Why Smoke Alarms Fall Short of Their Full Potential

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Introduction

Working smoke alarms can significantly reduce the likelihood of fatal fires by providing occupants with early warning and giving them additional time to escape. There is no doubt that smoke alarms have saved countless lives since its inception, and the link between the growth of its use and the decline of fire related death/injuries can be documented. Between 1977 and 2003, residential smoke alarms use increased from 22% to 95+%. During the same period, the home fire death rate, relative to resident population, declined by nearly 60% (Public/Private Fire Safety Council, 2006). However, from 2000 to 2004, 43% of all home fire deaths resulted from fires in homes with no smoke alarms, while 22% resulted from homes where smoke alarms were present but not working (Ahrens, 2008). These are hardly representative of ideal statistics when it comes to smoke alarms and life safety.

Despite the positive gains that smoke alarms have made in contributing to life safety, they have not yet reached their full potential, and improvements in their effectiveness and implementation are still needed. This paper will explore the gaps in smoke alarm use, reliability and effectiveness, and possible recommendations for needed improvements.

This paper focuses on residential related statistics, and the use of the terms “residential” and “homes” are used interchangeably. It is also important to note that these terms include one and two family dwellings, manufactured homes, apartments, townhouses, row houses, and condominiums. In addition, the statistics used in this paper come from U.S. studies, unless specifically noted otherwise. Although the U.S. and Canada’s fire stats can be very similar in nature, they may also have considerable differences, depending on the study and topic.

The Gaps and Needed Improvements in Smoke Alarm Use

Smoke alarms are still missing in 4% of homes in the United States (Public/Private Fire Safety Council, 2006). While this may seem like a small number, it accounts for 39% of reported home fires, almost half of all the reported home fire deaths, and represents over 4 million housing units (Public/Private Fire Safety Council, 2006). Therefore, there is a significantly large gap in smoke alarm usage in the United States. In Ontario, the absence of smoke alarms was determined for 16% of preventable fatal fires from 2002 to 2006, and 22% for all fires in total during the same period (OFM, 2008). Another issue to consider is the fact that these statistics do not include homes with only one smoke alarm throughout the whole structure, which is far from sufficient. Although there must be at least one smoke alarm on every level, studies have found that many homes do not have a smoke alarm on every level, especially in basements (Ahrens, 2008). With these statistics in mind, the goal of universal smoke alarm coverage must remain a top priority for the fire services. The general public must be educated and know the importance of using these life saving devices in their homes.

The Gaps and Needed Improvements in Smoke Alarm Reliability

Although 96% of U.S. homes have at least one smoke alarm, only three-quarters of all U.S. homes have at least one *working* smoke alarm (NFPA, 2007). According to the same study by the NFPA, in 22% of the home fire deaths, smoke alarms were present but did not sound (2007). Therefore, there seems to be an overall gap in smoke alarm reliability. But who's at fault? Is it technology, human behavior, or both? These are relevant questions, since the death rate in homes without working smoke alarms per 100 reported fires is twice as high as homes

with working smoke alarms – that's equivalent to an estimated 890 lives lost every single year (NFPA, 2007). These statistics are further detailed in figure 1.

In order to take a deeper look into the reliability gaps in smoke alarm use, let's first take a look at the reliability of their power sources. As stated by Ahrens and as shown in Figure 2:

> *"Sixty-seven percent of the smoke alarms present in non-confined home structure fires were powered by battery only. In 54% of the fires in which smoke alarms (all power sources) were present but failed to operate, batteries were missing or had been disconnected. In 19%, batteries were dead or discharged. Fourteen percent of the smoke alarms were hardwired without battery backup. However, only 7% of the smoke alarm failures were due to hardwired power disconnection, power failure or shutoff."* (2008, p.5).

Similar statistics for the Province of Ontario can be seen in figure 3 (OFM, 2008). From 2002 to 2006, Ontario experienced 51,708 residential fires. Of the 20% of smoke alarms that were inoperable in these fires, 36% had no battery power. In the case of fatal fires, over half of the alarms did not operate because of dead batteries (figure 4).

