Smoke Alarms –
Pilot Study of Nuisance Alarms Associated with Cooking

March 2010

The views expressed in this report are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

U.S. CONSUMER PRODUCT SAFETY COMMISSION
Bethesda, Maryland 20814

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Directorate for Engineering Sciences

SMOKE ALARMS – PILOT STUDY OF NUISANCE ALARMS ASSOCIATED WITH COOKING

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EXECUTIVE SUMMARY

In 2005, there were an estimated 375,100 unintentional residential structure fires resulting in 2,630 deaths, 12,820 injuries and $6.22 billion in property loss. Almost all households in the U.S. have at least one smoke alarm, yet from 2000-2004, smoke alarms were not operating or were intentionally disabled in almost half (46%) of the reported home fires. Nearly all of the non-working smoke alarms were due to dead or missing batteries.

Despite the almost universal presence of smoke alarms in homes, research on smoke alarms installed in homes has shown that many alarms are disabled by the occupants because of frequent nuisance alarms from cooking. As many as 20 percent of the smoke alarms installed in U.S. homes have been disabled, and that number may be higher in high risk areas, such as inner cities and rural communities.

In 2008, the U.S. Consumer Product Safety Commission (CPSC) staff initiated a study to investigate nuisance alarms from cooking. The study measured the number and rate of nuisance alarms generated by ionization, photoelectric, and dual-sensor smoke alarms during cooking activities. This information helped to determine the effect of an alarm location relative to the main cooking appliance in the kitchen and to various cooking routines, such as cooking methods, foods prepared, and mealtimes.

In this study, CPSC staff installed smoke alarms in nine different homes for a period of approximately 30 days.[1] The sample size of homes tested was limited and was not a random selection. These test homes were limited to those of CPSC employees or their acquaintances, and may not be representative of homes or cooking behaviors of the U.S. population in general.

The study used stand alone battery operated smoke alarms from two different manufacturers, and three different types of smoke alarms (ionization, photoelectric, and dual sensor) were used. The smoke alarms used in the testing do not represent all smoke alarms sold in the U.S. but offer a comparison between two different manufacturers and three types of smoke alarms.

Three groups of smoke alarms were installed at distances of 5 feet, 10 feet, and 20 feet from the main cooking appliance in each test home. Each group of smoke alarms consisted of an ionization, a photoelectric, and a dual-sensor smoke alarm. For each of the first eight homes, smoke alarms from one manufacturer (either manufacturer A or manufacturer B) were used for the entire suite of smoke alarms installed in a home. For the ninth home, smoke alarms from both manufacturers were used, and smoke alarm groups were installed in additional locations at 3 feet, 7.5 feet, and 15 feet from the main cooking appliance. The sound transducers of all the test smoke alarms were disabled during the test period to prevent occupants from hearing the alarms, but the signals were fed into a data acquisition system that recorded the time and date of all activations.

Participants were required to keep a daily log of their cooking behaviors, including times of cooking, cooking methods used, and foods that were cooked. Cooking behavior can vary greatly among homes for many reasons, such as ethnic background, age of the occupants, household size, availability of food type, and geographical location. The homes included in this study do not represent a statistical

[1] In the ninth home, the test period was extended an additional 30 days.

sample nor are they representative of homes in the U.S. in general, but they do offer some insight into the frequency of nuisance alarms for a variety of cooking behaviors. Although cooking behavior may vary seasonally due to weather, changes in activity, and availability of foods, these variations were not explored under this study.

Based on the CPSC staff tests, the following observations were made:

- All smoke alarm types tested, if placed too close to a cooking source, resulted in nuisance alarms as a result of cooking.
- The type of food prepared and the cooking method used influenced whether a smoke alarm activated (e.g., baking produced a higher percentage of nuisance alarms than other cooking methods for ionization and dual smoke alarms).
- The rate of nuisance alarms during preparation of dinner was higher than during other mealtimes.
- The frequency of nuisance alarms appears to be dependent on the type of smoke alarm and the distance from the nuisance source.
- Regardless of the smoke alarm type, smoke alarms placed greater than 10 to 15 feet from the main cooking appliance had a reduced number of nuisance alarms.
- Use of an exhaust fan resulted in a reduction in the number of nuisance alarms for smoke alarms installed close to the cooking appliance, but the frequency of nuisance alarms may still be too high (for consumer acceptance) over an extended period of time.
- For smoke alarms placed closer than 10 to 15 feet to a cooking appliance, photoelectric smoke alarms produced fewer nuisance alarms than other types tested.

Based on the CPSC staff tests, additional research in the following areas may be beneficial:

- Investigate the effects of an exhaust fan on nuisance alarms at different distances from the cooking appliance.
- Evaluate the effectiveness of smoke alarms in detecting cooking fires with various factors that may affect detection response. For example, it is important to examine whether selected sensor types for smoke alarms placed at different locations in the kitchen respond differently or the influence of an exhaust fan on the response.
- Evaluate the effect of a hush feature on smoke alarms on consumer behavior (e.g., would occupants disable the smoke alarms by removing the power source instead of frequently using the hush feature).
- Conduct additional research to expand the size of the study. The expanded research could examine more test homes, additional cooking behaviors, various types of kitchen ceilings, exhaust fan usage, and smoke alarm location.

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

In 2008, the U.S. Consumer Product Safety Commission (CPSC) staff initiated a study to determine the frequency of nuisance alarms from smoke alarms during cooking in residential homes. This report describes the results of CPSC staff tests to quantify the number of nuisance alarms generated by photoelectric, ionization, and dual-sensor smoke alarms associated with cooking.

1.1 Fire Hazard

In 2005, there were an estimated 375,100 unintentional residential structure fires resulting in 2,630 deaths, 12,820 injuries and $6.22 billion in property loss.[1]

Based on a telephone survey conducted in 2004, 96 percent of all homes have at least one smoke alarm. Overall, three-quarters of all U.S. homes have at least one working smoke alarm. Yet from 2000-2004, smoke alarms were not operating or were intentionally disabled in almost half (46%) of the reported home fires.[2] Nearly all of the non-working smoke alarms were due to dead or missing batteries.[3, 4, 7, 8, 9, 11] As many as 20 percent of the smoke alarms installed in U.S. homes have been disabled, and that number may be higher in high risk areas, such as inner cities and rural communities.[3, 4, 5, 6, 7, 8, 9, 10, 11] Nuisance alarms are reported to be the leading cause of residential occupants disabling their smoke alarms.[3, 4, 5, 6, 7, 8, 9, 10, 11] According to the National Fire Protection Association (NFPA), the most commonly reported reason for occupants disabling a smoke alarm is nuisance alarms associated with cooking.

1.2 Defining Nuisance Alarms

A nuisance alarm is an unwanted activation of a smoke alarm in response to a stimulus that is not the result of a potentially hazardous fire. During a nuisance alarm, the smoke alarm sensor operates, and it is usually a true indication of the present state of the sensor. Even though the smoke alarm is alarming to a non-hazardous source, the smoke alarm is detecting particles that may not be visible to the occupant and, therefore, the occupant may perceive the alarm activation as inconvenient, annoying, or vexatious. External nuisance sources include cooking particles, steam, dust, insects, tobacco smoke, air circulated from heating equipment, and candle combustion products. Both types of smoke alarm detection technologies, ionization and photoelectric, can be vulnerable to external nuisance sources.

1.3 Project Objectives

The objective of this pilot study was to examine the rate of nuisance alarms for different smoke detecting technologies in smoke alarms and how it may relate to the distance from the cooking source and to various cooking routines, such as cooking methods, foods cooked, and mealtimes.

1.4 Project Limitations

In this investigation, the number of homes was limited to nine to allow completion of the in-home testing portion within a nine-month period, from March to November 2008. The size of the home sample was limited, and the homes were not selected randomly (i.e., the study was limited to CPSC employees or their acquaintances) and, therefore, may not be representative of homes or cooking behaviors in the U.S. population in general.

CPSC staff identified only two manufacturers that produce and sell all three types of smoke alarms (ionization, photoelectric, and dual-sensor). The smoke alarms used in the testing do not represent all smoke alarms sold in the U.S. but offer a comparison between two different manufacturers and three types of smoke alarms.

Cooking behavior can vary greatly between homes for many reasons, such as ethnic background, age of the occupants, household size, availability of food type, and geographical location. The homes included in this study do not represent a statistical sampling or representation of the homes in the U.S. but do offer some insight into frequency of nuisance alarms for a variety of cooking behaviors. Although cooking behavior may vary seasonally due to weather, changes in activity, and availability of foods, these variations were not explored under this evaluation.

The test objectives did not include determining the propensity of an occupant to disable a smoke alarm. To discourage evaluation participants from disabling a smoke alarm due to frequent nuisance alarms, the sound transducers for the smoke alarms were disabled for the evaluation.

2.0 TYPES OF SENSORS USED IN RESIDENTIAL SMOKE ALARMS

There are two main types of sensors used in residential smoke alarms: ionization and photoelectric. A smoke alarm can use one or both types of sensors. Ionization and photoelectric sensors are sensitive to cooking gases, but several studies have shown that ionization sensors installed "too close" to a cooking appliance may have a higher frequency of nuisance alarms than photoelectric sensors; the ionization sensors are better at detecting smaller particles (less than one micron) that are typically generated during cooking. These studies suggest that the higher frequency of nuisance alarms results in more disabled smoke alarms.

2.1 Ionization Sensors

Ionization sensors have an ionization chamber and a source of ionizing radiation – a very small quantity of Americium-241. The Americium within the chamber constantly releases alpha particles, which knock electrons off of the atoms in the air inside the chamber. The ionization chamber consists of two plates that are charged; one plate is positively charged, and the other plate is negatively charged. Positive ions are attracted to the negative plate, and the electrons (negative ions) are attracted to the positive plate. This generates a small, continuous electric current, as shown in Figure 1. When smoke enters the ionization chamber, the smoke particles attach themselves to the ions, neutralizing them. This causes a reduction in electric current, which is sensed by the smoke alarm's circuitry, causing it to sound an alarm. Cooking particles entering the ionization chamber can also attach themselves to the ions and cause a reduction in electric current, therefore causing the unit to alarm.

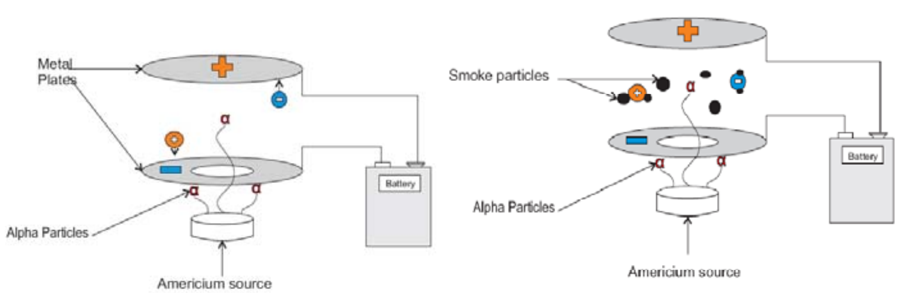


Figure 1. Ionization Chamber

2.2 Photoelectric Sensors

Photoelectric sensors have a light beam and a photocell in a "T" shaped chamber. Typically, for a photoelectric unit, the photocell is placed out of direct line of the light beam. When smoke particles enter the photo chamber – in the path of the light beam – it causes the light to scatter onto the photocell, as shown in Figure 2. The photocell, when exposed to light, generates an electric current that is detected by the smoke alarm's circuitry, causing it to sound an alarm. Cooking particles that enter the photo chamber can also cause the light to scatter onto the photocell, causing the unit to alarm. Cooking particles that are more reflective, such as oil and water droplets, can cause the light beam to scatter more readily.

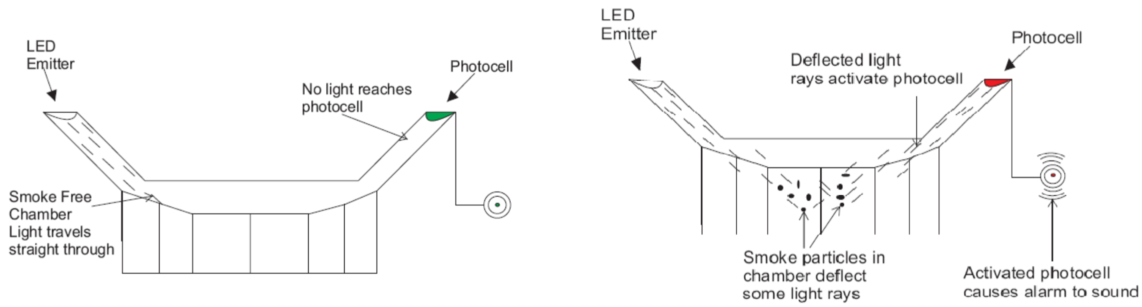


Figure 2. Photoelectric Chamber

3.0 NUISANCE ALARMS FROM COOKING (STUDIES IN THE LAST 20 YEARS)

The CPSC National Smoke Detector Project, initiated in 1991, showed that ionization smoke alarms placed too close to a cooking source can cause frequent nuisance alarms. The study found that while ionization alarms accounted for 87 percent (769/880) of installed smoke alarms, they accounted for 97 percent (32/33) of nuisance alarms.[12] The study reported that, for ionization smoke alarms, the main cause of nuisance alarms was being installed too close to a cooking appliance. In this study, 32 ionization smoke alarms were collected for reasons of nuisance alarming as listed in Table 1. Sixty-three percent (20/32) of these smoke alarms were installed 10 feet or less from a cooking appliance. Twenty-five percent (8/32) of the smoke alarms collected for nuisance alarming had higher sensitivity values than the average sensitivity value that was calculated for 125 ionization sensors measured. This higher sensitivity would lead to more frequent alarming from any external stimulus, such as cooking particles or smoke from a fire. The single photoelectric smoke alarm that was collected in the study for frequent nuisance alarming was determined to contain excess dirt and dust; the unit was located more than 10 feet from a cooking appliance.

Table 1. CPSC National Smoke Detector Project (1991)

Variable	Percent	Count	Population
Installed ionization smoke alarms	87%	768	880
Nuisance alarms (ionization smoke alarms)	97%	32	33
Nuisance alarms (photoelectric smoke alarms)	3%	1	33
Ionization smoke alarms installed less than 10 feet	63%	20	32
Higher sensitivity (ionization alarms)*	25%	8	32

* Based on the average sensitivity data for 125 ionization sensors measured

A survey of smoke alarm nuisance alarms in a Native American community conducted in 1995 found that the majority of homes, which had ionization smoke alarms, had experienced frequent nuisance alarms. Only a few homes had photoelectric smoke alarms, none of which experienced nuisance alarms.[8] The study survey included 26 questions, as well as physical measurements and visual observations. The distances from smoke alarms to ceiling/wall junctions and to potential nuisance sources, such as stoves, bathrooms, and fireplaces, were recorded. The survey included visits to 173 households, of which 80 households had one or more smoke alarms. In the 80 households, there were 112 smoke alarms, including 106 ionization types, three photoelectric types, and three unidentified types. Forty-four of the 112 alarms were inoperable; and in 86 percent of the 44 alarms, the power or batteries were disconnected because of frequent nuisance alarms. Of the three photoelectric smoke alarms, none was reported as having nuisance alarmed. Two of the photoelectric alarms were installed alongside ionization smoke alarms (within 6 inches). Even though the paired ionization smoke alarms experienced nuisance alarms from cooking, the photoelectric alarms did not sound from the same cooking sources. The third photoelectric smoke alarm was installed 6 feet closer to the stove than the ionization smoke alarm. Even though the photoelectric smoke alarm was closer, it did not have any reported nuisance alarms, whereas the ionization alarm sounded frequently during cooking. The study did not report the distance of the photoelectric smoke alarms relative to the cooking appliances.

