Recommendation Report Ohio Smoke Alarm Advisory Task Force

Prepared for:
Larry L. Flowers
Ohio State Fire Marshal
The Ohio Department of Commerce
Division of State Fire Marshal
8895 East Main Street
Reynoldsburg, Ohio 43068

Prepared by:

Robert Rielage, Chair
Gregg P. Costas
Lindy Espina Dejarme
Dennis Kovach
Gary Smith
John (Jay) Troy
Joseph Uecker

Executive Summary

Smoke Alarm Advisory Task Force
Executive Summary, Conclusion and Recommendations

In July 2011, State Fire Marshal Larry Flowers convened the Ohio Smoke Alarm Advisory Task Force and asked Robert Rielage, former State Fire Marshal and Chief of the Wyoming Fire-EMS Department, to chair this project. Chief Rielage was joined by a distinguished group of scientists, researchers, investigators and engineers consisting of Mr. John Troy, SFPE; Mr. Dennis Kovach, American Electric Power; Dr. Gary Smith, Nationwide Children's Hospital; Dr. Lindy Dejarme, Battelle Memorial Institute; and Mr. Gregg Costas, Bureau of Criminal Investigations, Ohio Attorney General. Also appointed was the Honorable Joseph Uecker, State Representative.

The Task Force was initially charged with the following:

1) To research existing smoke alarm technology and to compare any advantages of ionization and photoelectric smoke alarms.
2) To address the concern that some children may not respond to the standard alerting sound emitted by either type of smoke alarm.
3) To identify and acknowledge the lack of definitive data from the current NFIRS Reporting System on the types of smoke alarms in use.
4) To identify potential reasons why smoke alarms fail to alert occupants.
5) To address the need for interconnectivity among the smoke alarms within a residence.
6) To determine the life cycle of smoke alarms and to suggest options to guard against removal of smoke alarm batteries.

The SAATF determined the following additional concerns:

- Alerting sounds for special populations (e.g. older adults).
- "Hard to reach" persons: those that do not have nor maintain smoke alarms within their dwelling.

The SAATF met each month July 2011 through April 2012. The group spent the majority of that time reviewing the research and hearing testimony and presentations from a variety of interested parties. Each member of the SAATF also spent countless hours reviewing the work of many contributors and writing the various sections of this report.

The SAATF arrived at ten (10) conclusions:

1) The single most important conclusion is that working smoke alarms save lives. The dramatic reduction of fire fatalities in the United States since 1975 can be traced directly to the introduction and use of residential smoke alarms.
2) There are no statistical differences in the performance of the two existing types of smoke alarms initially discussed, i.e. ionization or photoelectric. Both meet the current performance standards.
3) Lack of battery maintenance in smoke alarms is one of the leading causes of smoke alarm failure to alert occupants. Tamper proof ten-year lithium batteries are one solution to this issue.
4) Manufacturers' suggested ten year "life cycle", with proper maintenance, should be further researched with an accelerated process to determine the minimum reliability of the "ten year" battery.
5) Emerging smoke alarm technology, labeled third generation, appears to meet or exceed the current performance standard and may provide an even greater choice to Ohio citizens and residents for use in various locations in their dwellings.
6) It is important for Ohio citizens and residents to make a distinction between detection and alerting. Special populations, including sleeping children, older adults, the hearing impaired, and those under drug/alcohol impairment, may not awaken to the sound of a smoke alarm. They may not comprehend that the alarm is alerting them to a fire and may not realize that they should immediately exit the dwelling. The alerting method may be more important to the safety of occupants than the detection technology.
7) There are alternatives to stand-alone smoke alarms, including other professionally designed alarm systems conforming to NFPA 72 or in combination with residential sprinkler systems as provided in NFPA 13D.
8) Smoke alarms should be installed near every sleeping area, not just in bedrooms.
9) Nuisance alarms can be avoided by installing smoke alarms away from sources known to activate them (such as near kitchens and bathrooms). Distances outlined in NFPA standards and published in the manufacturers' instructions can be used as reference.
10) Current NFIRS data collection fields need to be updated because current data does not differentiate among smoke alarm technologies nor does it provide a reason for failure in alerting occupants (e.g. no smoke alarm, no battery, and impaired occupants).

Following the review of existing literatures, testimonies and discussions, the SAATF presents to the Ohio State Fire Marshal thirteen (13) recommendations:

1) The fire service community should re-emphasize the basics of fire and life safety:
    i) To use and maintain residential smoke alarms in appropriate household locations
    ii) To plan and practice exit drills
    iii) To predetermine an emergency meeting place for all members of the household
2) Ohio citizens and residents should purchase smoke alarms that bear the label of a recognized testing laboratory (i.e. Underwriters Laboratories, Factory Mutual). These labels indicate compliance with recognized standards.
3) Smoke alarms should be installed according to NFPA standards with assured distances from potential sources of nuisance as outlined in the manufacturer's instructions.
4) A minimum of one (1) working smoke alarm should be properly installed on every level of a residence.
5) It is highly recommended to install smoke alarms near every sleeping area.
6) Smoke alarms must be tested regularly. Batteries should be changed according to manufacturers' recommendations.
7) Interconnected smoke alarms are recommended to increase the potential to alert all members of the household simultaneously.
8) Public education programs should be developed to assist Ohioans in selecting the best smoke alarm technologies for use in their dwellings.
9) More research is needed to better identify alerting signals that are effective for all populations.
10) A new fire service education campaign should be implemented to help citizens and residents choose the best technology for their home and any identified special needs.
11) The Fire Marshal should request that the USFA study the need for more exact data. Identified concerns show that information is needed on how occupants are alerted, with emphasis on the type of alarm and any conditions – such as a lack of maintenance or missing batteries – that lead to a failure to alert. Specific recommendations for consideration by the USFA appear in Section 5.2.
12) The National Fire Incident Reporting System (NFIRS) should be revised to provide better data about why occupants fail to heed the alert of a smoke alarm.
13) The State Fire Marshal should support efforts to update performance criteria for smoke alarms and their incorporation into published standards.

Approvals:

Robert Rielage SAATF Chair	4/24/2012 Date
Gregg Costas	4/24/2012 Date
Lindy Espina Dejarme	4/24/2012 Date
Dennis Kovach	4/24/2012 Date
Dr. Gary Smith	4/24/2012 Date
John (Jay) Troy	4/24/2012 Date
Joseph Uecker	4/24/2012 Date

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1. Introduction

In July 2011, Ohio State Fire Marshal Larry Flowers announced the creation of the Division of State Fire Marshal's Smoke Alarm Advisory Task Force (SAATF). The SAATF was charged to make recommendations to the State Fire Marshal on how Ohio citizens and residents can best protect themselves and their property through available smoke alarm technologies. The State of California and several national organizations had already addressed these concerns to varying degrees and issued both provisional and final position papers. The SAATF was asked to examine the various research, data and recommendations regarding the use and placement of photoelectric and ionization smoke alarms in residential properties, as well as the pending development of new technologies in smoke alarms that may also provide better alerting features.

In a media release, Marshal Flowers stated, "The members of the SAATF were specifically selected for their experience in analyzing and evaluating technical information. Their interest in the issues of home, fire and public safety, along with their integrity and widely accepted credibility, will provide us with a recommendation on smoke alarm protection for Ohio homes. The SAATF will be chaired by Robert Rielage, former Ohio State Fire Marshal and current fire chief for the City of Wyoming, near Cincinnati. The remaining members of the SAATF include: Ohio State Representative Joseph Uecker; Dr. Gary Smith, the Director of the Center for Injury Research and Policy at Nationwide Children's Hospital; Dr. Lindy Dejarme, a research scientist with Battelle Memorial Institute Laboratories; Mr. Gregg Costas, a criminal investigator with the Bureau of Criminal Investigation; Mr. Dennis Kovach, a fire protection engineer with American Electric Power; and Mr. John J. (Jay) Troy, a member of the Society of Fire Protection Engineers."

"Recent statistics show that as many as 90% of Ohio's fires with fatalities or injuries occur in homes with no smoke alarms, no working smoke alarms or smoke alarms that may not have activated. Additionally, new recommendations by some organizations have suggested the use of one smoke alarm detection technology over the other," added Shane Cartmill, Public Information Officer (PIO) for the Division of State Fire Marshal.

1.1 Members of the Smoke Alarm Advisory Task Force

SAATF member names were published on July 22, 2011. A brief background of each member is provided below. The Chair of the SAATF is listed first, followed by the members in alphabetical order.

1.1.1 Robert Rielage, Chair

Chief Robert R. Rielage, CFO, EFO, FIFireE, is the chief of the Wyoming (Ohio) Fire-EMS Department, a 78-member combination fire department bordering Cincinnati. He previously served as the State Fire Marshal of Ohio. A graduate of the Kennedy School's Program for Senior Executives in State and Local Government at Harvard University, Chief Rielage holds a Master's Degree in Public Administration from Norwich University and is a Past-President of the Institution of Fire Engineers (USA Branch). He is also a Contributing Editor for *Fire Chief Magazine.*

1.1.2 Gregg P. Costas

Mr. Gregg Costas is a Special Agent with the Bureau of Criminal Investigation, a division of the Ohio Attorney General's Office. A 22 year veteran, Agent Costas has conducted numerous/ diverse criminal investigations including, but not limited to: narcotics, homicide, fugitive location/apprehension, arson, public corruption, theft/fraud, organized crime, sexual assaults and crimes against children. Costas is a 1989 graduate of Youngstown State University, where he earned a Bachelor's Degree in Criminal Justice.