Of course, missing or dead batteries do not make smoke alarms inherently unreliable in and of themselves. When considering the link between missing batteries and the inoperability of smoke alarms, one must question why the batteries were missing in the first place. Since the maintenance of battery powered smoke alarms lies solely in the hands of humans, their reliability falls within the context of human behavior. To expand on this notion, one must consider the

relationship between a smoke alarm's success rate and human behavior (attitudes toward smoke alarms).

False alarms and nuisance activations are the leading cause for deliberately disabling smoke alarms, and may lead people to ignore its early warning of a fire (Ahrens, 2008). This makes nuisance alarms a considerable threat to the overall success rate of smoke alarm use. According to the CPSC's National Smoke Detector Project, the two leading problems leading to the removal of smoke alarm batteries were 1) alarming to cooking fumes, and 2) alarming continuously when powered (which may have been due to low battery indication) (Ahrens, 2008). Therefore, in terms of nuisance activations, significant improvements are needed in order to help deter any deliberate disabling of smoke alarms.

Apart from power source and human behavior issues, nuisance alarms in themselves can render smoke alarms to be unreliable. After all, if they cannot consistently and accurately detect when a fire is actually present, then they are not operating in a way that is desirable and reliable. Various studies can expand on this notion. For example, in the SAFE KIDS project, excess moisture (steam) was the leading cause for nuisance alarms (Public/Private Fire Safety Council, 2006). Although this study doesn't specify whether the alarms were ionization or photoelectric, a study was conducted in Texas back in 1980, where nuisance alarms were found to be five times more likely with ionization alarms as opposed to photoelectric alarms (Public/Private Fire Safety Council, 2006).

Gaps and Needed Improvements in Smoke Alarm Effectiveness

As consistent with prior findings, a study conducted by NIST confirmed that ionization alarms respond faster to flaming fires, and photoelectric alarms often provide considerably faster response times to smoldering fires (Averill et al, 2007). Therefore, not only do smoldering fire conditions extend the time for fire conditions to become deadly, but they also prolong detection time by ionization type smoke alarms. In addition, more than a quarter of home fire deaths involve an extended initial smoldering phase, and as found in a recent study, ionization type smoke alarms had unsatisfactory performance in fire scenarios that involved 30 to 120 minutes of initial smoldering (Public/Private Fire Safety Council, 2006). Since many homes today are using this type of smoke detector, there is a real need to improve the effectiveness of this technology.

Another gap in smoke alarm effectiveness is the fact that these devices, whether photoelectric or ionization, have audibility and waking effectiveness issues for some people. In 1999-2001 U.S. fires, operating smoke alarms failed to alert the occupants in 3% of fires, and "overall, 38% of fatal victims were asleep when fatally injured where smoke alarms were present and operated". (Public/Private Fire Safety Council, 2006, p.16). Waking effectiveness has also been documented for adults impaired by alcohol or some other drugs, as can be seen in figure 5 (Public/Private Fire Safety Council, 2006). It is troubling to observe that in all categories of this chart, the percentages for home fire deaths between 1999-2001 was the highest for incidents where a smoke alarm was present and operated.

A recent study suggested than older adults (65 years of age and older) may not fully benefit from conventional smoke alarm systems, particularly during sleeping hours (NFPA,

2006). Studies have also shown that the waking effectiveness of smoke alarms is a problem for young children as well. As addressed by Cormier, this issue has received attention across North America after television stations in Milwaukee, Wisconsin, and Forth Worth, Texas, coordinated demonstrations to determine the effectiveness of fire evacuation plans. When local families and fire departments took part in the study, it was found that some children slept soundly through the activated smoke alarms (2003). ULC's Director of Standards, Rae Dulmage stated that

> *"Based on what we heard from pediatric sleep experts and fire prevention officials, this is a complicated issue that might not have a single, easy answer…What we have heard so far seems to indicate that children's sleep patterns may prevent them from being able to hear and react appropriately to alarms. If, and until, a technological solution can be found, awareness of the issue will be a pressing concern for the fire safety community."* (Cormier, 2003).

Therefore, smoke alarms need to be equally effective for all types of populations, and must take into account that most fire fatalities happen during sleeping hours. This is a significant area of needed improvements that need to be made in order to aid in the maximum effectiveness of a smoke alarms ability to save lives.

