acknowledgements

The National Fire Protection Association thanks all the fire departments and state fire authorities who participate in the National Fire Incident Reporting System (NFIRS) and the annual NFPA fire experience survey. These firefighters are the original sources of the detailed data that make this analysis possible. Their contributions allow us to estimate the size of the fire problem. We are also grateful to the U.S. Fire Administration for its work in developing, coordinating, and maintaining NFIRS.

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National Fire Protection Association
One-Stop Data Shop
1 Batterymarch Park
Quincy, MA 02169-7471
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e-mail: osds@nfpa.org
phone: 617-984-7443

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Executive Summary

Smoke alarms have become such a common feature in U.S. homes that it is easy to take them for granted. Newspapers often report fires in which blaring smoke alarms alerted sleeping occupants to danger. These devices alert countless others to fires just as they are starting. A 2008 survey conducted for NFPA by Harris Interactive found that 24 of every 25 (96%) U.S. homes had at least one smoke alarm. Homes include one- and two-family homes, apartments, and manufactured housing.

Almost two-thirds of home fire deaths resulted from fires in properties without sounding smoke alarms.
In 2003-2006, smoke alarms were present in roughly two-thirds (69%)of reported home fires and sounded in roughly half (47%) of the home fires reported to U.S. fire departments. Forty percent of home fire deaths resulted from fires in which no smoke alarms were present at all. Twenty-three percent of the deaths were caused by fires in properties in which smoke alarms were present and but failed to operate. Smoke alarms operated in fires that caused 37% of the deaths. One percent of the deaths resulted from fires that were too small to activate the smoke alarm.

Smoke alarm failures usually result from missing, disconnected, or dead batteries.
When smoke alarms fail to operate, it is usually because batteries are missing, disconnected or dead. People are most likely to remove or disconnect batteries because of nuisance activations. Sometimes the chirping to warn of a low battery is interpreted as a nuisance alarm. Smoke alarms should be tested at least once every month to ensure that both the batteries and the units themselves are still working. Replaceable batteries should be replaced in accordance with the manufacturer's instructions, at least once every year.

In one-fifth of all homes with smoke alarms, none were working.
In 1992, the U.S. Consumer Product Safety Commission (CPSC) sent surveyors to people's homes to find out how common smoke alarms were and what portion of these devices were working in the general population's homes. In one of every five homes that had at least one smoke alarm installed, not a single one was working. Including homes without smoke alarms and homes with only non-working alarms, one-quarter of U.S. households do not have the protection of even one working smoke alarm. In follow-up visits after smoke alarm installation programs, typically a substantial portion of the installed alarms were not working.

Most homes do not yet have the protection recommended in the 2007 edition of NFPA 72.
The 2007 edition of NFPA 72, *National Fire Alarm Code®* required smoke alarms in every bedroom, outside each sleeping area, and on every level. They should also be interconnected so that when one sounds, they all sound. Most homes do not have this level of protection. The CPSC's 2004-2005 Residential Fire Survey asked about all fires, including incidents that were not attended by the fire service. Based on respondents' reports, 82% of the households that had fires and 84% of non-fire households had smoke alarms on every level. Only 22% of fire households had smoke alarms in all bedrooms compared to 31% of households without fires. Thirteen percent of the fire households and 19% of the non-fire households had interconnected smoke alarms. When interconnected smoke alarms were present, they operated in 53% of the

incidents and provided the only alert in 26% of the fires. In many cases, people are in the room or nearby when a fire starts and notice it before the smoke alarm sounds. In cases where the smoke alarms provided the only alert, the occupants had not been aware of the fire until the smoke alarm sounded. When the smoke alarms were *not* interconnected, they operated in only 27% of the fires and provided the only alert in 8%. When smoke alarms did not operate, it was typically reported that smoke did not reach the alarm.

Most homes still have smoke alarms powered by batteries only.
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 has required smoke alarms in new construction to be hardwired with 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. To be effective, the codes must be adopted and enforced.

People 55 or older were more likely to have smoke alarms that were more than 10 years old.
NFPA has long recommended that smoke alarms be replaced every ten years. The previously mentioned 2008 survey Harris Interactive survey found that, among households with smoke alarms, 10% of respondents of all ages and 17% of those at least 55 years old reported that their smoke alarms were more than ten years old.

The same survey asked for perceptions of how often smoke alarms should be replaced. Only 12% reported that smoke alarms should be replaced every 10 years. Thirty-five percent simply did not know or refused to answer the question. Four percent thought these devices never need replacing. Roughly two in five believe that smoke alarms should be replaced at least every 4-6 years, if not more often. Some of the confusion about how often smoke alarms should be replaced is likely due to different recommendations for replacement schedules of devices that detect smoke *and* carbon monoxide. Manufacturers of carbon monoxide alarms and combination smoke/carbon monoxide alarms often recommend more frequent replacement.

Fire Protection Research Foundation study found that strobe lights, used alone, were ineffective in waking people who were hard of hearing.
The Fire Protection Research Foundation studied the waking effectiveness of different types of alarm signals for various high risk groups. The authors of the 2007 report found that a loud low frequency square wave auditory signal was most effective in waking those with moderate to severe hearing loss. This signal performed better than bed or pillow shakers and strobe lights. Strobe lights, when used alone, were not effective in waking this population. The renamed 2010 edition of NFPA 72, *National Fire Alarm and Signaling Code*, will require that audible notification appliances used in bedrooms for those with mild to severe hearing loss produce a low frequency signal. Another new provision will require tactile notification appliances in addition to strobes for individuals with profound hearing loss. These provisions will take effect immediately upon adoption of the new code.

Follow these tips.
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 bears the label of a recognized testing laboratory.
- Install a smoke alarm in every bedroom, outside each sleeping area, and on every level of your home, including the basement.
- Interconnect all smoke alarms throughout the home. When one sounds, they all sound.
- Replace batteries in all smoke alarms at least once a year. If an alarm "chirps," warning the battery is low, replace the battery right away.
- Replace all smoke alarms, including alarms that use 10-year batteries and hard-wired alarms, when they are 10 years old or sooner if they do not respond properly when tested.
- Test your smoke alarms at least every month, using the test button or an approved smoke substitute and clean the units, both in accordance with the manufacturers' instructions.
- An ionization smoke alarm is generally more responsive to flaming fires and a photoelectric smoke alarm is generally more responsive to smoldering fires. For the best protection, both types of alarms, or a combination alarm (photoelectric and ionization), should be installed in homes.

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

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Fire Analysis and Research Division
One Batterymarch Park, Quincy, MA 02169
Email: osds@nfpa.org
www.nfpa.org

Smoke Alarms in Reported U.S. Home Fires

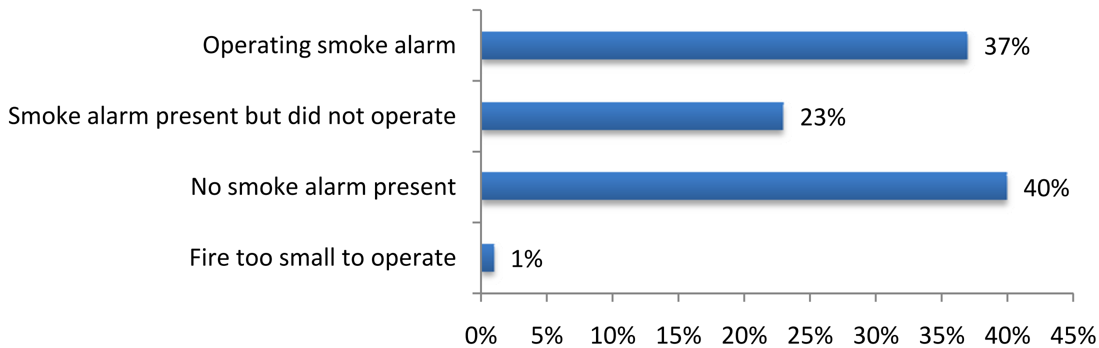
Ninety-six percent of all homes have at least one smoke alarm, according to a 2008 telephone survey. Overall, three-quarters of all U.S. homes have at least one *working* smoke alarm.

Smoke Alarm Presence and Performance

In 2003-2006, smoke alarms sounded in roughly half of the home fires reported to U.S. departments.

- Almost two-thirds of home fire deaths resulted from fires in homes with no smoke alarms or no working smoke alarms.
  - No smoke alarms were present in 40% of the home fire deaths.
  - In 23% of the home fire deaths, smoke alarms were present but did not sound.

Home Structure Fire Deaths by Smoke Alarm Performance 2003-2006



Interconnected smoke alarms on all floors increase safety

Interconnected smoke alarms were more likely to operate and alert occupants to a fire in a U.S. Consumer Product Safety Commission (CPSC) survey of households with any fires, including fires in which the fire department was not called.[1]

- When on all floors, alarms sounded in 37% of fires and alerted occupants in 15%.
- When smoke alarms were not on all floors, they sounded in only 4% of the fires and alerted occupants in only 2%.
- In homes that had interconnected smoke alarms, the alarms sounded in half (53%) of the fires and alerted people in one- quarter (26%) of the fires.
  - People may learn about or be alerted to a fire without hearing a smoke alarm.

[1]Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

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Homes include one- and two-family dwellings, manufactured homes, apartments, townhouses, rowhouses, and condominiums.

Home Smoke Alarm Power Sources

More than half of the smoke alarms found in reported fires and two-thirds of the alarms found in homes with fire deaths were powered by battery only.

In fires considered large enough to activate the alarm,

- Hardwired smoke alarms operated 91% of the time.
- Battery-powered smoke alarms operated in 75%.

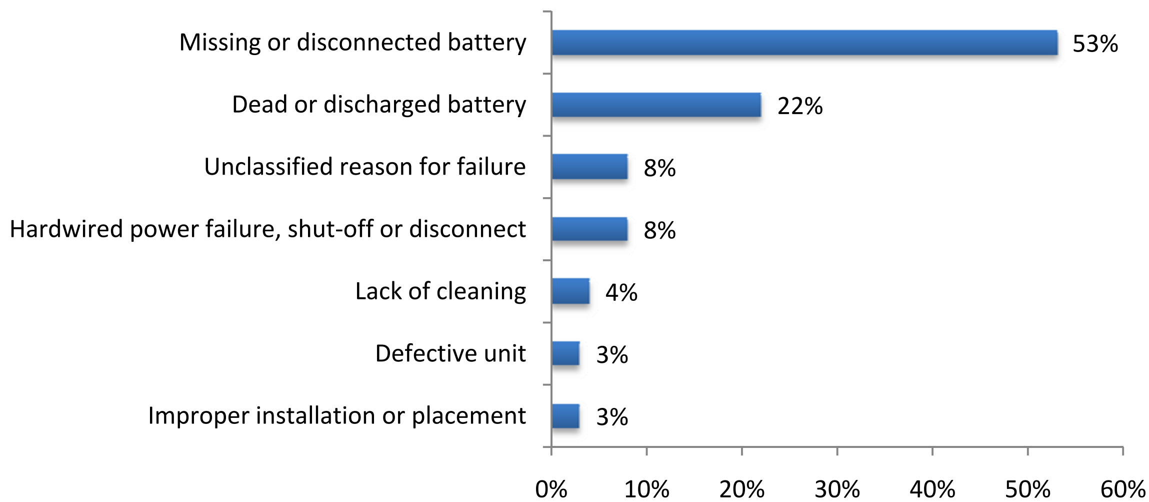
Little causal detail is required about certain categories of minor fires, identified by incident type and collectively called confined fires, by the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS). Confined fires were omitted from these calculations

Reasons for Smoke Alarm Failure

In more than half of the reported home fires[1] in which the smoke alarms were present but did not operate, batteries were missing or disconnected. Nuisance alarms were the leading reason for disconnected smoke alarms.

- Roughly one of every five smoke alarm failures was due to dead batteries.
- Only 8% of the failures were due to hardwired power source problems, including disconnected smoke alarms, power outages and power shut-offs.

Reason Smoke Alarm Failed to Operate in Home Structure Fires 2003-2006

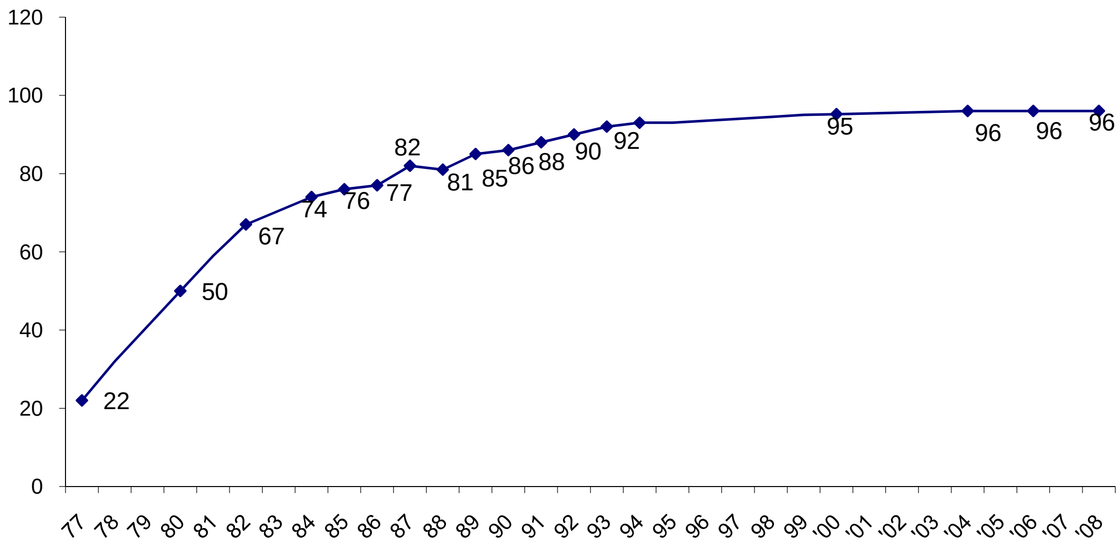


Home Smoke Alarm Presence and Operation

National Statistics

24 out of 25 homes surveyed by phone now have at least one smoke alarm.
As of 2008, 96% of all homes[1] surveyed by telephone reported having at least one smoke alarm.[2,3] The growth in home smoke alarm usage is shown in Figure 1. From 1977 to 1984, the use of home smoke alarms skyrocketed. Most of these smoke alarms were single-station, battery-operated, ionization-type devices. With this rapid growth in usage and the clear evidence from actual fire stories and fire statistics showing the life-saving effectiveness of these alarms, the home smoke alarm became the fire safety success story of the decade. The percentage of homes with at least one smoke alarm has been level at 96% in the three most recent phone surveys. Table 1 summarizes key results of the 2008 survey.

Figure 1. Growth in Home Smoke Alarm Usage: 1977-2008



"Smoke alarms" are not the same as "smoke detectors."
The terminology used in this report conforms, as much as possible, to industry practices. Most homes have what we now call "smoke alarms." These units detect the presence of smoke and sound the alarm. Many properties, particularly non-home properties, some multi-family complexes, and newer single-family homes, have smoke detectors that are components of an alarm system with a panel. The detection unit itself does not necessarily sound the alarm. Instead, the signal is transmitted to the control unit that then sounds the alarm throughout the

[1] The term home encompasses one- and two-family homes, including manufactured homes and apartments. Apartments include tenements, flats, and properties of similar configuration, regardless of ownership.
[2] Sources for homes with smoke alarms: 1977, 1980, 1982 estimates from sample surveys from by the U.S. Fire Administration; 1983-1995 estimates from Louis Harris Surveys for *Prevention Magazine*; 1997 Fire Awareness Survey for NFPA, 1999 NFPA National Fire Escape Survey, 2004 Fire Prevention Week survey for NFPA, Harris Interactive, Smoke Alarm Omnibus Question Report 2008.
[3] As of 2005, 92.4% of occupied households had telephone service. See Table 1099. "Utilization of Selected Media: 1980 to 2005" in the U.S. Census Bureau's *Statistical Abstract of the United States: 2008* (127th edition).

premises. Older studies of smoke detectors usually studied devices that would now be called smoke alarms. NFPA 72, *National Fire Alarm Code*® specifically requires smoke alarms or system-based smoke detectors in homes (home units) where occupancy codes require smoke detection.

Methodology

Statistics about smoke alarm performance in reported U.S. fires were derived from NFIRS 5.0 and NFPA's fire department survey.
Unless otherwise specified, the statistics in this analysis 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 estimates are projections based on the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS 5.0) and the National Fire Protection Association's (NFPA's) annual fire department experience survey. Consequently, 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. These include confined cooking fires, confined chimney or flue fires, confined trash fires, 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. However, this field does not indicate if a smoke alarm *or* occupants were even present. A yes or no answer as to the presence of detection equipment was provided in only 2% of confined home fires. The analyses of confined fires in the body of the report are based on the 2% of confined fires in which information about detection equipment presence was provided. An analysis of presence and operation of detection equipment in confined fires when occupants were and were not alerted is found in Appendix A. Another table in Appendix A shows the results obtained if all confined fires in which smoke alarms alerted occupants were treated as operating, and all confined fires in which smoke alarms did not alert occupants were assumed to have no operating smoke alarm. Because this field had usable data in 54% of the fires, some might prefer to rely on it rather than the presence and operation fields which were completed much less often for confined fires.

Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Property damage has not been adjusted for inflation. In the home section, fires are rounded to the nearest hundred, civilian deaths and injuries to the nearest ten, and direct property damage to the nearest million. Except for property use and incident type, fires with unknown or unreported data were allocated proportionally in calculations of national estimates. Additional details on the methodology and relevant NFIRS 5.0 forms may be found in Appendix B and D.

92% of the home fire detection devices were designed to detect smoke only.
Table 2 shows that 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 report when describing early fire warning devices or systems in the home. However, names of earlier studies have not been changed.

Smoke alarms were present and operated in almost half of all reported home fires.
The discussion that follows will focus on different aspects of Table A. Table A shows estimated annual averages of home fires reported to local fire departments in 2003-2006 by smoke alarm performance. Fire departments responded to an estimated average of 378,600 home structure fires per year during this four-year period.

Table A.
Home Structure Fires by Smoke Alarm Performance
2003-2006 Annual Averages

Detection Performance	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (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	22,600	(6%)	640	(23%)	2,060	(16%)	$714	(12%)
Smoke alarm present but did not operate in 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	82,600	(22%)	1,140	(40%)	3,040	(23%)	$1,695	(28%)
No smoke alarm present in confined fire	35,800	(9%)	0	(0%)	330	(3%)	$9	(0%)
Subtotal – No smoke alarm	*118,500*	*(31%)*	*1,140*	*(40%)*	*3,380*	*(26%)*	*$1,704*	*(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%)**

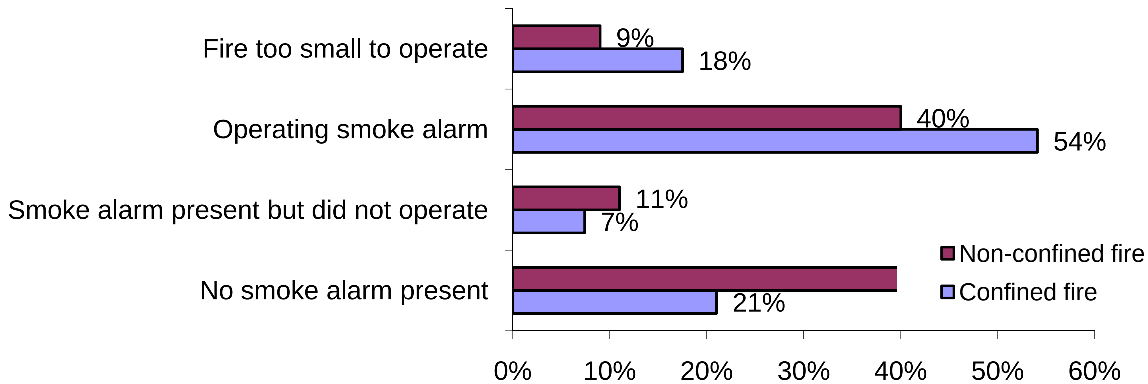
Note: Sums may not equal totals due to rounding errors. Confined and non-confined fires were analyzed separately. Smoke alarm presence or absence was reported in 69% of non-confined fires and 2% of confined fires. Fires with unknown or missing data were allocated proportionally among fires with missing data.

Source: NFIRS 5.0 and NFPA survey.

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. These estimates, like estimates throughout the report, include a proportional share of fires in which smoke alarm presence and performance were unknown or not reported.

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.

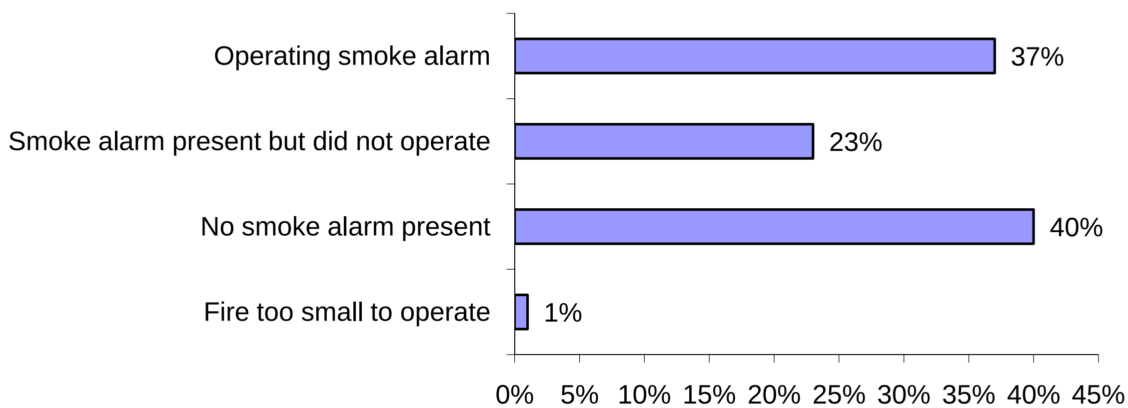
Figure 2. Confined and Non-Confined Home Structure Fires by Smoke Alarm Performance 2003-2006



Source: NFIRS 5.0 and NFPA survey.

Smoke alarms sounded in one of every three fire deaths.
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. Figure 3 shows that 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.

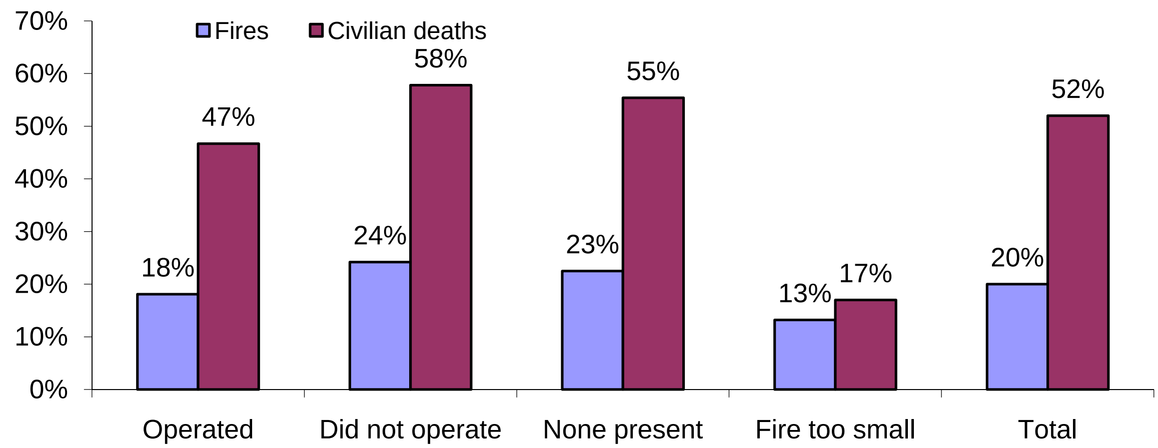
Figure 3. Home Structure Fire Deaths by Smoke Alarm Performance 2003-2006



Source: NFIRS 5.0 and NFPA survey.