1.1.3 Lindy Espina Dejarme, Ph.D., PMP

Dr. Lindy Dejarme is a senior research scientist at Battelle Memorial Institute (Columbus Operation) and has worked in a number of areas for the past 20 years: drug detection and interdiction, analytical instrumentation development, chemical demilitarization, and chemical forensics. He led a team of chemists to develop several methods for the analyses of chemical warfare agents, including GB and VX, and related compounds in caustic hydrolysates and other matrices using mass spectrometry based instrumentation with front end separation such as gas and liquid chromatography. Dr. Dejarme is a trained forensic microscopist and employs his microscopy background to solve selected problems encountered in demil operations and other concerns. Dr. Dejarme worked with the Ohio Department of Health in a field study for first responders' analytical equipments. Dr. Dejarme holds a BS Degree (Mindanao State University, Philippines), Masters Degree (Bucknell University, USA), and Ph.D. in Chemistry (Purdue University, USA). Dr. Dejarme holds patents on decontamination of VX, and, analyte separation process and apparatus.

1.1.4 Dennis Kovach, P.E.

Dennis M. Kovach, P.E., is a fire protection engineer for American Electric Power (AEP) in Columbus. He holds a bachelor's degree from the University of Maryland, College Park. He also volunteers as a firefighter/EMT with the Monroe Township Fire Department in Licking County.

1.1.5 Gary A. Smith, MD, DrPH

Dr. Gary Smith is Professor of Pediatrics, Emergency Medicine and Epidemiology at the Ohio State University, holds the Dimon R. McFerson Endowed Chair in Injury Research, and is board certified in pediatrics, pediatric emergency medicine, and general preventive medicine and public health. He is founder and director of the Center for Injury Research and Policy at Nationwide Children's Hospital, and is president of the Child Injury Prevention Alliance. Dr. Smith has been an active researcher and advocate in the field of injury prevention for more than 25 years, and has more than 120 injury-related peer-reviewed publications focusing on prevention of injuries to children and adolescents.

1.1.6 John (Jay) Troy

John (Jay) Troy, now retired, served more than 45 years as a consulting engineer in Fire Protection, Security and Safety. He holds a B.E. degree from Youngstown State University and has had licensees as a Professional Engineer in Ohio since 1964 and also in California, Michigan, Georgia, and Washington. Prior to his retirement he owned a consulting firm, FPC Sierra Inc., in California. Earlier, he was employed by Gage Babcock & Associates, BASF, Dow Chemical, and ASCOA. Mr. Troy served over 30 years on NFPA committees. He currently serves as Chair of the Ethics Committee for the Ohio Society of Professional Engineers, serves on the Citizens Police Advisory Board of Genoa Township and on several political action committees at state and local levels. As a consultant he was involved in fire protection systems design, fire investigations, fire department analysis, facilities review, code development, peer review and many other related activities. Mr. Troy is also a Life Member in the NFPA and the SFPE.

1.1.7 Joseph Uecker

State Representative Joseph Uecker, a former volunteer firefighter, is now serving his fourth term in the Ohio House of Representatives. He represents the 66th House District, which includes portions of Clermont County. Prior to joining the House of Representative Uecker was a Police Officer for 15 years, and also served as a Miami Township Trustee from 1990 to 2005. Representative Uecker has been recognized for his public service with numerous honors including the Watch Dog of the Treasury Award from the United Conservatives of Ohio, Cincinnati Moeller High School Distinguished Alumni Award, and Friend of Agriculture from the Ohio Farm Bureau Federation. Representative Uecker remains actively involved in the Greater Cincinnati Right to Life and Ohio Right to Life, Clermont County Chamber of Commerce, Clermont County Farm Bureau and National Rifle Association (Life Member). He remains an honorary member of the Pregnancy Center of Clermont County board of directors. He has been active with the National Assembly of Sportsmen's Caucus and serves as co-chairman of the Ohio House Sportsmen's Caucus.

1.2 Brief Background on Prompting Conditions Leading to the Inquiry and Creation of SAATF

The promotion of smoke alarms in residential settings has been one of the most successful programs that came out of the 90 recommendations contained in a report entitled *America Burning* issued by the National Commission on Fire Prevention and Control. The report was submitted to President Richard Nixon on May 4, 1973. Prior to the implementation of the recommendation from that landmark publication, there were nearly 13,000 fire deaths recorded in the United States. Thirty-five years later in 2010, that number was less than 3,000, and at least one fire prevention official recently indicated that number may be closer to 2,000 when the 2011 statistics are compiled. The percentage of fire deaths in the United States was 0.006 percent of the population of 205 million in 1975 as compared to 0.0006 percent of the current population of 311 million. This comparison shows that while the United States population increased by more than fifty percent between 1975 and 2005 the fire deaths decreased by eighty-five percent. Members of the SAATF strongly believe that there is room for improvement.

The most important factors in the reduction of fire fatalities have included proper use and maintenance of smoke alarms in the home and the constant reminder by the fire service that smoke alarms, along with planned and practiced exit drills in the home, save lives. Campaigns geared for those groups within our population who either remain unaware of the need for smoke alarms – or for others who choose not to have or to maintain smoke alarms for their protection – have been tried with varying success. Considerations should also be given to protecting persons with special needs.

1.2.1 Statement of the Problem

For several years there has been discussion about the effectiveness of residential smoke alarms and detection technologies that may best protect the general population from fire. Equally as important, a segment within the fire prevention community began advocating the use of photoelectric smoke alarms. They share the belief that photoelectric alarms may respond more quickly in the smoky, smoldering stage of an incipient fire than ionization alarms. Several jurisdictions in Ohio have passed legislation on the installation of photoelectric smoke alarms in all new residential construction.

Advocates for photoelectric technology point to data on the number of fatal fires that shows smoke alarms may have failed to alert occupants. They believe that today's incipient fires are slower to flame and that photoelectric alarms will activate faster than ionization alarms in a smoldering fire before it breaks into a flaming stage. The difficulty in evaluating this concern centers around the lack of comprehensive, accurate data on smoke alarm performance.

Many studies reviewed by the SAATF relied on data obtained from NFIRS. NFIRS has a large set of information on smoke alarm presence or performance for incidents reported as "Good Intent" or "False Alarm" or "False Call". Reported data depends on accurate determination by the fire department of the cause of the alarm. Often there is no indication whether the alarm was false (a detector malfunction), a nuisance alarm (the detector operated properly to smoke accidentally produced by activities such as cooking) or a hostile fire which was extinguished in its incipient stage. Additionally, the NFIRS system collects limited or no data on smoke alarm presence or performance for "confined" fires (i.e. a small cooking fire where damage was limited to the container of origin). Furthermore, a study commissioned by NFPA has estimated almost 40% of household fires are never reported to a fire department. In other words, there are a large number of smoke alarm "success" stories which may go unreported or may be underreported. Additionally, where data does exist, NFIRS does not collect information on the type of detector (photoelectric or ionization) involved. In spite of the shortcomings found in NFIRS, real world data (collected outside of laboratory or staged fire testing environments) on the performance of smoke alarms in the U.S. appears to be based primarily on statistics found in NFIRS data. This does not include some small studies involving fewer than 125 households.

1.2.2 Understanding Current Technologies of Commercial Smoke Alarms

There are two basic smoke alarm technologies: photoelectric and ionization. History and description of each technology follows in 1.2.2.1 and 1.2.2.2.

1.2.2.1 Photoelectric Smoke Alarm

The basic operation of a photoelectric smoke alarm is based on the use of photoelectric effect. The associated device is called a 'photoelectric' smoke alarm. The photoelectric effect phenomenon was explained by Dr. Albert Einstein leading to his Nobel Award in 1921. Photoelectric effect is the emission of electrons when matter such as metals, non-metals, liquids or gases absorb energy from electromagnetic radiation [such as] visible light (incandescent lamp) and ultraviolet radiation. The emission of electrons generates electrical current that is measurable. Photoelectric effect is employed in the manufacture of a photoelectric cell, the primary detector in a photoelectric smoke alarm. A photoelectric cell is an electronic device that consists of a light sensitive surface and generates electrical output when irradiated with visible light. The amount of electrical output is dependent on the intensity and flux density of the light. Simply put, the more light there is incident on the light sensitive surface, the more electrical output is produced.

Photoelectric effect is exploited in a photoelectric smoke alarm as a change in condition detector. In other words, a photoelectric smoke alarm does not differentiate between smoke, water vapor or particulates. It is a non-specific detector.

Since photoelectric effect generates electrons resulting to an electrical output, it is used to detect attenuation in light intensity (hence, reduced generation of electrons) which could be brought about by light dispersion or blockage. There are three examples of light dispersion or blockage that are worth mentioning here. Imagine driving on a highway at 65 miles per hour when suddenly you are unable to see beyond 100 yards because of fog. You turn on your high beam headlights. Visibility becomes worse because the angle of the light is raised to where the density of the fog is higher and the extent of light dispersion is higher. This results in blinding brightness near the nose of the car. No light penetrates the distant road ahead. Another example: You are driving near a forest fire. The thick smoke limits your vision to 50 yards because your vision is obscured by smoke particles. These particles are also capable of dispersing light. A final example: In March and April 2010, the Eyjafjallajökull volcano in Iceland erupted. Volcanic ash covered the sky. These conditions made it hazardous for airplanes to fly and darkened some cities in Europe because sunlight could not penetrate the ash cloud. As a side note, particulates disperse sunlight to give us a beautiful sunset.