Recommendations and Conclusions

Many of the smoke alarm reliability issues that were presented in this paper can be improved upon. More reliable sources of power need to be widely implemented, such as using hard-wired smoke alarms with battery backups, or the use of longer lasting lithium batteries, as opposed to the standard 9-volt batteries. However, this solution in itself will not prevent people

from deliberately removing batteries from the alarms. A more aggressive public education campaign coupled with more regular inspections is ideal. Another consideration is to construct smoke alarms in a way that makes it difficult to disable. This would be particularly effective if implemented in smoke alarms with a 10 year battery life, since they are recommended to be replaced during that duration.

As explained earlier, nuisance alarms are also a reliability issue, since it may contribute to the deliberate disablement of smoke alarms. The simplest solution to this would be to educated users in the proper placement, especially from cooking fumes and bath/shower areas, where steam can contribute to false alarms. A more involved solution would be to improve the technology behind its signal discrimination (e.g., use of multiple signals with or without algorithms to distinguish nuisance alarms from hostile fires) (Public/Private Fire Safety Council, 2006).

When comparing the effectiveness of photoelectric-mode fire alarms with ionization-mode fire alarms, it seems as though photoelectric models are the safer and more effective route. However, many users may be hindered to buy photoelectric alarms over ionization alarms do to their higher costs. Therefore, once again, public education is the key to making these devices more cost-attractive.

Another recommendation to combat the lack of smoke alarm effectiveness is to use "smart" smoke alarms where possible. These units can distinguish between hostile fires and nuisance sources; however, these units are much more expensive and will be more difficult to be applied to residential homes (Public/Private Fire Safety Council, 2006).

As stated earlier, the waking effectiveness of smoke alarms is also an issue. Therefore, smoke alarms need to be placed in bedrooms and they should also be interconnected, since the majority of fatal victims of U.S. home fires are not in the same room as the point of origin (Public/Private Fire Safety Council, 2006). To improve the waking effectiveness of children, older adults, and the hearing impaired, changes need to be made in the alarm's tone. As noted by the USFA, "*recent research indicates that lower pitches than those now specified greatly improve audibility. Voice messages, particularly those recorded using a familiar voice, also improve waking effectiveness, in part because voices fall in a lower pitch range when compared with the current signal"* (Public/Private Fire Safety Council, 2006). A study performed by the Fire Protection Research Foundation in 2005 (supported by the USFA) agrees with this notion (NFPA, 2006). In this study, it was concluded that the high frequency alarm signal typically used in smoke alarms today should be replaced by a signal that improves the waking effectiveness across the general population. The Research Foundation is currently undertaking further research on this topic.

Although this paper has outlined some of the important areas of needed improvements in smoke alarms, it does not intend to detract from the significant gains in their contribution to life safety. It is promising that over the years, smoke alarm technology and their implementation in all occupancies has evolved for the better, and there are no signs that this trend is on the decline. With further research and improvements in technology, smoke alarms will continue to make greater gains towards their full potential, and have a tremendous impact on saving lives.

Figure 1: (NFPA, 2007)