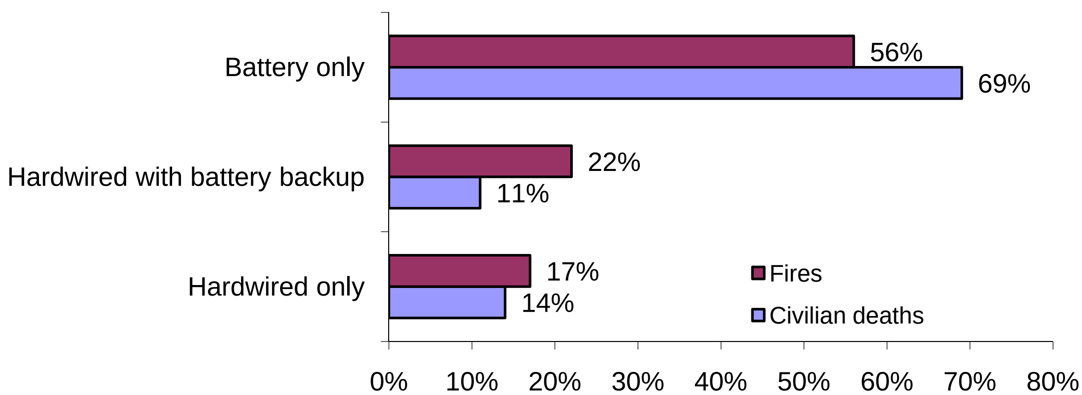
55-58% of the home fire deaths with no smoke alarms or no working smoke alarms resulted from fires reported between 11:00 p.m. and 7:00 a.m.
Figure 4 and Table 3 show that the percentages of home structure fires and fatal fire injuries reported between 11:00 p.m. and 7:00 a.m. were highest for properties with smoke alarms that did not operate or with no smoke alarms at all. Fifty-eight percent of the deaths from fires with non-working alarms and 55% of home fires with no smoke alarms at all resulted from fires reported during these hours. Slightly less than half (47%) of the deaths from home fires with operating smoke alarms were reported in the same hours. Only 13% of the fires that were too small to activate the alarm and 17% of the associated deaths occurred during this period.

Figure 4. Percent of Home Structure Fires and Fire Deaths Reported Between 11:00 PM and 7:00 AM: 2003-2006



More than half of the smoke alarms in reported home fires were powered by batteries only.
Table 4 and Figure 5 show that overall, 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. Half (50%) of the smoke alarms in confined home fires and 63% of the alarms in non-confined home fires were powered by batteries only.

Figure 5. Leading Smoke Alarm Power Sources in Home Structure Fires: 2003-2006

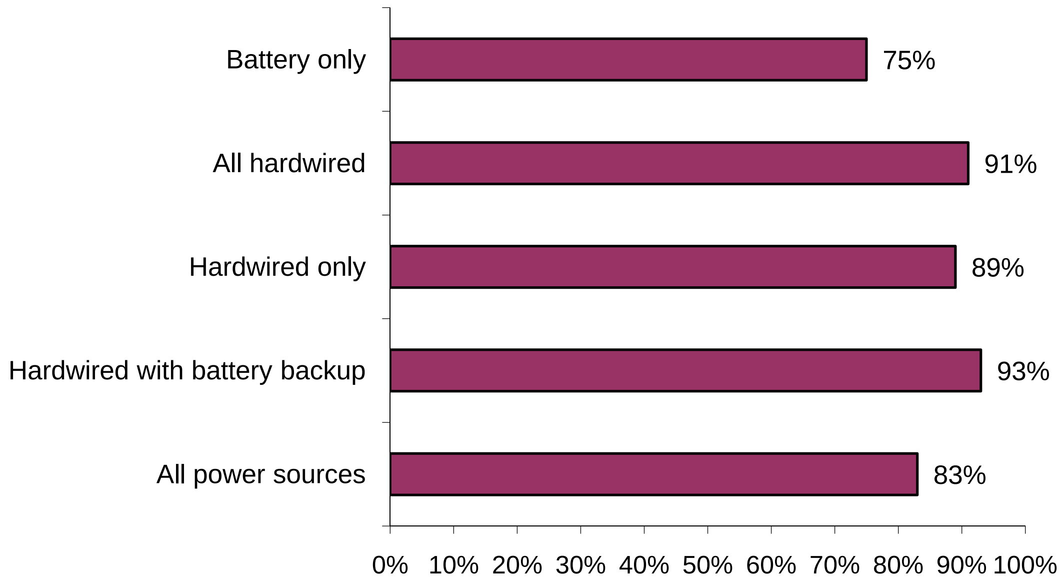


Source: NFIRS 5.0 and NFPA survey.

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. One-third (33%) of the smoke alarms present in non-confined home fires and 45% of the alarms present in non-confined home fires were hardwired. Hardwired alarms include those with and without battery backup.

Table 5 and Figure 6 show the percentage of smoke alarms operating in fires considered large enough to activate the alarm. When present and the fire was large enough to trigger the device, smoke alarms overall 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 6. Smoke Alarm Operation in Home Fires Considered Large Enough to Activate Alarm by Power Source: 2003-2006



Source: NFIRS 5.0 and NFPA survey.

Two-thirds of smoke alarms in 2007 *American Housing Survey* were powered by batteries. In 2007, the *American Housing Survey* (AHS) for the first time asked about working smoke alarms, smoke alarm power sources, and, for smoke alarms powered by batteries alone or by both electricity and batteries, whether the batteries had been replaced within the past six month. Field representatives conducted almost 52,000 interviews. Interviews were generally done in person.

Table 6 shows that 94% of the respondents in occupied housing units reported working smoke alarms.[4] This figure seems implausibly high. The Smoke Alarm Omnibus Questions done for NFPA in 2008 found that 96% of homes reported having smoke alarms regardless of whether they were working. It is likely that the AHS did not ask for any testing or verification to be sure

[4] 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.

that smoke alarms were actually working. For that reason, the other AHS results are presented as results about smoke alarms without mentioning whether they are working.

The AHS found majority of households in all types of circumstances reported this protection. Smoke alarms were reported to be less common in some groups:

- Homes in which the building had moderate to severe physical problems (83-85%)
- Hispanics (88%);
- Rural areas outside metropolitan statistical areas (90%),
- Manufactured homes (90%),
- The South (91%),
- Renters (92%),
- Blacks (92%), and
- Householder at least 65 years of age (92%).

In contrast, 99% of homes that were four years or less old reported having smoke alarms.

Sixty-seven percent of the respondents with smoke alarms reported that the units were powered by batteries only, 24% by electricity and batteries, and 9% by electricity only. More than three quarters (78%) of the smoke alarms in homes with physical problems were powered by batteries only.

Field investigators collected detailed data for CPSC's National Smoke Detector Project. The U.S. Consumer Product Safety Commission's (CPSC's) National Smoke Detector Project studied smoke alarm presence and operability in 1992 by sending field investigators into people's homes to ask a series of questions and to test all the alarms in their homes. This project surveyed the general population, not just people who had fires. It remains the most complete study of smoke alarm presence and operational status in the general population. Findings were released in 1993. About 88% of the households screened had at least one installed smoke alarm; 41% of households with these devices had more than one.[5]

Homes built since 1980 are more likely to have hardwired smoke alarms.
Codes such as NFPA's *Life Safety Code®* have required hardwired smoke alarms in new construction for years. Since 1976, new manufactured homes have been required to have hardwired A/C-powered smoke alarms; only 38% of the manufactured homes (all ages) surveyed in the CPSC study had battery-only smoke alarms. In the 1992 study, 81% of the homes (including apartments and manufactured homes) built *before* 1980 had battery-only devices; only 31% of the homes built in 1980 or later had smoke alarms powered only by batteries. Overall, 72% of the devices seen in the study had battery power only. Seventy-six percent of the single-family homes (excluding manufactured homes) had battery-only smoke alarms; 62% of the apartments had battery-only devices.

The same 1992 study found that 6% of households with smoke detection equipment in 1992 had them connected to off-site monitoring. This is even more protection than interconnected smoke

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

alarms alone provide. Unfortunately, NFIRS does not capture information about monitored systems.

More recent statistics on reported home fires and data about all households from the 2007 *American Housing Survey* suggest that the percentage of smoke alarms powered by batteries has fallen to roughly two-thirds. The same survey found that 37% of the smoke alarms in homes less than five years old were powered by batteries only.

In CPSC's 1992 National Smoke Detector Project, 20% of homes with smoke alarms had none that worked.
Two different kinds of studies examine smoke alarm status – studies of smoke alarm performance in fires and studies of smoke alarm operational status in homes in general. The National Smoke Detector Project's analysis of households in general is particularly valuable.

The National Smoke Detector Project found that in 20% of the households surveyed with at least one smoke alarm present, none were operational. However, *46% of the respondents in households in which no smoke alarms functioned thought that all of them were working.* About 20% of the tested devices did not have functioning power sources. These statistics reinforce the hypothesis that the 94% of homes with working smoke alarms found in the American Housing Survey is unrealistically high. Two studies focusing specifically on the accuracy of self-reporting of working smoke alarms are described in Appendix C.

Best estimates suggest that more than three-quarters (77%) of all homes have at least one working smoke alarm.
If 96% of U.S. homes surveyed by phone[6] now have smoke alarms and 20% of those have non-operational smoke alarms, (based on CPSC's field investigations), then 4% of homes have no smoke alarms at all (100% minus 96%) and another 19% of homes have smoke alarms that do not work (20% of 96%). Therefore, three of every four homes (77% of the homes with telephones) have at least one working smoke alarm (100% minus 4% minus 19%). Restoring operational status to the non-working smoke alarms could have a major impact and should be considered a priority, along with installing smoke alarms in the remaining homes that do not have them.

Homes with fires had less smoke alarm protection than homes in general.
In 2004-2005, CPSC staff conducted a telephone survey to estimate the total number of residential fires experienced by U.S. households, including fires that were not attended by fire departments.[7] The study also compared differences in households that had experienced fires in the previous three months with households that had not had a fire. They estimate that U.S. households experienced 7.4 million fires per year, including 7.2 million that were unattended.

Survey findings related to smoke alarms are shown in Table 7. Figure 7 shows 97% of households that did not have a fire reported that they had at least one smoke alarm. Ninety-three

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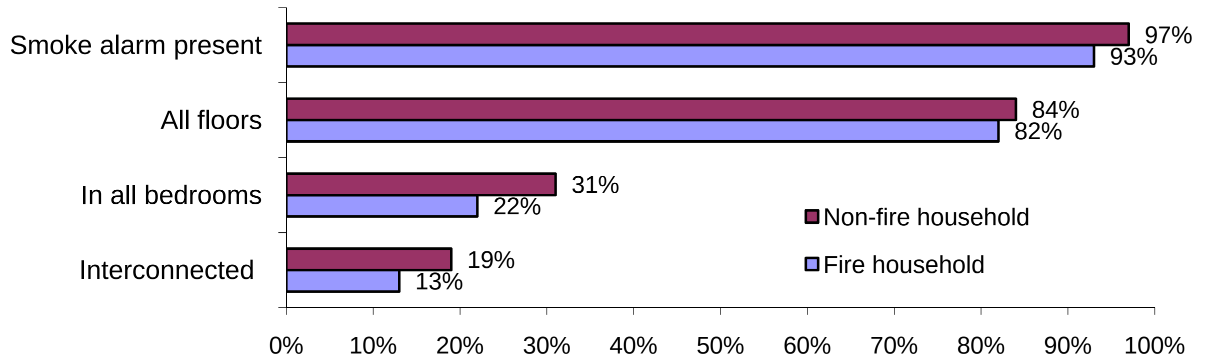
[6] Table 1099 "Utilization of Selected Media" in the U.S. Census Bureau's *Statistical Abstract of the United States: 2008* shows that 92.4% of U.S. households had telephone service in 2005.
[7] Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

percent of households that had fires reported having this protection. Households that did not have fires reported an average of 3.54 smoke alarms per household. Those that did have fires averaged 2.92 alarms each. Eighty-two percent of the fire households and 84% of non-fire households reported having smoke alarms on all levels. Only 13% of the fire households and 19% of non-fire households reported having interconnected smoke alarms.

Figure 7. Smoke Alarm Presence and Coverage in Fire and Non-Fire Households in CPSC's 2004-2005 Residential Fire Survey



Source: Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

Among fire and non-fire households combined, homes in which at least one person was under 18 were more likely to report smoke alarms on all floors and in all bedrooms. Homes in urban areas were also more likely to have this protection. Homes with at least one person over 65 or older or at least one smoker were less likely to report smoke alarms in all bedrooms.

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

One smoke alarm is usually not enough.

Thirteen percent of reported home fires were too small to activate smoke alarms that were present in 2003-2006. Some of these fires may have been out of range of the smoke alarm. Many homes need more than one smoke alarm for code-compliant complete protection. The 2007 edition of NFPA 72 required smoke alarms in all bedrooms, outside each sleeping area and on every level of the home. The 1992 CPSC National Smoke Detector Project found that 26% of the households surveyed had fewer than one alarm per floor, which indicated too few smoke alarms for compliance with the code provisions of the time. Additional households may have had too few smoke alarms to protect widely separated sleeping areas on the same floor. Closed doors that delay the spread of smoke may also delay smoke alarm response and decrease the likelihood that the signal will be heard. Audibility is discussed further later in this report. CPSC's National

Smoke Detector Project also estimated that 43% of the households had fewer than one *working* smoke alarm per floor.[8]

In 2008, NFPA commissioned Harris Interactive to include questions about smoke alarms in telephones surveys of more than 1,000 households.[9] Ninety-six percent of the respondents said they had at least one smoke alarm. Table 1 shows that, based on households with smoke alarms,

- 84% of had at least one on each level,
- 81% had smoke alarms outside each bedroom,
- 37% had smoke alarms inside each bedroom;
- 41% had interconnected smoke alarms;
- 92% had tested their smoke alarms at some point;
- 29% tested their smoke alarms at least once a month;
- 10% had smoke alarms that were more than 10 years old; and
- 17% of the respondents who were at least 55 had smoke alarms that were more than 10 years old.

Benefits of Working Smoke Alarms

LIVES SAVED

Working smoke alarms cut the risk of dying in reported home structure fires in half. Figure 8 shows that in 2003-2006, the death rate per 100 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 (1.16 vs. 0.59). In other words, having a working smoke alarm cuts the chances of dying in a reported fire in half.

This is not the same as saying you double your chances of surviving a fire big enough to be reported to a fire department. Ignoring fires where more than one person dies, death rates per 100 fires are the same as percentages of reported fires that are fatal. By that formulation, people die in 0.59% of fires with a working smoke alarm present and in 1.16% of fires with no working smoke alarm present. Turning those numbers around, people survive in 99.41% of fires with a working smoke alarm present and in 98.84% with no working smoke alarm present.

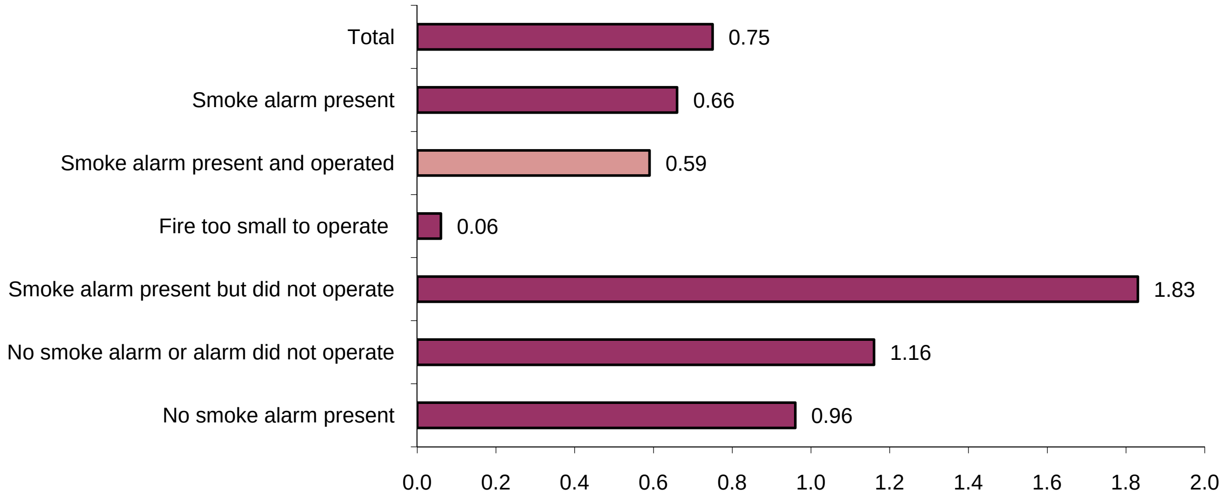
Survival rates in this form look high, but they are not a good guide to the acceptability of the associated risk of death or the associated death toll.

Consider the context provided by these fire statistics: With an annual average of 2,850 home fire deaths resulting from 378,600 reported home fires during this period, the overall death rate regardless of smoke alarm presence or operation was 0.75 per 100 fires, implying a survival chance of 99.25%. Even so, fire claimed nearly 3,000 lives per year.

[8] Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, 1993, p. 24.
[9] Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008.

As these figures imply, the safety of an activity is not determined solely by your survival chances in any one incident but by the number of times you "test the odds." The National Highway Traffic Safety Administration reported that in 2007, 37,248 (0.6%) of the 6,024,000 traffic crashes were fatal. These crashes resulted in almost 42,000 deaths, even though people survived 99.4% of all crashes.[10]

Figure 8. Death Rate per 100 Reported Home Structure Fires by Smoke Alarm Status: 2003-2006



Source: NFIRS 5.0 and NFPA survey.

SMOKE ALARMS AND EARLY DISCOVERY OF FIRE

U.K. data confirm that smoke alarms result in quicker fire discovery.
The United Kingdom tracks the interval between the time of ignition and the time of discovery.[11] Sixty-three percent 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 62% of these incidents.

Only 52% 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-five percent of these fires were confined to the item of origin. This suggests that homes with working smoke alarms will be alerted to a fire earlier and that fires in these homes are less likely to have the opportunity to spread.

Sometimes, people notice the fire first or no one hears the alarm.
In 2006, home smoke alarms were present, operated, and raised the alarm in 35% of the fires reported in the United Kingdom. (No smoke alarms were present in 47% of the home fires, and

[10] National Highway Traffic Safety Administration. *Traffic Safety Facts 2007: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting system and the General Estimates System.* Washington, DC: Department of Transportation, 2008. pp. 14-15, online at http://www-nrd.nhtsa.dot.gov/Pubs/811002.PDF.
[11] Department for Communities and Local Government. *Fire Statistics, United Kingdom, 2006*, London, U.K, May 2008, pp. 35-42, online at http://www.communities.gov.uk/documents/fire/pdf/firestats2006.pdf.

the device did not operate in 12% of the incidents.) Smoke alarms operated but did not raise the alarm in 6% of the fires. Analysts explored the reasons why some home smoke alarms operated but did not alert anyone. These situations remind us that smoke alarms merely provide information. In some cases, people are already aware of the problem; in others, no one receives the information. The leading reasons are given below:

- In 55% of these fires, a person raised the alarm before the system operated (Someone in the same room may notice a fire immediately.);
- In 21% of these home fires, no one was in earshot; and
- The occupants failed to respond in 11% of these fires.

Survey of the English population found that 12% of household fires were discovered when the smoke alarm sounded.

The Survey of English Households asked the general population about fires in or on their home properties, including outdoor fires. In 2004-2005, 1.5% reported having a fire within the past 12 months. Twelve percent of these fires were discovered when the smoke alarm went off. In some cases, someone was in the room and discovered the fire before the smoke alarm sounded. When the smoke alarm did not sound, the most common reason was that the smoke alarm was too far away from the fire.[12]

Smoke alarms provided the *only* alert in 10% of residential fires in CPSC's 2004-2005 survey of reported and unreported fires.

Findings on smoke alarm alerts from CPSC's 2004-2005 *Residential Fire Survey*[13] are consistent with the UK study above. In CPSC's survey, additional detail was sought on low severity fires within the past 14 days or high severity fires within the past 21 days. The authors of the study discovered that someone was home in 96% of these fires and at least one smoke alarm was present in 86%**.** At least one smoke alarm sounded in 30% of the incidents, the smoke alarm alerted people to the fire in 12% of the fires and provided the only alert in 10% of the fires. No alarm sounded in 55% of the fires with people home. This included 49% in which the fire was reported not to have produced enough smoke to activate the alarm.

When present, interconnected smoke alarms provided the only alert in 26% of residential fires in CPSC 2004-2005 survey.

Figure 9 shows that in the 2004-2005 CPSC study, greater coverage and interconnectedness increased the likelihood of smoke alarms operating, of alerting occupants, and of being the only alert. When smoke alarms were not on all floors, they sounded in only 4% of the fires and alerted occupants in only 2% of the fires. Such households may be the most likely to have smoke alarms that are not interconnected. In homes that had interconnected smoke alarms, the alarms sounded in 53% of the fires and provided the only alert in 26%. Less difference was seen between homes with smoke alarms in all bedrooms compared to homes that did not have the devices in all bedrooms. When present in all bedrooms, smoke alarms sounded in 36% of the fires and provided the only alert in 13%. In homes that did not have smoke alarms in every bedroom, the alarms sounded in 28% of the fires and provided the only alert in 9%.

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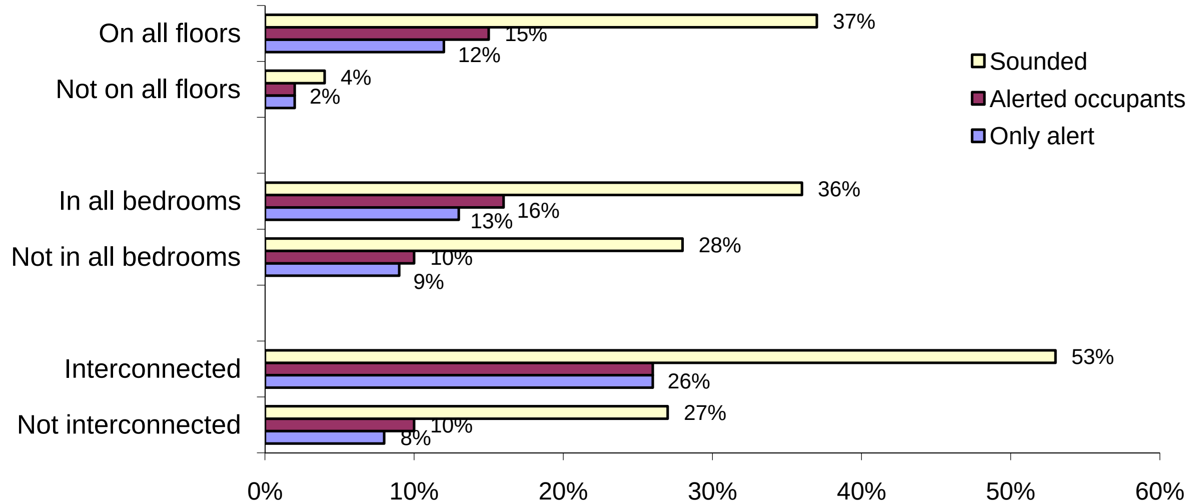
[12] Office of the Deputy Prime Minister. Fires in the Home: Findings from the 2004/05 Survey of English Housing, London, U.K., on line at http://www.communities.gov.uk/pub/313/FiresintheHomefindingsfromthe200405SurveyofEnglishHousingPDF423Kb_id1163313.pdf.