The Native American community study included an analysis of the ionization smoke alarms, since all of the nuisance alarms resulted from the 106 ionization smoke alarms. [8] According to the study, 77 percent of the respondents said that cooking was the cause for frequent nuisance alarms; and bathroom steam was attributed to 18 percent of the nuisance alarms. Cooking-related nuisance alarms for ionization smoke alarms were related to the distance from the smoke alarm to the cooking source. The cooking-related nuisance alarm rate was 68 percent for smoke alarms located less than 20 feet from the cooking appliance and 58 percent for smoke alarms located between 20 and 25 feet. If the smoke alarm was located more than 25 feet from the cooking appliance, the nuisance alarm rate dropped to 36 percent. Ionization smoke alarms placed farther than 25 feet from a cooking appliance resulted in a reduction in nuisance alarms.

A study of Alaskan Eskimo villages, published in 2000, found that ionization smoke alarms had a greater number of nuisance alarms than photoelectric smoke alarms when installed 10 to 15 feet from a nuisance source.[6] For the study, the researchers installed both ionization and photoelectric smoke alarms in homes with less than 1,000 square feet of living space. The smoke alarms were installed on the ceiling between 10 to 15 feet from the cooking and heating sources. The study found that 92 percent of homes with ionization smoke alarms experienced nuisance alarms compared with only 11 percent of homes with photoelectric smoke alarms, a ratio of more than 8 to 1. After six months, 19 percent of the installed ionization smoke alarms had been disconnected compared to only 4 percent of the installed photoelectric smoke alarms. The authors reported that, even though the ionization smoke alarms had silencing or hush buttons that allowed quieting the unit for 10 minutes, the batteries were still removed from the units because of frequent nuisance alarming.

Another study conducted in Washington state produced results similar to those reported in previous studies.[13] A randomized study was conducted with 761 households. Either ionization or photoelectric smoke alarms were installed in 757 eligible households between June 1, 2000, and July 31, 2002. The researchers returned to the homes after nine- and 15-month intervals to inspect the number of functional alarms. After nine months, 20 percent of the ionization smoke alarms were non-functional compared to 5 percent of the photoelectric smoke alarms. At 15 months, the differences in additional non-functional smoke alarms were similar to those reported at the nine-month inspection. The mean distances between a smoke alarm and the kitchen stove were 136 inches (11.3 feet) and 137.8 inches (11.5 feet) for the ionization and photoelectric alarms, respectively. The study states that the most common reason for a non-functional smoke alarm at the nine- and 15-month inspections was a disconnected or absent battery. The most commonly reported reason for occupants to disable a smoke alarm was nuisance alarms from cooking. Low-battery chirp was the second most common reason for disabling a smoke alarm.

4.0 NUISANCE ALARMS FROM NON-COOKING SOURCES

Non-cooking sources that cause a smoke alarm to sound also may lead an occupant to disable their smoke alarm. Non-cooking sources, such as dust, insects, and low-battery chirp, which cause the smoke alarm to sound, may be perceived by the occupant as a nuisance. Smoke alarms installed too close to a heating or air conditioning intake or return can cause the smoke alarm to nuisance alarm frequently. One of the problems experienced by early smoke alarm designs was that of insects entering the ionization chambers and causing the smoke alarm to sound. To address this, the Underwriters Laboratories Inc. (UL) voluntary standard, *UL 217 Single- and Multiple-Station Smoke Alarms*, was modified to incorporate a performance test to reduce the likelihood of insects entering the ionization chamber.

The UL 217 standard for smoke alarms requires smoke alarms with batteries to emit an audible trouble warning when the battery voltage becomes low. The trouble warning indicator allows the smoke alarm to continue to operate as intended for a minimum of 7 days. Even though a smoke alarm is warning occupants that the battery is low and should be replaced, occupants may perceive the low-battery chirping as a nuisance. A lack of understanding or awareness of the meaning of the low battery chirp may be a contributing factor for occupants disabling, rather than replacing, the batteries in their smoke alarms.[4, 14] Both ionization and photoelectric smoke alarms are vulnerable to disabling because of low-battery chirping. The inherent higher power consumption of photoelectric and dual-sensor smoke alarms could cause a higher rate of low-battery chirping compared to ionization-only smoke alarms, increasing the chance that occupants will disable their smoke alarms. Installing smoke alarms that are powered by household 120 VAC or 10-year batteries can reduce the frequency of low battery chirping and could lessen the likelihood that occupants will disable their smoke alarms because of it.

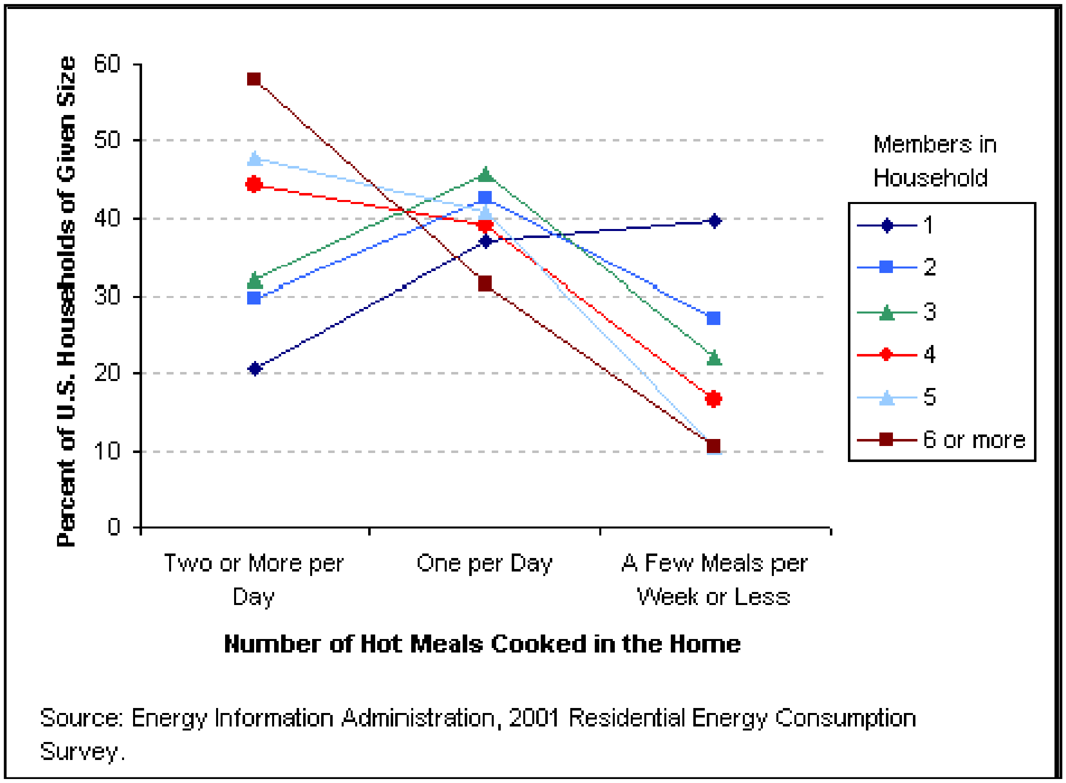
5.0 COOKING IN U.S. HOMES

5.1 Rise in Home Cooking

The amount of cooking that occurs at home is on the rise due in large part to the increasing population in the United States. In 2005, it was reported that most Americans cooked dinner at home most nights of the week.[15] Approximately 43 percent of Americans cooked six to seven nights a week. Focusing on individual age groups, 44 percent of the elderly (64 years old and older) were reported to more likely cook food every night of the week, compared to 23 percent of Americans between 18 and 29 years old. In 2003, the amount of time spent to prepare food averaged between 13 and 52 minutes for men and women, respectively.[16]

Besides age and sex, household size affects the frequency of cooking. The larger the household size, the higher the tendency to cook. If the household consisted of only two people, at least one meal a day was cooked 72.1 percent of the time. The percentage rose with each additional person; 89.4 percent of households with six or more people cooked at least once a day.[17]

Figure 3 shows the percentage of households of given sizes and the number of hot meals that they cook. There is a direct correlation between the household size and the number of households that cook twice a day or more. For example, as the number of members in the household increase so does the percentage of households that cook twice a day or more. The reverse happens when the cooking drops to a few meals a week or less. As the number of members in the household decreases so does the percentage of households that cook only a few times a week or less. [17]



Source: Energy Information Administration Department of Energy Number of Meals Cooked in the Home by Household Size, 2001, Cooking Trends in the United States: Are We Really Becoming a Fast Food Country? [18].

Figure 3. Number of Hot Meals Cooked in the Home by Household Size, 2001

5.2 Cooking Behavior

Traditional breakfast foods, such as eggs, sausage, and bacon, are often cooked in oils or contain animal fats that can generate high levels of cooking particles in a short amount of time. Bread products, such as toast, bagels, and other foods that need to be heated in an oven, toaster, or toaster oven have the potential to produce small cooking particles. An average of 54 percent of Americans ages 19 to 54 years old have breakfast and of those, two in ten have eggs and one in ten has toast, bagels, muffins, or pastry. Between men and women, men are 15 percent more likely to have eggs.[18]

Americans' per capita consumption rates of cooking oils and baking and frying fats increased by 23 percent from 1972 to 1992.[19] A survey conducted by the University of Nebraska concluded that Nebraskans, when cooking beef, pork, or poultry, chose to fry more often than any other cooking method by 40 percent – much greater than any other method. Seafood was fried 21 percent of the time.[20]

6.0 FIRE ALARM CODE FOR SMOKE ALARM INSTALLATIONS

The NFPA 72 *National Fire Alarm Code* requirements for smoke alarms installed near a cooking appliance, such as in a kitchen, have changed over time. The 2007 edition of NFPA 72 requires that smoke alarms installed within 20 feet of a cooking appliance be either a photoelectric smoke alarm or an ionization smoke alarm with a hush (silencing) feature, as shown in Figure 4.[21] A dual-sensor smoke alarm that contains an ionization sensor can be installed within 20 feet of the cooking appliance as long as it contains the hush feature.

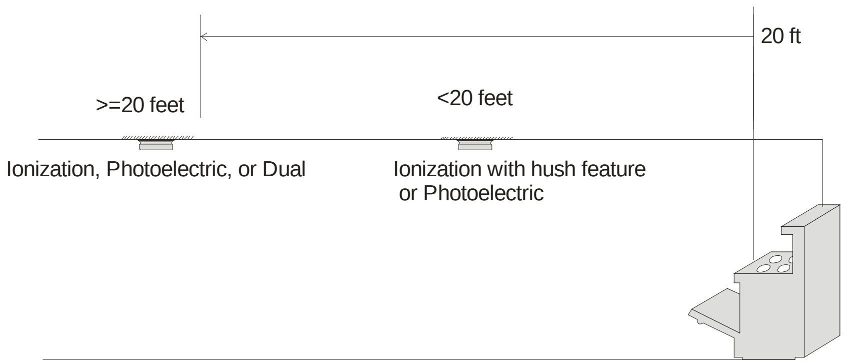


Figure 4. NFPA 72 (2007), Chapter 11, Installation Requirements for a Residential Home

Changes to the NFPA 72 requirements for smoke alarms installed near a cooking appliance may be proposed for the 2011 edition.[23] Proposed changes would restrict smoke alarms from being installed within 10 feet of a cooking appliance, would allow ionization smoke alarms with a hush feature or photoelectric smoke alarms to be installed between 10 and 20 feet from the main cooking appliance, and would include an exception for smoke alarms to be installed within 10 feet of a cooking appliance only to satisfy requirements in other parts of the code. For example, if another part of the code such as the requirement for a smoke alarm to be installed outside the sleeping area would force a smoke alarm to be installed within 10 feet of a cooking appliance, the code requirement for a smoke alarm outside the sleeping area would supersede the requirement to restrict a smoke alarm to be installed within 10 feet of the cooking appliance.

7.0 NUISANCE ALARMS ASSOCIATED WITH COOKING

When particles enter a smoke alarm, today's typical smoke alarm sensors cannot distinguish between threatening and non-threatening scenarios. Cooking particles can be mistaken as smoke particles from a fire. There also may be scenarios that transition from non-threatening cooking to hazardous situations. During non-threatening cooking situations, a smoke alarm ideally will not sound, to avoid the nuisance alarms that may result in an occupant disabling the smoke alarm. A disabled smoke alarm would leave the occupants unprotected in a scenario that transitions to a threatening situation.

To determine the performance of smoke alarm sensor types in response to cooking scenarios in actual homes, CPSC staff conducted tests using ionization, photoelectric, and dual-sensor smoke alarms installed in nine homes. Alarms from two manufacturers were used in these tests.

7.1 Test Setup, Instrumentation, and Test Protocol

All of the smoke alarms selected for the tests were UL listed, battery-powered smoke alarms. A new 9 volt battery was installed in each of the test smoke alarms before each test series. Smoke alarms from two manufacturers (manufacturers A and B) were used in the testing.

The smoke alarms were modified for the testing so that they would not sound. In addition to disconnecting the sound transducer, the horn-sounding signal from each smoke alarm was connected to a data acquisition system. The data acquisition system recorded transitional changes in the signal. Since the data acquisition system had limited solid state memory, and to prevent the memory from filling up before the end of the test period, the smoke alarm signal was conditioned with a custom-built circuit, as shown in Figure 5. The circuit processed the signal by latching and re-latching the signal as long as the smoke alarm's temporal-three pattern continued to activate. If the smoke alarm signal paused or stopped for more than 1.5 seconds, the data logger would reset for the next activated signal.

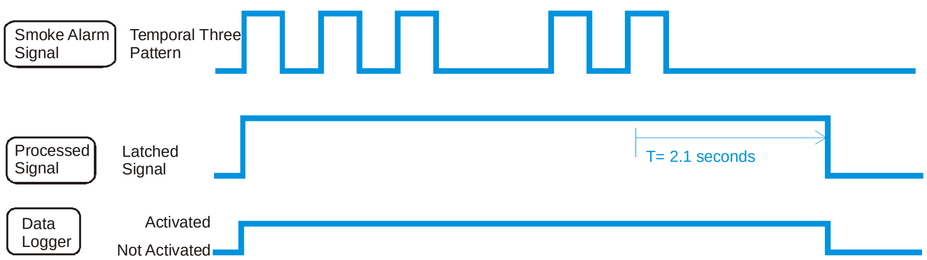


Figure 5. Conditioned Signal from the Smoke Alarm

The first eight homes included in the study (homes 1 - 8) had three groups of smoke alarms installed at 5 feet, 10 feet, and 20 feet from the main cooking appliance in the kitchen, as shown in Figure 6. Each group of smoke alarms consisted of an ionization, photoelectric, and dual-sensor smoke alarm. For each of the eight homes, the entire suite of smoke alarms installed in a house was from a single manufacturer (either manufacturer A or manufacturer B). All of the smoke alarms were mounted on the ceiling, except in home 8. In home 8, the smoke alarms were installed on the wall because the ceiling was textured. (The smoke alarms were mounted using removable double-sided tape and would not adhere to the irregular surface of the textured ceiling.)