The three examples of environmental conditions above lead to fluctuation (attenuation, dispersion, and blockage) of available light. How then, is light fluctuation used in a photoelectric smoke alarm? There are two geometric configurations that explain how the photoelectric effect is exploited in a photoelectric alarm. One is in-line configuration achieved by constantly shining light directly at a photoelectric cell as shown in Figure 1. The other is perpendicular configuration achieved by detecting dispersed light as shown in Figure 2.

In Figure 1, the light source represented by arrows directed to the right passes through an empty chamber toward the photocell as Condition A. In this condition, the electrical output of the photocell would be constant because there is nothing to block, disperse, or attenuate the light. With Condition B, water vapor (fog), smoke, or dust (represented by solid circles) are present between the light and the photoelectric cell leading to a decrease of electron production proportional to the density of the interference. The change in production of electrons corresponds to a change in electrical output that can be used as an input to another device that makes mono-tonal sound, spoken broadcast, or alerting light.

The second configuration is represented by Figure 2 where, for Condition A, the light source is directed away from the photocell. The photocell does not detect any light in this condition. With Condition B, water vapor (fog), smoke or dust gets in between the path of light and light dispersion occurs. The dispersed light is now hitting the photocell resulting to an electrical output.

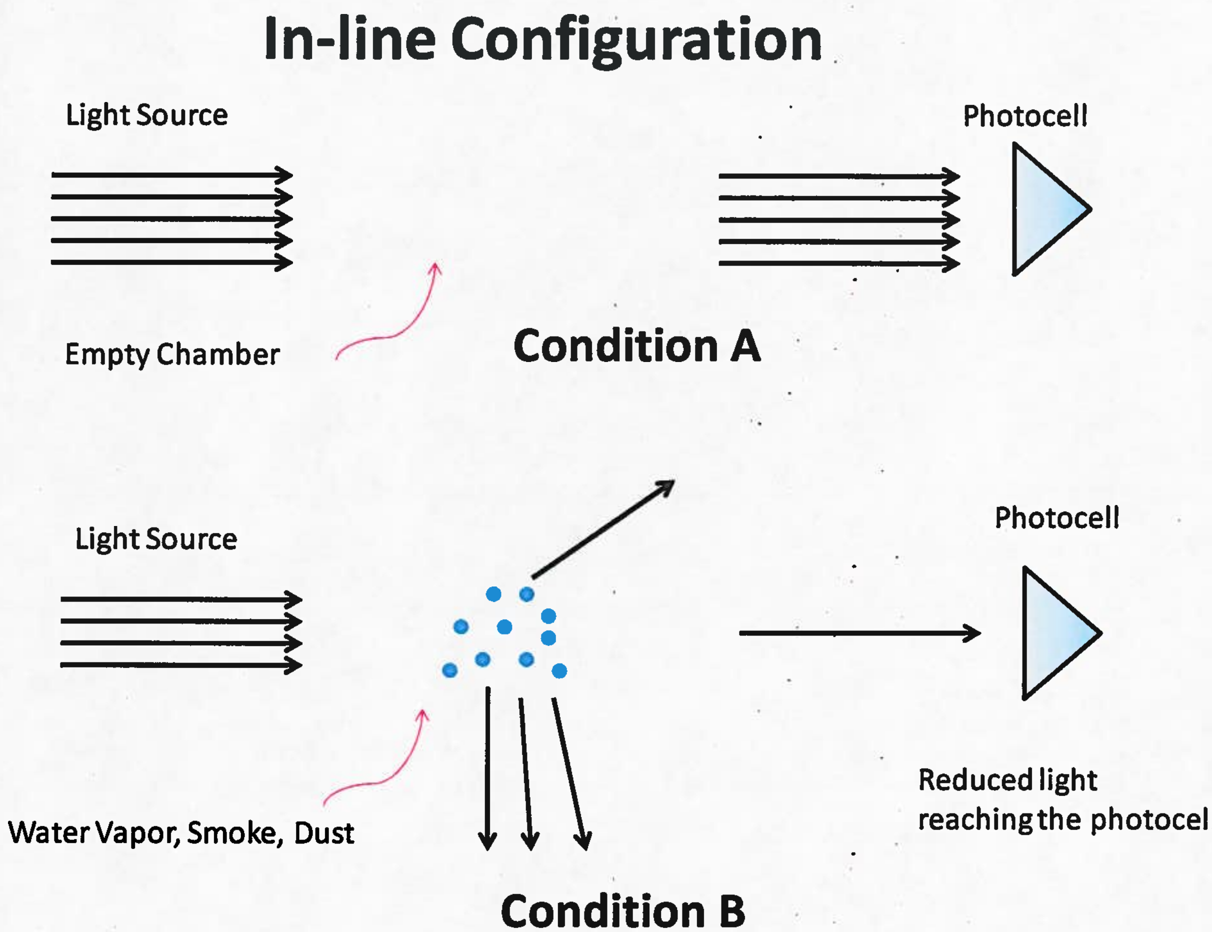

Figure 1. In-line configuration of light source and the photocell

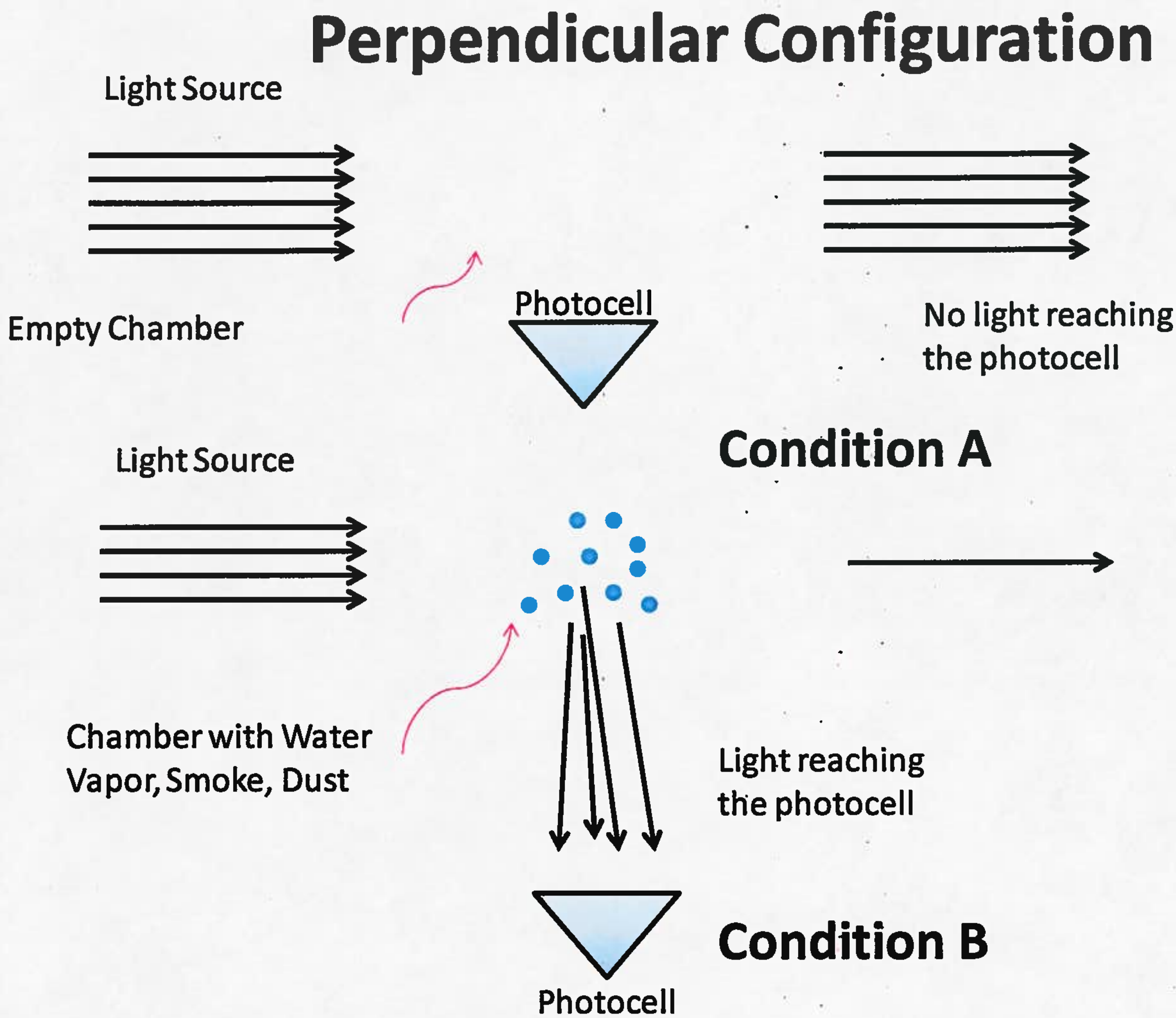

Figure 2. Perpendicular configuration of the light source and the photocell

With Figures 1 and 2, it should now be obvious why a photoelectric smoke alarm activates when dust is generated when sawing wood inside the house.