[13] Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

Figure 9. Smoke Alarm Coverage by Operation and Occupant Alert in CPSC's 2004-2005 Residential Fire Survey



Source: Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

Much of the discussion so far has focused on the level of smoke alarm protection installed in the home and the benefits of working smoke alarms. With 23% of the home fire deaths resulting from fires in which a smoke alarm was present, should have operated, but failed to do so, it is clear that the problem of non-working smoke alarms must be addressed.

New Zealand Smoke Alarm Installation Program

Smoke alarms provided warning of real fires in 7% of smoke alarms installed in New Zealand study, but 38% of households reported nuisance alarm problems. Between November 1997 and September 1999, a smoke alarm distribution program visited 4,453 homes in eight communities in New Zealand.[14] After this program, 97% of the households had at least one working smoke alarm. In the spring of 2000, fire service volunteers attempted follow-up visits to 500 households and obtained completed surveys from 437 households. Smoke alarms in thirty, or 7%, of the households had provided warning of real fires since their installation. The majority of the fires were related to cooking activities. In seven cases, the occupant was either asleep or away from the home. Neighbors alerted authorities in two cases. In one case, the smoke alarm alerted a sleeping smoker to a smoldering mattress.

At least one working smoke alarm was found in 72% of participating households at follow-up. The proportion was higher for smoke alarms installed in the previous 18 months. They also discovered that 256 of the 779 smoke alarms had been installed were not operating or were missing. The reasons are shown below:

- 48% of the non-working or missing smoke alarms were missing batteries,
- 20% had batteries that were not fully connected,
- the batteries were dead in 10% of the cases,
- the smoke alarm was defective 8% of the time,
- the unit had been damaged in 7% of the cases, and
- the smoke alarm had been removed in 4% of the cases.

Thirty-eight percent of the households reported problems with nuisance alarms. Thirty-six percent 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.)

They also found that smoke alarms were more likely to be functional in homes:

- That were owner-occupied as opposed to rental;
- With someone over 65 as opposed to all occupants under 65;
- Without any smokers as opposed to those with smokers, and
- Without pre-school children as opposed to with young children.

Fifty-three percent of the households had changed at least one battery since installation. Sixty-three percent of the batteries were changed because they chirped, and 14% were changed on a "nominated day."

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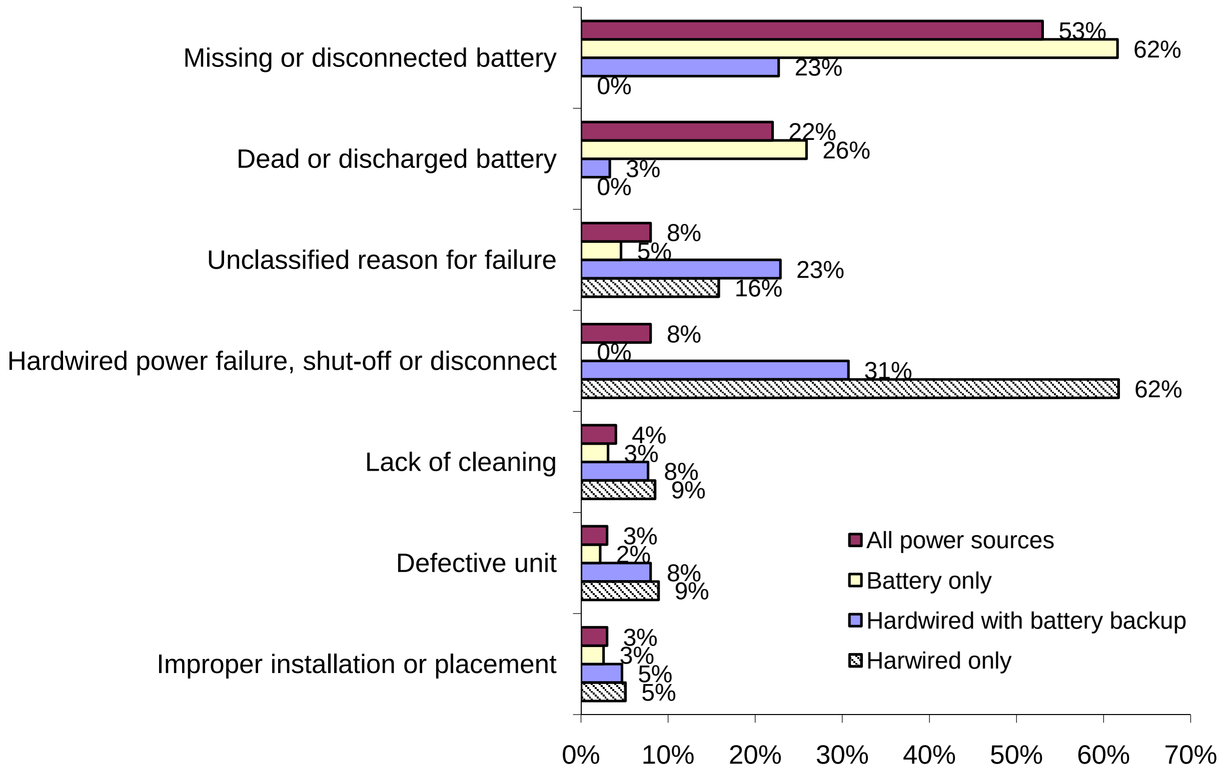
[14] Mavis Duncanson, Katherine Lawrence, Jean Simpson and Alistair Woodward, *Follow-up Survey of Auahi Whakatupato Smoke Alarm Installation Project in the Eastern Bay of Plenty*, New Zealand Fire Service Commission Research Report Number Seven, University of Otago, August 2000, from http://www3.fire.org.nz/CMS_media/pdf/98ae995639dd13b93f3af49e08d73bac.pdf.

Factors in Smoke Alarm Non-Operationality

Three-quarters of non-working smoking alarms used battery power only.
Table 8 shows that 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 10 and Table 9 show power source issues were the leading reason smoke alarms failed to operate in non-confined home fires. The reasons shown are based on the code choices for detector failure reason in the NFIRS 5.0 structure fire module. 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 failures.

Figure 10. Reason Smoke Alarm Failed to Operate in Non-Confined Home Structure Fires: 2003-2006



Source: NFIRS 5.0 and NFPA survey.

When hardwired smoke alarms with 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 as well as temporary power outages or power shutoff to the home.

When hardwired smoke alarms with 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.

It appears that the fire service had a harder time identifying causes of failures in hardwired smoke alarms. 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 3-5 times as high for hardwired smoke alarms as for battery-powered alarms.

Homes that test smoke alarms regularly are more likely to have working smoke alarms.
Many smoke alarm owners do not test or maintain their smoke alarms as often as they should. The 1992 National Smoke Detector Project found somewhat more encouraging news, as a majority of respondents who stated their testing frequency – and nearly half overall – had tested their alarms within the past month. The value of testing was borne out in other parts of the study.

Of those surveyed, 78% believed all their alarms worked, in the majority of cases because they had tested the alarm(s). Eighty-eight percent (88%) of this group were correct; testing showed they did indeed have working smoke alarms. Another 11% of those surveyed did not know whether theirs were working, and of those, only 61% proved to have working smoke alarms when testing was done.

In a 2008 telephone survey done for NFPA, 92% of households with working smoke alarms said that they had tested their smoke alarms at some point, and 29% said they tested them at least once a month.[15]

CPSC conducted an engineering study of reasons for smoke alarm failures in homes that had fires.
The CPSC also conducted a 15-city study of smoke alarm failures in homes with fires in 1992 and 1993. If the alarm did not sound after power was connected and the unit sprayed with aerosol smoke, the unit was, when possible, collected for further study. The devices were also collected if the unit did not respond to the test button, if it had been disconnected due to a problem, if it had a dead battery and the occupant could not recall hearing the warning chirp, and if an AC-powered detector could not be tested but failed during the fire.[16]

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

Half of the smoke alarms that failed to sound in field tests did so when tested in the laboratory. It was suggested that horn corrosion may have been a factor, and that contact continuity may have

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[15] Harris Interactive. *Smoke Alarm Omnibus Question Report*, November 2008.
[16] Linda E. Smith, *Fire Incident Study: National Smoke Detector Project*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, pp. 4-5.

been restored during removal, packing and transporting. One-quarter sounded after repairs were made. Fire-damaged and corroded components were replaced.[17] Disconnected smoke alarms were collected and tested when the occupants reported that the alarms had been disconnected because of problems. Nuisance alarms were the most common complaint. These devices were found to be more sensitive than devices collected for other reasons and devices tested in the *Smoke Detector Operability Study*. Foreign objects such as dust, dirt or insects can increase sensitivity, as can fire products. Because the sensitivity levels before the fires are unknown, the conclusions that can be drawn are limited.

Nuisance Activations and Smoke Alarm Operability

Smoke alarms provide early warning in the event of a fire. Frustration occurs when they operate in response to normal cooking, steam, or for other non-fire reasons or when a smoke detection system malfunctions. Non-fire activations increase the likelihood that the alarm will be disabled or removed. When nuisance alarms are frequent, people may assume that smoke alarms can be ignored.

Unwanted activations far outnumber actual fires.
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.[18]

An earlier study of home smoke detection as units in an Automatic Remote Residential Alarm System (ARRAS) in The Woodlands, TX, found 27 unwanted activations for every real alarm, or unwanted activations in six of every seven homes each year.[19] The 2000 New Zealand smoke alarm installation follow-up discussed earlier found that smoke alarms provided warnings of actual fires in 7% of the households, but 38% of the households reported problems with nuisance alarms.

In a 2004 survey conducted for the NFPA, 40% of the respondents with smoke alarms reported that one had sounded at least once in the past twelve months.[20] Sixty-nine percent reported activations due to cooking activities, 13% were due to battery problems, including the low-battery chirping, 5% were due to steam (frequently from a shower), and 4% of the activations were due to smoke alarm tests.

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[17] Julie I. Shapiro, *Fire Incident Study Sample Analysis*, Bethesda, MD: U.S. Consumer Product Safety Commission, January 1995, pp. 9-10.
[18] 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.
[19] Remote Detection and Alarm for Residences - The Woodlands System, Washington: U.S. Fire Administration, May 1980.
[20] 2004 Fire Prevention Week Survey conducted for National Fire Protection Association by Harris Interactive Market Research, pp. 11-14.

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

- 24% said that food had burned;
- 11% thought about how to turn off the smoke alarm;
- 11% were unconcerned because they knew what caused it to sound;
- 8% investigated;
- O*nly 8% thought there was a fire and they should get out;*
- 7% recognized the low battery signal;
- 7% were annoyed at what they assumed to be a nuisance alarm;
- 3% noted that the smoke alarm works;
- 3% thought they should have used the exhaust fan; and
- 2% didn't recognize it as a smoke alarm and wondered what it was.

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.

To some people, the stress of nuisance alarms outweighs the benefit of smoke alarm protection.

In 1999-2002, a U.K study conducted group and individual interviews with 58 adults to explore perceptions of fire risk, the benefits and problems associated with smoke alarms and whether they would recommend smoke alarms to others.[21] They also interviewed children ages 7-11 at school. Some adults described feeling very stressed by false alarms and had difficulty getting the noise to stop. One woman's smoke alarm activated after she burned something. The noise scared her three-year-old daughter and the girl started screaming. The woman used a broom to try to silence the alarm and broke the alarm in the process. High ceilings posed a challenge in dealing with nuisance alarms and for battery changes. One individual expressed resentment about the smoke alarm going off during what was perceived as normal cooking. Some children reported that smoke alarms activated any time someone was cooking. Equipment activations were not viewed as emergencies. An eight-year-old said, "When the smoke alarm goes off, I have to turn up the television." The authors remark, "In a population already managing a range of health risks, a public health intervention that makes mealtime more, rather than less, stressful, where noise can threaten leisure or relationships with fellow occupants, alarms could pose a threat to immediate wellbeing."

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

[21] H. Roberts, K. Curtis, K. Liabo, D.Rowland, C. DiGuiseppi, and I. Roberts. "Putting Public Health Evidence into Practice: Increasing the Prevalence of Working Smoke Alarms in Disadvantaged Inner City Housing, *J. Epidemiol. Community Health*, 2004:48:280-285, online at http://jech.bmj.com/cgi/reprint/58/4/280.

frequent as removal to use the batteries in another product.[22] The leading problems cited for smoke alarms with dead batteries or missing or disconnected power sources were: 1) alarming to cooking fumes, and 2) alarming continuously when powered. (Some of the latter may have been the device chirping to indicate a low battery.) These two were cited with roughly equal frequency. Sounding too often for unspecified reasons was the next most frequently cited unwanted alarm problem. Alarming to steam or humidity was cited about one-fourth to one-third as often as either of the two leading problems.

1/3 of alarms cited for nuisance activations in CPSC's 1992 study were installed too close to something that could trigger the alarm.

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

Ionization devices had a disproportionate share of nuisance alarms.

Cooking smoke tends to contain more of the smaller particles (less than one micron) that activate an ionization-type device rather than the larger particles that activate a photoelectric-type device. In 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.

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

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.[23]

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.[24] 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

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

[23] Bukowski et al, 2008 revision, p. 250.

[24] 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.

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 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 homes with limited living space and frequent false alarms."

NIST study found that accumulation of cigarette smoke could trigger smoke alarms.
NIST researchers conducted two tests in which two smokers seated in a manufactured home's kitchen area smoked one cigarette each over a period of about four minutes. No alarm thresholds were reached in the first test, but in the second, two thresholds were reached in the ionization alarm closest to the smokers. They also noted that: "The mass concentrations during both tests appear to be approaching threshold levels for photoelectric alarms, suggesting repeated smoking, or more smokers, could produce threshold level values."[25]

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 systems. [26] He surveyed fire departments protecting populations of 47,000 to 67,000 and found 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. Eighty-nine percent of the fire departments did not consider smoke from cooking or burnt food to be a false alarm, and 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 offenders.

Many 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. Section 11.7.8.2 of the *2007* edition of NFPA 72, *National Fire Alarm Code,*® allows remote monitoring stations to "verify alarm signals prior to reporting them to the fire service provided that the verification process does not delay the reporting by more than 90 seconds." This

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[25] Bukowski, et al, 2008 revision, p. 194.
[26] 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.

provision applies to household alarms only. Three-quarters of the departments that responded to Finley's survey did not permit verification of residential alarms.

Ontario Fire Marshal "Make It Stop" campaign addresses nuisance alarms.
Because of concern that nuisance alarms are driving people to disable their smoke alarms, the Ontario, Canada Fire Marshal's Office has started a campaign to address nuisance alarms called "Make It Stop." Their website, http://www.makeitstop.ca/ , provides clear and prominent advice for consumers. They have also been working with local fire departments to get the word out to the media.[27]

Multi-faceted approach is necessary to solving the nuisance alarm problem.
The best solution would seem to involve working with fire alarm companies and homeowners or tenants to ensure that appropriate equipment is used in the correct locations and perhaps switching to photoelectric detection equipment in areas exposed to cooking smoke. NFPA 72 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. Sometimes, the threat of penalties may facilitate a search for a solution. However, the threat may also deter and delay the reporting of real fires. Most people do not automatically assume a sounding smoke alarm is an emergency situation. In some cases, they know what caused the alarm and know that they are safe. However, lives have been lost when real alarms were mistakenly considered false. Unwanted activations can generate a dangerous sense of complacency.

[27] Gilbert, Bev. Personal communication, February 6, 2006.

Table 1.
Findings from Harris Interactive 2008 Smoke Alarm Omnibus Question Report

	Percentage of Homes with Smoke Alarms	All Homes
Homes with at least one smoke alarm	96%	
On each level	84%	81%
Outside each bedroom	81%	78%
Inside each bedroom	37%	36%
Interconnected smoke alarms	41%	39%
Test their alarms ever	92%	87%
Alarms tested at least once a month	29%	25%
Smoke alarms more than 10 years old	10%	9%
When householder is at least 55	17%	16%

Source: Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008. Unknown and refused responses were allocated proportionally among known data.

Table 2.
Type of Detection in Home Structure Fires with Detection Equipment Present
2003-2006 Annual Averages

A. In All Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	238,700	(92%)	1,620	(95%)	9,180	(95%)	$4,021	(91%)
Combination smoke and heat	13,100	(5%)	30	(2%)	250	(3%)	$175	(4%)
More than one type present	4,400	(2%)	40	(2%)	180	(2%)	$99	(2%)
Heat	1,600	(1%)	10	(1%)	50	(1%)	$26	(1%)
Unclassified detection equipment	1,300	(0%)	10	(1%)	30	(0%)	$22	(0%)
Sprinkler with water flow detection	1,100	(0%)	0	(0%)	20	(0%)	$100	(2%)
Total	260,100	(100%)	1,710	(100%)	9,720	(100%)	$4,442	(100%)

B. In Non-Confined Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	117,200	(94%)	1,610	(95%)	7,980	(95%)	$3,987	(91%)
Combination smoke and heat	4,600	(4%)	30	(2%)	190	(2%)	$173	(4%)
More than one type present	1,600	(1%)	40	(2%)	140	(2%)	$98	(2%)
Unclassified detection equipment	800	(1%)	10	(1%)	30	(0%)	$22	(0%)
Heat	700	(1%)	10	(1%)	40	(0%)	$26	(1%)
Sprinkler with water flow detection	400	(0%)	0	(0%)	20	(0%)	$98	(2%)
Total	125,400	(100%)	1,700	(100%)	8,400	(100%)	$4,403	(100%)

C. In Confined Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	121,500	(90%)	10	(100%)	1,200	(91%)	$34	(88%)
Combination smoke and heat	8,500	(6%)	0	(0%)	60	(5%)	$2	(5%)
More than one type present	2,900	(2%)	0	(0%)	50	(3%)	$1	(4%)
Heat	800	(1%)	0	(0%)	10	(1%)	$0	(0%)
Sprinkler with water flow detection	600	(0%)	0	(0%)	0	(0%)	$1	(3%)
Unclassified detection equipment	500	(0%)	0	(0%)	0	(0%)	$0	(0%)
Total	134,700	(100%)	10	(100%)	1,320	(100%)	$39	(100%)

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

Table 3A.
Reported Home Structure Fires by Smoke Alarm Status and Alarm Time
2003-2006 Annual Averages

Alarm Time	Operated	Did Not Operate	None Present	Fire Too Small	Total
Midnight - 12:59 a.m.	3%	3%	3%	2%	3%
1:00 - 1:59 a.m.	2%	3%	3%	2%	3%
2:00 - 2:59 a.m.	2%	3%	3%	1%	2%
3:00 - 3:59 a.m.	2%	3%	3%	1%	2%
4:00 - 4:59 a.m.	2%	3%	2%	1%	2%
5:00 - 5:59 a.m.	2%	3%	2%	1%	2%
6:00 - 6:59 a.m.	2%	2%	2%	2%	2%
7:00 - 7:59 a.m.	2%	3%	3%	3%	3%
8:00 - 8:59 a.m.	3%	3%	3%	2%	3%
9:00 - 9:59 a.m.	4%	4%	3%	4%	4%
10:00 - 10:59 a.m.	4%	4%	4%	5%	4%
11:00 - 11:59 a.m.	4%	5%	4%	5%	5%
Noon - 12:59 p.m.	5%	4%	5%	5%	5%
1:00 - 1:59 p.m.	5%	4%	5%	5%	5%
2:00 - 2:59 p.m.	5%	5%	5%	5%	5%
3:00 - 3:59 p.m.	6%	6%	6%	5%	6%
4:00 - 4:59 p.m.	6%	6%	6%	6%	6%
5:00 - 5:59 p.m.	7%	6%	6%	8%	7%
6:00 - 6:59 p.m.	8%	6%	6%	8%	7%
7:00 - 7:59 p.m.	7%	6%	6%	9%	7%
8:00 - 8:59 p.m.	6%	5%	5%	8%	6%
9:00 - 9:59 p.m.	5%	5%	5%	6%	5%
10:00 - 10:59 p.m.	4%	4%	4%	4%	4%
11:00 - 11:59 p.m.	3%	4%	4%	3%	3%
Total	100%	100%	100%	100%	100%
Average	4%	4%	4%	4%	**4%**
11:00 p.m. - 7:00 a.m.	18%	24%	23%	13%	20%

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

Table 3B.
Reported Home Structure Fire Deaths by Smoke Alarm Status and Alarm Time
2003-2006 Annual Averages

Alarm Time	Operated	Did Not Operate	None Present	Fire Too Small	Total
Midnight - 12:59 a.m.	5%	6%	7%	0%	6%
1:00 - 1:59 a.m.	6%	10%	7%	0%	7%
2:00 - 2:59 a.m.	6%	6%	8%	5%	7%
3:00 - 3:59 a.m.	11%	6%	8%	6%	8%
4:00 - 4:59 a.m.	3%	10%	4%	0%	6%
5:00 - 5:59 a.m.	7%	8%	7%	0%	7%
6:00 - 6:59 a.m.	4%	6%	6%	0%	5%
7:00 - 7:59 a.m.	4%	4%	4%	0%	4%
8:00 - 8:59 a.m.	4%	5%	5%	7%	4%
9:00 - 9:59 a.m.	4%	3%	3%	7%	3%
10:00 - 10:59 a.m.	3%	2%	3%	5%	3%
11:00 - 11:59 a.m.	2%	1%	2%	7%	3%
Noon - 12:59 p.m.	2%	3%	2%	19%	2%
1:00 - 1:59 p.m.	2%	2%	2%	13%	2%
2:00 - 2:59 p.m.	3%	2%	2%	0%	3%
3:00 - 3:59 p.m.	2%	3%	2%	6%	2%
4:00 - 4:59 p.m.	6%	1%	3%	0%	3%
5:00 - 5:59 p.m.	2%	1%	3%	0%	2%
6:00 - 6:59 p.m.	3%	4%	2%	7%	3%
7:00 - 7:59 p.m.	4%	0%	2%	6%	3%
8:00 - 8:59 p.m.	4%	3%	3%	0%	3%
9:00 - 9:59 p.m.	4%	3%	3%	0%	3%
10:00 - 10:59 p.m.	4%	3%	5%	8%	4%
11:00 - 11:59 p.m.	5%	6%	7%	7%	6%
Total	100%	100%	100%	100%	100%
Average	4%	4%	4%	4%	4%
11:00 p.m. - 7:00 a.m.	47%	58%	55%	17%	52%

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

Table 4.
Smoke Alarm Power Source in Home Structure Fires
2003-2006 Annual Averages

A. In All Home Fires

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	145,900	(56%)	1,180	(69%)	5,800	(60%)	$2,411	(54%)
Hardwired with battery backup	58,100	(22%)	190	(11%)	1,930	(20%)	$1,056	(24%)
Hardwired only	43,900	(17%)	230	(14%)	1,580	(16%)	$719	(16%)
Multiple detection devices and power supplies	6,600	(3%)	80	(5%)	250	(3%)	$175	(4%)
Plug-in with battery backup	2,800	(1%)	10	(1%)	70	(1%)	$42	(1%)
Unclassified power source	1,600	(1%)	0	(0%)	50	(1%)	$23	(1%)
Plug-in	900	(0%)	0	(0%)	20	(0%)	$9	(0%)
Mechanical	300	(0%)	0	(0%)	10	(0%)	$7	(0%)
Total	260,100	(100%)	1,710	(100%)	9,720	(100%)	$4,442	(100%)

B. In Non-Confined Home Fires

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	79,100	(63%)	1,170	(69%)	5,240	(62%)	$2,394	(54%)
Hardwired with battery backup	24,000	(19%)	190	(11%)	1,520	(18%)	$1,045	(24%)
Hardwired only	17,300	(14%)	230	(14%)	1,320	(16%)	$711	(16%)
Multiple detection devices and power supplies	2,600	(2%)	80	(5%)	200	(2%)	$172	(4%)
Plug-in with battery backup	1,300	(1%)	10	(1%)	50	(1%)	$41	(1%)
Unclassified power source	600	(0%)	0	(0%)	40	(1%)	$23	(1%)
Plug-in	400	(0%)	0	(0%)	20	(0%)	$9	(0%)
Mechanical	200	(0%)	0	(0%)	10	(0%)	$7	(0%)
Total	125,400	(100%)	1,700	(100%)	8,400	(100%)	$4,403	(100%)

Table 4.
Smoke Alarm Power Source in Home Structure Fires
2003-2006 Annual Averages
(Continued)

C. In Confined Home Fires

Power Source	**Fires**		**Civilian Deaths**		**Civilian Injuries**		**Direct Property Damage (in Millions)**	
Battery only	66,800	(50%)	10	(100%)	560	(42%)	$17	(45%)
Hardwired with battery backup	34,200	(25%)	0	(0%)	410	(31%)	$11	(28%)
Hardwired only	26,700	(20%)	0	(0%)	270	(20%)	$7	(18%)
Multiple detection devices and power supplies	4,000	(3%)	0	(0%)	50	(4%)	$2	(6%)
Plug-in with battery backup	1,500	(1%)	0	(0%)	20	(2%)	$0	(1%)
Unclassified power source	900	(1%)	0	(0%)	10	(1%)	$0	(0%)
Plug-in	500	(0%)	0	(0%)	0	(0%)	$0	(1%)
Mechanical	200	(0%)	0	(0%)	0	(0%)	$0	(0%)
Total	134,700	(100%)	10	(100%)	1,320	(100%)	$39	(100%)

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally. Smoke alarm presence, operation, and power source are not required fields in NFIRS 5.0. Smoke alarm presence was completed in 69% of non-confined fires but only 2% of confined fires. Estimates of these elements in non-confined fires are therefore more reliable than estimates for confined fires and totals but non-confined estimates exclude many minor fires.