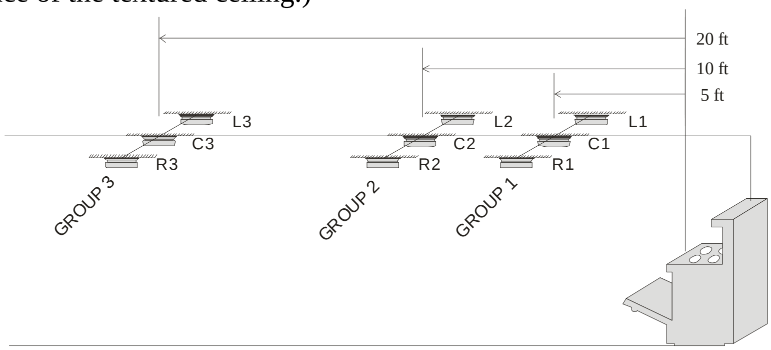


Figure 6. Test Setup for Homes 1-8

The last home tested (home 9) used all the available test hardware and data acquisition systems. In addition to smoke alarm groups at 5, 10, and 20 feet, smoke alarm groups were placed at 3, 7.5, and 15 feet from the main cooking appliance, as shown in Figure 7. The number of smoke alarms in a group included all three sensor types of both manufacturers of smoke alarms, doubling the number of smoke alarms in each group from three to six.

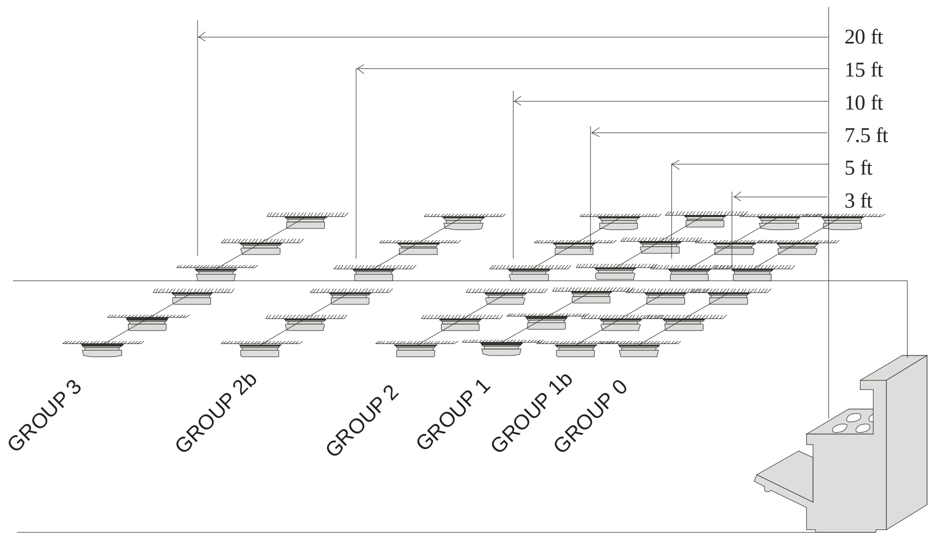


Figure 7. Test Setup for Home 9

Table 2 lists the home number, smoke alarm manufacturer notation, and distances from the cooking appliance. A data acquisition system was used to record the smoke alarm activations in a home.[2]

Table 2. Smoke Alarm Set-Up (Homes 1-9)

Home Number	Manufacturer	Distance to Cooking Appliance (ft)
1	A	5, 10, 20
2	A	5, 10, 20
3	A	5, 10, 20
4	B	5, 10, 20
5	B	5, 10, 20
6	B	5, 10, 20
7	B	5, 10, 20
8	A	5, 10, 20
9	A, B	3, 5, 7.5, 10, 15, 20*

*The actual distance was 19 feet, but for simplicity in reporting, the distance will be referred to as 20 feet.

The placement (left, center, or right) for each type of smoke alarm in a group was determined by using a random number generator. Each smoke alarm type was assigned a number range. The random number generator first selected the type of smoke alarm to be placed at the left location (facing the cooking appliance). The random number generator was then limited to the number range for the two remaining smoke alarm types. The random number generator selected the center location, and the remaining smoke alarm was used in the right location. A similar method was used for home 9, which had six alarms in each group. The smoke alarms' mounting orientations were random. Appendix A contains the specific type of smoke alarm installed at each location.

Each smoke alarm was tested after it was installed in the home and at the end of the test period before it was removed from the home. The smoke alarms were tested using the test button and a UL listed aerosol for testing smoke alarms. Since the sound transducers were disabled, alarming was verified by a signal to the data acquisition system.

[2] The resolution of the data acquisition system was 1 second.

The smoke alarms were installed in the test homes for approximately 30 days. The participants were provided with a log book and were asked to record when they cooked, how long they cooked, what they cooked, and the cooking method(s) used for each meal. Cooking included use of the rangetop, oven, toaster oven, toaster, or any other cooking appliance. Participants also were asked to document whether a kitchen ceiling fan or exhaust fan (hood or downdraft) was used during cooking and to indicate if any of their own smoke alarms sounded. After the test period, the data from the data loggers were downloaded and analyzed. The number of cooking events was tabulated using the log books.

A general definition for cooking is to prepare food for eating by applying heat. In this study, a cooking event was considered to have occurred if food was prepared using heat. If leftover food was reheated in a microwave oven or on a stovetop, this was not considered a cooking event since only the food's temperature was being changed and no food was actually being prepared. Table 3 lists some of the common kitchen activities during the study that were defined as either cooking events or non-cooking events.

Table 3. Defined Cooking/Non-Cooking Events

Cooking Events	Non-Cooking Events
Baking – cakes, pies, casseroles, meats, etc	Microwave or stove – reheat
Stir fry and sautés	Coffee brewing
Toasting – bagels, bread, waffles, pastries, etc.	Kettle - boiling water only
Skillet – meats, veggies, etc.	Stove - boiling water only
Boiling – pasta, veggies, etc.	
Microwave cooking – popcorn, bacon, etc.	
Stove – oatmeal, sauces, etc.	
Steaming - veggies, rice, etc.	
Broiler – meats, cheeses	
Deep frying – meats, veggies, etc.	
Indoor grilling – meats, veggies, bread, etc.	

A single cooking event may consist of multiple cooking methods. For example, a breakfast cooking event may have had multiple actions such as frying bacon, boiling eggs, and toasting bread. The first smoke alarm activation for each smoke alarm during a cooking event was counted, and multiple reactivations from the same smoke alarm during a single cooking event was counted as a single activation.

8.0 DATA ANALYSIS

This section presents an analysis of the data collected during the course of the study as a whole. Data associated with individual homes are contained in Appendix A.

8.1 Characteristics of Occupants and Homes

Nine homes (homes 1-9) were selected among CPSC employees or acquaintances of the principal investigator.

For all of the homes included in the study, there were at least two occupants living in the home; the number of occupants for all homes ranged from two to six. As a whole, the occupants mainly were young children 12 years old and younger, adults between 30 and 50 years old, and adults over the age of 50 years, as shown in Figure 8.

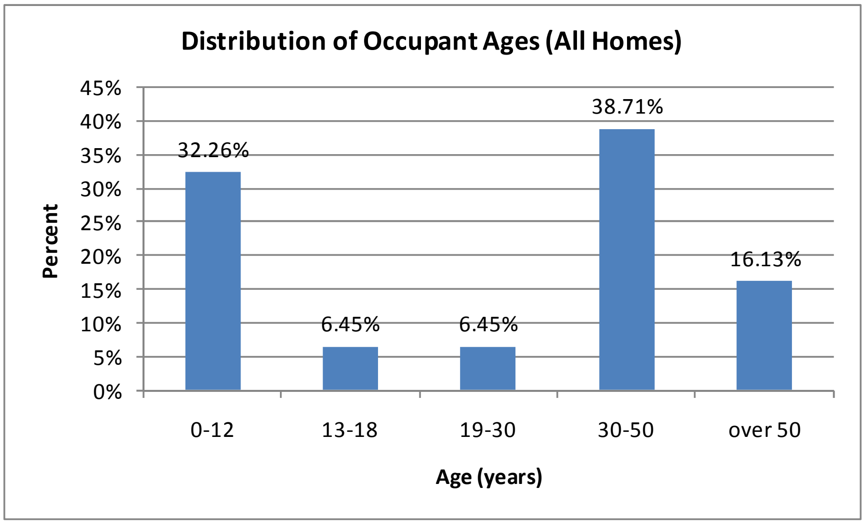
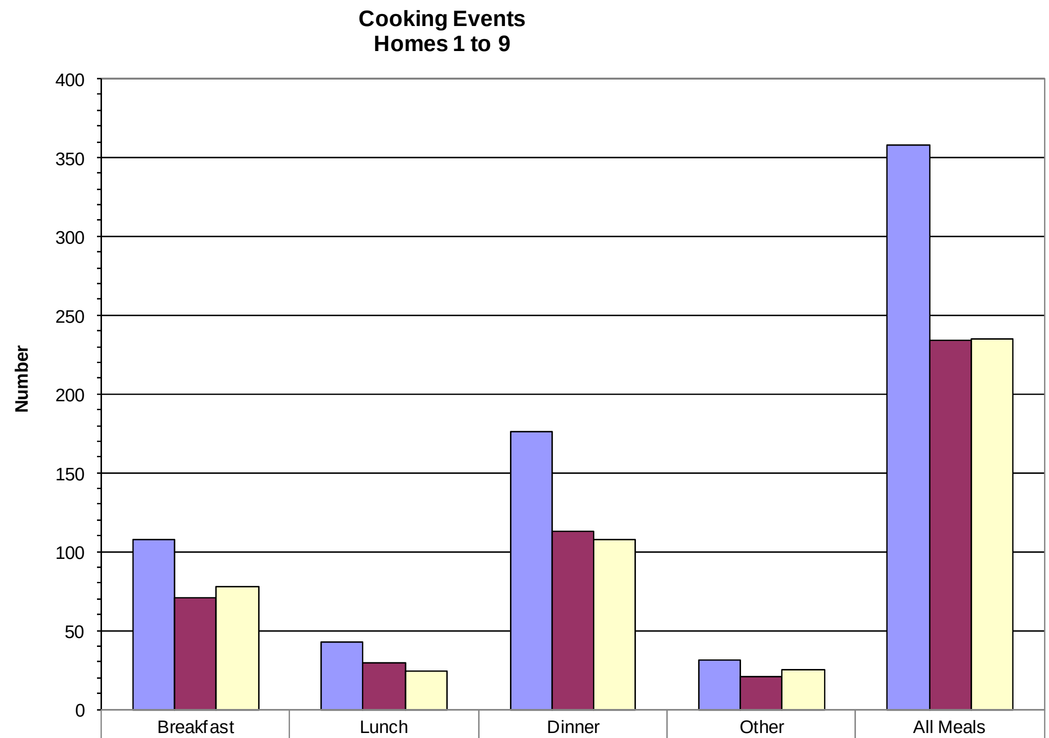


Figure 8. Distribution of Occupant Ages (All Homes)

Two of the nine homes had at least one occupant who smoked cigarettes. In both of these homes, the occupants smoked indoors. Eight of the nine homes were single family homes. Home 8 was an attached townhome or townhouse. The average age of the homes was about 30 years old. The newest home was 8 years old, and the oldest home was 82 years old. Six homes used natural gas or propane for the range/oven, and three homes used electric ranges/ovens. All the homes had freestanding ranges/ovens. None of the homes in the study used a mixed supply for their oven and stove (e.g., gas range with electric oven). Seven homes contained exhaust hoods that could exhaust cooking fumes to the outside. One home had a recirculating exhaust hood; and the other home did not have any exhaust hood, but there was a window adjacent to the stove.

8.2 Cooking Events

There were a total of 358 cooking events recorded for the nine homes. Figure 9 shows the distribution of cooking events. Four homes contained smoke alarms from manufacturer A, and four homes contained smoke alarms from manufacturer B. Home 9 had smoke alarms from both manufacturers. The total number of cooking events in the figure does not take into account both manufacturers in home 9. If home 9 is calculated using both manufacturers, the total number of cooking events would double for home 9, and the total number of cooking events for homes 1 to 9 would be 469. Between manufacturers, the number of cooking events for each mealtime period was similar (123 cooking events with manufacturer A and 124 cooking events with manufacturer B). Lunchtime had the fewest cooking events (43/358), which was expected since, in eight of the nine homes tested, both parents were working. Dinnertime had the most cooking events (176/358), and breakfast time had the second most cooking events (108/358).



	Breakfast	Lunch	Dinner	Other	All Meals
All Homes	108	43	176	31	358
Homes with manufacturer A	71	29	113	21	234
Homes with manufacturer B	78	24	108	25	235

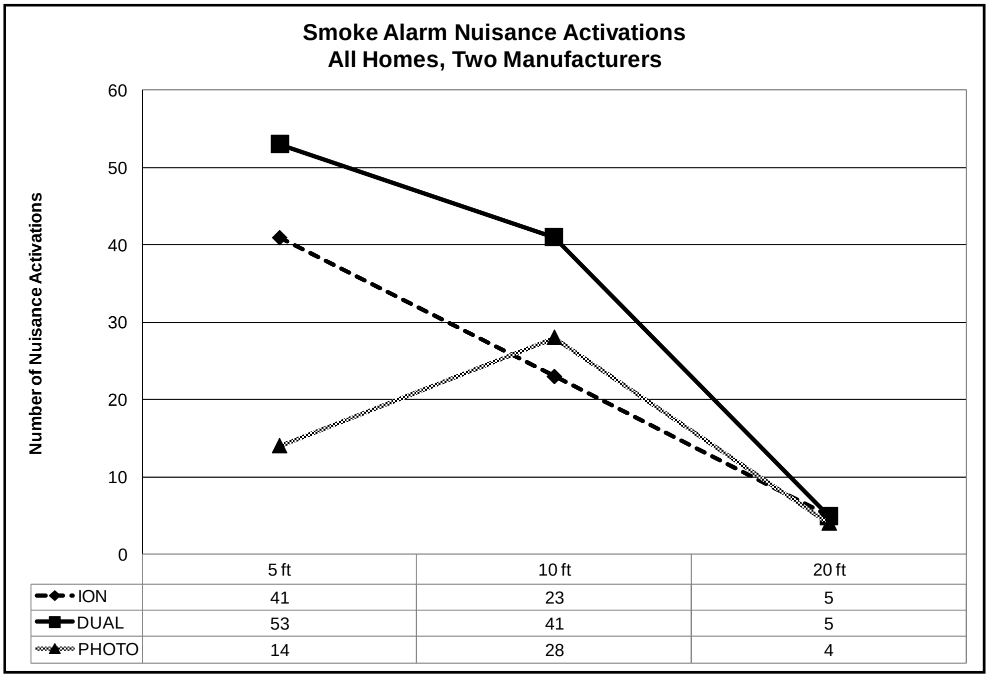
The figure total is displayed without normalizing for home 9, which contained both smoke alarm manufacturers.