The photoelectric effect based smoke alarm (or photoelectric smoke alarm) was first developed in the 1930s, but residential use was hampered by the need for a larger power source. Battery power was inadequate; therefore 110 volt AC was needed to operate this type of device. Photoelectric smoke alarm technology was used primarily in commercial settings. With advances in electronics technology and the development of the light emitting diode (LED) the photoelectric smoke alarm can now be operated with batteries.

1.2.2.2 Ionization Smoke Alarm

Ionization smoke detection is based on the use of a synthetic radioactive material, Americium-241, which is an alpha-emitter with high cross section as shown in Figure 3. α-particle is a high energy helium ion with two (2) positive charges (hence, +2). α-particle is an ionizing radiation, but because it has short penetration depth, a few centimeters of air or a piece of paper would stop its travel. Figure 4 shows the chemical reactions of an α-particle. When an α-particle hits air, the air components such as nitrogen and oxygen are ionized via removal of electron: singly-charged nitrogen and oxygen are formed. Helium could be neutralized in the process or be absorbed somewhere else. When vapor, dust or smoke is present the alpha-particle becomes neutralized or absorbed and nothing happens to nitrogen and oxygen.

$$^{241}_{95}Am \xrightarrow{\alpha} {}^{237}_{93}Np \qquad \alpha \text{ means alpha}$$

Alpha-decay results to formation of He^{+2}

Figure 3. α-decay of americium (Am)

$$He^{+2} + N_2 + O_2 \longrightarrow He + N_2^{+} + O_2^{+}$$

$$He^{+2} + N_2 + O_2 \xrightarrow[\text{Smoke}]{\text{Dust}} He + N_2 + O_2$$

Vapor

Figure 4. The gaseous chemical reaction of the α-particle (He^{+2}) with nitrogen and oxygen in air, dust, smoke vapor

How are the gaseous chemical reactions of the α-particle exploited in a smoke alarm? Figure 5 shows a schematic diagram of the process. A small amount of americium-241 is used as the radiation source. The α-particle radiation is passed in between two electric grids with DC potential applied across the grids, resulting to opposite polarity of the two sides. The pair of grids, also called electrodes, is the chamber filled with air. The α-particle ionizes nitrogen and oxygen in air as shown in Figure 5 resulting to a constant current flow as indicated by the up-current for Condition A. If water vapor, smoke, or dust is present in the ionization chamber the α-particle is absorbed and the ionization of nitrogen and oxygen is decreased proportionately to the density of the water vapor, smoke or dust. The decrease in the ion density constitutes a change in the electrical output which can then be used as an input into an alerting device.

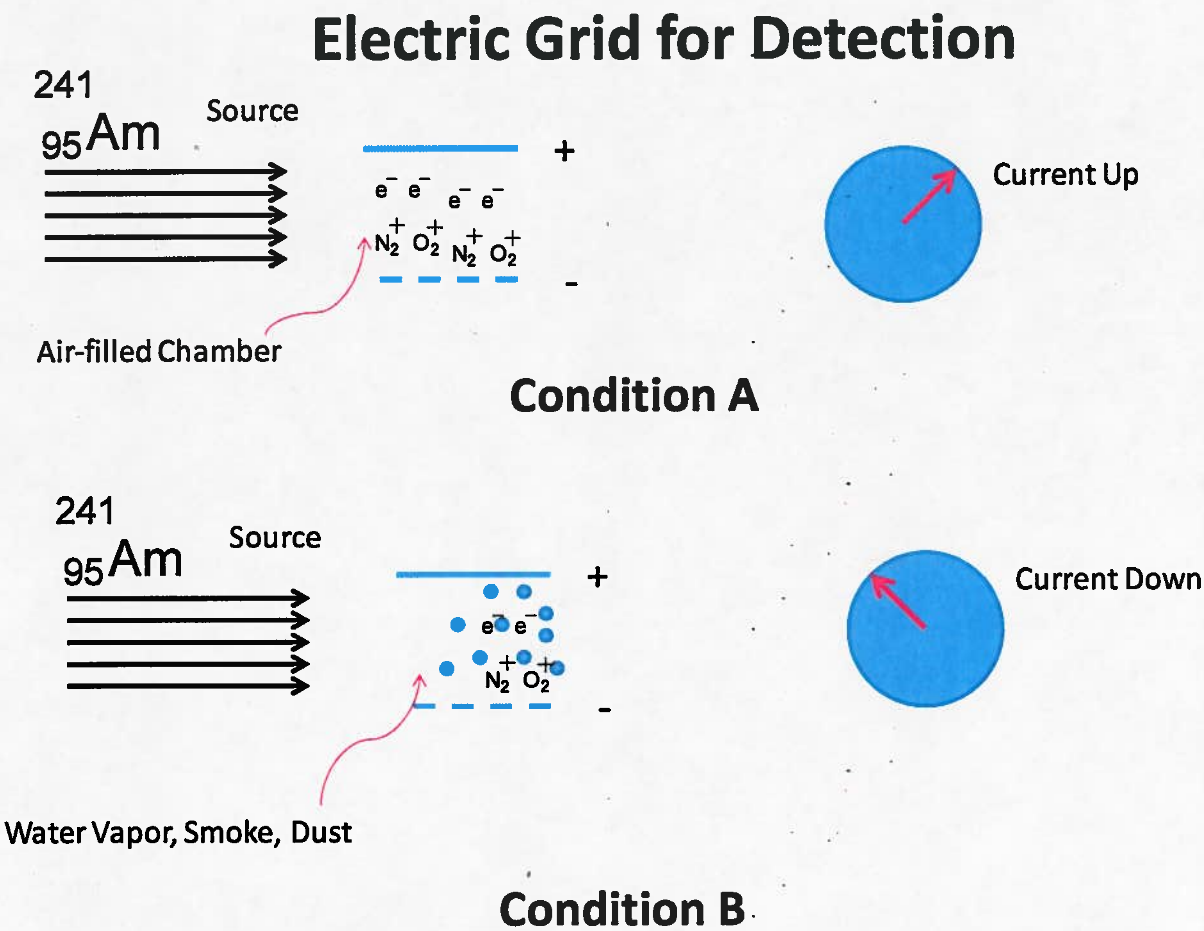

Figure 5. Schematic Diagram for the Ionization Smoke Detector

Ionization smoke alarms were first mass produced and commercially available to the public in the 1970s, but those early detectors used very expensive and cumbersome batteries in the ten to fifteen volt range. With advances in electronics technology, ionization smoke alarms can now be operated with readily available nine (9) volt batteries or AA batteries (1.5 volts).

1.2.2.3 Advances in Electronics Technology and Power Sources

Advances in electronics technology and power sources benefited the ionization and photoelectric smoke alarms. These advances reduced the size and the cost of smoke alarms making them affordable and desirable in most households. Power sources for smoke alarms now come in different types and sizes and are readily available. These include batteries to be replaced annually, ten-year lithium batteries, or an AC power source with battery back-up.

1.3 Charge from SFM

The SAATF was charged to make recommendations to the State Fire Marshal on how Ohio citizens and residents can best protect themselves through available smoke alarm technologies. The SAATF was asked to examine the various research, data and recommendations regarding residential use and placement of photoelectric and ionization smoke alarms. The SAATF was also asked to explore the development of new technologies in smoke alarms that may also provide better alerting features.

1.3.1 Objective, Scope, and Basis for Recommendation

The rationale in creating the SAATF is due to recent statistics that show that as many as 90 percent of Ohio fires with fatalities or injuries occur in homes with no smoke alarms, no working smoke alarms or smoke alarms that may not have activated. Additionally, new recommendations by some organizations have suggested the use of one smoke alarm detection technology over the other. In order for the SAATF to accomplish the work it was created to do broad tasks were translated into a set of objectives. These led to a scope of study which helped to determine the basis for recommendations.

1.3.1.1 Set of Objectives

1) To understand the significance of smoke alarms for fire protection.
2) To recognize the different perspectives in the use of smoke alarms.
3) To assess developing smoke alarm technologies in the US.
4) To determine commercially available smoke alarm technologies useful to the citizens and residents of Ohio.
5) To compare basic and enhanced smoke alarm functions.
6) To assess the dynamics of fire protection based on smoke alarm alerts, human responses, and overall preparedness for fire emergencies.
7) To determine which smoke alarm technology may be best: ionization or photoelectric.

1.3.1.2 Scope

The work of the SAATF was largely defined by the set of objectives as listed above, the amount of reference materials received and reviewed, and the number of testimonies provided by manufacturer representatives, fire service personnel, and other interested parties. Reference materials were reviewed and assessments made on their value to the SAATF. Testimonies were heard and presenters were asked relevant questions by SAATF members. Additionally, members of the SAATF offered their professional experiences to shed light on issues of fire protection that may not have been easily resolved from reference materials or testimonies. Lengthy discussions about human response were held based on available literature and firsthand experience. The SAATF recognized that smoke alarm alerts are only effective when persons respond appropriately. Residential sprinkler systems were discussed as an important part of the arsenal for fire protection.