Source: NFIRS 5.0 and NFPA survey.

Table 5.
Smoke Alarm Operation in Home Fires Considered Large Enough to Activate Alarm
By Power Source
2003-2006 Annual Averages

A. In All Home Fires

Power Source	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage
Battery only	75%	52%	65%	78%
All hardwired	91%	75%	87%	89%
Hardwired only	*89%*	*69%*	*84%*	*87%*
Hardwired with battery backup	*93%*	*83%*	*90%*	*91%*
All power sources	83%	62%	75%	83%

B. In Non-Confined Home Fires

Power Source	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage
Battery only	73%	52%	65%	78%
All hardwired	87%	76%	86%	89%
Hardwired only	*82%*	*69%*	*82%*	*87%*
Hardwired with battery backup	*91%*	*83%*	*90%*	*91%*
All power sources	79%	62%	74%	83%

C. In Confined Home Fires

Power Source	Fires	Civilian Deaths	Civilian Injuries	Direct Property Damage
Battery only	81%	100%	71%	81%
All hardwired	94%	*	92%	92%
Hardwired only	*93%*	*	*94%*	*88%*
Hardwired with battery backup	*95%*	*	*91%*	*94%*
All power sources	88%	100%	83%	87%

* An average of 10 home fire deaths per year were reported in confined fires with battery-powered smoke alarms. No deaths were reported in confined fires with hardwired smoke alarms.

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally. Smoke alarm presence, operation, and power source are not required fields in NFIRS 5.0. Smoke alarm presence was completed in 69% of non-confined fires but only 2% of confined fires. Estimates of these elements in non-confined fires are therefore more reliable than estimates for confined fires and totals, but non-confined estimates exclude many minor fires. Operation was calculated based on the number of fires in which smoke alarms were present and operated/divided by the number preset that operated and failed to operate. Fires that were too small to operate were excluded. Minor power sources are not shown separately but are include in the entry for all power sources.

Source: NFIRS 5.0 and NFPA survey.

Table 6.
2007 American Housing Survey Findings on Households with Smoke Alarms Based on Self-Reports Collected during In-Person Interviews

Characteristic	All Homes	Smoke Alarm Powered by: Electricity and Battery	Electricity Only	Battery Only	Batteries Replaced in Last Six Months
Total	94%	24%	9%	67%	77%
Owner	94%	28%	9%	64%	77%
Renter	92%	16%	10%	74%	75%
Newer home - four years old or less	99%	53%	10%	37%	68%
Manufactured home	90%	27%	14%	59%	78%
Home (property) has severe physical problems	85%	27%	9%	78%	77%
Home (property) has moderate physical problems	83%	13%	8%	78%	73%
Black householder	92%	15%	9%	76%	77%
Hispanic householder	88%	15%	10%	74%	78%
Householder at least 65 years old	92%	19%	11%	70%	78%
Householder moved in past year	93%	22%	9%	69%	73%
Household below poverty line	93%	15%	10%	76%	77%
In central city	93%	19%	9%	73%	76%
In suburb of central city	95%	26%	10%	64%	78%
In rural area outside metropolitan statistical area	90%	23%	8%	68%	78%
Northeast	96%	21%	10%	69%	82%
Midwest	96%	22%	7%	71%	79%
South	91%	25%	10%	65%	75%
West	93%	27%	9%	65%	71%

Note: The survey reported these data as "working smoke alarms." However, it appears the survey did not ask separate questions about smoke alarm presence and operability and did not verify that the smoke alarms were working. For that reason, the AHS results presented here do not mention whether they are working.

Source: 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.

Table 7.
Smoke Alarm Findings from CPSC's 2004-2005 Residential Fire Survey

A. Smoke Alarm Coverage in Fire and Non-Fire Households

Based on weighted responses from 916 fire households and 2,161 non-fire households

Alarm Coverage	Fire Household	Non-Fire Household
Smoke alarm present	93%	97%
On all floors	82%	84%
In all bedrooms	22%	31%
Interconnected	13%	19%

Sections B, C and D are based on weighted responses from 270 households having low severity fires within the past 14 days or high severity fires within the past 21 days. In Section B, indentation indicates a sequence – In 86% of the fires, someone was home and at least one alarm was present.

B. Smoke Alarm Performance and Effectiveness

Condition	Percent of All Fires
Fires with someone home	96%
At least one alarm present	86%
Smoke alarm sounded	30%
Alerted people	12%
Provided only alert	10%
Alarm did not sound	55%
Not enough smoke	49%

C. Smoke Alarm Performance and Effectiveness by Extent of Coverage

Alarm Coverage	Sounded	Alerted Occupants	Only Alert
On all floors	37%	15%	2%
Not on all floors	4%	2%	2%
In all bedrooms	36%	16%	13%
Not in all bedrooms	28%	10%	9%
Interconnected	53%	26%	26%
Not interconnected	27%	10%	8%

D. Smoke Alarm Performance and Effectiveness by Cause of Fire

Cause of Fire	Sounded	Alerted Occupants	Only Alert
Stove fires	41%	16%	13%
Other cooking	30%	16%	11%
Cigarette/match	28%	8%	8%
Candle	20%	7%	6%
Lighting/wiring	6%	5%	5%
Heating/cooling	18%	4%	1%

Source: Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.

Table 8.
Power Source in Smoke Alarms That Did Not Operate
in Non-Confined Home Structure Fires Considered Large Enough to Activate Alarm
2003-2006 Annual Averages

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	17,500	(77%)	530	(82%)	1,650	(80%)	$496	(69%)
Hardwired only	2,600	(12%)	60	(10%)	220	(11%)	$95	(13%)
Hardwired with battery backup	1,900	(8%)	30	(5%)	140	(7%)	$93	(13%)
Multiple detectors and power supplies	300	(1%)	20	(4%)	30	(1%)	$20	(3%)
Plug-in with or without battery backup	200	(1%)	0	(0%)	10	(1%)	$8	(1%)
Other known power source	100	(0%)	0	(0%)	10	(0%)	$2	(0%)
Total	22,600	(100%)	640	(100%)	2,060	(100%)	$714	(100%)

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

Table 9.
Reason Smoke Alarm Did Not Operate in Non-Confined Home Structure Fires Considered Large Enough to Activate Alarm 2003-2006 Annual Averages

A. All Power Sources Combined

Reason for Failure	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Missing or disconnected battery	11,900	(53%)	470	(72%)	1,320	(64%)	$356	(50%)
Dead or discharged battery	4,900	(22%)	50	(8%)	340	(17%)	$121	(17%)
Unclassified reason for failure	1,800	(8%)	30	(4%)	100	(5%)	$109	(15%)
Hardwired power failure, shut-off or disconnect	1,700	(8%)	50	(8%)	140	(7%)	$68	(9%)
Lack of cleaning	900	(4%)	20	(3%)	80	(4%)	$22	(3%)
Defective unit	700	(3%)	10	(2%)	40	(2%)	$10	(1%)
Improper installation or placement	700	(3%)	20	(3%)	40	(2%)	$28	(4%)
Total	22,600	(100%)	640	(100%)	2,060	(100%)	$714	(100%)

B. Battery Only

Reason for Failure	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Missing or disconnected battery	11,200	(62%)	460	(84%)	1,270	(72%)	$330	(64%)
Dead or discharged battery	4,700	(26%)	40	(8%)	330	(19%)	$117	(23%)
Unclassified reason for failure	800	(5%)	10	(2%)	50	(3%)	$33	(6%)
Lack of cleaning	600	(3%)	10	(2%)	50	(3%)	$15	(3%)
Improper installation or placement	500	(3%)	20	(3%)	40	(2%)	$15	(3%)
Defective unit	400	(2%)	0	(0%)	20	(1%)	$6	(1%)
Total	18,200	(100%)	550	(100%)	1,750	(100%)	$516	(100%)

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

Table 9.
Reason Smoke Alarm Did Not Operate in Non-Confined Home Structure Fires
Considered Large Enough to Activate Alarm
2003-2006 Annual Averages
(Continued)

C. Hardwired Only

Reason for Failure	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Hardwired power failure, shut-off or disconnect	1,600	(62%)	60	(87%)	150	(64%)	$56	(60%)
Unclassified reason for failure	400	(16%)	0	(4%)	40	(17%)	$20	(22%)
Defective unit	200	(9%)	0	(5%)	20	(8%)	$4	(5%)
Lack of cleaning	200	(9%)	0	(4%)	20	(9%)	$4	(5%)
Improper installation or placement	100	(5%)	0	(0%)	10	(2%)	$8	(9%)
Total	2,600	(100%)	70	(100%)	230	(100%)	$93	(100%)

D. Hardwired with Battery Backup

Reason for Failure	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Hardwired power failure, shut-off or disconnect	1,900	(31%)	50	(25%)	70	(13%)	$53	(26%)
Unclassified reason for failure	1,400	(23%)	60	(31%)	140	(27%)	$106	(51%)
Missing or disconnected battery	1,400	(23%)	0	(0%)	170	(34%)	$29	(14%)
Defective unit	500	(8%)	30	(18%)	20	(5%)	$2	(1%)
Lack of cleaning	500	(8%)	0	(0%)	60	(11%)	$5	(3%)
Improper installation or placement	300	(5%)	30	(18%)	20	(4%)	$10	(5%)
Dead or discharged battery	200	(3%)	20	(9%)	30	(6%)	$1	(1%)
Total	6,200	(100%)	200	(100%)	510	(100%)	$207	(100%)

Note: Sums may not equal totals due to rounding errors. Unknowns have been allocated proportionally.

Source: NFIRS 5.0 and NFPA survey.

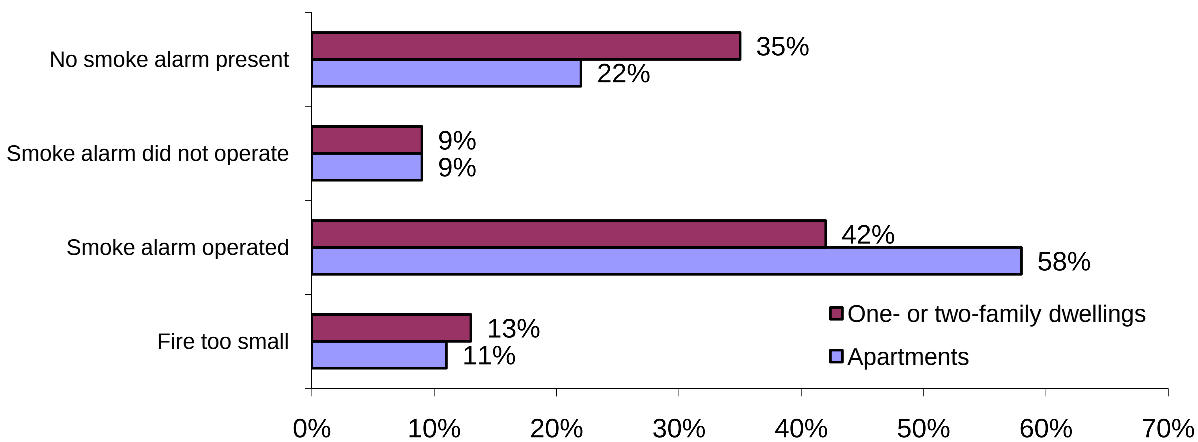
Smoke Alarms in One- and Two-Family Homes vs. Apartments

Smoke alarms operated in 42% of the reported fires in one- and two-family homes and 58% of the reported apartment fires.

Seventy percent of the reported home fires and 84% of the home fire deaths in 2003-2006 occurred in one- and two-family homes (including manufactured homes). Consequently, the profile for smoke alarm performance for all homes resembles that of one-and two-family homes. But there are major differences between one- and two-family homes and the more heavily regulated apartments.[28] Tables 10 and 11 and Figure 11 show that smoke alarms operated in 58% of the reported apartment fires but less than half (42%) of the reported fires in one and two-family homes.

The NFIRS coding system counts smoke alarms in the fire area as present, although the term "fire area" is not specifically defined. It does not capture when in the fire's development the device activated or how close it was to area of origin. A fire that starts in an apartment that has no working smoke alarm may activate a smoke alarm in a common hallway or a unit nearby. Residents of the other units may benefit from these smoke alarms' warnings even when the unit of origin lacks the protection. Similarly, a fire that starts on a second story without a smoke alarm may eventually activate a smoke alarm on the first floor.

Figure 11. Smoke Alarm Status in Reported One- and Two-Family Home vs. Apartment Fires: 2003-2006



Source: NFIRS 5.0 and NFPA survey.

54% of apartment fire deaths and 32% of one-and two-family home fire deaths resulted from fires with operating smoke alarms.

Figure 12 shows that only one-third (32%) of the fire deaths in one-and two-family homes resulted from fires with operating smoke alarms compared to more than half (54%) in apartments. Almost half (46%) of the deaths resulting from fires in one- or two-family homes

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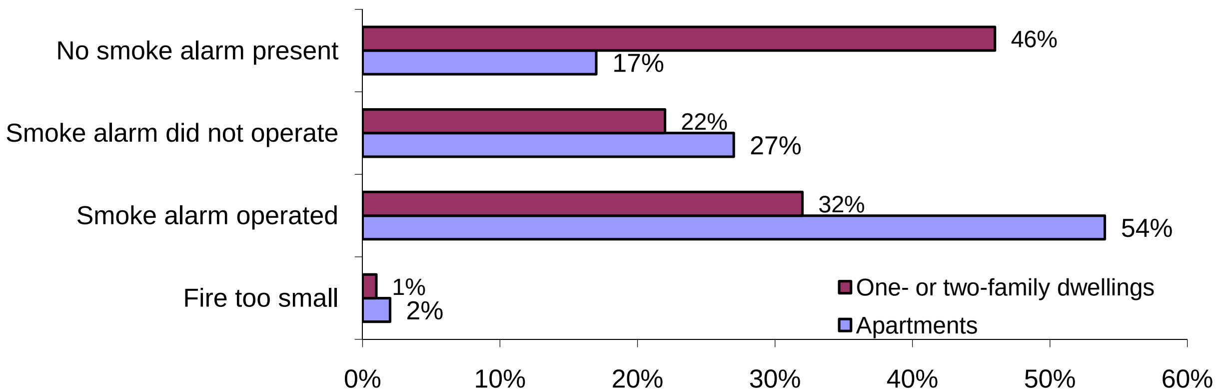
[28] The category of apartment includes tenements, flats and properties of similar configuration. Townhouses normally involve three or more separate housing units per building and so would be grouped with apartments. Most condominiums would also be grouped with apartments, but it is important to note that "condominium" is a type of ownership, not a type of building or property use.

occurred in properties with no smoke alarms at all compared to only 17% of the deaths from apartment fires with no smoke alarms.

Figure 12. Smoke Alarm Status in Deaths Resulting from Fires in One- and Two-Family Homes vs. Apartments: 2003-2006

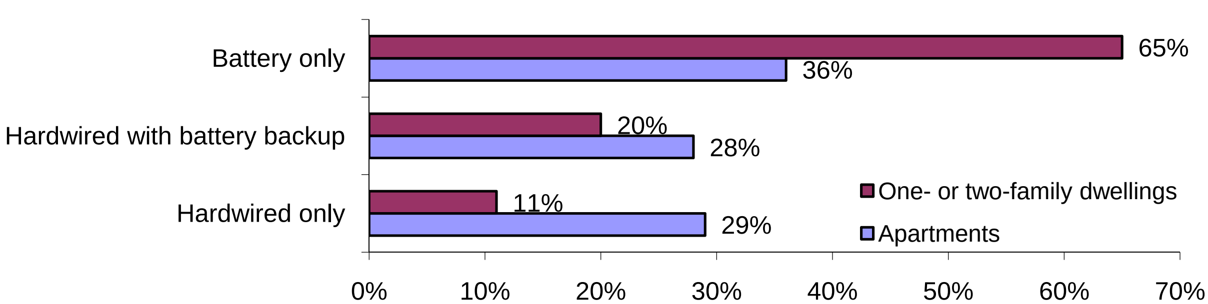


Source: NFIRS 5.0 and NFPA survey.

Hardwired smoke alarms were more common in apartment fires.
Tables 12 and 13 show that there is little difference in the type of detection equipment found in reported fires in one- and two-family homes and apartments. Equipment designed to detect smoke only accounted for 94% of the detection equipment in one- and two-family homes and 87% of such equipment in apartments. Combination smoke and heat alarms accounted for an additional 5% of the detection types found in one-and two-family homes and 6% of the detection types in apartments. Apartments were more likely to have more than one type of detection equipment present (4% vs. 1%).

Power sources do differ by occupancy. Figure 13 and Tables 14 and 15 show that only 36% of the smoke alarms in apartment structure fires were powered by batteries only compared to 65% in one- and two-family homes.

Figure 13. Leading Smoke Alarm Power Sources in Reported Home Fires, by Occupancy 2003-2006



Source: NFIRS 5.0 and NFPA survey.

When hardwired smoke alarms were present in one-and two-family home fires, the alarms were more likely to have battery backup than were the hardwired smoke alarms in apartment fires. It is possible that hardwired smoke alarms in one- and two-family homes are newer, on average, because the emphasis on battery backup is a more recent development.

Apartment fatal fire victims were more likely to be in the room of fire origin.
Table 16 is an overview of characteristics of fatal victims and their fires during 2003-2006, in a) one- and two-family homes, and b) apartments, with operating smoke alarms, with smoke alarms that were present but did not operate, and with no smoke alarms at all. Many of the differences in Table 16 are small. Some groups of characteristics seem to be measuring the same or similar phenomena but show inconsistent patterns in doing so. In many cases, the differences seem to vary more by occupancy than by smoke alarm status. The number of apartment fatalities is relatively small and should be viewed with caution. The most striking differences in Table 16 are seen in the victim's proximity to the fire. Regardless of smoke alarm status, apartment victims were more likely to have been in the general area of the fire at ignition than were the victims in one- and two-family homes. When smoke alarms operated, 59% of the victims of fatal fires in one-and two-family homes were in the general area of origin at time of fatal injury compared to 76% of the apartment victims who were that close to the fire. Apartment victims were also more likely to have been in the area of origin and involved in the ignition than victims in one- and two-family homes. This suggests that there were proportionally more people in apartments who were so close to the fire that they may not have had time to escape, even with the warning from a working smoke alarm.

Table 10.
Smoke Alarm Status in One- and Two-Family Home Fires
2003-2006 Annual Averages

Smoke Alarm Status	**Fires**		**Civilian Deaths**		**Civilian Injuries**		**Direct Property Damage (in Millions)**	
Smoke alarm operated in non-confined fire	64,400	(24%)	750	(31%)	3,830	(41%)	$2,791	(56%)
Smoke alarm operated in confined fire	47,900	(18%)	10	(0%)	470	(5%)	$21	(0%)
Subtotal – Operating smoke alarm	*112,300*	*(42%)*	*760*	*(32%)*	*4,300*	*(46%)*	*$2,812*	*(56%)*
Smoke alarm present but did not operate in non-confined fire	18,000	(7%)	520	(22%)	1,530	(17%)	$562	(11%)
Smoke alarm present but did not operate in confined fire	6,700	(3%)	0	(0%)	90	(1%)	$3	(0%)
Subtotal – Smoke alarm present but did not operate	*24,700*	*(9%)*	*520*	*(22%)*	*1,620*	*(18%)*	*$565*	*(11%)*
Fire too small to operate in non-confined fire	14,800	(6%)	20	(1%)	290	(3%)	$95	(2%)
Fire too small to operate in confined fire	19,900	(8%)	0	(0%)	90	(1%)	$4	(0%)
Subtotal – Fire too small to operate alarm	*34,700*	*(13%)*	*20*	*(1%)*	*380*	*(4%)*	*$99*	*(2%)*
Subtotal – Smoke alarm present	*171,700*	*(65%)*	*1,300*	*(54%)*	*6,300*	*(68%)*	*$3,475*	*(69%)*
No smoke alarm present in non-confined fire	71,400	(27%)	1,110	(46%)	2,680	(29%)	$1,530	(31%)
No smoke alarm present in confined fire	22,100	(8%)	0	(0%)	270	(3%)	$8	(0%)
Subtotal – No smoke alarm	*93,600*	*(35%)*	*1,110*	*(46%)*	*2,950*	*(32%)*	*$1,538*	*(31%)*
Subtotal – No working smoke alarm present	*118,300*	*(45%)*	*1,630*	*(68%)*	*4,570*	*(49%)*	*$2,103*	*(42%)*
Total	**265,300**	**(100%)**	**2,400**	**(100%)**	**9,250**	**(100%)**	**$5,013**	**(100%)**

Note: Sums may not equal totals due to rounding errors. Confined and non-confined fires were analyzed separately. Smoke alarm presence or absence was reported in 69% of non-confined fires and 2% of confined fires. Fires with unknown or missing data were allocated proportionally among fires with missing data.