Figure 9. Distribution of Cooking Events (All Homes)

8.3 Nuisance Alarms (All Homes)

This section presents an analysis of the data for all smoke alarms tested in all nine test homes. All recorded smoke alarm activations were interpreted as being nuisance alarms, since no hazardous fire conditions occurred during the course of the testing at any of the homes.

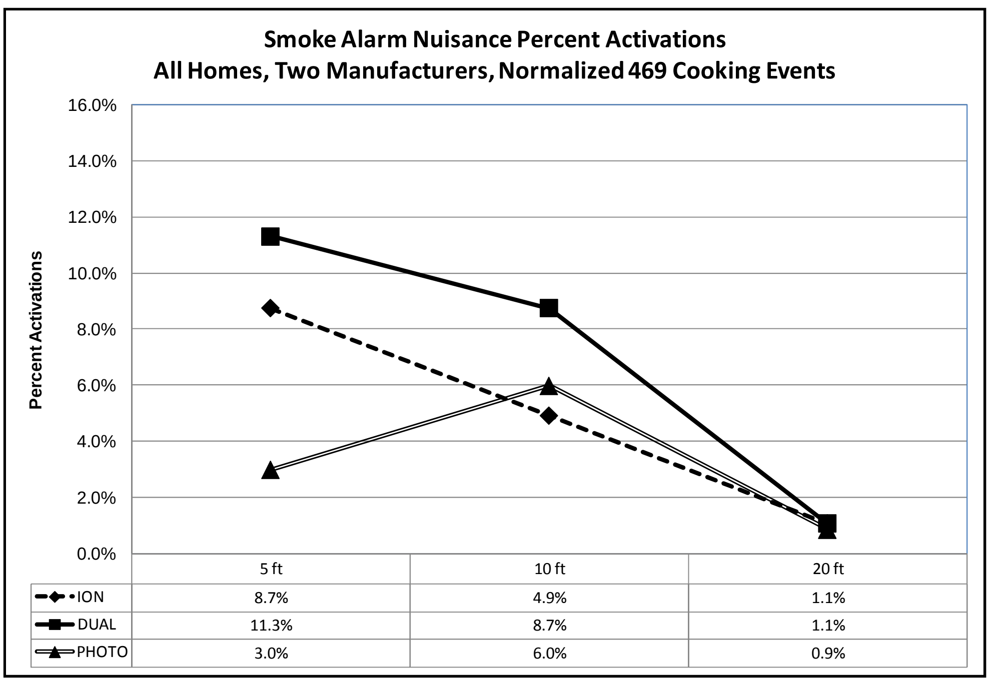
Figure 10 shows that the number of nuisance alarms was highest for smoke alarms at a distance of 5 feet from the cooking appliance, with dual-sensor smoke alarms producing the most nuisance alarms (53/469 normalized). A decline in nuisance alarms was observed at 20 feet for all smoke alarm types. The ionization and dual-sensor smoke alarms showed declines in activations as the distance from the cooking appliance increased, as might be expected; but the photoelectric smoke alarms showed an unexpected increase in activations at a distance of 10 feet, before declining at 20 feet. The peak associated with nuisance alarms involving photoelectric smoke alarms at 10 feet is further analyzed later in the report.



	5 ft	10 ft	20 ft
ION	41	23	5
DUAL	53	41	5
PHOTO	14	28	4

Figure 10. Number of Activations (All Homes)

Figure 11 shows the percentage of activations for the three smoke alarm types as a function of distance for the 358 cooking events, but normalized to 469 because home 9 contained both manufacturers. The dual-sensor smoke alarms at 5 feet produced nuisance alarms 11 percent of the time. A dual smoke alarm at 10 feet produced the same percentage (8%) of nuisance alarms as an ionization smoke alarm at 5 feet.



	5 ft	10 ft	20 ft
ION	8.7%	4.9%	1.1%
DUAL	11.3%	8.7%	1.1%
PHOTO	3.0%	6.0%	0.9%

Figure 11. Frequency of Activations (All Homes)

9.0 DATA ANALYSIS (HOMES 1-8)

This section presents an analysis of the data collected for all smoke alarms installed in homes 1-8. Figure 12 shows that the number of nuisance alarms was highest for smoke alarms installed at a distance of 5 feet from the cooking appliance, as expected. A decrease in nuisance alarms was observed at 10 feet. When the data from home 9 was excluded from the data set, the previously-observed increase in activations associated with photoelectric smoke alarms at 10 feet (as seen in Figure 10) was no longer observed. At 20 feet, the number of nuisance alarms among the types of smoke alarms was similar.

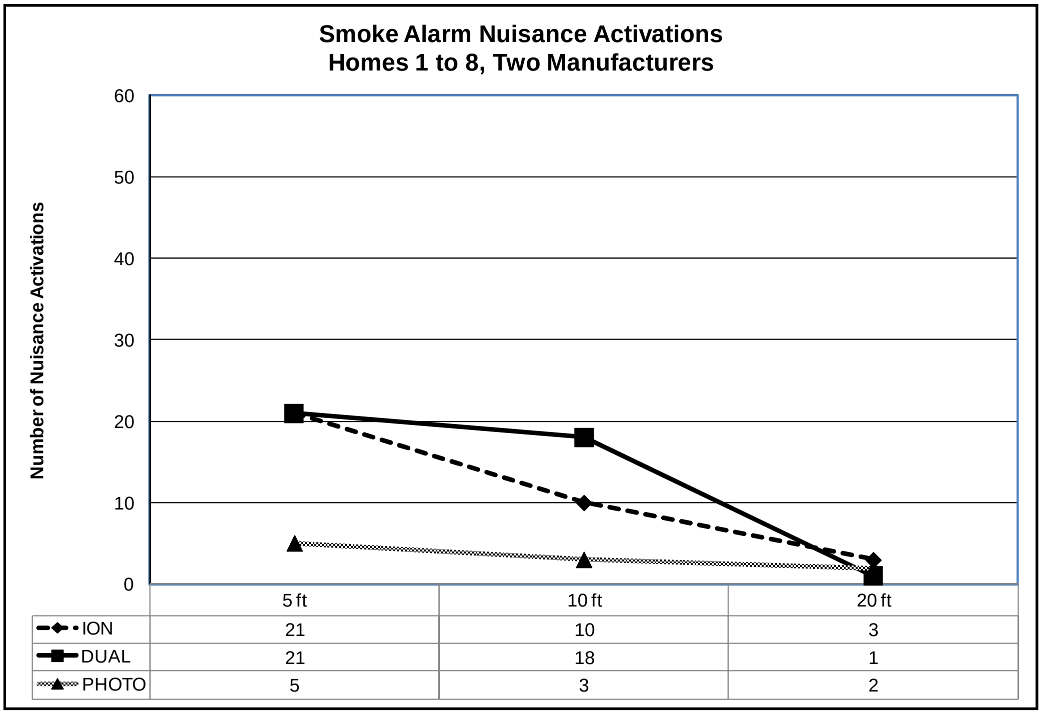


Figure 12. Number of Activations (Homes 1-8)

Figure 13 shows the percentage of activations for the three smoke alarm types as a function of distance for 234 cooking events for homes 1-8. For ionization and dual-sensor smoke alarms, the frequency of nuisance alarms was similar to that shown in Figure 11, which included home 9.

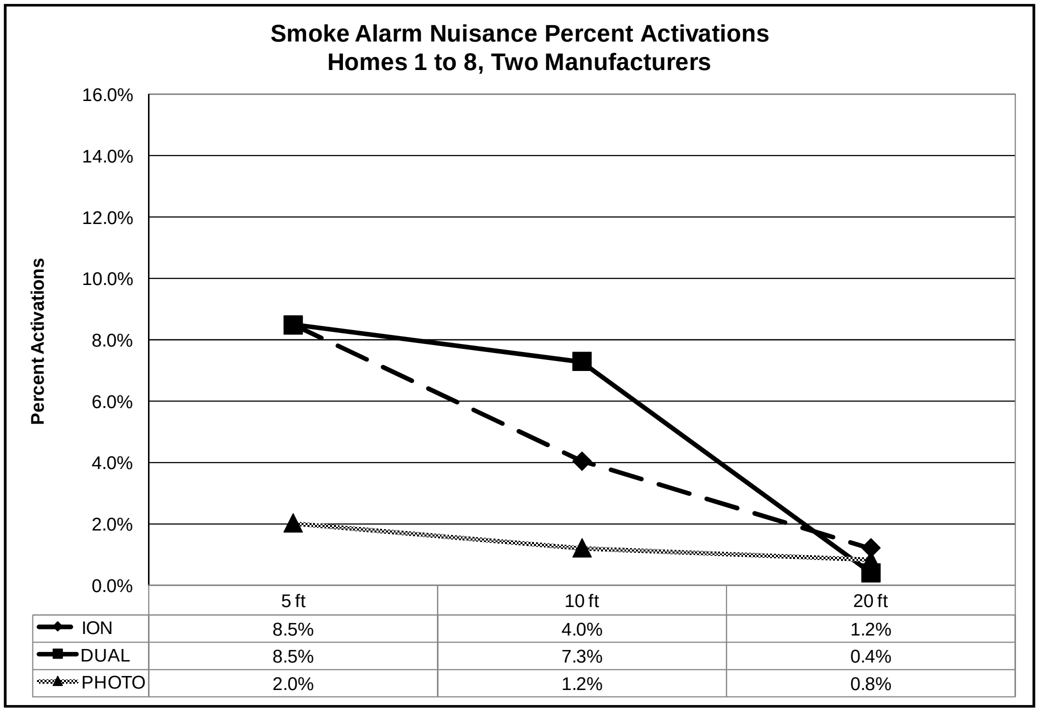
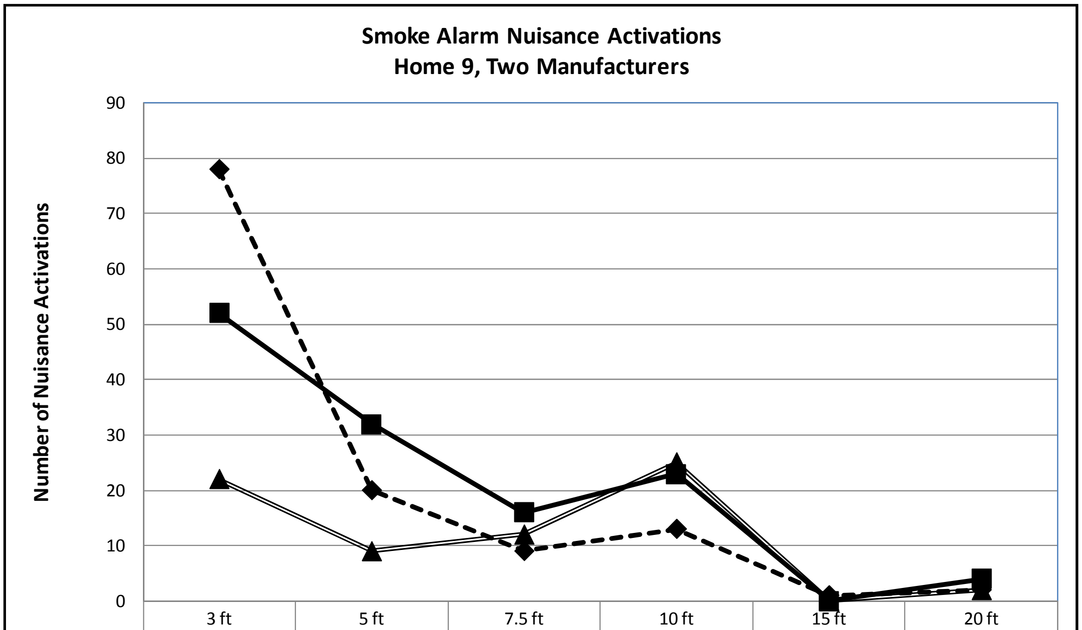


Figure 13. Frequency of Activations (Homes 1-8)

10.0 DATA ANALYSIS (HOME 9)

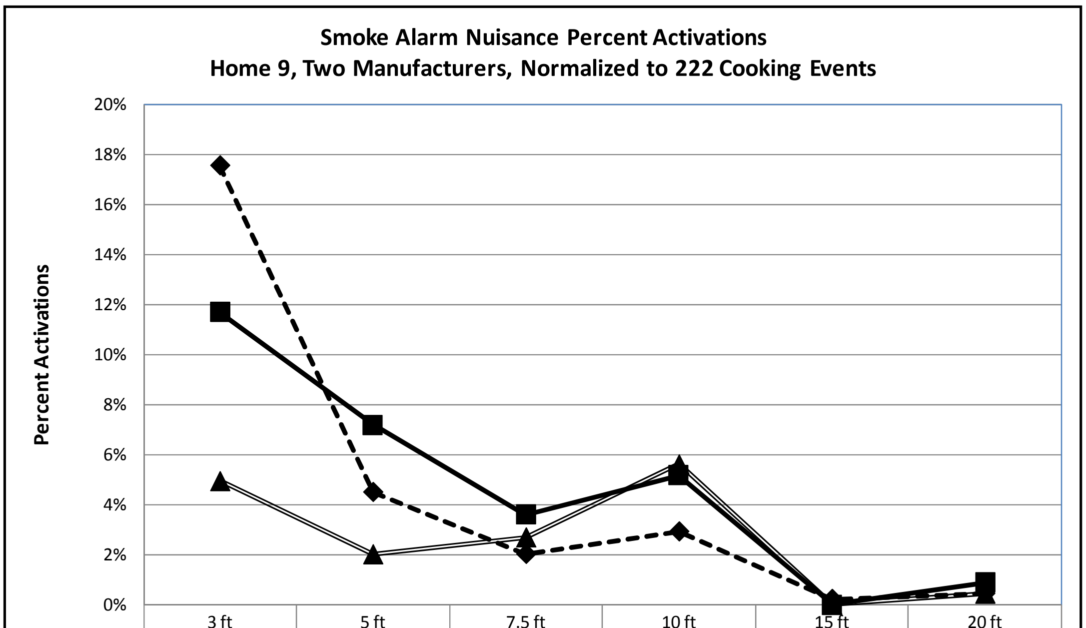
Home 9 included smoke alarms from manufacturers A and B at each location, and the number of smoke alarm groups was increased from three to six. (For some analyses, the number of cooking events was doubled to normalize the data with the data from homes 1-8.)

Regardless of the type of smoke alarm, the number of activations increased or was the same at 10 feet as compared to the number of activations at 7.5 feet, as shown in Figures 14 and 15. The photoelectric smoke alarms showed an increase in the number of activations at 7.5 feet as compared to the number of activations at 5 feet. The number of activations for the photoelectric smoke alarms was slightly higher at 10 feet than at 3 feet, which was unexpected. An analysis of possible causes for the increased activations at 10 feet is discussed later in this report. Figure 15 shows the percentage of activations for 111 cooking events, but normalized to 222 because both manufacturers of each sensor types were installed at each group location.