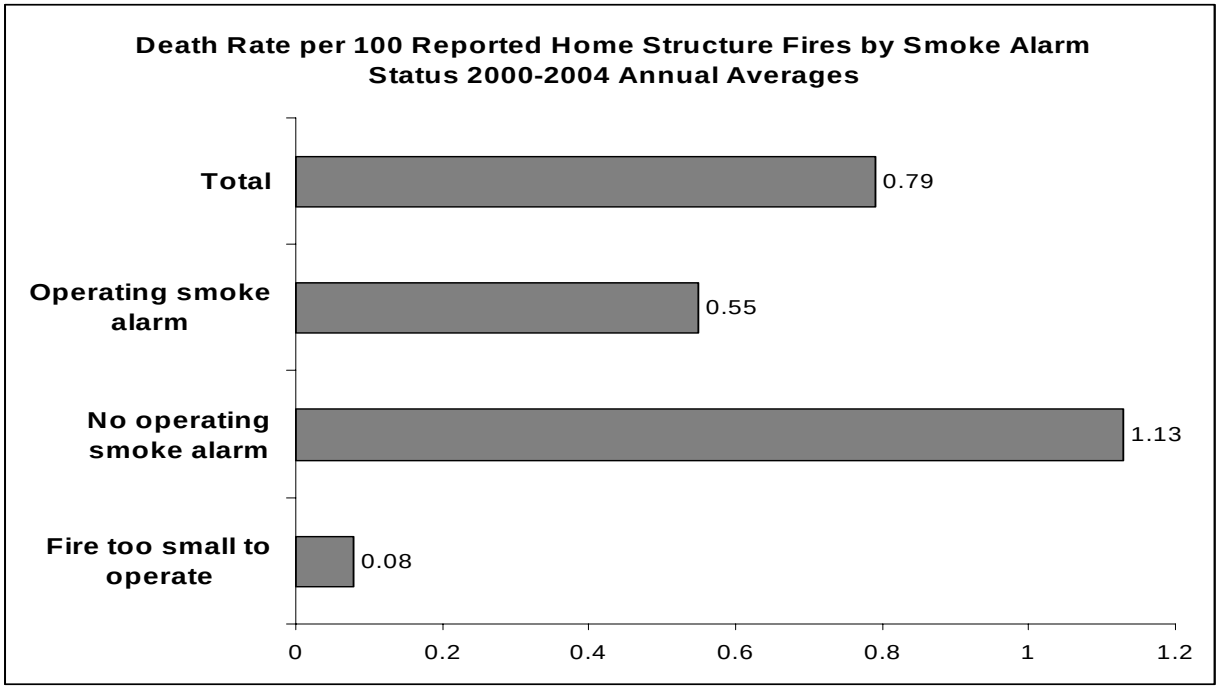


Figure 2: (Ahrens, 2008)

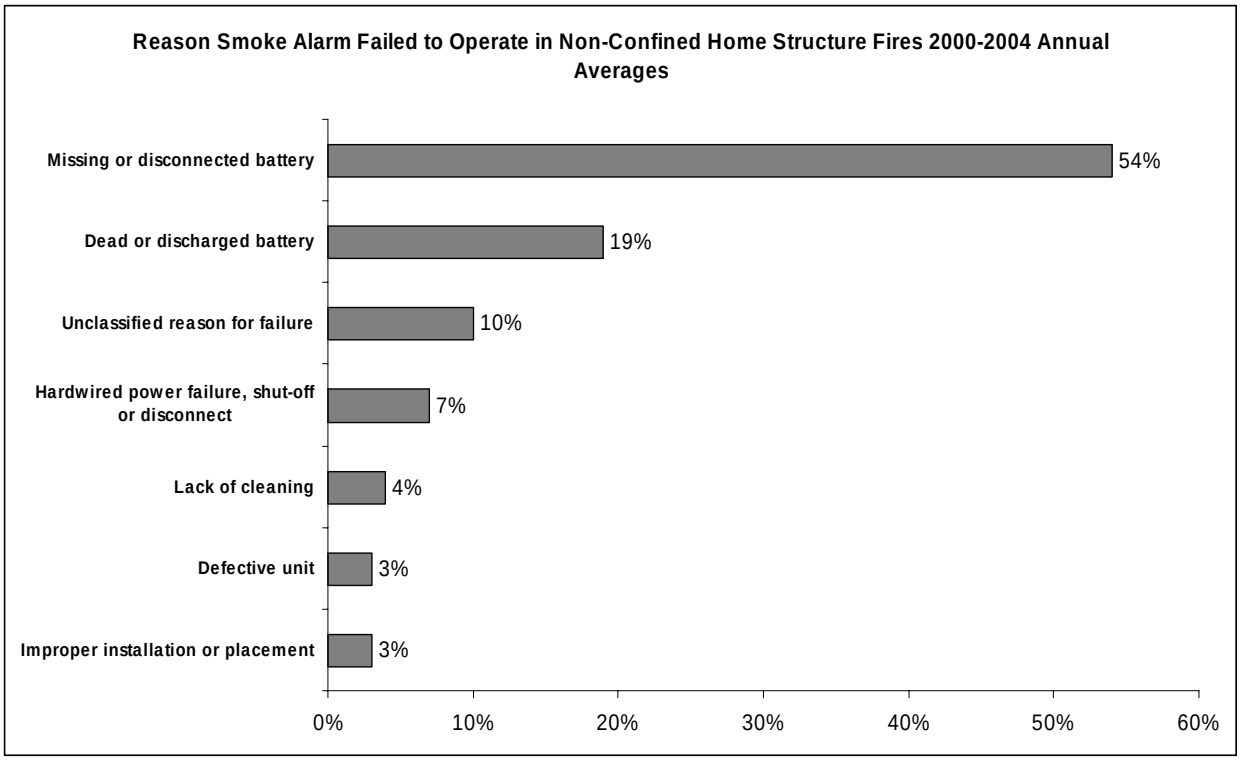


Figure 3: (OFM, 2008)