1.3.1.3 Basis of Recommendation

Recommendations were provided to give the State Fire Marshal a firm foundation to carry forward with adequate operational rationale. Some issues were identified that may require future evaluation or consideration. These were not immediately pertinent to the objectives, scope or basis of recommendation as identified by the SAATF.

1.4 Meeting Schedule

July 21, 2011	Introductory Meeting	Name of Organization
August 15,2011	Planning session	SAATF Members
September 21, 2011	Testimony Hearing: 1. Wendy Gifford 2. John Andres	Universal Security instruments Kidde
October 21, 2011	Testimony Hearing: 1. Dean Dennis 2. Howard Hopper 3. Thomas Fabian	Dean & Doug (Advocates for Photoelectric Smoke Alarms) UL Underwriters Laboratories UL Underwriters Laboratories
November 9, 2011	Testimony Hearing: Joseph M. "Jay" Fleming	Boston Fire Department
December 7, 2011	Review Testimonies, research, outline format of Recommendation Report	SAATF Members
January 25, 2012	Assign various sections of the Recommendation Report to SAATF members,	SAATF Members
February 16, 2012	Review initial draft of the format for the Recommendation Report	SAATF Members
March 15, 2012	Review Draft	SAATF Members
April 24, 2012	Review Final Draft	SAATF Members

Table 1. Schedule of meeting dates and testimony

2 Technical Approach and Methodology

The SAATF understands that there are multiple ways to approach the broad subject of smoke alarms. Considering the available human resources, time constraints and the life cycle of the SAATF, the members chose the technical approach that focused on current technology and commercially available smoke alarms. There are three components of the technical approach: Solicitation/Investigation/Inquiry, Data Research, and Limitations. Again, the first two components could have been taken in multiple directions but the SAATF chose to limit such exercise. Hence, limitation is the self-imposed break to ensure that the work is focused and the job gets done within the time frame of the SAATF existence.

2.1 Solicitation, Investigation and Inquiry

This is the component of the technical approach where input was requested. The stakeholders include smoke alarm manufacturers, representatives of families who lost loved ones to fire, experts in the field of smoke alarms, firefighters, and scholars. The stakeholders were invited to present their testimony and relative information. A schedule of presenters is listed in Table 1.

2.2 Data Research

The SAATF members recognized that they had neither expertise nor knew the engineering of smoke alarms and that data research was necessary to help them understand the presentations being made. Many team members visited local stores such as Home Depot, Lowes and Menards to learn more about commercially available smoke alarms. The mention of the local stores names does not constitute an endorsement.

The SAATF collected several published materials pertaining to laboratory testing of smoke alarms, full scale live fire testing, comparative literature, advocacy papers, and fire death related statistics. A list of these publications can be found in the bibliography. Publications from sources such as the California State Fire Marshal Smoke Alarm Task Force were reviewed to determine their study and recommendations. The SAATF also acknowledges on-going studies being conducted by such groups as the United States Fire Administration (USFA) and the National Institute of Standards and Technology (NIST).

2.3 Limitations

The SAATF understands that its purpose is to advise State Fire Marshal Flowers based on sound knowledge gained from the testimonies and review of literature. Therefore, the SAATF refrained from the engineering aspects of the smoke alarms, such as design packaging, while acknowledging the future development of smoke alarms. If engineering questions were asked, it was to help understand smoke alarms as used in residences, but not how to make them or how to improve the current commercially available devices.

The SAATF did not conduct any verification or perform experiments regarding the performance of smoke alarms.

3 Narrative Description of Findings

3.1 *Smoke Alarm Detection*

Smoke alarm detection is a very limited symbiotic relationship between the smoke alarm device and the person using it. The smoke alarm only sounds an alert. The person reacts to the alarm, determines the presence of smoke, and decides to exit the house. In other words, reacting to a smoke alarm should be an immediate action, much as one should react to a low fuel gauge in the car. When the fuel gauge indicates yellow, it is close to being empty. If no action is taken the car will soon quit running. As with stalled cars on highways that can cause fatal accidents, unheeded smoke alarm alerts can also cause death. With respect to personal safety, smoke alarm activation is only one component of escaping residential fires.

A smoke alarm is a tool for smoke detection and not a ceiling ornament. Its function should be communicated to every occupant in the dwelling. When the smoke alarm alerts, it must be taken seriously.

3.1.1 How Ohio Citizens and Residents Can Best Protect Their Family and Property

A smoke alarm should be installed and used according to the manufacturer's recommendations in all dwellings. Every household should have a fire plan and conduct exit drills together. The training exercise in the corporate world is mandated, but the practice should be adopted in residences as well.

The fire plan and exit drills should identify the individual, family members or occupants that may need the most help.

3.1.2 Nuisance Alarms

Smoke alarms, though named as such, are non-specific detectors. They respond to material that made its way to the detection chamber of the devices. These materials could be gases, smoke and dust. Gases such as water vapor are indicators of a heat source and therefore legitimate triggers for alarms. In cases where water is intentionally being boiled, such as in a kitchen, or in a bathroom where hot water is used, the alarm is still legitimate. Construction inside the house generates dust especially when sawing wood. Repairs when soldering electronics or when plumbing often generate smoke. The difference, however, is that the cause is known. Prior to installing smoke alarms, the user should consult the manufacturer recommendations for proper location.

3.2 *Smoke Alarm Alerting Capability Including Special Populations*

In addition to the ability to detect the presence of a fire, a smoke alarm must consistently be able to effectively alert occupants to an emergency and prompt their escape. The effectiveness of smoke alarms varies among several special populations that are at increased risk for injury or death in residential fires. Sleeping persons, including children younger than 12 years, older adults, those with hearing impairment, and persons under the influence of alcohol or drugs that interfere with arousal from sleep are all at risk.

3.2.1 Sleep as a Risk Factor for Residential Fire-related Injury or Death

Being asleep at the time of a residential fire is an important risk factor for fire-related death. Approximately half of residential fire deaths occur at night, with the victims asleep at the time of the fire (Runyun, *et al.*, 1992). Even in daytime fires, many deaths occur as a result of the victim being asleep at the time of the emergency (Brennan, 1995). Indeed, the fire fatality rate during sleep is approximately 3 times higher than at other periods (Bruck and Ball, 2007).

Sleep Stages

Sleep consists of several stages that cycle throughout the night, with one complete sleep cycle lasting approximately 90 to 100 minutes. The sleep cycle begins with 3 stages of non-REM (non-rapid eye movement) sleep, with each consecutive stage (stages N1-3) characterized by increased slowing of the frequency of electro-encephalogram (EEG) wave patterns and increased refractoriness to arousal. Stage N3 sleep is also known as slow wave sleep (SWS).

Sleep Inertia

Another problem inherent in relying on smoke alarms to save lives is that upon awakening from sleep, many adults have been found to have difficulty with sleep inertia, which impairs decision making. There is a tendency to return to sleep that occurs immediately after awakening. In a study of 12 adults monitored in a sleep lab for one night and twice awakened by fire alarms, Bruck and Pisani (1999) found that decision-making performance was as little as 51% of optimum (i.e., baseline) during the first few minutes after awakening. The initial effects of sleep inertia were significantly greater after SWS arousal than after REM arousal. Bruck, *et al.* (2004) used subjective ratings of "clear-headedness" to measure sleep inertia among 6-10 year-olds in three studies. Splaingard, et al. (2007) studied sleep inertia using objective measures among 6-12 year old children awakening from SWS. The degree of impairment was age-dependent (younger children were more susceptible to sleep inertia) and influenced by sleep cycle (sleep inertia was greater during the second sleep cycle than the first). To survive an actual house fire, individuals not only need to awaken, but also must be able to perform escape behaviors that require decision-making and action, which are vulnerable to impairment by sleep inertia. Voice notification offers the potential advantage of providing verbal instructions for escape, which may assist in life-saving decision-making and action despite the influence of sleep inertia.

3.2.2 Children Younger Than Twelve Years

Children 5-12 years of age have a higher residential fire-related fatality rate than teens and adults up to age 35 years (Flynn, 2010). Conventional residential smoke alarms generally produce a high-frequency (approximately 3,200 Hz) tone of 85 dB, using the international standard T-3 signal pattern, which will awaken most sleeping adults (Nober, *et al.*, 1981; Bruck and Horasan, 1996). However, auditory arousal thresholds (AATs) are age-dependent (Busby, *et al.*, 1994), and children can be remarkably resistant to awakening by sound when asleep. Despite recognition of the magnitude and importance of this problem, there is a critical gap in knowledge regarding the key characteristics of a smoke alarm that will awaken children and prompt their escape.

Several factors associated with sleep place children at greater risk for fire-related injury and death. First, children sleep more than adults and are therefore more likely to be sleeping when a fire occurs. Furthermore, during each stage of sleep, the average auditory stimulus intensity required to elicit an arousal in children is much higher than in adults. Children also have disproportionately more SWS than adults, which has a higher AAT than other stages of sleep. Most SWS occurs during the early sleep cycles, and unfortunately, house fires also are more common during the early hours of the night. Hence, children are more likely than adults to be in a stage of sleep that is refractory to arousal at the time of a nocturnal residential fire (Underwriters Laboratories Committee, 2003).