Source: NFIRS 5.0 and NFPA survey.

Table 11.
Smoke Alarm Status in Apartment Fires
2003-2006 Annual Averages

Smoke Alarm Status	**Fires**		**Civilian Deaths**		**Civilian Injuries**		**Direct Property Damage (in Millions)**	
Smoke alarm operated in non-confined fire	19,000	(17%)	240	(54%)	2,020	(53%)	$763	(67%)
Smoke alarm operated in confined fire	46,900	(41%)	0	(0%)	470	(12%)	$7	(1%)
Subtotal – Operating smoke alarm	*65,900*	*(58%)*	*240*	*(54%)*	*2,490*	*(65%)*	*$771*	*(68%)*
Smoke alarm present but failed to operate in non-confined fire	4,500	(4%)	120	(27%)	540	(14%)	$149	(13%)
Smoke alarm present but did not operate in confined fire	6,200	(5%)	0	(0%)	90	(2%)	$1	(0%)
Subtotal – Smoke alarm present but did not operate	*10,700*	*(9%)*	*120*	*(27%)*	*630*	*(16%)*	*$150*	*(13%)*
Fire too small to operate in non-confined fire	3,800	(3%)	10	(2%)	130	(3%)	$20	(2%)
Fire too small to operate in confined fire	8,200	(7%)	0	(0%)	90	(2%)	$2	(0%)
Subtotal – Fire too small to operate alarm	*12,000*	*(11%)*	*10*	*(2%)*	*230*	*(6%)*	*$21*	*(2%)*
Subtotal – Smoke alarm present	*88,600*	*(78%)*	*370*	*(83%)*	*3,350*	*(87%)*	*$942*	*(83%)*
No smoke alarm present in non-confined fire	12,100	(11%)	80	(17%)	430	(11%)	$188	(17%)
No smoke alarm present in confined fire	12,600	(11%)	0	(0%)	60	(2%)	$1	(0%)
Subtotal – No smoke alarm	*24,700*	*(22%)*	*80*	*(17%)*	*490*	*(13%)*	*$189*	*(17%)*
Subtotal – No working smoke alarm present	*35,400*	*(31%)*	*200*	*(44%)*	*1,120*	*(29%)*	*$339*	*(30%)*
Total	**113,300**	**(100%)**	**450**	**(100%)**	**3,840**	**(100%)**	**$1,132**	**(100%)**

Note: Sums may not equal totals due to rounding errors. Confined and non-confined fires were analyzed separately. Smoke alarm presence or absence was reported in 69% of non-confined fires and 2% of confined fires. Fires with unknown or missing data were allocated proportionally among fires with missing data.

Source: NFIRS 5.0 and NFPA survey.

Table 12.
Type of Detection in One- and Two-Family Home Structure Fires
with Detection Equipment Present
2003-2006 Annual Averages

A. In All One- and Two-Family Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	160,700	(94%)	1,240	(96%)	6,100	(97%)	$3,171	(91%)
Combination smoke and heat	7,900	(5%)	20	(1%)	130	(2%)	$138	(4%)
More than one type present	1,500	(1%)	10	(1%)	40	(1%)	$40	(1%)
Unclassified detection equipment	900	(0%)	10	(1%)	10	(0%)	$14	(0%)
Heat	800	(0%)	10	(1%)	20	(0%)	$15	(0%)
Sprinkler with water flow detection	100	(0%)	0	(0%)	0	(0%)	$96	(3%)
Total	171,700	(100%)	1,300	(100%)	6,300	(100%)	$3,475	(100%)

B. In Non-Confined One- and Two-Family Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	92,000	(95%)	1,230	(96%)	5,480	(97%)	$3,145	(91%)
Combination smoke and heat	3,500	(4%)	20	(1%)	110	(2%)	$136	(4%)
More than one type present	700	(1%)	10	(1%)	30	(0%)	$40	(1%)
Unclassified detection equipment	500	(1%)	10	(1%)	10	(0%)	$14	(0%)
Heat	500	(0%)	10	(1%)	20	(0%)	$15	(0%)
Sprinkler with water flow detection	0	(0%)	0	(0%)	0	(0%)	$96	(3%)
Total	97,200	(100%)	1,290	(100%)	5,640	(100%)	$3,448	(100%)

C. In Confined One- and Two-Family Home Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	68,700	(92%)	10	(100%)	620	(94%)	$26	(94%)
Combination smoke and heat	4,300	(6%)	0	(0%)	20	(3%)	$1	(5%)
More than one type present	800	(1%)	0	(0%)	10	(2%)	$0	(0%)
Unclassified detection equipment	300	(0%)	0	(0%)	0	(0%)	$0	(0%)
Heat	300	(0%)	0	(0%)	10	(1%)	$0	(0%)
Sprinkler with water flow detection	0	(0%)	0	(0%)	0	(0%)	$0	(0%)
Total	74,500	(100%)	10	(100%)	660	(100%)	$28	(100%)

Note: Sums may not equal totals due to rounding errors. Entries of zero may actually be zero or may have rounded to zero.

Source: NFIRS 5.0 and NFPA survey.

Table 13.
Type of Detection in Apartment Structure Fires with Detection Equipment Present
2003-2006 Annual Averages

A. In All Apartment Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	77,500	(87%)	340	(92%)	3,040	(91%)	$832	(88%)
Combination smoke and heat	5,400	(6%)	10	(2%)	120	(3%)	$36	(4%)
More than one type present	3,300	(4%)	20	(5%)	130	(4%)	$51	(5%)
Sprinkler with water flow detection	1,100	(1%)	0	(0%)	20	(0%)	$6	(1%)
Heat	900	(1%)	0	(0%)	30	(1%)	$10	(1%)
Unclassified detection equipment	300	(0%)	0	(1%)	20	(1%)	$7	(1%)
Total	88,600	(100%)	370	(100%)	3,350	(100%)	$942	(100%)

B. In Non-Confined Apartment Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	24,700	(90%)	340	(92%)	2,460	(92%)	$824	(88%)
Combination smoke and heat	1,000	(4%)	10	(2%)	80	(3%)	$36	(4%)
More than one type present	800	(3%)	20	(5%)	100	(4%)	$50	(5%)
Sprinkler with water flow detection	300	(1%)	0	(0%)	20	(1%)	$5	(1%)
Unclassified detection equipment	200	(1%)	0	(1%)	20	(1%)	$7	(1%)
Heat	200	(1%)	0	(0%)	20	(1%)	$10	(1%)
Total	27,300	(100%)	370	(100%)	2,690	(100%)	$932	(100%)

C. In Confined Apartment Fires

Type of Detection Equipment	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Smoke	52,800	(86%)	0	(NA)	580	(88%)	$8	(77%)
Combination smoke and heat	4,400	(7%)	0	(NA)	40	(6%)	$0	(3%)
More than one type present	2,600	(4%)	0	(NA)	30	(5%)	$1	(9%)
Sprinkler with water flow detection	800	(1%)	0	(NA)	0	(0%)	$1	(9%)
Heat	600	(1%)	0	(NA)	10	(1%)	$0	(1%)
Unclassified detection equipment	100	(0%)	0	(NA)	0	(0%)	$0	(1%)
Total	61,300	(100%)	0	(NA)	660	(100%)	$11	(100%)

NA – Not applicable because total is zero.

Note: Sums may not equal totals due to rounding errors. Entries of zero may actually be zero or may have rounded to zero.

Source: NFIRS 5.0 and NFPA survey.

Table 14.
Smoke Alarm Power Source in One- and Two-Family Home Structure Fires
2003-2006 Annual Averages

A. In All One- and Two-Family Home Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	111,300	(65%)	1,020	(79%)	4,520	(72%)	$2,048	(59%)
Hardwired with battery backup	34,300	(20%)	110	(8%)	980	(16%)	$784	(23%)
Hardwired only	19,600	(11%)	110	(8%)	600	(10%)	$479	(14%)
Multiple detection devices and power supplies	3,000	(2%)	40	(3%)	110	(2%)	$95	(3%)
Plug-in (with or without battery backup)	2,400	(1%)	20	(1%)	60	(1%)	$46	(1%)
Other known	1,100	(1%)	10	(0%)	40	(1%)	$23	(1%)
Total	171,700	(100%)	1,300	(100%)	6,300	(100%)	$3,475	(100%)

B. In Non-Confined One- and Two-Family Home Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	67,600	(70%)	1,010	(78%)	4,140	(73%)	$2,033	(59%)
Hardwired with battery backup	16,800	(17%)	110	(8%)	810	(14%)	$777	(23%)
Hardwired only	9,400	(10%)	110	(8%)	540	(10%)	$476	(14%)
Multiple detection devices and power supplies	1,500	(2%)	40	(3%)	80	(1%)	$94	(3%)
Plug-in (with or without battery backup)	1,300	(1%)	20	(1%)	40	(1%)	$45	(1%)
Other known	500	(1%)	10	(0%)	30	(0%)	$23	(1%)
Total	97,200	(100%)	1,290	(100%)	5,640	(100%)	$3,448	(100%)

C. In Confined One- and Two-Family Home Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	43,700	(59%)	10	(100%)	380	(58%)	$16	(56%)
Hardwired with battery backup	17,400	(23%)	0	(0%)	170	(25%)	$7	(26%)
Hardwired only	10,200	(14%)	0	(0%)	60	(9%)	$4	(13%)
Multiple detection devices and power supplies	1,500	(2%)	0	(0%)	30	(4%)	$1	(2%)
Plug-in (with or without battery backup)	1,100	(2%)	0	(0%)	10	(2%)	$1	(2%)
Other known	500	(1%)	0	(0%)	10	(1%)	$0	(0%)
Total	74,500	(100%)	10	(100%)	660	(100%)	$28	(100%)

Note: Sums may not equal totals due to rounding errors. Entries of zero may actually be zero or may round to zero.
Source: NFIRS 5.0 and NFPA survey.

Table 15.
Smoke Alarm Power Source in Apartment Structure Fires
2003-2006 Annual Averages

A. In All Apartment Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	31,700	(36%)	170	(46%)	1,310	(39%)	$375	(40%)
Hardwired only	26,000	(29%)	60	(17%)	880	(26%)	$259	(28%)
Hardwired with battery backup	24,900	(28%)	100	(27%)	970	(29%)	$223	(24%)
Multiple detection devices and power supplies	3,900	(4%)	30	(9%)	140	(4%)	$73	(8%)
Plug-in (with or without battery backup)	1,200	(1%)	0	(0%)	30	(1%)	$6	(1%)
Other known	900	(1%)	0	(0%)	20	(1%)	$6	(1%)
Total	88,600	(100%)	370	(100%)	3,350	(100%)	$942	(100%)

B. In Non-Confined Apartment Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	12,100	(44%)	170	(46%)	1,130	(42%)	$373	(40%)
Hardwired only	7,000	(26%)	100	(27%)	720	(27%)	$219	(24%)
Hardwired with battery backup	6,600	(24%)	60	(17%)	670	(25%)	$256	(27%)
Multiple detection devices and power supplies	1,000	(4%)	30	(9%)	120	(4%)	$71	(8%)
Plug-in (with or without battery backup)	300	(1%)	0	(0%)	30	(1%)	$6	(1%)
Other known	200	(1%)	0	(0%)	20	(1%)	$6	(1%)
Total	27,300	(100%)	370	(100%)	2,690	(100%)	$932	(100%)

C. In Confined Apartment Fires with Smoke Alarms

Power Source	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Battery only	19,600	(32%)	0	(*)	180	(27%)	$2	(22%)
Hardwired only	19,400	(32%)	0	(*)	210	(31%)	$3	(29%)
Hardwired with battery backup	17,900	(29%)	0	(*)	250	(37%)	$3	(32%)
Multiple detection devices and power supplies	2,900	(5%)	0	(*)	20	(3%)	$2	(15%)
Plug-in (with or without battery backup)	900	(1%)	0	(*)	10	(1%)	$0	(2%)
Other known	600	(1%)	0	(*)	0	(0%)	$0	(0%)
Total	61,300	(100%)	0	(*)	660	(100%)	$11	(100%)

Note: Sums may not equal totals due to rounding errors. Entries of zero may actually be zero or may round to zero.
Source: NFIRS 5.0 and NFPA survey.

Table 16.
Characteristics of Fatal Fires and Victims in Non-Confined Home Structure Fires by Occupancy and Smoke Alarm Status 2003-2006

	One- and Two-Family Homes						*Apartments*					
Characteristic	**Alarm Operated**		**Did Not Operate**		**No Alarms**		**Alarm Operated**		**Did Not Operate**		**No Alarms**	
Total*	**750**	**(100%)**	**520**	**(100%)**	**1,110**	**(100%)**	**240**	**(100%)**	**120**	**(100%)**	**80**	**(100%)**
Victim in area of origin at time of incident and involved	310	(42%)	150	(29%)	370	(33%)	140	(74%)	40	(33%)	40	(53%)
Victim in general area of fire at time of injury	440	(59%)	220	(42%)	520	(47%)	180	(76%)	70	(56%)	50	(71%)
Fire spread flames beyond room of origin	540	(71%)	380	(73%)	890	(81%)	140	(57%)	70	(55%)	50	(66%)
Victim unconscious, restrained, physically or possibly mentally disabled or impaired by drugs or alcohol**	290	(39%)	280	(37%)	400	(36%)	110	(45%)	50	(39%)	50	(68%)
Victim age 65 or older	260	(34%)	110	(22%)	280	(25%)	80	(35%)	20	(19%)	10	(18%)
Victim age under five	50	(7%)	40	(7%)	130	(12%)	10	(6%)	20	(14%)	10	(17%)
Victim unable to act or acted irrationally	190	(19%)	60	(12%)	110	(10%)	50	(19%)	10	(11%)	10	(19%)
Victim attempting fire control or rescue	100	(9%)	20	(4%)	60	(6%)	20	(8%)	10	(10%)	0	(0%)

* The totals are provided for context only. Because the entries in this table are pulled from different fields, the sums will greatly exceed the totals. This table does not include fire deaths resulting from fires that were too small to activate the smoke alarm. Entries of zero may actually be zero or may have rounded to zero.

**Multiple entries are allowed in this field so double counting is possible.

Note: Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Characteristics of Victims in Fires with and without Working Smoke Alarms

As shown in Figure 8, the death rate per 100 reported home structure fires with working smoke alarms is half the rate found in reported fires in which either no smoke alarms were present at all or smoke alarms were present but did not operate. This section examines the characteristics and circumstances in which death occurred despite the presence of a working smoke alarm.

Compared to deaths resulting from fires in which no smoke alarms were present or alarms were present but did not operate, 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,

21% of fatal home fire victims with working smoke alarms were alerted but did not respond.

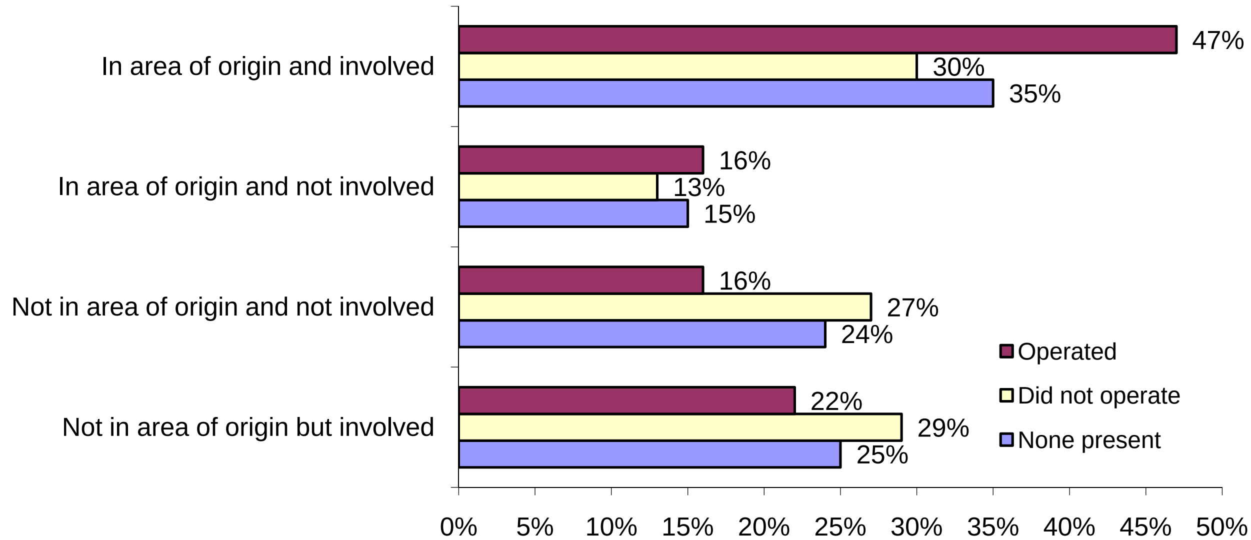
Version 5.0 of NFIRS captures information about the effectiveness of operating smoke alarms in terms of occupant response. Table 17 shows that in 79% of the non-confined home fires with operating smoke alarms, the occupants were alerted and responded. The 3% of non-confined home fires in which smoke 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.

Some additional differences can be seen in the circumstances of fatalities resulting from non-confined home fires with different smoke alarm statuses. Fatalities resulting from fires that were too small to activate the smoke alarm or from confined fires are excluded from this discussion.

When smoke alarms operated, victims of fatal fires were more likely to have been in the area of origin.

Table 18 shows that when victims of home fires in which the smoke alarms operated were fatally injured, they were more likely to have been in the area of fire origin compared to victims in fires with no smoke alarms at all or alarms that did not operate. Figure 14 and Table 19 show 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. 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.

Figure 14. Victim's Location at Time of Incident by Smoke Alarm Status 2003-2006



Source: NFIRS 5.0 and NFPA survey.

Table 20 shows that flame damage was confined to the room of origin in a higher percentage of deaths resulting from fires with working smoke alarms than in fires with no smoke alarms at all. All these characteristics are probably related. A person in the area of origin is more likely to be fatally injured before a smoke alarm is activated or at least before he or she can respond to an alert. Someone in the area of origin can be fatally injured by a smaller fire than someone a distance away.

Victims of fires with working smoke alarms were less likely to be sleeping and more likely to be fighting the fire or unable to act when fatally injured than victims without working alarms.
Table 21 and Figure 15 show that when smoke alarms were present and operating, the victims were more likely to be engaged in fire control or unable to take action to save themselves and less likely to be sleeping compared to fires in which no working smoke alarms were present.

Table 22 and Figure 16 show that fatal fire victims with working smoke alarms were less likely to be asleep but more likely to be physically disabled than were victims of fires in which the smoke alarms did not sound or were not present at all. The estimates of alcohol impairment derived from NFIRS are lower than the results of studies that use autopsy data.

A disproportionate share of fatalities with working smoke alarms were at least 65.
Table 23 and Figure 17 show 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 15. Victim's Activity at Time of Fatal Home Fire Injury by Smoke Alarm Status 2003-2006

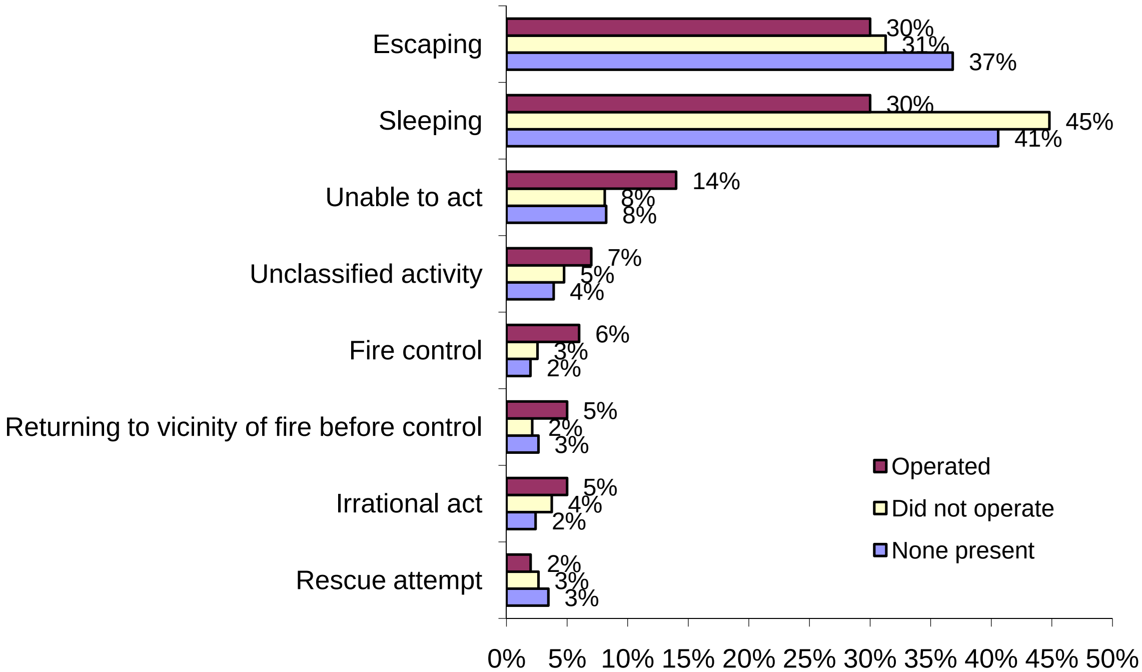
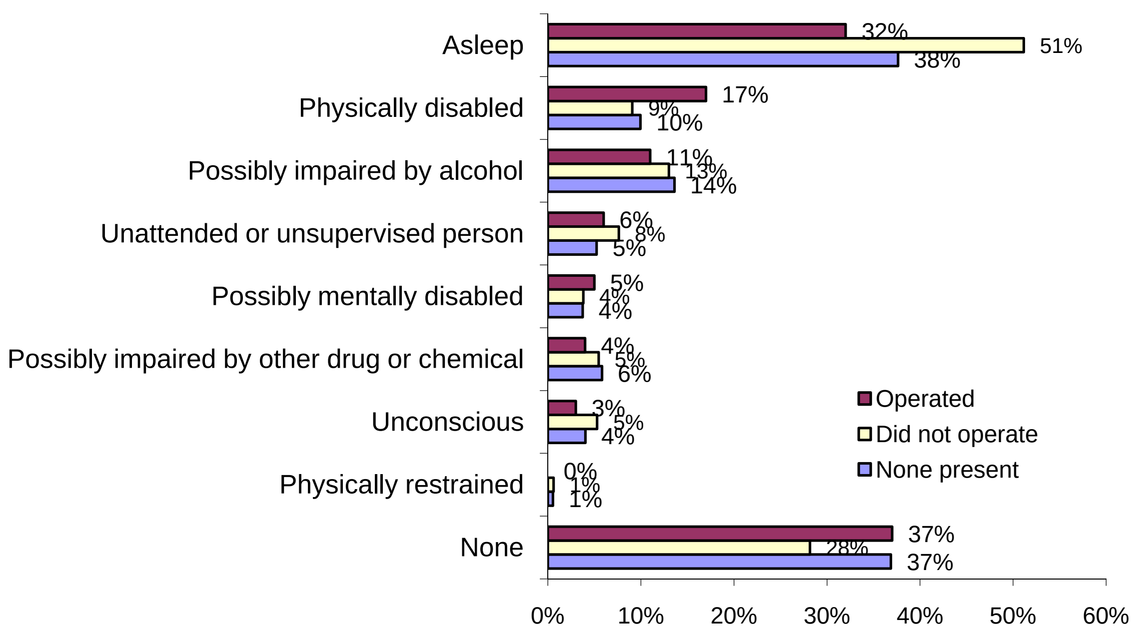
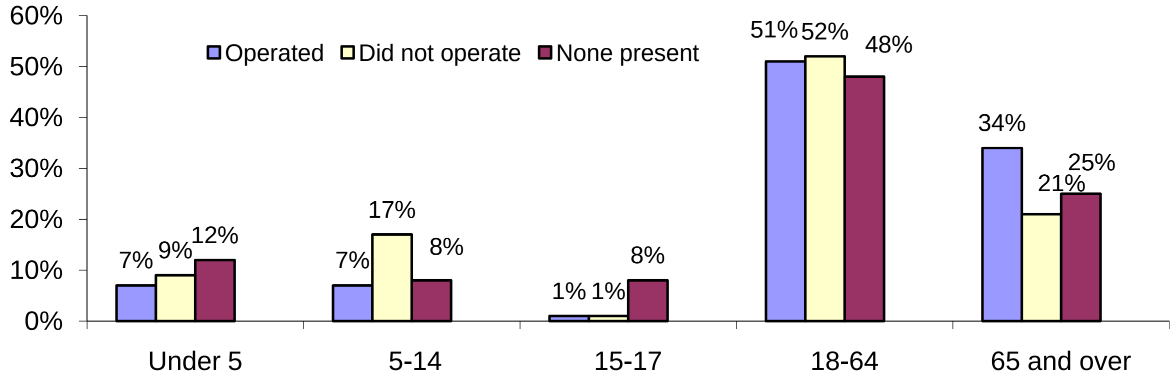


Figure 16. Human Factors Contributing to Fatal Home Fire Injury by Smoke Alarm Status 2003-2006



Source: NFIRS 5.0 and NFPA survey.