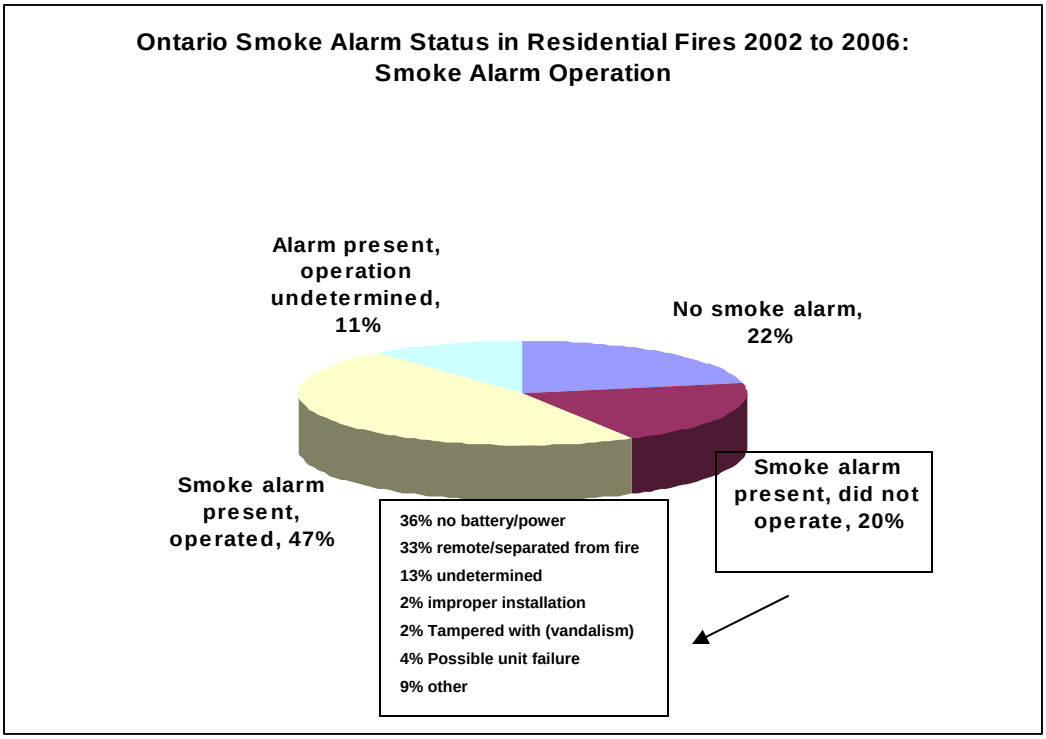


Figure 4: (OFM, 2008)