Only two research teams have conducted studies to evaluate arousals from sleep to different types of smoke alarms among children. Bruck, *et al.* (2004) and Smith, *et al.* (2006) conducted research demonstrating that young children (ages 6-10 years and 6-12 years, respectively) awaken better to the sound of their mother's voice than to a conventional high-pitched tone alarm. Bruck, *et al.* (2004) also demonstrated that young children awaken to the sound of a female stranger's voice and to a low-pitched tone alarm better than to the high-pitched tone alarm. These studies had several limitations, such as small sample size and design issues, and additional research is needed to define the differences among these auditory alarm stimuli. Future studies should 1) monitor sleep stage, which is a critical factor influencing arousal from sleep, 2) assess the performance of a simulated escape procedure upon awakening (in addition to awakening, people must escape to survive a residential fire), and 3) assess the influence of sleep inertia on performance of the escape procedure.

3.2.3 Older Adults

Adults older than 65 years have the highest residential fire fatality rate among all age groups (Flynn, 2010), with the rate for 75-84 year-olds almost 2.5 times higher than that of the all-ages average rate. Older adults commonly have high frequency hearing loss and are less likely to awaken to a conventional high frequency tone smoke alarm (Bruck, *et al.*, 2006; and Bruck and Thomas, 2008). Low frequency tone signals appear to be the most successful in awakening older adults; however, additional research is needed because of the small sample size and methodological limitations of existing studies.

3.2.4 Persons with Hearing Impairment

Auditory smoke alarms are a core component of the current national public health strategy to prevent residential fire-related mortality and morbidity. However, persons who are deaf or have substantial hearing impairment may not respond to an auditory stimulus. Bruck and Thomas (2009) conducted a study of the ability of selected auditory, visual and tactile stimuli to awaken adults with hearing impairment. A 520 Hz square wave auditory signal performed the best in their study with bed and pillow shakers performing intermediately and high intensity strobe lights performing inadequately. However, the hearing impairment among the participants in this small study (38 subjects) was only mild to moderate with hearing loss varying from 25 to 70 dB. Further research is needed in deaf and hearing impaired populations.

3.2.5 Persons Under the Influence of Alcohol or other Drugs

Ball and Bruck (2004) demonstrated in a small study (12 participants) of young adults (18 to 25 years old) that drinking alcohol, even in moderation, will impair the ability to awaken to a smoke alarm. Epidemiological studies from multiple countries have repeatedly demonstrated the association of alcohol consumption and increased risk of fire-related death across all age groups (Runyun, et al., 1992; Squires and Busuttil, 1997), including fatalities associated with smoking-related residential fires (Ballard, et al., 1992; Howland and Hingson, 1987). Little is known about the influence of illegal and prescription drugs on the response to smoke alarm signals. However, based on data from the National Fire Incident Reporting System for 2005 – 2009, possible impairment by a non-alcohol drug or chemical was a contributing factor in 5% of home fire fatalities (Evarts, 2011). The impact of drugs and medications on response to smoke alarms is an area awaiting further important research attention.

3.3 Adequacy of NFIRS Data on Alarm

Advocates for photoelectric technology point to data on the number of fatal fires that shows smoke alarms may have failed to alert occupants. They believe that today's incipient fires are slower to flame and that photoelectric alarms will activate faster than ionization alarms in a smoldering fire before it breaks into a flaming stage. The difficulty in evaluating this concern centers around the lack of comprehensive, accurate data on smoke alarm performance. Many studies reviewed by the SAATF included or relied upon data obtained from NFIRS, yet there are inherent limitations with the NFIRS data which must be discussed.

The National Fire Incident Reporting System (NFIRS) is a voluntary program run by the U.S. Fire Administration (USFA). The purpose of NFIRS is twofold: "to help state and local governments develop fire reporting and analysis capability for their own use, and to obtain data that can be used to more accurately assess and subsequently combat the fire problem at a national level."[1] Because participation in this program is voluntary, not all states participate nor does every fire department. However, by the USFA's own estimate, as many as 75% of all fires that fire departments attend to in the United States are captured in the program's data. Ohio's statistics are even better, with approximately 97% of fire departments reporting data. It is important to note that in Ohio fire incident data reporting is mandated by law under both the Ohio Revised Code[2] and the Ohio Administrative Code[3].

The widespread use of NFIRS makes it the largest source of data about fires in the United States. Because the program is federally sponsored the data is publicly available. The combination of these two factors appears to make NFIRS the most widely cited source of data with respect to research on the effectiveness of smoke alarms.

NFIRS is managed by the National Fire Data Center (NFDC), a branch of the USFA. The NFDC's charges include[4]:

[1] http://www.usfa.fema.gov/fireservice/nfirs/about.shtm
[2] Ohio Revised Code 3737.23 and 3737.24
[3] Ohio Administrative Code 1301:7-7-01 (D) (3) (i) 104.6.3.1
[4] http://www.usfa.fema.gov/about/orgchart/nfp.shtm

1. Coordinate and manage the collection, analysis, and dissemination of data and information about fire and other emergency incidents involving fire department response.
2. Encourage and assist State, local and other agencies, public and private, in developing standardized reporting methods and in reporting information.
3. Manage the National Fire Incident Reporting System (NFIRS), the Fire Department Census and other National databases and systems containing information related to the fire problem and the fire and emergency services.
4. Support adoption of new fire detection and suppression technology nationwide.

The NFDC publishes the regular reports on fire statistics which are released by the USFA. The NFDC also serves as the primary point of contact for the public when inquiries are made regarding national fire statistics.

NFIRS collects information on smoke alarm/smoke detector performance under three separate headings. The majority of data comes from incidents reported as structure fires:

- Building fires
- Fires in structures, other than in a building

Under the structure fire category within NFIRS, there are six additional categories for "confined" fires which did not spread beyond the container of origin such as "cooking fires involving the contents of a cooking vessel without fire extension beyond the vessel." For confined fires completing fields on detector performance (as well as several over data fields) is optional. The confined fires category was not introduced in the NFIRS system until version 5.0 was released in January 1999. It is suspected that prior to this many such instances were either unreported or reported as a non-fire incident. In 2007, confined fires accounted for 19% of all fires and 44% of reported structure fires[5]. Because reporting of smoke alarm information is optional for confined fires, however, the data for smoke alarm performance in such instances is sparse[6,7].

Another NFIRS category exists for false alarms and false calls, and there is an option in this field for "Smoke detector activation due to malfunction." The NFIRS reference guide[8] instructs the user that malfunctions should be characterized as "improper performance of fire alarm system that is not a result of proper system response to environmental stimuli such as smoke or high heat conditions." Most NFIRS reports are completed in an electronic format using software from USFA-authorized vendors. An evaluation of one of these software products revealed that there are no prompts to explain 'malfunction' to the end user. There is a second option under the false alarms and false calls field for "smoke detector activation (no fire), unintentional." This field is supposed to include proper responses to conditions such as non-hostile smoke (in other words, proper operation).

A third and final position in the NFIRS reports for collecting smoke alarm performance information exists under the basic information field. If there is a confined fire (but not an unconfined structure fire), the user must select one of the following three options:

[5] Fire in the United States Fifteenth Edition (2003-2007)
[6] National Fire Incident Reporting System 5.0 Fire Data Analysis Guidelines and Issues (July 2011)
[7] Smoke Alarms in U.S. Home Fires (NFPA, September 2011)
[8] National Fire Incident Reporting System Complete Reference Guide (July 2010)

- Detector alerted occupants
- Detector did not alert them
- Unknown

No distinction is made as to what type of detector is in place (smoke alarm, heat detector, carbon monoxide detector, etc.)

It should be noted that detector performance data has been collected since the first iteration of NFIRS was released in 1976, but even 35 years ago the NFIRS form did not define the type of detector in place. Reporting fields on the type of detector present, however, were not added until NFIRS 5.0 was released. In 2001, Ohio switched to NFIRS 5.0 and in 2008 it was mandated that all reporting be done electronically. The USFA, however, continued to accept NFIRS 4.1 data until January 1, 2010.

The USFA publishes a document on NFIRS "Fire Data Analysis Guidelines and Issues." Many of the limitations on collection of smoke alarm data are discussed. Clarifications are also presented, such as the fact that 'unknowns' are not presented when USFA distributes data on smoke alarms. This document suggests that smoke alarm performance data be categorized into two subsets: confined and non-confined fires. This guideline also clearly shows that smoke alarm performance data cannot be directly correlated with information on deaths or injuries because none of the smoke alarm or detector data collection fields is directly tied to the casualty information fields. The guideline goes on to say, "Currently, the USFA has opted to present the undistributed data for presence, operation, and effectiveness. Other smoke alarm variables are not analyzed at this time." It does not appear that any data from false alarms or false calls is included with the performance statistics regularly produced by the USFA.

The USFA has limited quality assurance/quality control resources in place to audit the NFIRS data. A USFA document talks directly to the problem of data quality and goes so far as to use the adage, "Garbage In, Garbage Out" in reference to fire department reports.[9] NFIRS relies upon data submitted by tens of thousands of different users, many of whom have never received formal training on how to complete a NFIRS report. Typically, it is the responsibility of a fire department to develop a quality control program for the data reported to NFIRS. It does not appear that the USFA makes any attempt to quantify the accuracy of the NFIRS data, nor is there a conceivable way to perform such an assessment.