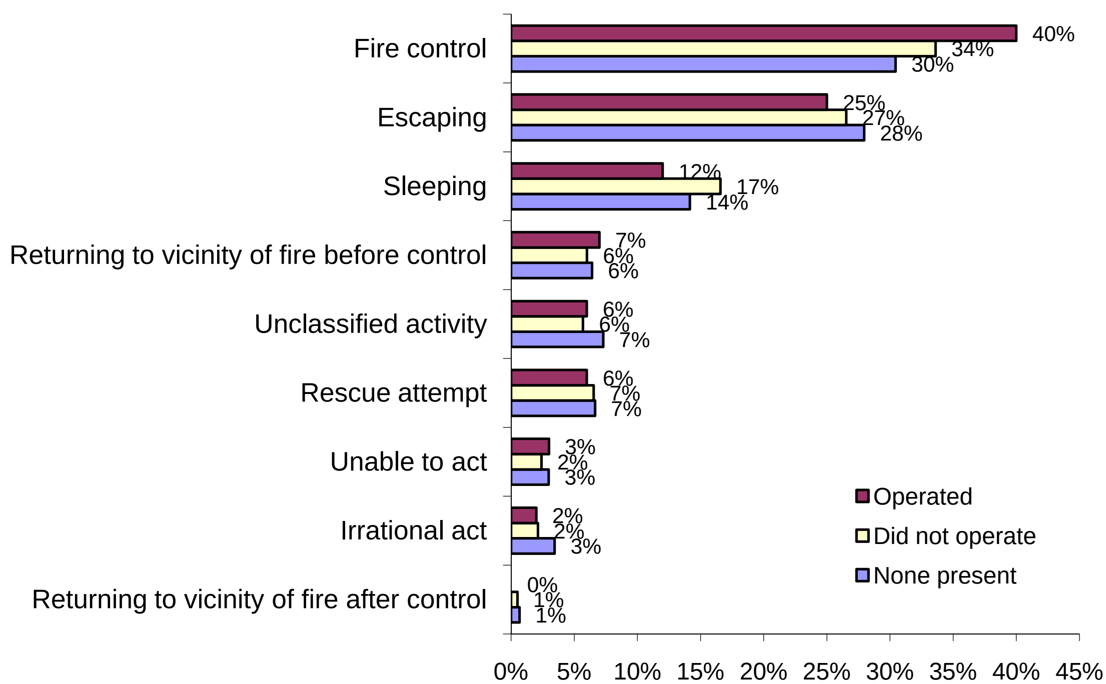
Figure 17. Fatal Home Fire Victims by Age and Smoke Alarm Status, 2003-2006



Source: NFIRS 5.0 and NFPA survey.

A larger share of civilians are injured fighting the fire in fires with working smoke alarms. Table 24 and Figure 18 show that 40% of the reported non-fatal civilian injuries in non-confined home fires with operating smoke alarms occurred when the civilian was trying to control the fire. When smoke alarms failed to operate, 34% of the civilian fire injuries occurred while trying to control the fire. In homes with no smoke alarms at all, only 30% were injured while attempting fire control. This suggests that civilians may be more likely to attempt fire control when they are alerted by a smoke alarm. Such a fire is more likely to be discovered earlier in its development. More training is needed to help the public learn how and when they can safely attempt to handle a fire themselves and when such efforts are too dangerous.

Figure 18. Victim's Activity at Time of Non-Fatal Home Fire Injury by Smoke Alarm Status, 2003-2006



Source: NFIRS 5.0 and NFPA survey.

People do not always evacuate when fire alarms sound.
In her article about how people respond to fire alarms, Guylène Proulx wrote that fire alarms are intended to meet four objectives: 1) warning occupants, 2) getting them to respond immediately, 3) starting the evacuation process, and 4) providing enough time to escape.[29] She found that, in practice, people who hear a fire alarm tend to seek the reason for the alarm rather than assuming that a fire is occurring. They seek other cues such as the smell of smoke, the sound of sirens, etc. If they do recognize a fire, they may engage in other activities such as fighting the fire, calling the fire department before evacuating, collecting belongings, or warning others.

Proulx noted that people often fail to respond for a variety of reasons:

- Sometimes the signal is not recognized as a fire alarm. The alarm may be misinterpreted as a burglar, elevator, or security door alarm.
- Sometimes, particularly outside the home environment, people do not know what they should do. This may be particularly true in a commercial space.
- Because of nuisance alarms, people may not believe the smoke alarm signals a real danger.
- They may not hear the signal due to distance from the alarm, background noise, or individual characteristics.

Audibility and waking effectiveness are discussed at greater length in the next section.

[29] Guylène Proulx. "Response to Fire Alarms" *Fire Protection Engineering,* Winter 2007, pp. 8-15.

Table 17.
Effectiveness of Operating Smoke Alarms
In Non-Confined Home Structure Fires
2003-2006 Annual Averages

Effectiveness	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Alerted occupants and occupants responded	66,800	(79%)	710	(69%)	5,150	(87%)	$2,492	(70%)
Alerted occupants but occupants 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%)

Table 18.
Victim's General Location at Time of Fatal Injury by Smoke Alarm Presence and Operation in Non-Confined Home Structure Fire Deaths
2003-2006 Annual Averages

Victim's Location	Present and Operated		Present but Did Not Operate		None Present	
In area of origin	670	(65%)	290	(45%)	560	(49%)
In building, but not in area of origin	350	(34%)	350	(55%)	580	(51%)
Outside of building	10	(1%)	0	(0%)	0	(0%)
Total	1,030	(100%)	640	(100%)	1,140	(100%)

Table 19.
Victim's General Location at Time of Incident by Smoke Alarm Presence and Operation in Non-Confined Home Structure Fire Deaths
2003-2006 Annual Averages

Victim's Location	Present and Operated		Present but Did Not 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%)
Subtotal --In 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%)
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. Entries of zero may actually be zero or may have rounded to zero.

Source: NFIRS 5.0 and NFPA survey.

Table 20.
Extent of Flame Damage by Smoke Alarm Presence and Operation in Non-Confined Home Structure Fire Deaths 2003-2006 Annual Averages

Extent of Flame Damage	Present and Operated		Present but Did Not Operate		None Present	
Confined to object of origin	70	(7%)	40	(7%)	80	(7%)
Confined to room of origin	280	(27%)	160	(25%)	150	(14%)
Confined to floor of origin	160	(15%)	80	(13%)	100	(9%)
Confined to building of origin	460	(45%)	320	(49%)	650	(57%)
Extended beyond building of origin	60	(6%)	40	(6%)	160	(14%)
Total	1,030	(100%)	640	(100%)	1,140	(100%)

Table 21.
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		Present but Did Not 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 these tables. Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Table 22.
Human Factor Contributing to Injury* by Smoke Alarm Presence and Operation in Non-Confined Home Fire Deaths
2003-2006 Annual Averages

Human Factor	**Present and Operated**		**Present but Did Not Operate**		**None Present**	
Asleep	330	(32%)	330	(51%)	430	(38%)
Physically disabled	180	(17%)	60	(9%)	110	(10%)
Possibly impaired by alcohol	120	(11%)	80	(13%)	150	(14%)
Unattended or unsupervised person	60	(6%)	50	(8%)	60	(5%)
Possibly mentally disabled	50	(5%)	20	(4%)	40	(4%)
Possibly impaired by other drug or chemical	40	(4%)	40	(5%)	70	(6%)
Unconscious	30	(3%)	30	(5%)	50	(4%)
Physically restrained	0	(0%)	0	(1%)	10	(1%)
None	380	(37%)	180	(28%)	420	(37%)
Total entries*	1,190	(115%)	800	(124%)	1,340	(117%)
Total	1,030	(100%)	640	(100%)	1,140	(100%)

* Multiple entries are allowed, meaning that the totals will exceed the sums.

Table 23.
Non-Confined Home Structure Fire Deaths by Victim's Age and Smoke Alarm Status
2003-2006 Annual Averages

Age Group	**Present and Operated**		**Present but Did Not Operate**		**None Present**	
Under 5	70	(7%)	60	(9%)	130	(12%)
5-14	80	(7%)	110	(17%)	100	(8%)
15-17	10	(1%)	0	(1%)	90	(8%)
18-64	520	(51%)	340	(52%)	540	(48%)
65 and over	350	(34%)	130	(21%)	280	(25%)
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. Sums may not equal totals due to rounding errors. Entries of zero may actually be zero or may have rounded to zero.

Source: NFIRS 5.0 and NFPA survey.

Table 24.
Activity at Time of Victim's Non-Fatal Injury by Smoke Alarm Presence and Operation in Non-Confined Home Structure Fires
2003-2006 Annual Averages

Activity	Present and Operated		Present but Did Not Operate		None Present	
Fire control	2,360	(40%)	690	(34%)	930	(30%)
Escaping	1,460	(25%)	550	(27%)	850	(28%)
Sleeping	680	(12%)	340	(17%)	430	(14%)
Returning to vicinity of fire before control	410	(7%)	120	(6%)	200	(6%)
Unclassified activity	360	(6%)	120	(6%)	220	(7%)
Rescue attempt	330	(6%)	130	(7%)	200	(7%)
Unable to act	150	(3%)	50	(2%)	90	(3%)
Irrational act	130	(2%)	40	(2%)	100	(3%)
Returning to vicinity of fire after control	20	(0%)	10	(1%)	20	(1%)
Total	5,910	(100%)	2,060	(100%)	3,040	(100%)

Note: Fire deaths or injuries 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.

Issues of Audibility, Waking Effectiveness, Sensor Technology, and Smoke Alarm Age

AUDIBILITY AND WAKING EFFECTIVENESS

A single-station smoke alarm may not be heard in other parts of the home.
An alarm sounding on one floor of a home may not alert a resident on another floor or even in another room with the door closed. 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.[30] Note that single-station alarms are not interconnected. Since single-station, battery-operated units still predominate in *existing* homes, wider use of interconnected smoke alarms is another opportunity for further improvement in home smoke alarm protection. Table 17 showed that operating smoke alarms failed to alert the occupants in 3% of the reported non-confined home fires and 9% of the associated deaths. Some of these failures to alert may be due to audibility issues.

Several factors influence the effectiveness of smoke alarms in waking people.
One of the main benefits of smoke alarms is the ability to detect a fire while occupants sleep and to sound an alarm that wakes them in time to escape. Several years ago, questions were raised about how effective smoke alarms are at waking particular groups, starting with school-age children. Interconnected smoke alarms, with alarms that sound in each bedroom in response to a fire anywhere in the home, address many of these concerns. Even if a child does not wake, if the parent wakes to the alarm, the parent can in most cases get the child to safety. Table 1 shows that in a 2008 survey done for NFPA, 41% of the respondents with smoke alarms (39% of all households) reported they had interconnected smoke alarms.[31] Table 5 shows that in CPSC's 2004-2005 survey, only 13% of households that had fires and 19% of non-fire households reported having interconnected smoke alarms.[32] Both surveys found that a majority of homes did not have interconnected smoke alarms.

CPSC studied the sound effectiveness of residential smoke alarms.[33] Although children under 16 have longer periods of deep sleep than adults and do not reliably wake in response to smoke alarms, "There is no evidence that children have a higher fire death rate because of the inability to wake to a smoke alarm." 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 be reliable for older adults with hearing loss. The

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[30] 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 http://www.cpsc.gov/LIBRARY/FOIA/FOIA05/os/audibility.pdf.
[31] Harris Interactive. *Smoke Alarm Omnibus Question Report*, November 2008.
[32] Michael A. Greene and Craig D. Andres, *2004-2005 Residential Fire Survey*, Presentation to the Public-Private Fire Safety Council, May 15, 2008.
[33] Arthur Lee, Jonathan Midgett and Sharon White. *A Review of the Sound Effectiveness of Residential Smoke Alarms*, U.S. Consumer Product Safety Commission, December 2004, online at http://www.cpsc.gov/library/foia/foia05/os/alarm1.pdf.

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

Studies examined the effectiveness of different signals in waking high-risk individuals. In her review of the literature on sleep and waking to fire alarms,[34] Dorothy Bruck concluded that louder signals are needed when significant background noise is present. She also found that arousal thresholds vary significantly from individual to individual. Sleep deprived adults, too, 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. [35] 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 low frequency T-3 signal were both more effective than the high-pitched Australian standard alarm.[36] However, even a blood alcohol concentration of 0.05 significantly reduced the likelihood of waking to any of the auditory signals. With blood alcohol levels of 0.08, the waking was even less frequent but the decrease was much less than was seen between the sober and the 0.05 BAC. Individual responses varied widely.

Bruck, Thomas, and Ball conducted additional research on the effectiveness of different signals in waking young adults with a 0.05 blood alcohol concentration from deep sleep as part of a Fire Protection Research Foundation study.[37] They found that the 400 Hz and 520 Hz square wave T-3 sounds were more effective than the 500 Hz and 3100 Hz pure tone sounds, bed or pillow shakers, and strobe lights.

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. [38] The four signals included a high-frequency

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[34] Dorothy Bruck, "The Who, What, Where and Why of Waking to Fire Alarms: A Review," *Fire Safety Journal*, Volume 36 (2001), pages 623-639.
[35] 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.
[36] 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.
[37] 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 http://www.nfpa.org/assets/files//PDF/Research/alcohol&alarmsreport.pdf.
[38] 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.*

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 who woke to 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.

Bruck and Thomas also conducted research on the effectiveness of different signals in waking people with moderate to severe hearing loss. People who were deaf were not included. The authors found that a loud low frequency square wave auditory signal (i.e., the same as the mixed frequency T-3) was most effective. This signal performed better than bed or pillow shakers and strobe lights. Subjects who were 60 or older and hard of hearing were less likely to wake to the bed shaker than younger subjects with impaired hearing. Strobe lights, when used alone, were not effective in waking this population.[39]

PERFORMANCE DIFFERENCES FOR DIFFERENT DETECTION TECHNOLOGIES

Different sensing technologies operate faster in different types of fires.
Most home smoke alarms use either ionization, photoelectric, or both sensing systems to detect a fire. Ionization-type smoke alarms have a small amount of radioactive material between two electrically charged plates which ionize the air and cause current to flow between the plates. When smoke enters the chamber, it disrupts the flow of ions, reducing the flow of current and activating the alarm.

Photoelectric-type alarms aim a light source into a sensing chamber at an angle away from the sensor. Smoke enters the chamber, reflecting light onto the light sensor and triggering the alarm. Photoelectric alarms respond slightly faster to smoldering fires; ionization alarms respond slightly faster to flaming fires. Ionization alarms are less expensive and, because of this, are the most widely used.

Most consumers do not know the differences between the technologies.
In a 2008 survey, 72% of people with smoke alarms did not know the difference between ionization and photoelectric smoke alarms.[40] Only 31% said that they knew which single type of smoke alarm(s) they had. Six percent reported having both. In a follow-up question asking these 37% specifically what kind of alarms they had, 24% were not sure, 24% had ionization, 24% had photoelectric, and 27% had combination. When adjustments are made for those who could not

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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..

[39] 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.

[40] Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008.

answer the question on specific type, 78% either did not know or were not sure what type of smoke alarms were in their homes.

NIST study found fire growth is faster today but both photoelectric and ionization smoke alarms provided adequate warning in most scenarios.
The National Institute of Standards and Technology (NIST), in cooperation with the CPSC, USFA, NFPA, Centers for Disease Control and Prevention (CDC), and other organizations, 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. The full report, revised in 2008, may be found at http://smokealarm.nist.gov.

Researchers found that both ionization and photoelectric smoke alarms "consistently provided time for occupants to escape from most residential fires." They also noted that fire growth was faster in the current tests than in 1975, resulting in less available escape time based on reduction in visibility due to smoke. The tests in 1975 were obtained from a store selling used items. The more recent study involved chairs that were a year or two old and mattresses that were new. Products sold today have different properties than those sold in the past. These properties affect their behavior in fires. Adequate escape time may only be available if the fire safety advice is followed. People who are intimate with ignition or directly involved or exposed to the fire when it starts may not be protected by operating smoke alarms.[41]

Smoke characterization study examined how today's homes and home products behave in fires.
The Fire Protection Research Foundation and Underwriters Laboratories (UL) collaborated on a study of the characteristics of smoke and how materials in today's homes burn in fires.[42] Cone calorimeter tests showed that synthetic materials produce higher heat and smoke release rates than natural materials. In the flaming mode, synthetic materials also generate larger mean smoke particle sizes than natural materials. They also found that in non-flaming fires, smoke build-up changes over time, resulting in smoke stratification below the ceiling and less obscuration at the ceiling level.

When does a smoldering fire become deadly?
In a 2007 analysis, John Hall noted that fires starting with upholstered furniture or mattresses and bedding ignited by something other than an open flame caused about one-third of the home fire deaths in 2002-2005.[43] Except for fires in which medical oxygen was involved, almost all of these fires are believed to have smoldered initially. About one-sixth of home fire deaths resulted from fires starting with: other soft goods such as clothing, linen, or curtains; electrical wire or

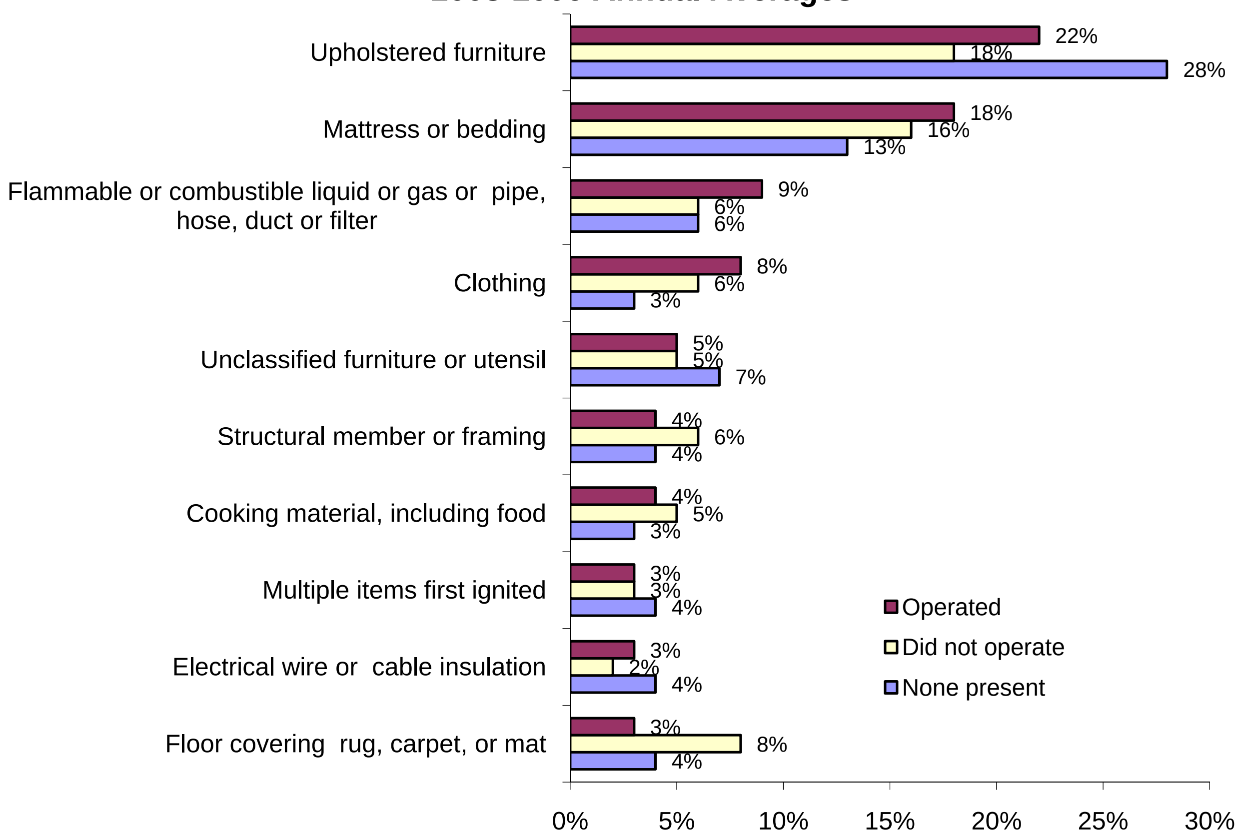
[41] Richard W. Bukowski, Richard D. Peacock, Jason D. Averill, Thomas G. Cleary, Neslon P. Bryner, William D. Walton, Paul A. Reneke, and Erica D. Kuligowski, NIST Technical Note 1455, *Performance of Home Smoke Alarms: Analysis of the Response of Several Available Technologies in Residential Fire Settings*, 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/.
[42] Thomas Z. Fabian and Pravinray D. Gandhi. *Smoke Characterization Project*, Quincy, MA: The Fire Protection Research Foundation, 2007, online at http://www.nfpa.org/assets/files//PDF/Research/SmokeCharacterization.pdf.
[43] John R. Hall, Jr. *Summary of Best Evidence on the Characteristics of Fatal Fires Related to Smoke Alarm performance and Related Issues in the Quantification of Smoke Alarm Performance.* Quincy, MA: NFPA, 2008.

cable insulation; or with the ignition of something other than a flammable or combustible liquid or gas by a lighted tobacco product. About one-quarter of home fire deaths results from fires not started by an open flame such as a match, lighter, candle or torch and were not included in the previous group. When combined, these fatalities account for roughly three-quarters of hone fire deaths. Upholstered furniture and mattresses and bedding are large, thick items that can themselves fuel a serious fire. The other items mentioned are thinner and typically insufficient to fuel a serious fire unless secondary items become involved. Fire spread to other items generally does not occur until the fire transitions to flaming. Smoldering fires are unlikely to spread. Hall cites the findings of Babrauskas and Krasny who noted that transition times from smoldering to flaming range from 20 minutes to five hours after ignition. Unfortunately, it is impossible with existing data to document the exact point in actual fires that conditions became lethal.