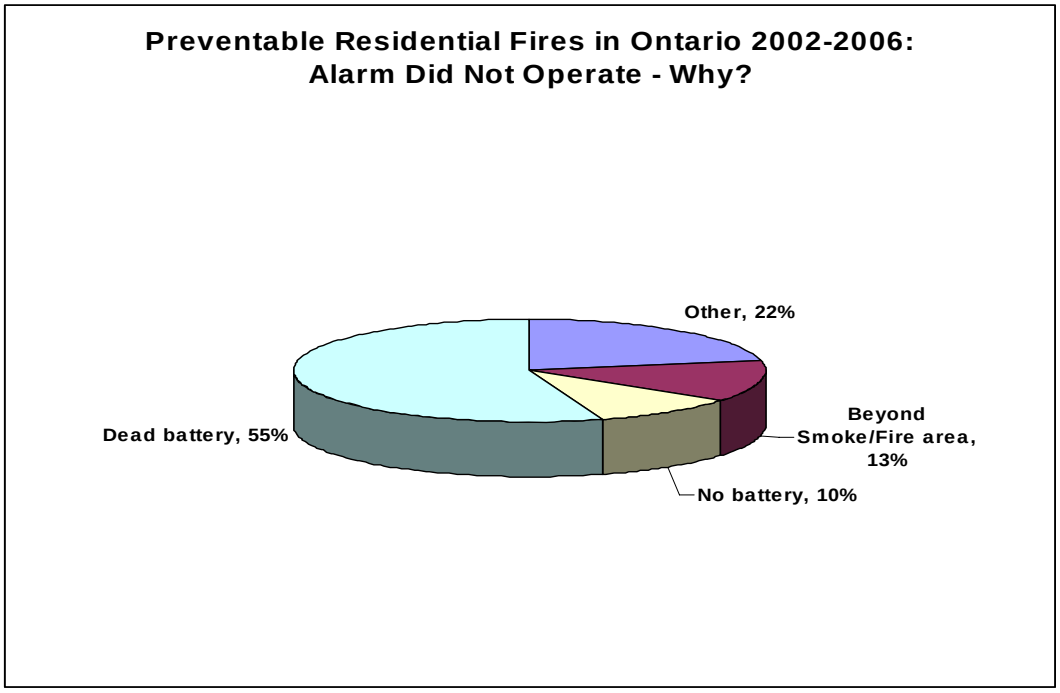
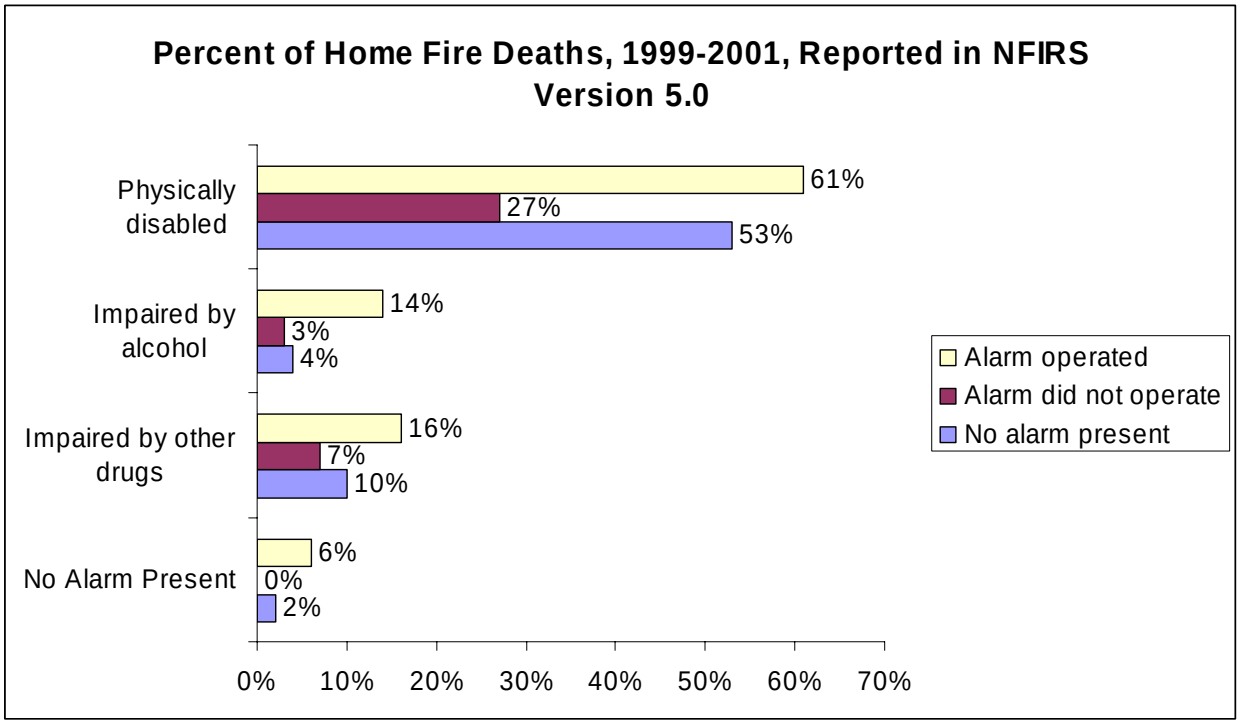


Figure 5: (Public/Private Fire Safety Council, 2006)



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