Another key issue with the NFIRS data is that some fire departments do not report statistics every year. For example, reporting using NFIRS 4.1 peaked in 1993 with more than 14,000 fire departments reporting data. As the shift was made to NFIRS 5.0 in 1999, this number dropped to just over 11,000 departments. By 2008, electronic reporting and greater state level participation resulted in the participation of more than 22,000 fire departments. Correlations could be made using the number of reporting fire departments, but the results would be inaccurate since correlated data does not match the population base or fire department run volume. For example, the Washington, D.C. fire department (DCFD) has reported data to NFIRS in the past, but did not report information in 2008. According to *Firehouse Magazine's* Annual Run Survey, DCFD responded to more than 30,000 fire calls in 2008. Including DCFD's runs in the 2008 NFIRS

[9] FA-266 Fire Data Analysis Handbook Second Edition (January 2004)

data would add approximately 2.5% more fires. This shows how including or excluding data from one large fire department can have a dramatic impact on the NFIRS statistics. Moreover, the NFDC does not regularly identify which departments do or do not report data in a given year.

In spite of these numerous shortcomings, references to NFIRS data on smoke alarm performance are made in several of the documents reviewed by the SAATF in preparation of this report. Aside from some small studies (less than 125 households), real world data (outside of laboratory or staged fire testing environments) on the performance of smoke alarms in the U.S. appears to be based largely on statistics from NFIRS. While some of the documents reviewed by the SAATF make mention of the limitations of NFIRS data, many do not. Furthermore, the fact that NFIRS does not collect any data on the type of smoke detection technology in place greatly reduces its usefulness to the SAATF in our attempts to evaluate and respond to the photoelectric and ionization debate.

NFIRS contains a large amount of data, but the information about smoke alarm performance may be questionable. Because there are no other identical sources of information, the use of NFIRS data to analyze smoke alarm performance is likely to continue. NFIRS is a well-established means of collecting real-world data and has the capability to collect good information. With that said, considering changes to the information gathered on smoke alarm presence and performance, as well as educating the fire service about the importance of collecting this information, is paramount.

The SAATF has many concerns about the data available from the NFIRS system. The members struggled to use this data to analyze concerns about smoke alarm performance. Because of this, the following recommendations are being made by the SAATF to improve the collection of smoke alarm-related data using the NFIRS system:

- The NFDC should modify the NFIRS reporting form, preferably Section L, and add a field for collecting information on the type of smoke alarm (i.e. ionization or photoelectric) installed where fire incidents are reported. Collecting this information is likely to have a substantial impact on resolving the photoelectric and ionization debate.
- The NFDC should modify the NFIRS reporting form to make the detector field more descriptive in order to capture the performance of smoke alarms versus other types of detectors. Without distinguishing the type of detector being reported in this field, use of this data is very limited.
- The NFDC should require that Section L of the NFIRS fire module be completed when reporting confined fires. It is believed that a large number of detector success stories go unreported because detector performance data does not have to be collected for small fires.
- The NFDC should educate fire service personnel on the importance of reporting accurate data about smoke alarm performance. If the other recommendations about changes to the NFIRS system are implemented without an explanation, fire service personnel are likely to view the changes as burdensome and unnecessary. Because new information will be collected it may take time for fire service personnel to remember to capture such data. This delay may lead to a large number of 'undetermined' responses when data is collected. Educating fire service personnel on the importance of reporting accurate information can only serve to improve the data.

3.4 *New Technologies and Interconnectivity*

3.4.1 New Technologies

The SAATF heard many presentations that made it clear that smoke alarm design advancements are ongoing. Within a short time, the form of the smoke alarm may be significantly different than it is today. SAATF recommendations should not impede or limit that advancement. Smoke alarms are being developed that combine current technologies with new technologies and that interpret measurements differently – all toward improving accuracy and reducing nuisance alarms. The use of wireless communication is increasing. The advancement of battery technology has changed the utilization of smoke detectors significantly and continues to develop. Any recommendations that 'freeze' technology can be considered to be inappropriate.

3.4.2 Interconnectivity

Any working smoke alarm is a significant tool to detect fire and to alert occupants in a dwelling. Adding smoke alarms to an interconnected system greatly magnifies the ability to perform both the fire detection and alerting functions and significantly increases reliability. The use of a fire alarm with 110 AC wired power and battery backup provides the ability to also interconnect the units for alerting throughout the dwelling. Placing fire alarms on all levels of the structure and in all sleeping areas also provides an alert throughout the dwelling. Non-interconnected fire alarms activated in basements or bedrooms may not be heard throughout the dwelling.

3.5 *Life Cycle of Alarms*

Although the SAATF is focused on the performance of smoke alarms, it must acknowledge that the ultimate goal of saving lives due to fire requires a look at the life-span of a smoke alarm. To achieve success a smoke alarm program involves a number of steps: legislation and rule making, public education, selection and installation of smoke alarms, maintenance, appropriate response to alerts, and eventual replacement of smoke alarms. Part of a program should include measurements to define success and continuous improvement in the program.

3.6 *Public Education*

A strong and continuous public education program contains information about the need for smoke alarms, proper use, planning for escape, maintenance, and eventual replacement. Encouraging state and local fire service agencies to work together can help to build more effective public education campaigns.

3.6.1 Maintenance and Replacement

A common reason that smoke alarms fail to alert is due to dead or missing batteries. Although some batteries are designed to last the life of the smoke alarm, most should be replaced annually.

Manufacturers recommend that smoke alarms be replaced within ten years. Maintenance and replacement usually depends on the actions of the dwelling occupants. Public education efforts should focus on the need to follow manufacturer recommendations.

3.6.2 Safe Escape

Smoke alarm activation by itself is inadequate to save lives. Survival is dependent upon the actions of the occupants. Planning, practice and response can result in survival during a fire. Public education efforts can help members of the community learn effective methods for fire planning and escape.

3.7 Choices in Technology Platforms for Smoke Alarms

One objective for the SAATF is "To settle the debate on which current Smoke Alarm technology is better: ionization or photoelectric." The SAATF reviewed multiple documents and heard testimonies regarding photoelectric and ionization smoke alarms. One testimony presented statistics on how many lives were saved with photoelectric smoke alarms. However, in the same testimony there were no statistics presented to indicate how many lives were saved or lost with ionization smoke alarms. That testimony did not treat the issue objectively and was not useful to the SAATF to help determine which technology is better. Furthermore, when independent studies on smoke alarm testing were presented, the SAATF found that neither technology outperforms the other in all areas. There are advantages and disadvantages to both technologies.

After careful consideration of all of the content reviewed, the SAATF does not recommend one existing smoke alarm technology (ionization and photoelectric) over another. Indeed, endorsing a specific technology may not be prudent, because technologies will continue to change. Rather, smoke alarms should meet national performance standards, regardless of the technology. These performance standards should be reviewed periodically, especially as future advances in fire detection technologies are introduced. The SAATF supports the use of smoke alarms that meet national performance standards. Further, the SAATF believes that a more important issue is that all residences have working smoke alarms on every floor, with special attention given to all sleeping areas and special needs considerations.

3.7.1 Samples of Smoke Alarms

There are many brands of smoke alarms available in the marketplace and these brands include either ionization or photoelectric technology. All have basic functions for smoke detection and have been tested by accepted testing laboratories such as UL. Many have enhancements such as power sources, digital display, mono-tonal alarm, broadcasting alarm, etc. Table 2 lists the smoke alarms available at Home Depot, but the store holds more inventory of smoke alarms than shown. Many of the brands are also available in other stores such as Menards, Lowes, Wal-Mart and similar retailers. There are many additional features that can be listed in Table 2 but these have been purposely excluded from this report. The SAATF believes that Ohio citizens and residents must research smoke alarms to assist them in making decisions about which smoke alarm matches their needs. Table 1 is arranged according to considered parameters of smoke alarm features. Smoke alarms are identified as samples 1 to 14.

Table 2. List of Samples of Smoke Alarms

Considered Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Brand Name	Kidde	Kidde	FireX	First Alert	Kidde	Gentex	Kidde	First Alert
Manufacturer	Kidde	Walter Kidde	Walter Kidde	First Alert	Kidde	Gentex Corporation	Kidde	First Alert
Power Source	Battery	AC, 120V	AC, 120V	Battery	AC, 120V	AC, 120V	Battery	Battery
Battery Back-Up	No	Yes	Yes	Yes	Yes	No	No	Yes
Digital Display*	No	No	No	No	No	No	No	No
Smoke Detector	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
CO Detector*	No	No	No	No	No	No	No	Yes
Ionization Sensor	yes	Yes	Yes				Yes	Yes
Photoelectric Sensor					Yes			
Test/Reset Button	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Visible Sensor*	No	No	No	No	No	No	No	No
Voltage (volts)	9 V	120 V	120 V	9 V	120 V	120 V	9 V	9 V
Wired or Wireless*	Wireless	Wired	Wired	Wireless	Wired	Wired	Wireless	Wireless
Assembled Depth (in.)	1.5 in	9 in	3 in	6.31 in	1.55 in	1.75 in	1.55 in	7 in
Assembled Height (in.)	1.5 in	6.5 in	6.25 in	8.56 in	5.6 in	6 in	5.6 in	8.56 in
Assembled Width (in.)	5 in	6.5 in	6.63 in	2.29 in	5.6 in	6 in	5.6 in	3.17 in
Additional* Features	NA	NA	NA	Escape Light	3 Evacuation Tone	NA	NA	Interconnectible
Packaging	$4866 per 720	49 per 4	NA	NA	NA	NA	NA	NA
Price	$6.75	$12.25	$13.94	$14.97	$17.97	$19.84	$19.97	$29.97

- Parameters with * are enhancements of the smoke alarms. Prices were taken from Home Depot Public web site on 03/03/2012.