Higher percentages of operating smoke alarms are seen when the item first ignited is typically close to the victim or flames quickly.

Table 25 and Figure 19 show the leading items first ignited in non-confined home fires 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, or likely to quickly result in flames, such as flammable or combustible liquids, gases, or parts associated with their delivery, was higher when smoke alarms operated than when no alarms were present.

Figure 19. Non-Confined Home Structure Fire Deaths by Leading Items First Ignited and Smoke Alarm Status 2003-2006 Annual Averages



Source: NFIRS 5.0 and NFPA survey.

Table 25 also shows the death rate per 100 reported non-confined home fires for these items by smoke alarm status. While the death rates per 100 fires for some items, particularly cooking materials and rubbish, would be much lower if confined fires were included,[44] 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.

66% of the victims of upholstered furniture smoking-material fires and 86% of mattress and bedding smoking-material fires were in the area of origin when fatally injured. 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.[45] 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.[46] 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.

Use both ionization and photoelectric technologies together to get the best protection. As noted earlier, an ionization smoke alarm is generally more responsive to flaming fires, and a photoelectric smoke alarm is generally more responsive to smoldering fires. For the best protection, both types of alarms or a combination alarm (photoelectric and ionization) should be installed in homes.

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[44] See discussion of confined fires on page 2.
[45] Marty Ahrens. *Home Fires that Began with Upholstered Furniture,* Quincy, MA: NFPA, 2008, p. 12.
[46] Marty Ahrens. *Home Fires that Began with Mattresses and Bedding,* Quincy, MA: NFPA, 2008, p. 12.

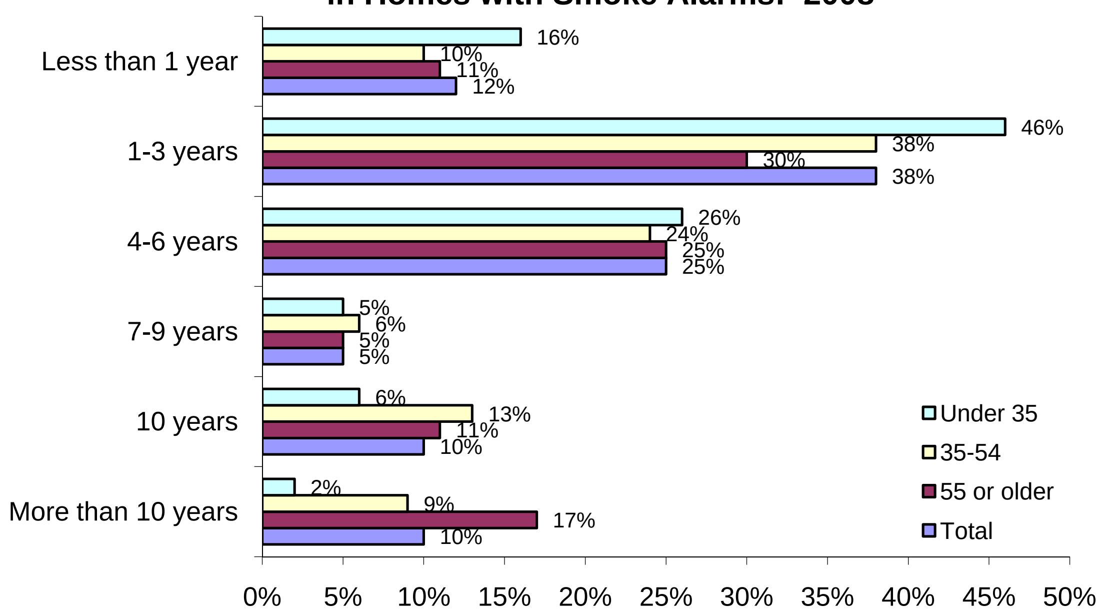
Aging Home Smoke Alarms

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

Roughly half of the smoke alarms collected as inoperable and studied in the National Smoke Detector Project were more than 10 years old, hence older than the currently recommended replacement age.[47] Alarms designed solely to detect smoke should be replaced every 10 years.

Older individuals are more likely to have smoke alarms more than ten years old.
A survey done for NFPA in 2008 found that in 10% of homes with smoke alarms, the smoke alarms were more than 10 years old.[48] Figure 20 shows that when the householder is 55 or older, 17% of the smoke alarms were more than 10 years old.

Figure 20. Age of Smoke Alarm by Age of Individual in Homes with Smoke Alarms: 2008



Source: Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008.

Many people don't know how often smoke alarms should be replaced.
The same survey asked individuals how often their smoke alarms should be replaced. Figure 21 shows that only 12% reported that smoke alarms should be replaced every 10 years. Thirty-five percent simply did not know. Four percent thought these devices never need replacing. Roughly two in five believe that smoke alarms should be replaced *at least* every 4-6 years, if not more often. This suggests that most people with an opinion were erring on the conservative side.

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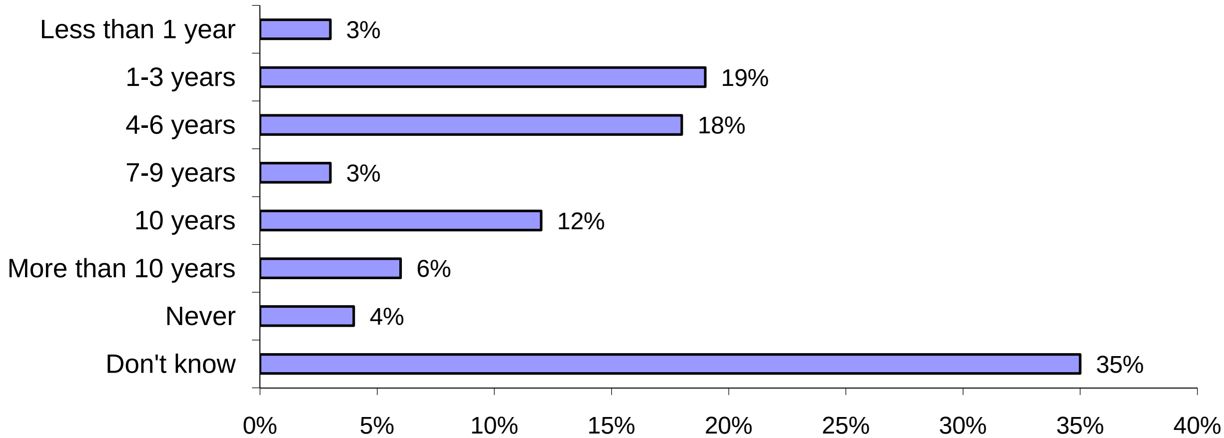
[47] Charles L. Smith, *Smoke Detector Operability Survey – Report on Findings*, Bethesda, MD: U.S. Consumer Product Safety Commission, November 1993, Appendix B, p. 23.
[48] Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008.

Figure 21. Perceptions of How Often Smoke Alarms Should Be Replaced: 2008



Source: Harris Interactive. *Smoke Alarm Omnibus Question Report,* November 2008.

Follow manufacturer's directions for replacement of combination smoke/CO alarms. Some of the confusion about how often smoke alarms should be replaced is likely due to different recommendations for replacement schedules of devices that detect smoke *and* carbon monoxide. Manufacturers of carbon monoxide alarms and combination smoke/carbon monoxide alarms often recommend more frequent replacement due to the life of the CO sensor.

Table 25.
Non-Confined Home Structure Fire Deaths by Leading Items First Ignited and Smoke Alarm Status 2003-2006 Annual Averages

	Present and Operated			Present but Did Not Operate			None Present		
Item First Ignited	**Civilian Deaths**		**Deaths per 100 Fires**	**Deaths**		**Deaths per 100 Fires**	**Deaths**		**Deaths per 100 Fires**
Upholstered furniture	220	(22%)	7.6	110	(18%)	12.8	310	(28%)	9.1
Mattress or bedding	180	(18%)	3.5	100	(16%)	6.4	150	(13%)	3.1
Flammable or combustible liquid or gas, or pipe, hose, duct or filter	90	(9%)	2.8	40	(6%)	5.6	60	(6%)	1.7
Clothing	80	(8%)	2.2	40	(6%)	3.3	40	(3%)	1.3
Unclassified furniture or utensil	60	(5%)	2.1	30	(5%)	4.7	80	(7%)	3.4
Structural member or framing	50	(4%)	0.7	40	(6%)	1.8	50	(4%)	0.6
Cooking material, including food	40	(4%)	0.3	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 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 fires. Confined fires are identified by NFIRS 5.0 incident types 113-118 and include: cooking fires confined to vessel of origin; confined chimney or flue fires; fuel burner or boiler delayed ignitions or malfunctions; confined incinerator or compactor fires; and trash or waste fires that did not spread to the contents or structure. NFIRS does not require causal information such as item first ignited for confined fires although it is sometimes provided. The death rate per 100 fires for items commonly first ignited in these confined fires would be much lower had these fires been included in the table. Fire deaths or injuries 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.

Increasing the Benefits of Smoke Alarm Protection in the Community

Most of the report to this point has focused on the performance of smoke alarms and victim characteristics based on smoke alarm performance. This section focuses on what and how life safety educators and community groups can increase the prevalence of working smoke alarms in the community and help community members get t he maximum benefit from the early warning that smoke alarms provide.

CDC-sponsored research supported the need for installation programs.
The National Center for Injury Prevention and Control at the Centers for Disease Control and Prevention (CDC) compared the effectiveness of two programs providing free smoke alarms. Households with either one or more children under five or an adult age 65 or older from selected communities in Arkansas, Maine, Maryland, Massachusetts, and North Carolina received either vouchers for free smoke alarms or installed smoke alarms. At follow-up, six to twelve months after the intervention, 90% of the households in the installation group had working smoke alarms compared to 65% of the households in the voucher group. Forty-seven percent of the households in the voucher group did not redeem them.[49] This study demonstrated how important it was for programs to actually install the smoke alarms.

Planning and Implementing a Successful Smoke Alarm Installation Program
NFPA has published a guide to help communities conduct a smoke alarm installation program. Information is provided on: organizing a planning committee; identifying the target audience; identifying high-risk residents in the community; soliciting financial support and donations; promoting the program; recruiting volunteers; training, tools and materials for volunteers; overcoming challenges; evaluating the program; installation guidelines; and more. The guide is available at http://www.nfpa.org/assets/files/PDF/Public%20Education/AlarmInstallGuide.pdf.

Installing a smoke alarm is the first step. Programs also need to educate the recipients about smoke alarm testing and escape planning. Once installed, smoke alarms should be tested at least once a month to ensure that they are working. Everyone in the household should recognize the sound and know the escape plan.

PLAN TO RESPOND WHEN A SMOKE ALARM SOUNDS

Develop and practice home escape plans to use when the smoke alarm sounds.
Buying, installing, testing and maintaining home smoke alarms is essential protection from fire, but it is not enough. A smoke alarm merely sounds the warning. It cannot, by itself, control a fire or remove people from harm's way. Many households have not developed the escape plans that would allow them to use the extra warning time smoke alarms provide to best advantage. Escape plans identify any obstacles to secondary exits if the main door is blocked, a meeting

[49] 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.

place outside the home for household members to gather, and makes provisions for household members who need help.

High-Rise Building Evacuation

14% of residential high-rise survey respondents had some type of limitation or condition that would make walking to evacuate difficult. Almost 250 people living in high-rise residential buildings in Chicago, New York City, and San Francisco were surveyed about safety and emergency evacuation perceptions in a Fire Protection Research Foundation study.[50] Ninety-five percent knew that there was a fire exit but 5% were not certain. Eighty-three percent knew that there was an alternative exit, 12% were uncertain, and 5% reported no alternative exit. Sixty percent knew that their building had a public address system, 30% were uncertain and 14% said their building did not have such a system. Roughly 14% said they had some type of limiting factor such as difficulty hearing alarms or verbal instructions or physical condition that would make it hard for them to walk out of the structure. Fifty-eight percent said they would not wait for a floor warden or public address system to tell them to leave if a fire alarm sounded on their floor. One-quarter believed going to the roof was a possible alternative.

Table B shows that roughly half to two-thirds of households said they have an escape plan. However, a much smaller percentage have actually practiced it. In the latest surveys, roughly one-quarter of U.S. households reported that they had actually developed and practiced an escape plan.

Table B.
Household Escape Plans: Results of Several Studies

Year	Have Escape Plan	Households with Plan That Practiced It	Percent of All Households That Have and Practiced Plan
1994[51]	60%	17%	10%
1997[52]	53%	21%	16%
1999[53]	60%	42%	25%
2004[54]	66%	35%	23%

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50 Mia Zmud. *Public Perceptions of High Rise Building Safety and Emergency Evacuation Procedures Research Report*, Quincy, MA: The Fire Protection Research Foundation, ,July 2007, online at http://www.nfpa.org/assets/files//PDF/Research/NuStats_Final_HighRise.pdf.

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

52 *1997 Fire Awareness/Escape Planning Study* for National Fire Protection Association, Quincy, MA, August 1997, Table 3.

53 *1999 NFPA National Fire Escape Survey*, pp. 19-20.

54 2004 Fire Prevention Week Survey conducted for National Fire Protection Association by Harris Interactive Market Research.

The 1994 CDC study found that the poor, people with less than a high school education and people who rent their homes were less likely to have discussed any kind of an escape plan

The NFPA made *Fire Drills: The Great Escape* the theme of Fire Prevention Week for 1998-2000. Families around the U.S. and Canada practiced leaving their homes and going to their meeting places during Fire Prevention Week. As Table B shows, this unique three-year program was associated with a nine percentage point increase (from 16% to 25%) in the percentage of households who developed and practiced an escape plan. This increase was largely sustained over time, as the 2004 survey results show.

In a 1999 study, also sponsored by the NFPA, 60% of the households surveyed said they had escape plans. While the percentage with plans had increased only slightly, the percentage of those with plans who had practiced them doubled to 42%. While progress has been made, there is still considerable room for improvement. More information on developing a home escape plan can be found at www.nfpa.org.

Safety Tips

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 bears the label of a recognized testing laboratory.
- Install a smoke alarm in every bedroom, outside each sleeping area, and on every level of your home, including the basement.
- Interconnect all smoke alarms throughout the home. When one sounds, they all sound.
- Replace batteries in all smoke alarms at least once a year. If an alarm "chirps," warning the battery is low, replace the battery right away.
- Replace all smoke alarms, including alarms that use 10-year batteries and hard-wired alarms, when they are 10 years old or sooner if they do not respond properly when tested.
- Test your smoke alarms at least every month, using the test button or an approved smoke substitute and clean the units, both in accordance with the manufacturers' instructions.
- An ionization smoke alarm is generally more responsive to flaming fires and a photoelectric smoke alarm is generally more responsive to smoldering fires. For the best protection, both types of alarms, or a combination alarm (photoelectric and ionization), should be installed in homes.

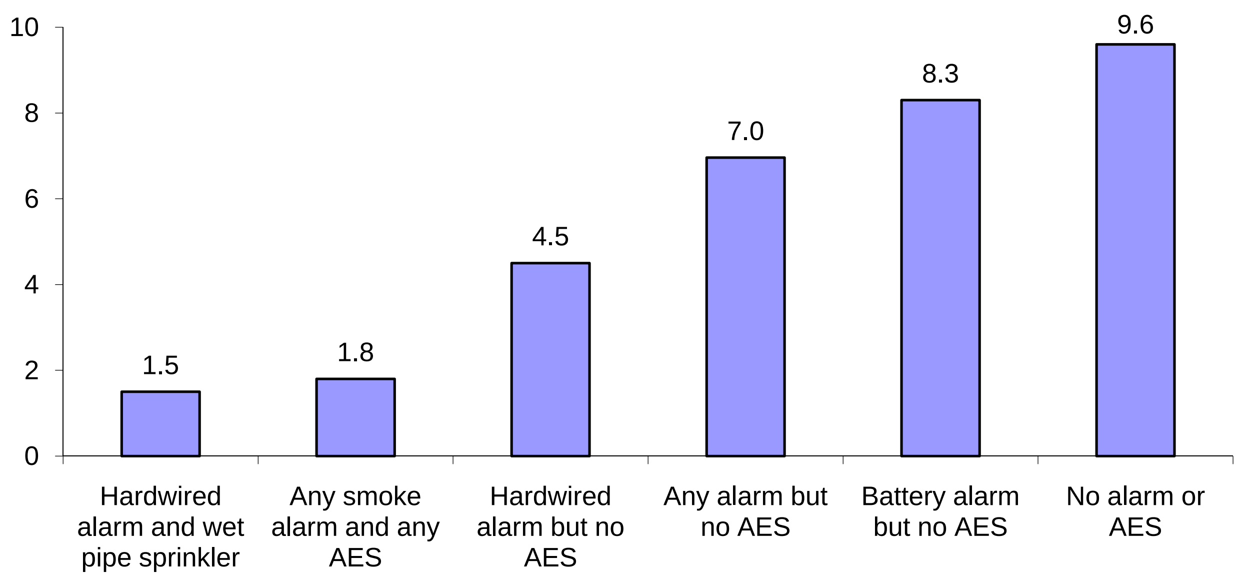
Home Fire Death Rate by Fire Protection Equipment Presence

Smoke alarms are an important part of home fire protection, but they are not the only part. The risk of fire death per 1,000 reported home fires steadily declines as levels of fire protection increase. Figure 22 shows that the death rate is lowest in homes with wet pipe sprinklers and hardwired smoke alarms. These rates are based on presence only. Operation is not considered.

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.

Figure 22. Average Fire Death Rate per 1,000 Reported Home Structure Fires by Presence of Smoke Alarms and Automatic Extinguishing Systems 2003-2006



Source: NFIRS 5.0 and NFPA survey

Table 5 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. In addition, hardwired smoke alarms are more likely to be interconnected, so that if any of the alarms in the home operates, all sound, and the warning is sounded more widely through the home. A single station smoke alarm must be close enough to the fire for the smoke to activate the device. A smoke alarm sounding on one floor might not be heard by occupants on another. The lowest death rates were observed in fires with wet pipe sprinklers and hard-wired smoke alarms.

NIST researchers compared the performance of sprinkler actuating elements with other detection technologies in their 21st century study of home smoke alarm performance.[55] 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.

The rates shown in the graph are based solely on fire data. 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 more affluent 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.

[55] Bukowski, et al. 2008 revision, page 260.

Appendix A.
Sensitivity Analysis of Home Smoke Alarm Performance Using Non-Required Fields in Confined Fires

According to the NFIRS 5.0 rules, the structure fire module that contains detailed information about fire detection equipment and performance is not required for confined fires. The only required field for these incidents asks simply if a detector did or did not alert occupants. Usable information was provided in 54% of these fires. Roughly 2% of the confined home fires have data indicating if smoke alarms were or were not present. For those 2%, the remaining detection elements were completed about as often the non-confined fire data elements were completed.

Non-required data provided for confined fires are likely to be less representative than required data. Also, some inconsistencies exist. Table A1 shows smoke alarm presence and operation when smoke alarms did or did not alert occupants in confined fire. While it is quite probable that smoke alarms operated but did not alert occupants in some fires, incidents in which smoke alarms alerted occupants but no smoke alarm was present, the fire was too small to operate the alarm, or the alarm failed to operate, are problematic. Unknown or missing data were allocated proportionally. The order in which the unknown data are allocated can have an impact on the results.

Table A1.
Smoke Alarm Presence and Operation When Detector Alerted and Did Not Alert Occupant in Confined Home Structure Fires
2003-2006 Annual Averages

Smoke Alarm Status	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Alerted occupants	**113,800**	**(67%)**	**0**	**(33%)**	**920**	**(56%)**	**$29**	**(61%)**
Present	107,800	(63%)	0	(33%)	880	(53%)	$28	(58%)
Fire too small to operate	3,800	(2%)	0	(0%)	40	(2%)	$0	(1%)
Operated	103,300	(61%)	0	(33%)	840	(51%)	$27	(57%)
Failed to operate	700	(0%)	0	(0%)	0	(0%)	$0	(0%)
None present	6,100	(4%)	0	(0%)	40	(3%)	$1	(2%)
Did not alert occupants	**56,700**	**(33%)**	*****	*****	**730**	**(44%)**	**$19**	**(39%)**
Present	38,300	(22%)	*	*	470	(29%)	$12	(25%)
Fire too small to operate	17,700	(10%)	*	*	140	(8%)	$3	(6%)
Operated	8,800	(5%)	*	*	70	(4%)	$4	(8%)
Failed to operate	11,900	(7%)	*	*	260	(16%)	$5	(11%)
None present	18,400	(11%)	*	*	260	(16%)	$7	(14%)
All confined fires	**170,500**	**(100%)**	**10**	**(100%)**	**1,650**	**(100%)**	**$47**	**(100%)**

* Smoke alarm presence was not reported in deaths resulting from confined fires in which a smoke alarm did not alert occupants.
Note: Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Table A2 combines the data with that from Table A1 and data for non-confined fires to develop estimates of smoke alarm performance. In Table A in the body of the text, smoke alarm operation is only asked for fires in which detection equipment was reported as present. In Table A2, presence is not considered when calculating the operation of smoke alarms in confined fires. Inconsistencies are carried forward.