	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
ION	78	20	9	13	1	2
DUAL	52	32	16	23	0	4
PHOTO	22	9	12	25	0	2

Figure 14. Number of Activations (Home 9)



	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
ION	17.6%	4.5%	2.0%	2.9%	0.2%	0.5%
DUAL	11.7%	7.2%	3.6%	5.2%	0.0%	0.9%
PHOTO	5.0%	2.0%	2.7%	5.6%	0.0%	0.5%

Figure 15. Frequency of Activations (Home 9)

11.0 ANALYSIS BY SMOKE ALARM BY MANUFACTURER

An analysis was conducted by examining the number of activations by smoke alarm manufacturer. This analysis is limited to the data collected from home 9, which was the only home that contained smoke alarms from both manufacturers. Since homes 1-8 had either manufacturer A or B installed, the data sets cannot be compared directly because of confounding variables such as cooking methods and behaviors, home layout, and smoke alarm locations. That is, the data set for homes 1 to 8 doesn’t indicate how (a) different home environments might affect nuisance alarms and (b) how different manufacturer’s smoke alarms would work.

11.1 Analysis by Manufacturer (Home 9 only)

At 15 feet and beyond, there were very few nuisance activations for all types of smoke alarms, regardless of manufacturer. Only the photoelectric smoke alarms showed a similarity in the number of activations at the various locations for both manufacturers A and B, as shown in Figure 16a. The dual-sensor smoke alarms showed more differences in number of activations between manufacturers. Manufacturer B dual-sensor smoke alarms had about 16 times more activations at 3 feet than manufacturer A as shown in Figure 16b. The ionization smoke alarms had similar numbers of activations at 3 feet, and showed wider variation at the 5- to 10-foot locations, as shown in Figure 16c.

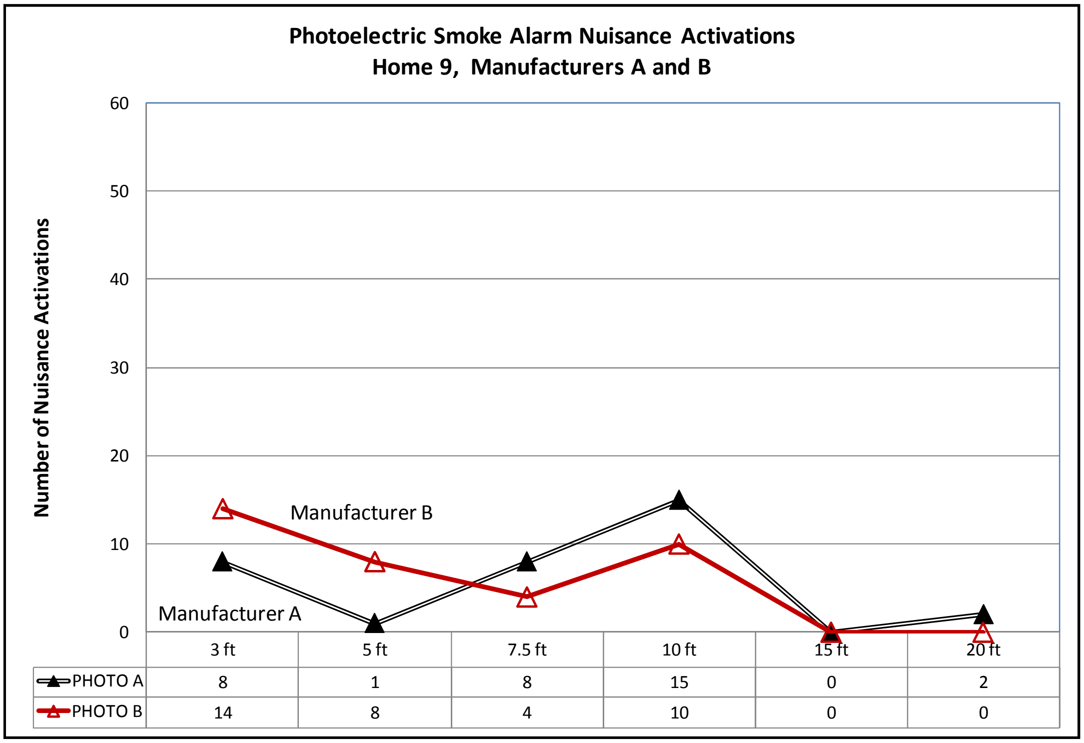
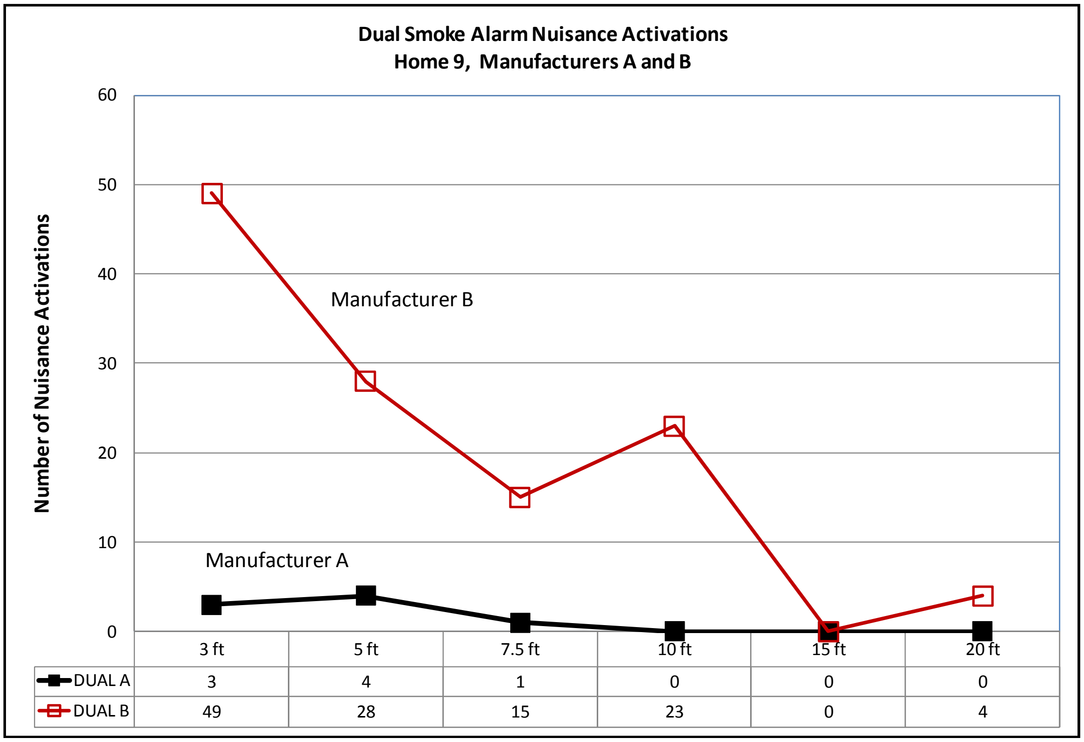
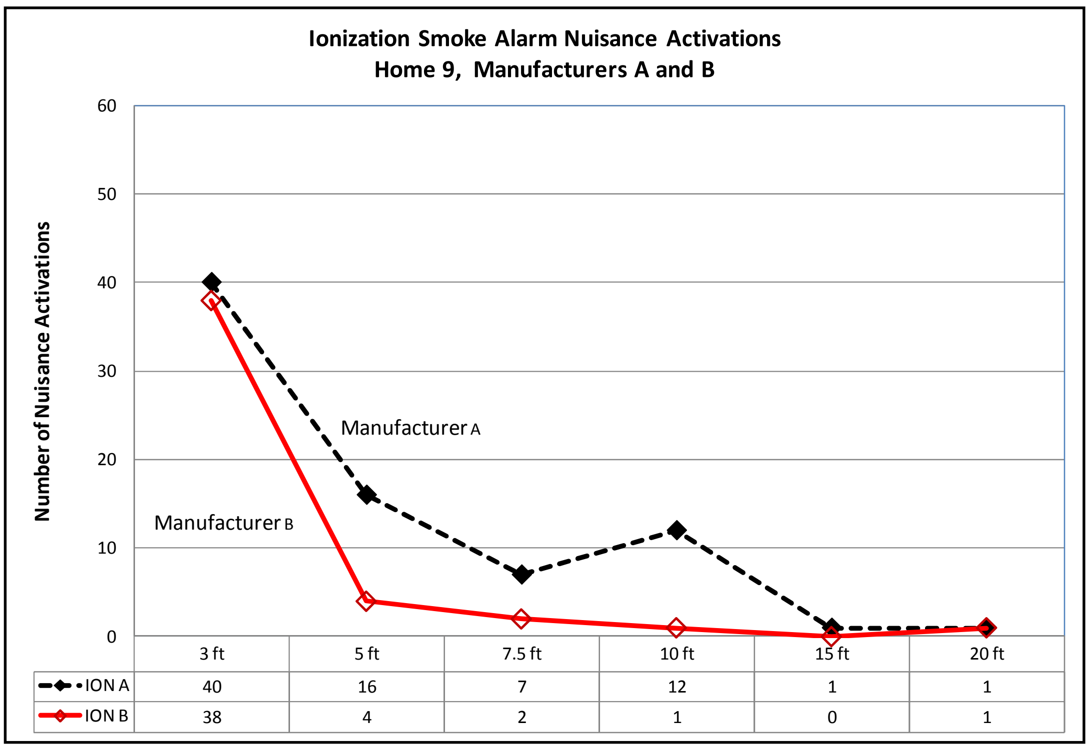


Figure 16a. Photoelectric Smoke Alarm Activations by Manufacturer (Home 9)



	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
DUAL A	3	4	1	0	0	0
DUAL B	49	28	15	23	0	4

Figure 16b. Dual-Sensor Smoke Alarm Activations by Manufacturer (Home 9)



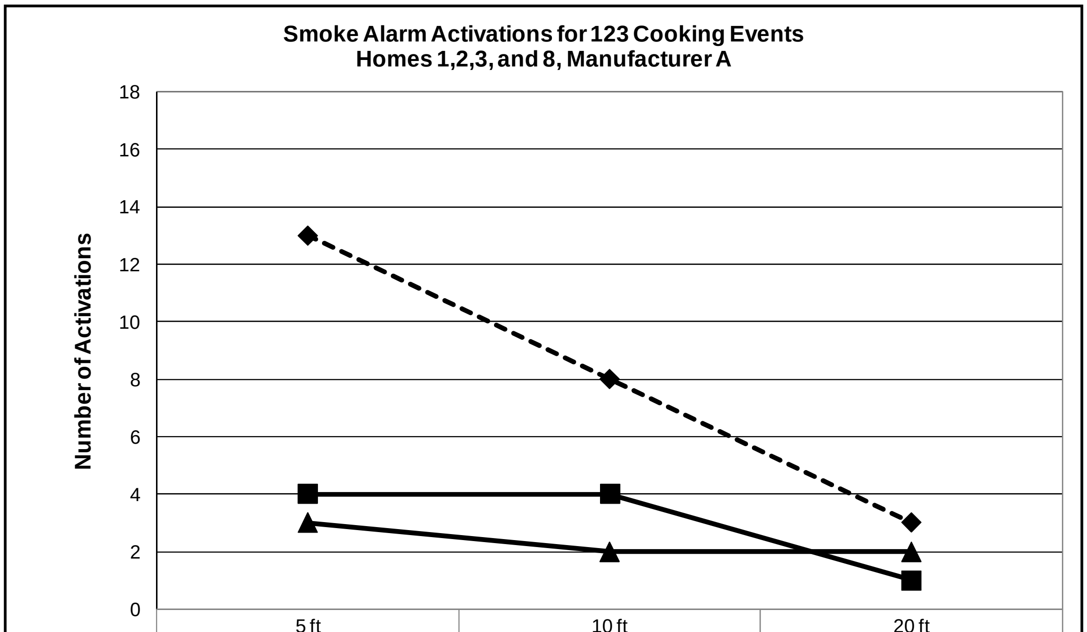
	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
ION A	40	16	7	12	1	1
ION B	38	4	2	1	0	1

Figure 16c. Ionization Smoke Alarm Activations by Manufacturer (Home 9)

11.2 Analysis of Activations Involving Manufacturer A

An analysis of the data collected from the homes tested with smoke alarms from manufacturer A was conducted (homes 1, 2, 3, and 8). (An analysis of the data from home 9 is presented separately.)

Figure 17 shows the number of activations for homes 1-8 that were tested using smoke alarms from manufacturer A. For 123 cooking events, there were 40 activations of smoke alarms involving manufacturer A. At a distance of 5 feet from the cooking appliance, the number of nuisance alarms for ionization smoke alarms (13) was higher than the number of activations involving dual-sensor (4) or photoelectric (3) smoke alarms. At 10 feet, the number of nuisance alarms for ionization smoke alarms (8) decreased, but there were still more activations for ionization alarms than for either the dual-sensor (4) or photoelectric (2) smoke alarms. At 20 feet, the number of nuisance alarms was similar, regardless of the type of smoke alarm (3 ionization, 1 dual-sensor, and 2 photoelectric).

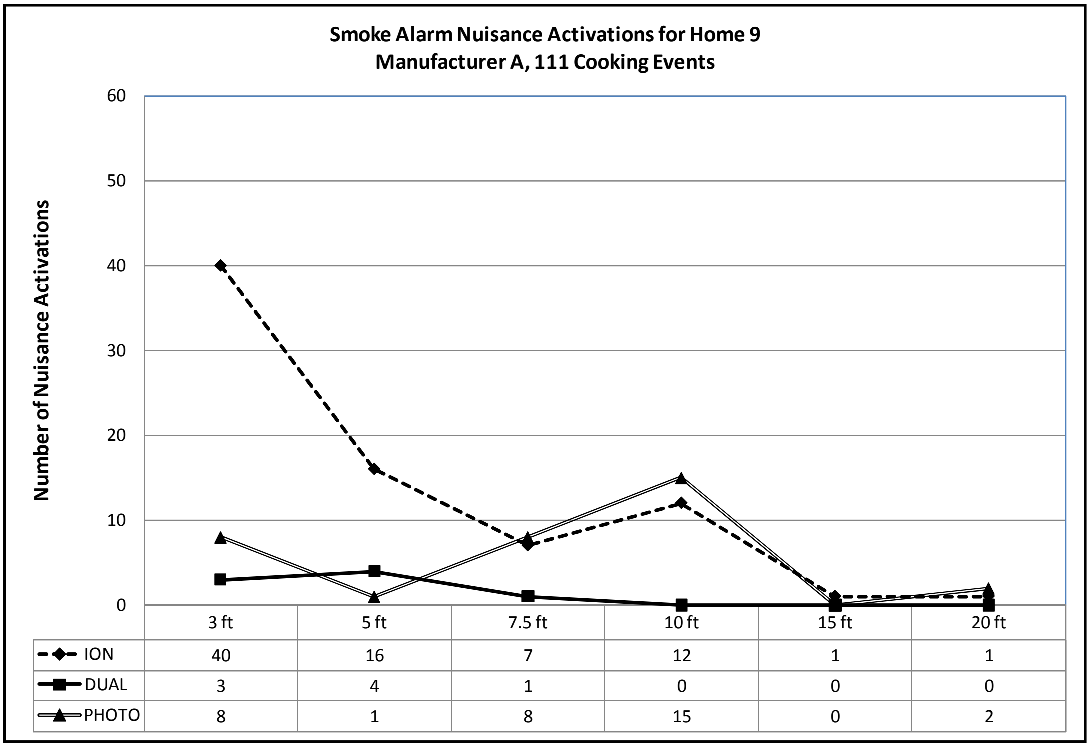


	5 ft	10 ft	20 ft
ION	13	8	3
DUAL	4	4	1
PHOTO	3	2	2

Figure 17. Activations for Manufacturer A (Homes 1, 2, 3 and 8)

Figure 18 shows the number of activations for home 9, which included smoke alarms from manufacturer A. For 111 cooking events, there were 119 activations of smoke alarms involving manufacturer A. The number of activations at 3 and 5 feet involving ionization smoke alarms (40 and 16, respectively) was higher than the number of activations for dual-sensor (3 and 4, respectively) or photoelectric (8 and 1, respectively) smoke alarms. There were fewer ionization activations at 7.5 feet (7) than at 3 or 5 feet, but then the number of activations at 10 feet (12) increased. The number of activations decreased to near zero at 15 and 20 feet.