Table 2. List of Samples of Smoke Alarms (Continuation)

Considered Parameters	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14
Brand Name	First Alert	Kidde	Kidde	Universal Security Instruments	Universal Security Instruments	Gentex
Manufacturer	First Alert	Kidde	Walter Kidde	Universal Security Instruments	Universal Security Instruments	Gentex Corporation
Power Souce	Battery	Battery	Battery	Battery	AC, 120V	AC, 120V
Battery Back-Up	Yes	No	No	Yes	Yes	Yes
Digital Display*	No	No	No		No	No
Smoke Detector		Yes	No	Yes	Yes	Yes
CO Detector*	Yes	Yes	Yes	Yes	Yes	No
Ionization Sensor			Yes	Yes		
Photoelectric Sensor					Yes	Yes
Test/Reset Button	Yes	Yes	Yes		Yes	Yes
Visible Sensor*	No	No	No		No	Yes
Voltage (volts)	4.5 V	9 V	1.3 V		120 V	120 V
Wired or Wireless	Wireless	Wireless	Combo		Wired	Wired
Assembled Depth (in.)	7 in	6 in	9.50 in	2 in	2 in	4.75 in
Assembled Height (in.)	8.56 in	1.5 in	11.75 in	6 in	6 in	5.5 in
Assembled Width (in.)	3.17 in	5.75 in	7.94 in	6 in	6 in	5.5 in
Additional Features*	Voice and Location	Voice Alert	Voice Alert	NA	NA	Hearing Impaired Strobe Light
Packaging	NA	NA	NA	NA	$160 per 4	NA
Price	$36.97	$36.97	$38.97	$40.00	$40.00	$88.97

- Parameters with * are enhancements of the smoke alarms. Prices were taken from Home Depot Public web site on 03/03/2012.

4 Conclusions

1) The single most important conclusion is that working smoke alarms save lives. The dramatic reduction of fire fatalities in the United States since 1975 can be traced directly to the introduction and use of residential smoke alarms.
2) There are no statistical differences in the performance of the two existing types of smoke alarms initially discussed, i.e. ionization or photoelectric. Both meet the current performance standards.
3) Lack of battery maintenance in smoke alarms is one of the leading causes of smoke alarm failure to alert occupants. Tamper proof ten-year lithium batteries are one solution to this issue.
4) Manufacturers' suggested ten year "life cycle", with proper maintenance, should be further researched with an accelerated process to determine the minimum reliability of the "ten year" battery.
5) Emerging smoke alarm technology, labeled third generation, appears to meet or exceed the current performance standard and may provide an even greater choice to Ohio citizens and residents for use in various locations in their dwellings.
6) It is important for Ohio citizens and residents to make a distinction between detection and alerting. Special populations, including sleeping children, older adults, the hearing impaired, and those under drug/alcohol impairment, may not awaken to the sound of a smoke alarm. They may not comprehend that the alarm is alerting them to a fire and may not realize that they should immediately exit the dwelling. The alerting method may be more important to the safety of occupants than the detection technology.
7) There are alternatives to stand-alone smoke alarms, including other professionally designed alarm systems conforming to NFPA 72 or in combination with residential sprinkler systems as provided in NFPA 13D.
8) Smoke alarms should be installed near every sleeping area, not just in bedrooms.
9) Nuisance alarms can be avoided by installing smoke alarms away from sources known to activate them (such as near kitchens and bathrooms). Distances outlined in NFPA standards and published in the manufacturers' instructions can be used as reference.
10) Current NFIRS data collection fields need to be updated because current data does not differentiate among smoke alarm technologies nor does it provide a reason for failure in alerting occupants (e.g. no smoke alarm, no battery, and impaired occupants).

4.1 Conclusions about Alerting and Special Populations

In addition to the ability to detect the presence of a fire, a smoke alarm must consistently be able to effectively alert occupants to an emergency and prompt their escape. The effectiveness of smoke alarms varies among several special populations that are at increased risk for injury or death in residential fires. Sleeping persons, including children younger than 12 years, older adults, those with hearing impairment, and persons under the influence of alcohol or drugs that interfere with arousal from sleep are all at risk.

4.2 Conclusions about NFIRS

NFIRS contains a large amount of data, but the information about smoke alarm performance may be questionable. Because there are no other identical sources of information, the use of NFIRS data to analyze smoke alarm performance is likely to continue. NFIRS is a well-established means of collecting real-world data and has the capability to collect good information. With that said, considering changes to the information gathered on smoke alarm presence and performance, as well as educating the fire service about the importance of collecting this information, are paramount.

4.3 Conclusions about Technology

Advances in electronics technology and power sources benefited the ionization and photoelectric smoke alarms. These advances reduced the size and the cost of smoke alarms making them affordable and desirable in most households. Power sources for smoke alarms now come in different types and sizes and are readily available. These include batteries to be replaced annually, ten-year lithium batteries, or an AC power source with battery back-up.

5 Recommendations

1) The fire service community should re-emphasize the basics of fire and life safety:
    a. To use and maintain residential smoke alarms in appropriate household locations
    b. To plan and practice exit drills
    c. To predetermine an emergency meeting place for all members of the household
2) Ohio citizens and residents should purchase smoke alarms that bear the label of a recognized testing laboratory (i.e. Underwriters Laboratories, Factory Mutual, etc.). These labels indicate compliance with recognized standards.
3) Smoke alarms should be installed according to NFPA standards with assured distances from potential sources of nuisance as outlined in the manufacturer's instructions.
4) A minimum of one (1) working smoke alarm should be properly installed on every level of a residence.
5) It is highly recommended to install smoke alarms near every sleeping area.
6) Smoke alarms must be tested regularly. Batteries should be changed according to manufacturers' recommendations.
7) Interconnected smoke alarms are recommended to increase the potential to alert all members of the household simultaneously.
8) Public education programs should be developed to assist Ohioans in selecting the best smoke alarm technologies for use in their dwellings.
9) More research is needed to better identify alerting signals that are effective for all populations.
10) A new fire service education campaign should be implemented to help citizens and residents choose the best technology for their home and any identified special needs.
11) The Fire Marshal should request that the USFA study the need for more exact data. Identified concerns show that information is needed on how occupants are alerted, with emphasis on the type of alarm and any conditions – such as a lack of maintenance or missing batteries – that lead to a failure to alert. Specific recommendations for consideration by the USFA appear in Section 5.2.
12) The National Fire Incident Reporting System (NFIRS) should be revised to provide better data about why occupants fail to heed the alert of a smoke alarm.
13) The State Fire Marshal should support efforts to update performance criteria for smoke alarms and their incorporation into published standards.

5.1 Recommendations about Alerting and Special Populations

- Further research about voice notification/verbal instruction smoke alarms should be conducted.
- Additional studies are needed to monitor sleep stages of children, assess the performance of a simulated escape procedure upon awakening, and assess the influence of sleep inertia on performance of the escape procedure.
- Continued research is needed to determine the effectiveness of low frequency tone alarms to awaken older adults.
- Further study is needed to address alerting options for deaf and hearing impaired populations.
- Research is needed to determine the impact of drugs and medications on response to smoke alarms.

5.2 Recommendations about NFIRS

- The NFDC should collect information on the type of smoke alarm (i.e. ionization or photoelectric) installed.
- The NFDC should make the detector field more descriptive in order to capture the performance of smoke alarms versus other types of detectors.
- The NFDC should require that Section L of the NFIRS fire module be completed when reporting confined fires.
- The NFDC should educate fire service personnel on the importance of reporting accurate data about smoke alarm performance.

5.3 Recommendations About Technology

- The SAATF does not recommend one existing smoke alarm technology (ionization and photoelectric) over another.
- Smoke alarms should meet national performance standards, regardless of the technology.
- Performance standards should be reviewed periodically.
- All residences should have working smoke alarms on every floor, with special attention given to all sleeping areas and special needs considerations.

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Glossary

AAT .... Auditory Arousal Threshold
AC .... Alternating Current
Alarm .... Audible and/or visual signal
Announcement Alarm .... Enunciated broadcast of specific alarm
DC .... Direct Current
EEG .... Electro-encephalogram
FEMA .... Federal Emergency Management Agency
Fire Signatures .... Fire chemical components of unknown chemical composition from known materials
LED .... Light Emitting Diode
NFDC .... National Fire Data Center
NFIRS .... National Fire Incident Reporting System
NFPA .... National Fire Protection Association
NIST .... National Institute of Science and Technology
Nuisance Alarm .... Unintended Alarm
OFIRS .... Ohio Fire Incident Reporting System
OH .... Ohio
OSFM .... Ohio State Fire Marshal
PIO .... Public Information Officer
REM .... Rapid Eye Movement
SAATF .... Smoke Alarm Advisory Task Force
SFM .... State Fire Marshal
SFPE .... Society of Fire Protection Engineers
SWS .... Slow Wave Sleep
US .... United States
USFA .... United States Fire Administration