Table A2.
Smoke Alarm Performance in Confined and Non-Confined Home Structure Fires
Using Data from Table A1 for Confined Fires
2003-2006 Annual Averages

Detection Performance	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (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	112,100	(30%)	0	(0%)	910	(7%)	$31	(1%)
Subtotal – Operating smoke alarm	*196,300*	*(52%)*	*1,040*	*(36%)*	*6,830*	*(52%)*	*$3,606*	*(59%)*
Smoke alarm present but failed to operate in non-confined fire	22,600	(6%)	640	(23%)	2,060	(16%)	$714	(12%)
Smoke alarm present but did not operate in confined fire	12,500	(3%)	0	(0%)	260	(2%)	$5	(0%)
Subtotal – Smoke alarm present but did not operate	*35,100*	*(9%)*	*640*	*(23%)*	*2,320*	*(18%)*	*$719*	*(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	21,500	(6%)	0	(0%)	180	(1%)	$3	(0%)
Subtotal – Fire too small to operate alarm	*40,100*	*(11%)*	*30*	*(1%)*	*600*	*(5%)*	*$117*	*(2%)*
Subtotal – Smoke alarm present	*271,400*	*(72%)*	*1,710*	*(60%)*	*9,750*	*(74%)*	*$4,442*	*(72%)*
No smoke alarm present in non-confined fire	82,600	(22%)	1,140	(40%)	3,040	(23%)	$1,695	(28%)
No smoke alarm present in confined fire	24,500	(6%)	0	(0%)	300	(2%)	$8	(0%)
Subtotal – No smoke alarm present	*107,100*	*(28%)*	*1,140*	*(40%)*	*3,350*	*(26%)*	*$1,703*	*(28%)*
Subtotal – No operating smoke alarm present	*142,200*	*(38%)*	*1,780*	*(63%)*	*5,670*	*(43%)*	*$2,422*	*(39%)*
Total	*378,600*	*(100%)*	*2,850*	*(100%)*	*13,090*	*(100%)*	*$6,145*	*(100%)*

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

Table A3 is comparable to Table A in the 2007 report. Fires in which smoke alarms operated in confined fires were assumed to have present and operating smoke alarms. When smoke alarms did not alert occupants, it was assumed that no *working* smoke alarms were present. In actuality, some of the fires were too small to operate the alarm, occupants sometimes discovered the fire before the alarm sounded, and sometimes the alarm sounded when no occupants were present. Consequently, this approach underestimates the number of fires with working alarms and overestimates homes without this protection. Nor can it provide information about how many fires were reported in homes with no smoke alarms at all compared to homes with smoke alarms that did not sound. Because this field was completed with usable data in 54% of the confined fires compared to only 2% with usable data in the presence field, it is more representative of the entire country.

Table A3.
Home Structure Fires by Smoke Alarm Performance
2003-2006 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 operating in non-confined fire	84,200	(22%)	1,030	(36%)	1.22	5,910	(45%)	7.02	$3,575	(58%)
Smoke alarm alerted occupants in confined fire*	113,800	(30%)	0	(0%)	0.00	920	(7%)	0.81	$29	(0%)
Subtotal – Operating smoke alarm	198,100	(52%)	1,040	(36%)	0.52	6,830	(52%)	3.45	$3,604	(59%)
Smoke alarm present but failed to operate in non-confined fire	22,600	(6%)	640	(23%)	2.85	2,060	(16%)	9.12	$714	(12%)
No smoke alarm present in non-confined fire	82,600	(22%)	1,140	(40%)	1.38	3,040	(23%)	3.68	$1,695	(28%)
Smoke alarm did not alert occupants in confined fire*	56,700	(15%)	10	(0%)	0.01	730	(6%)	1.29	$19	(0%)
Subtotal – No operating smoke alarm	161,900	(43%)	1,790	(63%)	1.10	5,840	(45%)	3.60	$2,427	(39%)
Fire too small to operate in non-confined fire	18,600	(5%)	30	(1%)	0.15	420	(3%)	2.28	$114	(2%)
Total	378,600	(100%)	2,850	(100%)	0.75	13,090	(100%)	3.46	$6,145	(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: Sums may not equal totals due to rounding errors.

Source: NFIRS 5.0 and NFPA survey.

Appendix B.
How National Estimates Statistics Are Calculated

The statistics in this analysis are estimates derived 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 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. Roughly two-thirds of U.S. fire departments participate, although not all of these departments provide data every year. Fires reported to federal or state fire departments or industrial fire brigades are not included in these estimates.

NFIRS provides the most detailed incident information of any national database not limited to large fires. NFIRS is the only database capable of addressing national patterns for fires of all sizes by specific property use and specific fire cause. NFIRS also captures information on the extent of flame spread, and automatic detection and suppression equipment. For more information about NFIRS visit http://www.nfirs.fema.gov/. Copies of the paper forms may be downloaded from http://www.nfirs.fema.gov/documentation/design/NFIRS_Paper_Forms_2008.pdf.

NFIRS has a wide variety of data elements and code choices. The NFIRS database contains coded information. Many code choices describe several conditions. These cannot be broken down further. For example, area of origin code 83 captures fires starting in vehicle engine areas, running gear areas or wheel areas. It is impossible to tell the portion of each from the coded data.

Methodology may change slightly from year to year.
NFPA is continually examining its methodology to provide the best possible answers to specific questions, methodological and definitional changes can occur. *Earlier editions of the same report may have used different methodologies to produce the same analysis, meaning that the estimates are not directly comparable from year to year.*

NFPA's fire department experience survey provides estimates of the big picture.
Each year, NFPA conducts an annual survey of fire departments which enables us to capture a summary of fire department experience on a larger scale. Surveys are sent to all municipal departments protecting populations of 50,000 or more and a random sample, stratified by community size, of the smaller departments. Typically, a total of roughly 3,000 surveys are returned, representing about one of every ten U.S. municipal fire departments and about one third of the U.S. population.

The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities have fewer people protected per department and are less likely to respond to the survey. A larger number must be surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did respond are truly representative of fire departments their size.) On the other hand, large city departments are so few in number and protect such a large proportion of the total U.S.

population that it makes sense to survey all of them. Most respond, resulting in excellent precision for their part of the final estimate.

The survey includes the following information: (1) the total number of fire incidents, civilian deaths, and civilian injuries, and the total estimated property damage (in dollars), for each of the major property use classes defined in NFIRS; (2) the number of on-duty firefighter injuries, by type of duty and nature of illness; 3) the number and nature of non-fire incidents; and (4) information on the type of community protected (e.g., county versus township versus city) and the size of the population protected, which is used in the statistical formula for projecting national totals from sample results. The results of the survey are published in the annual report *Fire Loss in the United States*. To download a free copy of the report, visit http://www.nfpa.org/assets/files/PDF/OS.fireloss.pdf.

Projecting NFIRS to National Estimates

As noted, NFIRS is a voluntary system. Different states and jurisdictions have different reporting requirements and practices. Participation rates in NFIRS are not necessarily uniform across regions and community sizes, both factors correlated with frequency and severity of fires. This means NFIRS may be susceptible to systematic biases. No one at present can quantify the size of these deviations from the ideal, representative sample, so no one can say with confidence that they are or are not serious problems. But there is enough reason for concern so that a second database -- the NFPA survey -- is needed to project NFIRS to national estimates and to project different parts of NFIRS separately. This multiple calibration approach makes use of the annual NFPA survey where its statistical design advantages are strongest.

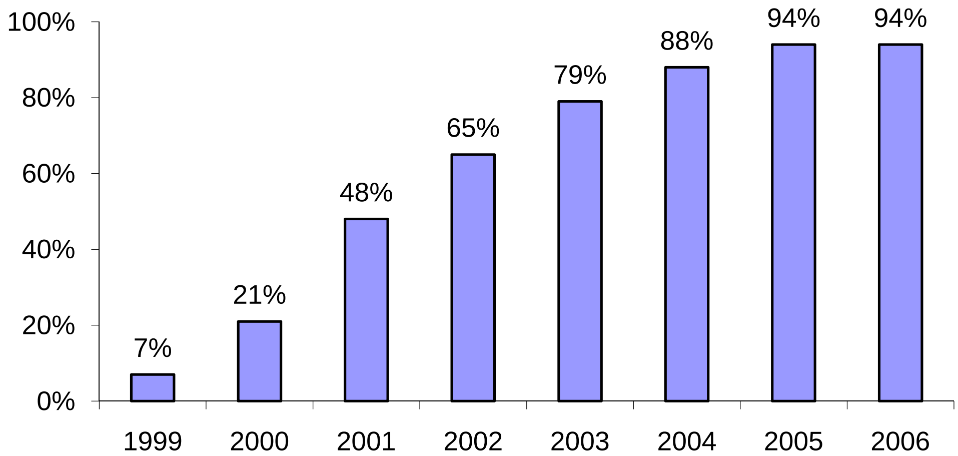
Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific fire problems and circumstances are obtained by multiplying the NFIRS data by the scaling ratios. Reports for incidents in which mutual aid was given are excluded NFPA's analyses.

Analysts at the NFPA, the USFA and the Consumer Product Safety Commission developed the specific basic analytical rules used for this procedure. "The National Estimates Approach to U.S. Fire Statistics," by John R. Hall, Jr. and Beatrice Harwood, provides a more detailed explanation of national estimates. A copy of the article is available online at http://www.nfpa.org/osds or through NFPA's One-Stop Data Shop.

Version 5.0 of NFIRS, first introduced in 1999, used a different coding structure for many data elements, added some property use codes, and dropped others. The essentials of the approach described by Hall and Harwood are still used, but some modifications have been necessary to accommodate the changes in NFIRS 5.0.

Figure 1 shows the percentage of fires originally collected in the NFIRS 5.0 system. Each year's release version of NFIRS data also includes data collected in older versions of NFIRS that were converted to NFIRS 5.0 codes.

Figure 1. Fires Originally Collected in NFIRS 5.0 by Year



For 2002 data on, analyses are based on scaling ratios using only data originally collected in NFIRS 5.0:

$$\frac{\text{NFPA survey projections}}{\text{NFIRS totals (Version 5.0)}}$$

For 1999 to 2001, the same rules may be applied, but estimates for these years in this form will be less reliable due to the smaller amount of data originally collected in NFIRS 5.0; they should be viewed with extreme caution.

NFIRS 5.0 introduced six categories of confined structure fires, including:

- cooking fires confined to the cooking vessel,
- confined chimney or flue fires,
- confined incinerator fire,
- confined fuel burner or boiler fire or delayed ignition,
- confined commercial compactor fire, and
- trash or rubbish fires in a structure with no flame damage to the structure or its contents.

Although causal and other detailed information is typically not required for these incidents, it is provided in some cases (typically 10-20%). Some analyses, particularly those that examine cooking equipment, heating equipment, fires caused by smoking materials, and fires started by playing with fire, may examine the confined fires in greater detail. Because the confined fire incident types describe certain scenarios, the distribution of unknown data differs from that of all fires. Consequently, allocation of unknowns must be done separately.

Some analyses of structure fires show only non-confined fires. In these tables, percentages shown are of non-confined structure fires rather than alls structure fires. This approach has the advantage of showing the frequency of specific factors in fire causes, but the disadvantage of possibly overstating the percentage of factors that are seldom seen in the confined fire incident types.

Other analyses include entries for confined fire incident types in the causal tables and show percentages based on total structure fires. In these cases, the confined fire incident type is treated as a general causal factor.

For most fields other than Property Use, NFPA allocates unknown data proportionally among known data. This approach assumes that if the missing data were known, it would be distributed in the same manner as the known data. NFPA makes additional adjustments to several fields. *Casualty and loss projections can be heavily influenced by the inclusion or exclusion of unusually serious fire.*

In the formulas that follow, the term "all fires" refers to all fires in NFIRS on the dimension studied.

Factor Contributing to Ignition: In this field, the code "none" is treated as an unknown and allocated proportionally. For Human Factor Contributing to Ignition, NFPA enters a code for "not reported" when no factors are recorded. "Not reported" is treated as an unknown, but the code "none" is treated as a known code and not allocated. Multiple entries are allowed in both of these fields. Percentages are calculated on the total number of fires, not entries, resulting in sums greater than 100%. Although Factor Contributing to Ignition is only required when the cause of ignition was coded as: 2) unintentional, 3) failure of equipment or heat source; or 4) act of nature, data is often present when not required. Consequently, any fire in which no factor contributing to ignition was entered was treated as unknown.

In some analyses, all entries in the category of electrical failure or malfunction (factor contributing to ignition 30-39) are combined and shown as "electrical failure or malfunction." This category includes:

31. Water-caused short circuit arc;
32. Short-circuit arc from mechanical damage;
33. Short-circuit arc from defective or worn insulation;
34. Unspecified short circuit arc;
35. Arc from faulty contact or broken connector, including broken power lines and loose connections;
36. Arc or spark from operating equipment, switch, or electric fence;
37. Fluorescent light ballast; and
30. Electrical failure or malfunction, other.

Type of Material First Ignited (TMI). This field is required only if the Item First Ignited falls within the code range of 00-69. NFPA has created a new code "not required" for this field that is applied when Item First Ignited is in code 70-99 (organic materials, including cooking materials and vegetation, and general materials, such as electrical wire, cable insulation, transformers, tires, books, newspaper, dust, rubbish, etc..) and TMI is blank. The ratio for allocation of unknown data is:

$$\frac{\text{(All fires – TMI Not required)}}{\text{(All fires – TMI Not Required – Undetermined – Blank)}}$$

Heat Source. In NFIRS 5.0, one grouping of codes encompasses various types of open flames and smoking materials. In the past, these had been two separate groupings. A new code was added to NFIRS 5.0, which is code 60: “Heat from open flame or smoking material, other.” NFPA treats this code as a partial unknown and allocates it proportionally across the codes in the 61-69 range, shown below.

61. Cigarette;
62. Pipe or cigar;
63. Heat from undetermined smoking material;
64. Match;
65. Lighter: cigarette lighter, cigar lighter;
66. Candle;
67 Warning or road flare, fuse;
68. Backfire from internal combustion engine. Excludes flames and sparks from an exhaust system, (11); and
69. Flame/torch used for lighting. Includes gas light and gas-/liquid-fueled lantern.

In addition to the conventional allocation of missing and undetermined fires, NFPA multiplies fires with codes in the 61-69 range by

$$\frac{\text{All fires in range 60-69}}{\text{All fires in range 61-69}}$$

The downside of this approach is that heat sources that are truly a different type of open flame or smoking material are erroneously assigned to other categories. The grouping “smoking materials” includes codes 61-63 (cigarettes, pipes or cigars, and heat from undetermined smoking material, with a proportional share of the code 60s and true unknown data.

Equipment Involved in Ignition (EII). NFIRS 5.0 originally defined EII as the piece of equipment that provided the principal heat source to cause ignition if the equipment malfunctioned or was used improperly. In 2006, the definition was modified to “the piece of equipment that provided the principal heat source to cause ignition.” However, much of the data predates the change. Individuals who have already been trained with the older definition may not change their practices. To compensate, NFPA treats fires in which EII = NNN and heat source is not in the range of 40-99 as an additional unknown.

To allocate unknown data for EII, the known data is multiplied by

$$\frac{\text{All fires}}{\text{(All fires – blank – undetermined – [fires in which EII =NNN and heat source <>40-99])}}$$

In addition, the partially unclassified codes for broad equipment groupings (i.e., code 100, - heating, ventilation, and air conditioning, other; code 200- electrical distribution, lighting and power transfer, other; etc.) were allocated proportionally across the individual code choices in their respective broad groupings (heating, ventilation, and air conditioning; electrical distribution, lighting and power transfer, other; etc.). Equipment that is totally unclassified is not allocated further. This approach as the same downside as the allocation of heat source 60 described above. Equipment that is truly different is erroneously assigned to other categories.

In some analyses, various types of equipment are grouped together. (Confined fire incident types are not discussed here)

Code Grouping	EII Code	NFIRS definitions
Central heat	132	Furnace or central heating unit
	133	Boiler (power, process or heating)
Fixed or portable space heater	131	Furnace, local heating unit, built-in
	123	Fireplace with insert or stove
	124	Heating stove
	141	Heater, excluding catalytic and oil-filled
	142	Catalytic heater
	143	Oil-filled heater
Fireplace or chimney	121	Fireplace, masonry
	122	Fireplace, factory-built
	125	Chimney connector or vent connector
	126	Chimney – brick, stone or masonry
	127	Chimney-metal, including stovepipe or flue
Wiring, switch or outlet	210	Unclassified electrical wiring
	211	Electrical power or utility line
	212	Electrical service supply wires from utility
	214	Wiring from meter box to circuit breaker
	216	Electrical branch circuit
	217	Outlet, receptacle
	218	Wall switch
Power switch gear or overcurrent protection device	215	Panel board, switch board, circuit breaker board
	219	Ground fault interrupter
	222	Overcurrent, disconnect equipment
	227	Surge protector
Lamp, bulb or lighting	230	Unclassified lamp or lighting
	231	Lamp-tabletop, floor or desk
	232	Lantern or flashlight
	233	Incandescent lighting fixture
	234	Fluorescent light fixture or ballast
	235	Halogen light fixture or lamp
	236	Sodium or mercury vapor light fixture or

		lamp
	237	Work or trouble light
	238	Light bulb
	241	Nightlight
	242	Decorative lights – line voltage
	243	Decorative or landscape lighting – low voltage
	244	Sign
Cord or plug	260	Unclassified cord or plug
	261	Power cord or plug, detachable from appliance
	262	Power cord or plug- permanently attached
	263	Extension cord
Torch, burner or soldering iron	331	Welding torch
	332	Cutting torch
	333	Burner, including Bunsen burners
	334	Soldering equipment
Portable cooking or warming equipment	631	Coffee maker or teapot
	632	Food warmer or hot plate
	633	Kettle
	634	Popcorn popper
	635	Pressure cooker or canner
	636	Slow cooker
	637	Toaster, toaster oven, counter-top broiler
	638	Waffle iron, griddle
	639	Wok, frying pan, skillet
	641	Breadmaking machine

Item First Ignited. In most analyses, mattress and pillows (item first ignited 31) and bedding, blankets, sheets, and comforters (item first ignited 32) are combined and shown as "mattresses and bedding." In many analyses, wearing apparel not on a person (code 34) and wearing apparel on a person (code 35) are combined and shown as "clothing." In some analyses, flammable and combustible liquids and gases, piping and filters (item first ignited 60-69) are combined and shown together

Area of Origin. Two areas of origin: bedroom for more than five people (code 21) and bedroom for less than five people (code 22) are combined and shown as simply "bedroom."

Rounding and percentages. The data shown are estimates and generally rounded. An entry of zero may be a true zero or it may mean that the value rounds to zero. Percentages are calculated from unrounded values. It is quite possible to have a percentage entry of up to 100%, even if the rounded number entry is zero. The same rounded value may account for a slightly different percentage share. Because percentages are expressed in integers and not carried out to several decimal places, percentages that appear identical may be associated with slightly different values.

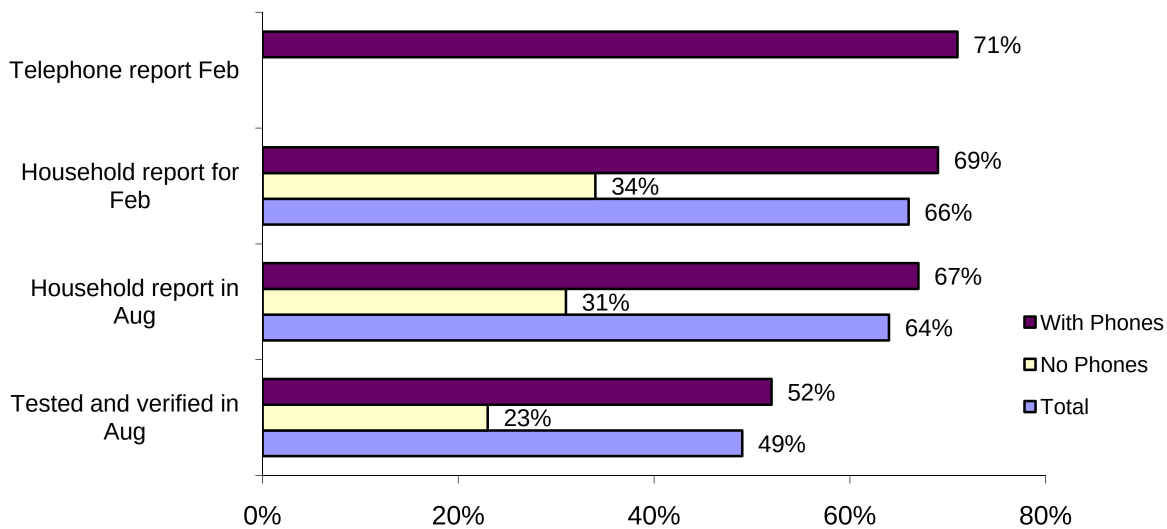
Inflation. Property damage estimates are not adjusted for inflation unless so indicated.

Appendix C.
Working Smoke Alarms: Self-Reported vs. Field Tests

Self-reporting may overstate the presence of working smoke alarms.
As the National Smoke Detector Project found, estimates of working smoke alarms based on actual testing are much lower than estimates based on self-reports. Two other studies found similar results. In February 1990, Douglas. Mallonee and Istre conducted a random telephone survey of functioning smoke alarms in a low-income section of Oklahoma City followed by a retrospective random household survey. Seventy-one percent of the 927 households who completed the phone survey reported working smoke alarms, 18% had no smoke alarms at all, 9% were not sure if their smoke alarm was working, and 2% said that their alarm did not work. Firefighters visited homes in the same area in August 1990. Sixteen percent of the visits were to homes without telephones. Sixty-six percent of the households told the firefighters that their smoke alarms had been working in February; 64% said they were currently working. When the alarms said to be working were actually tested, 20% were not functional, a finding consistent with CPSC's study. Overall, only 49% of the smoke alarms tested were working.

For households without telephones, 34% said their alarms had been working in February and 31% were currently working. Testing showed that only 23% had working smoke alarms compared to 52% with telephones.[56]

Working Smoke Alarms in Low-Income Area of Oklahoma City in 1990
Reported by Telephone, in Household Visit, and by Testing



A smaller but more recent study of working smoke alarms, stair gates or related protection, adult medication in locked cabinets, and environmental feasibility of safety devices was conducted in 2005 and early 2006. Participants were 32 pregnant women and mothers with infants under 12 months old in East Baltimore's Healthy Start program. A parent self-report questionnaire was

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56 Malinda Reddish Douglas, Sue Mallonee, and Gregory Istre. "Estimating the Proportion of Homes with Functioning Smoke Alarms: A Comparison of Telephone Survey and Household Survey Results. *American Journal of Public Health,* July 1999, vol. 89, No. pp.113-114.

administered over the phone or in the home. A home safety checklist was completed on site by the principal investigator, typically within a week of the self-report. All participants reported having at least one smoke alarm, 88% reported having working smoke alarms on every level of the home and 81% reported changing batteries within the past month. The home safety checklist revealed that one of the 32 homes did not have a smoke alarm. Non-working smoke alarms were found in 55% of the homes reported to have a working smoke alarm on every level. Only 41% actually had working smoke alarms on every level. Beeping smoke alarms indicating weak batteries were found in 6 (19%) of the 32 homes. The authors noted that high ceilings and battery costs may make replacing batteries difficult. In all measures studied, the self-reports of safety practices were higher than what was found upon investigation.[57]

These findings suggest that the American Housing Survey's estimate of 94% of homes with working smoke alarms is likely to be too high. Despite these limitations, self-reports do provide important indicators of trends, priorities, and the intent people have to comply with codes and recommended practices.

[57] Kimberly E. Stone, Emmanuella M. Eastman, Andrea Gielen, Barbara Squires. Glenda Hicks, Dana Kaplin, and Janet Serwin. "Home Safety in Inner Cities: Prevalence and Feasibility of Home-Safety Product Use in Inner-City Housing," *Pediatrics,* August 2007, Vol. 20, No. 2, pp. 346-353. DOI: 10.1542/peds.2006-2169.

Appendix D.
NFIRS Forms