For photoelectric smoke alarms, there were fewer activations at 5 feet (1) than at 3 feet (8), but there was an increase in activations at 7.5 feet (8) and even more at 10 feet (15). For photoelectric smoke alarms the increase in the number of activations at 7.5 and 10 feet was similar to the increase observed for ionization smoke alarms. After 10 feet, the number of activations dropped to near zero. The dual-sensor smoke alarms showed the least variation between distances and the least number of activations at all locations except at 3 (3) and 5 (4) feet.



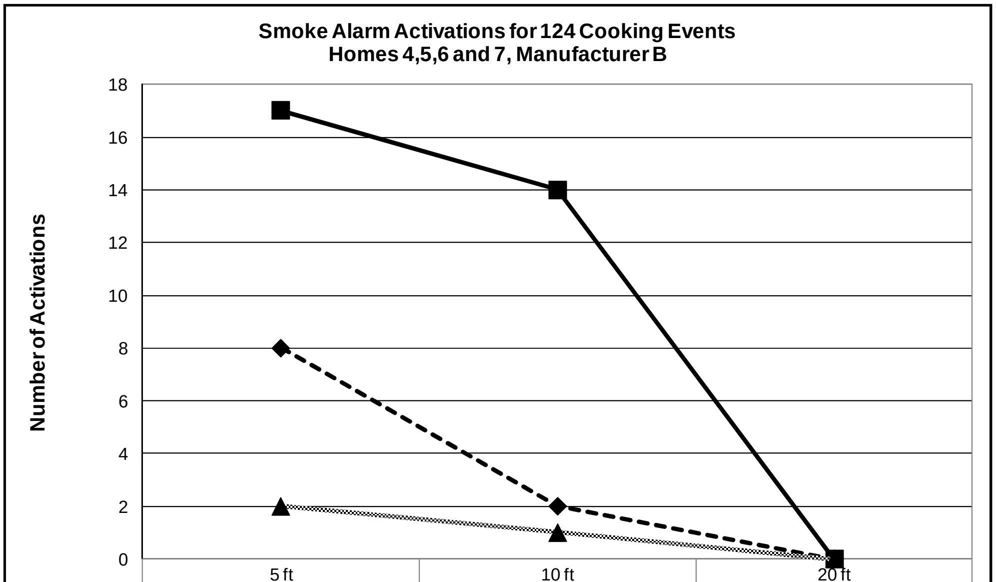
	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
ION	40	16	7	12	1	1
DUAL	3	4	1	0	0	0
PHOTO	8	1	8	15	0	2

Figure 18. Activations for Manufacturer A (Home 9)

11.3 Analysis of Activations Involving Manufacturer B

An analysis of the data collected from the homes tested with smoke alarms from manufacturer B was conducted (homes 4, 5, 6, and 7). (An analysis of the data from home 9 is presented separately.)

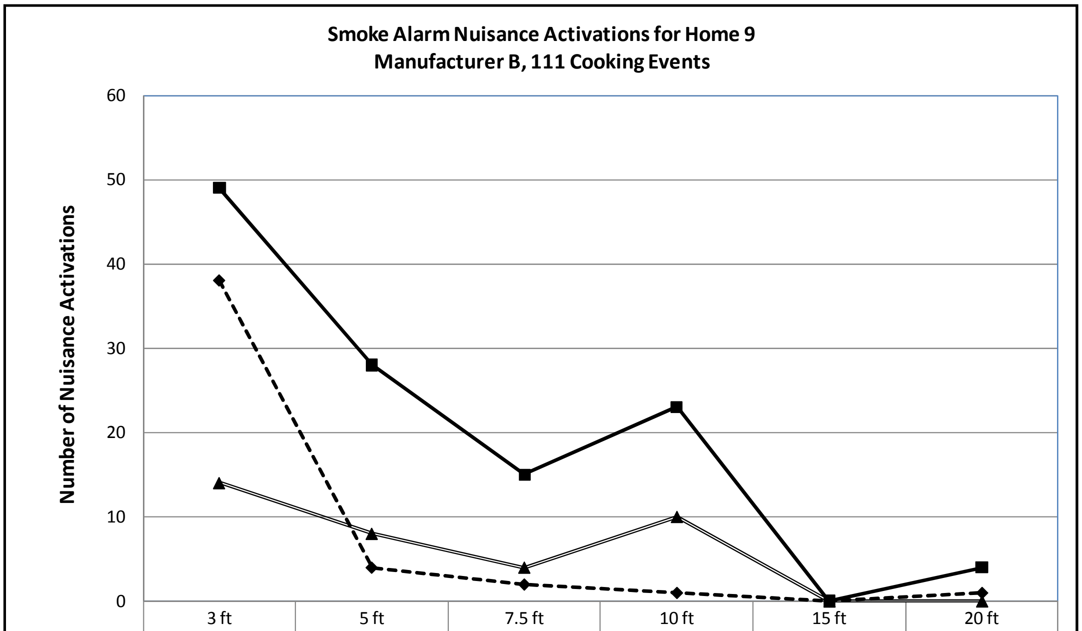
Figure 19 shows the number of activations for homes that were tested using smoke alarms from manufacturer B. For 124 cooking events, there were 44 activations of smoke alarms involving manufacturer B. At distances of 5 and 10 feet from the main cooking appliance, the number of nuisance alarms for dual-sensor smoke alarms (17 and 14, respectively) was higher than the number of activations for ionization (8 and 2, respectively) or photoelectric (2 and 1, respectively) smoke alarms. The number of ionization smoke alarm activations at 10 feet was similar to the number of photoelectric smoke alarm activations at 5 feet. The photoelectric smoke alarms had two activations at 5 feet and a single activation at 10 feet. At 20 feet, the number of nuisance alarms was zero, regardless of the type of smoke alarm.



	5 ft	10 ft	20 ft
ION	8	2	0
DUAL	17	14	0
PHOTO	2	1	0

Figure 19. Activations for Manufacturer B (Homes 4, 5, 6, and 7)

Figure 20 shows the number of activations for home 9 which included smoke alarms from manufacturer B. For 111 cooking events, there were 201 activations of smoke alarms involving manufacturer B. At 3 feet, the number of activations involving dual-sensor (49) and ionization (39) smoke alarms was higher than the number of activations for photoelectric (14) smoke alarms. Overall, the number of activations for the dual-sensor smoke alarms was higher than the ionization and photoelectric smoke alarms out to 10 feet. At 7.5 feet, there were fewer activations – for all smoke alarm types – than at either 3 feet or 5 feet. At 10 feet, the number of activations for the dual-sensor (23) and photoelectric (10) smoke alarms increased, before decreasing to near zero at 15 feet and 20 feet. For the ionization smoke alarms, there was very little difference between the number of activations at 7.5 feet (2) and at 10 feet (1). After 10 feet, the number of activations decreased to near zero. The ionization smoke alarms showed the least variation in number of activations between distances beyond 3 feet.



	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
ION	38	4	2	1	0	1
DUAL	49	28	15	23	0	4
PHOTO	14	8	4	10	0	0

Figure 20. Activations for Manufacturer B (Home 9)

12.0 ANALYSIS BY MEALTIME

This section presents an analysis of the data for the frequency of nuisance alarms by mealtime (breakfast, lunchtime, or dinnertime). (The data from home 9 was included in this analysis. To normalize the data with the other homes, the number of cooking events for home 9 was doubled, because home 9 included smoke alarms from both manufacturers.)

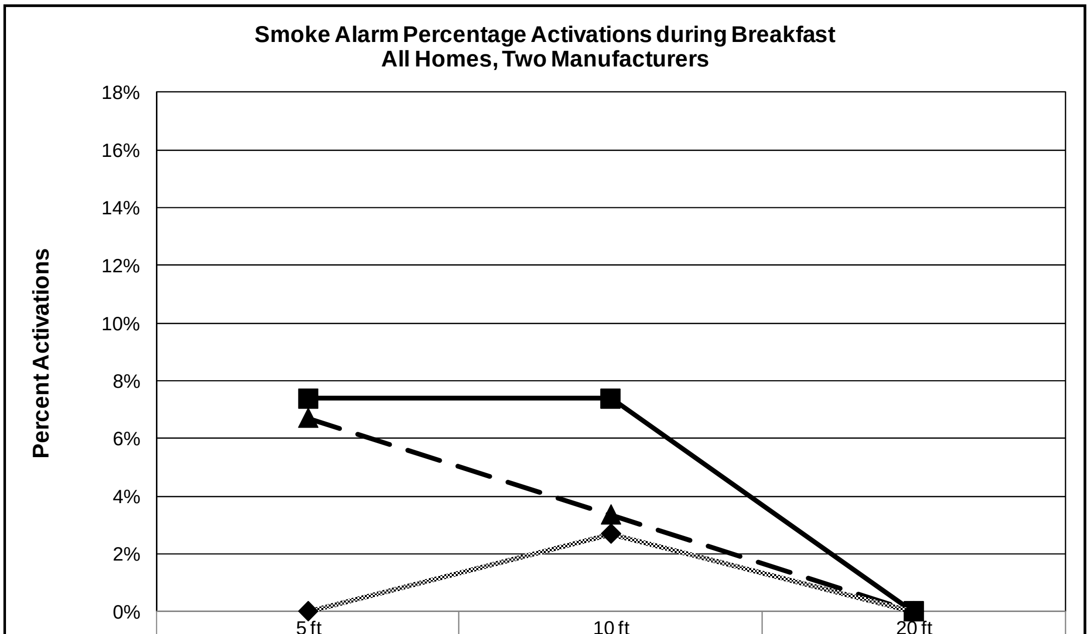
It should be noted that the cooking appliance that initiated the cooking particles during breakfast, and in some cases during lunch, may not have been the main cooking appliance (range or stove). Portable appliances, such as toaster ovens, indoor grills, steamers, and toasters, may not have been located near the range and could have been closer to smoke alarm groups that were farther away from the main cooking appliance. The types of portable appliances in the kitchen were recorded, but the locations of the portable appliances were not noted.

12.1 Mealtime Analysis (All Homes)

Figures 21, 22, and 23 show the percentage of smoke alarm activations during different mealtimes. During breakfast, normalized 149 cooking events, the ionization (6.7%) and dual-sensor (7.4%) smoke alarms had the highest percentage of activations at 5 feet, as shown in Figure 21. The photoelectric smoke alarms did not have any activations at 5 feet. At 10 feet and 20 feet, the percentage of activations was similar (around 3%) for all types of smoke alarms.

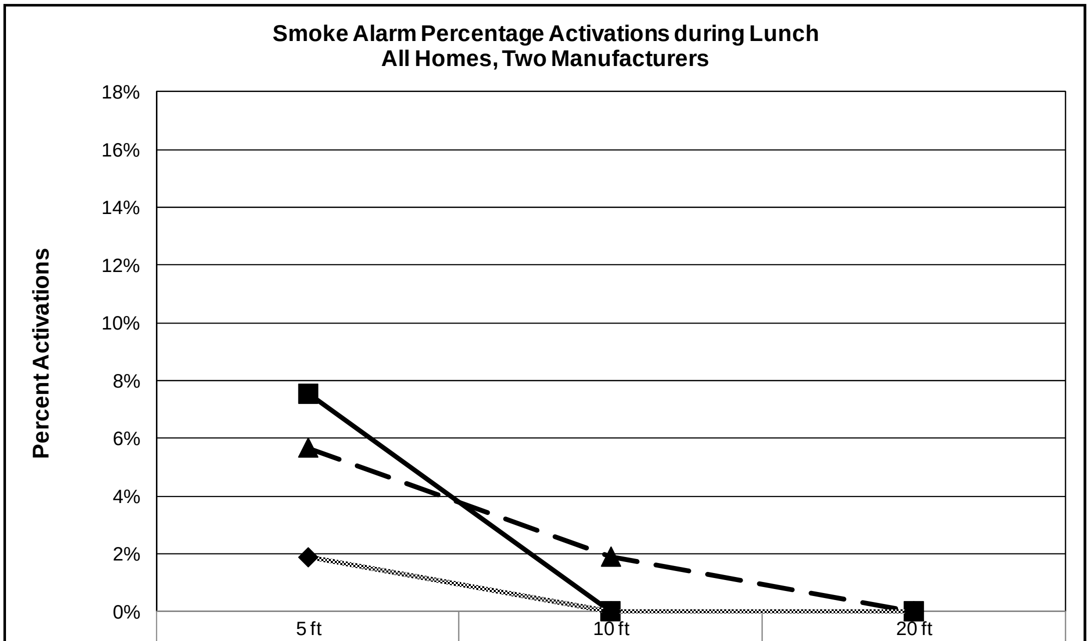
At lunchtime, normalized 53 cooking events, the ionization (5.7%) and dual-sensor (7.6%) smoke alarms had the highest percentage of activations at 5 feet, as shown in Figure 22. The photoelectric had the lowest percentage (1.9%) of activations at 5 feet during lunchtime. At 10 feet, there were no activations for the dual-sensor and photoelectric smoke alarms. At 20 feet, there were no activations of smoke alarms, regardless of type.

At dinnertime, normalized 221 cooking events, the dual-sensor smoke alarms had the highest percentage (16.7%) of activations at 5 feet, followed by the ionization smoke alarms (12.7%), as shown in Figure 23. At 10 feet, the percentage of activations decreased for the ionization and dual-sensor smoke alarms (7.7% and 13.6%, respectively), but increased for the photoelectric smoke alarms (5.9% to 10.9%). (This is a result of including the data set from home 9.) At 20 feet, the percentage of activations was similar for all types of smoke alarms.



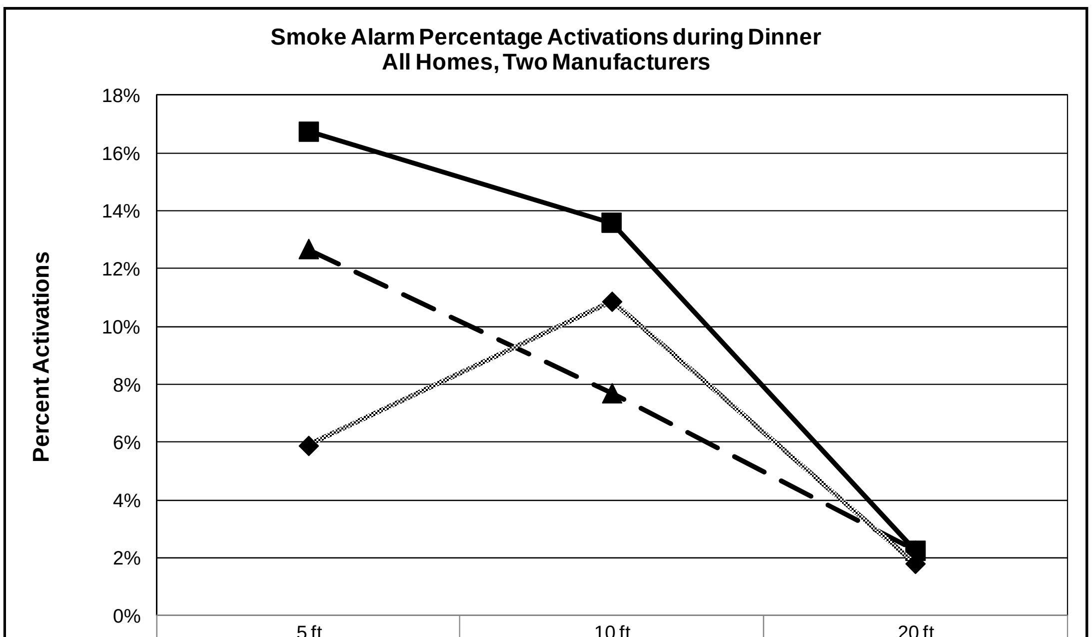
	5 ft	10 ft	20 ft
ION	6.71%	3.36%	0.00%
DUAL	7.38%	7.38%	0.00%
PHOTO	0.00%	2.68%	0.00%

Figure 21. Frequency of Activations during Breakfast (All Homes)



	5 ft	10 ft	20 ft
ION	5.66%	1.89%	0.00%
DUAL	7.55%	0.00%	0.00%
PHOTO	1.89%	0.00%	0.00%

Figure 22. Frequency of Activations during Lunchtime (All Homes)



	5 ft	10 ft	20 ft
ION	12.67%	7.69%	2.26%
DUAL	16.74%	13.57%	2.26%
PHOTO	5.88%	10.86%	1.81%

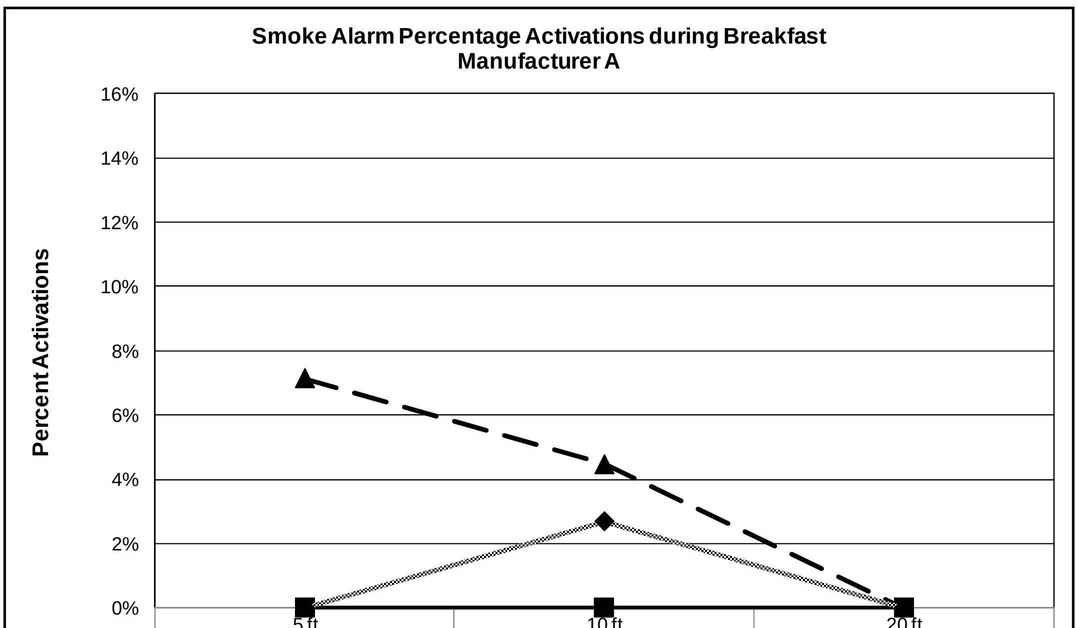
Figure 23. Frequency of Activations during Dinnertime (All Homes)

12.2 Mealtime Analysis for Manufacturer A Smoke Alarms

Figures 24, 25, and 26 show the percentage of smoke alarm activations at different mealtimes for manufacturer A. During breakfast, normalized to 112 cooking events, the ionization smoke alarms had the most activations (7.1%) at 5 feet, as shown in Figure 24. The photoelectric and dual-sensor smoke alarms did not have any activations at 5 feet. At 10 feet, the percentage of activations (4.5%) for ionization smoke alarms decreased, while the percentage of activations (2.7%) for photoelectric smoke alarms increased. At 20 feet, there were no activations of smoke alarms, regardless of type. The dual-sensor smoke alarms did not have any activations for all three locations.

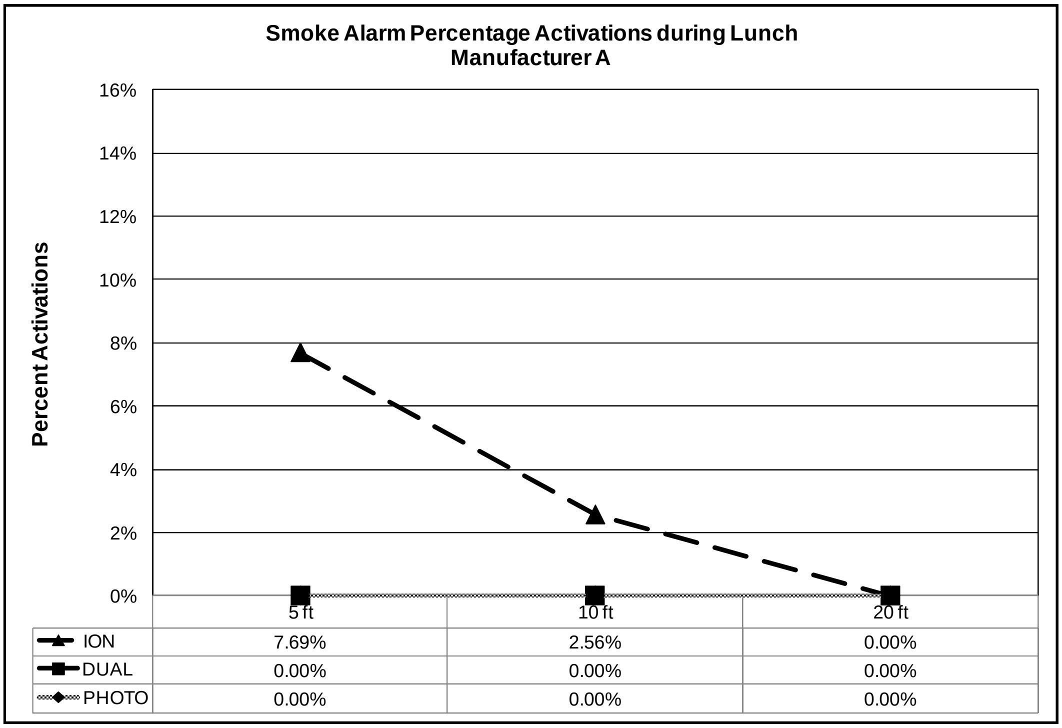
At lunchtime, normalized 39 cooking events, the ionization smoke alarms had the highest percentage of activations (7.7%) at 5 feet, as shown in Figure 25. At 10 feet, the percentage of activations (2.6%) for the ionization smoke alarms decreased. At 20 feet, there were no activations of smoke alarms, regardless of type. The photoelectric and dual-sensor smoke alarms did not have any activations at any locations during lunchtime.

At dinnertime, normalized 158 cooking events, the ionization smoke alarms had the highest percentage of activations (11.4%) at 5 feet, as shown in Figure 26; this was followed by the dual-sensor (5.1%) smoke alarms and then the photoelectric (2.5%) smoke alarms. At 10 feet, the percentage of activations decreased for the ionization (4.4%) and dual-sensor (2.5%) smoke alarms but increased for the photoelectric (8.9%) smoke alarms . (As noted previously, this is a result of including the data set from home 9.) At 20 feet, the percentage of activations was similar for all types of smoke alarms.



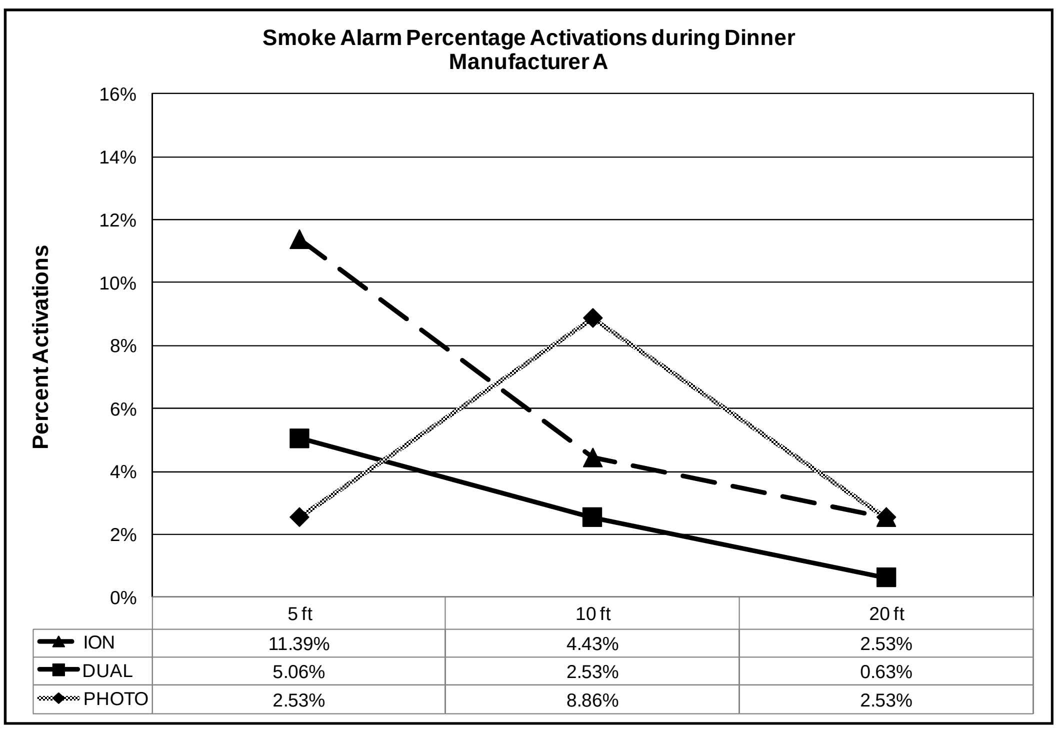
	5 ft	10 ft	20 ft
ION	7.14%	4.46%	0.00%
DUAL	0.00%	0.00%	0.00%
PHOTO	0.00%	2.68%	0.00%

Figure 24. Frequency of Activations during Breakfast (Manufacturer A)



	5 ft	10 ft	20 ft
ION	7.69%	2.56%	0.00%
DUAL	0.00%	0.00%	0.00%
PHOTO	0.00%	0.00%	0.00%

Figure 25. Frequency of Activations during Lunchtime (Manufacturer A)



	5 ft	10 ft	20 ft
ION	11.39%	4.43%	2.53%
DUAL	5.06%	2.53%	0.63%
PHOTO	2.53%	8.86%	2.53%

Figure 26. Frequency of Activations during Dinnertime (Manufacturer A)

12.3 Mealtime Analysis for Manufacturer B Smoke Alarms

Figures 27, 28, and 29 show the percentage of activations for each type of smoke alarm at different mealtimes for manufacturer B. During breakfast, normalized to 119 cooking events, the dual-sensor smoke alarms had the highest percentage of activations (9.2%) at 5 feet, as shown in Figure 27. The photoelectric smoke alarms did not have any activations at 5 feet, and the ionization (1.7%) smoke alarms had a low percentage of activations. At 10 feet, the percentage of activations for the dual-sensor smoke alarms was the same as at 5 feet; and the photoelectric smoke alarms showed a slight increase (0.8%) in percent activations. At 20 feet, there were no activations of smoke alarms, regardless of type.

At lunchtime, normalized 34 cooking events, the dual-sensor smoke alarms had the highest percentage of activations (11.8%) at 5 feet, as shown in Figure 28. The ionization smoke alarms did not have any activations at any location during lunchtime. After 10 feet, there were no activations of smoke alarms, regardless of type.

At dinnertime, normalized 153 cooking events, the dual-sensor smoke alarms at 5 and 10 feet had higher percentages of activations (19% and 17%, respectively) than the ionization (6.5% and 2%, respectively) or photoelectric (5.9% and 6.5%, respectively) smoke alarms, as shown in Figure 29. The ionization (6.5%) and photoelectric (5.9%) smoke alarms had similar percentages of activations at 5 feet. At 10 feet, the percentages of activations decreased for the ionization and dual-sensor smoke alarms, but increased slightly for the photoelectric smoke alarms. (As noted previously, this is a result of including the data set from home 9.) At 20 feet, the percentage of activations was similar for all types of smoke alarms.

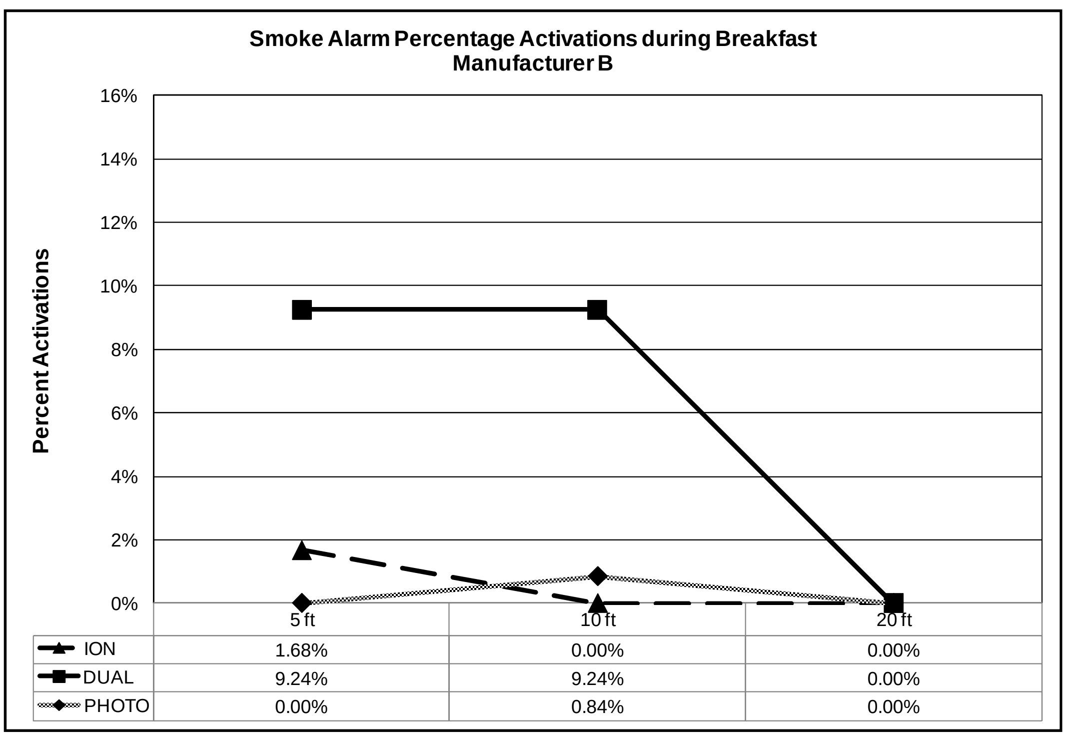
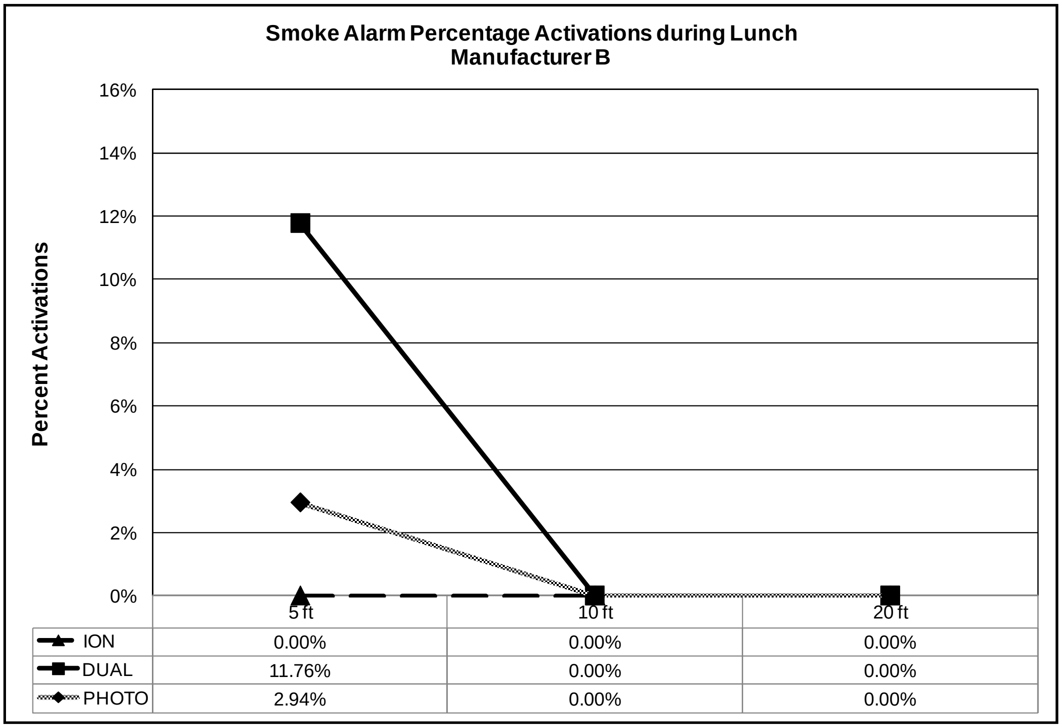
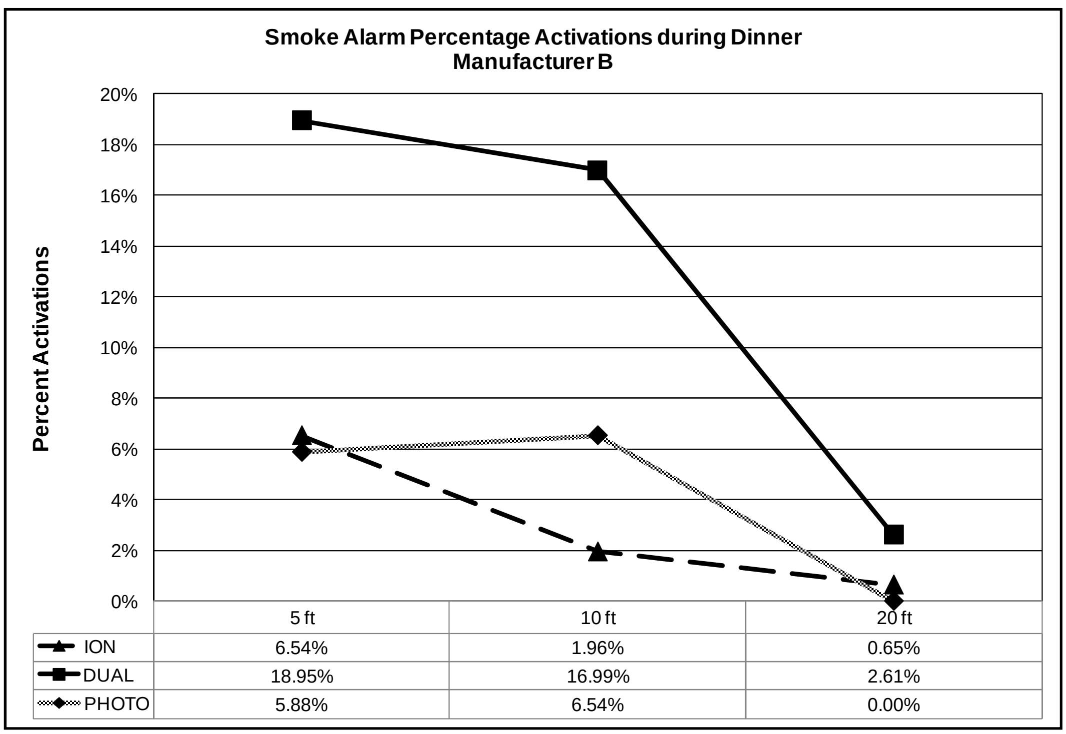


Figure 27. Frequency of Activations during Breakfast (Manufacturer B)



	5 ft	10 ft	20 ft
ION	0.00%	0.00%	0.00%
DUAL	11.76%	0.00%	0.00%
PHOTO	2.94%	0.00%	0.00%

Figure 28. Frequency of Activations during Lunchtime (Manufacturer B)



	5 ft	10 ft	20 ft
ION	6.54%	1.96%	0.65%
DUAL	18.95%	16.99%	2.61%
PHOTO	5.88%	6.54%	0.00%

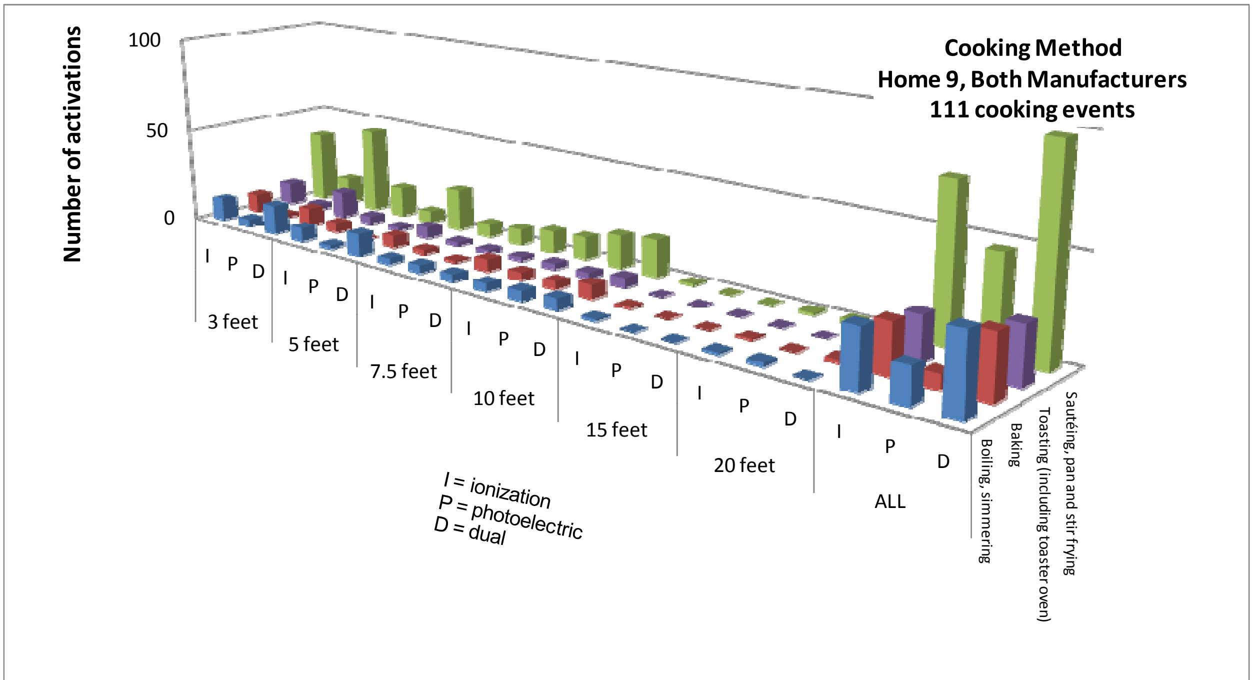
Figure 29. Frequency of Activations during Dinnertime (Manufacturer B)

13.0 ANALYSIS OF COOKING METHODS (HOME 9)

This section presents an analysis of cooking methods for the data collected from home 9, which contained smoke alarms from both manufacturers A and B. The cooking method played as an important role as smoke alarm placement in the number of smoke alarm activations.

The cooking methods were divided into four categories: frying, toasting, baking, and boiling. There was no deep frying recorded for home 9. Frying included sautéing, pan frying, and stir frying using a pan, pot, or wok on the stove. This type of cooking typically consisted of browning meats or vegetables using enough oils to coat the cooking surface. Toasting consisted of using a toaster or toaster oven to heat items, such as bread products or small portions of meat, placed in these portable appliances. Baking consisted of cooking in the main oven. Boiling included boiling, simmering, and steaming a large amount of liquid for cooking. This included items such as pasta, soups, vegetables, and shell fish. The microwave oven was used to reheat foods, but there were no records of using the microwave oven to cook meals. (This was the case for homes 1-8 as well.)

Figure 30 shows an overview of the number of smoke alarm activations at each location, the type of smoke alarm involved, and the cooking methods that caused alarm activation for home 9. Frying produced the most activations overall.



	3 feet			5 feet			7.5 feet			10 feet			15 feet			20 feet			ALL		
	I	P	D	I	P	D	I	P	D	I	P	D	I	P	D	I	P	D	I	P	D
Boiling, simmering	12	4	15	7	2	12	3	4	4	4	5	6	1	0	0	1	2	0	28	17	37
Baking	10	2	9	5	0	6	3	1	6	4	4	7	1	0	0	1	0	2	24	7	30
Toasting (including toaster oven)	12	3	14	4	2	6	2	2	2	3	3	5	0	0	0	0	0	0	21	10	27
Sautéing, pan and stir frying	37	14	45	16	6	22	7	8	11	12	17	19	1	0	0	1	2	1	74	47	98

Figure 30. Activations vs. Distance, Cooking Method, and Type of Smoke Alarm (Home 9)

The photoelectric smoke alarms had the fewest activations for all cooking methods, as shown in Figure 31. Sautéing, pan frying, and stir frying produced many more nuisance alarms than other cooking methods; this was mostly attributed to the higher frequency of this cooking method. Sautéing, pan frying, and stir frying comprised around 50% of the cooking events.

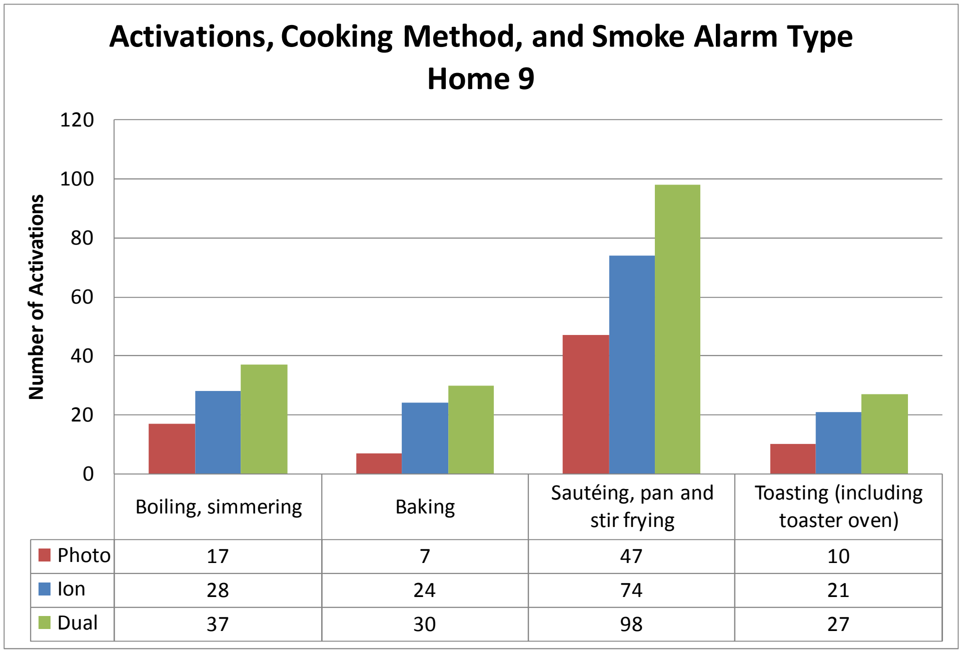
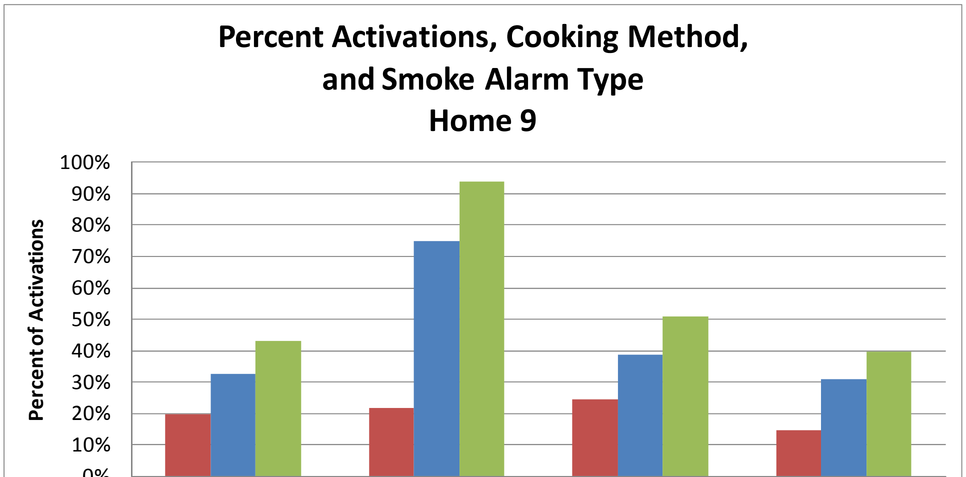


Figure 31. Activations vs. Cooking Method and Type of Smoke Alarm (Home 9)

Figure 32 shows the percentage of activations for different cooking methods. For home 9, baking produced a higher percentage of nuisance alarms for ionization and dual-sensor smoke alarms at 75% and 93.8%, respectively. This may be attributed to the large quantity of small particles that are released when the oven door is opened during and after cooking. The photoelectric smoke alarms produced the most consistent percent activation among cooking methods. Toasting produced the lowest percentage of nuisance alarms at 14.7%, and frying produced the highest percentage at 24.5%. Photoelectric smoke alarms had the lowest percentage of activations for each cooking method, whereas the dual-sensor smoke alarms had the highest percentage of activations for each cooking method.

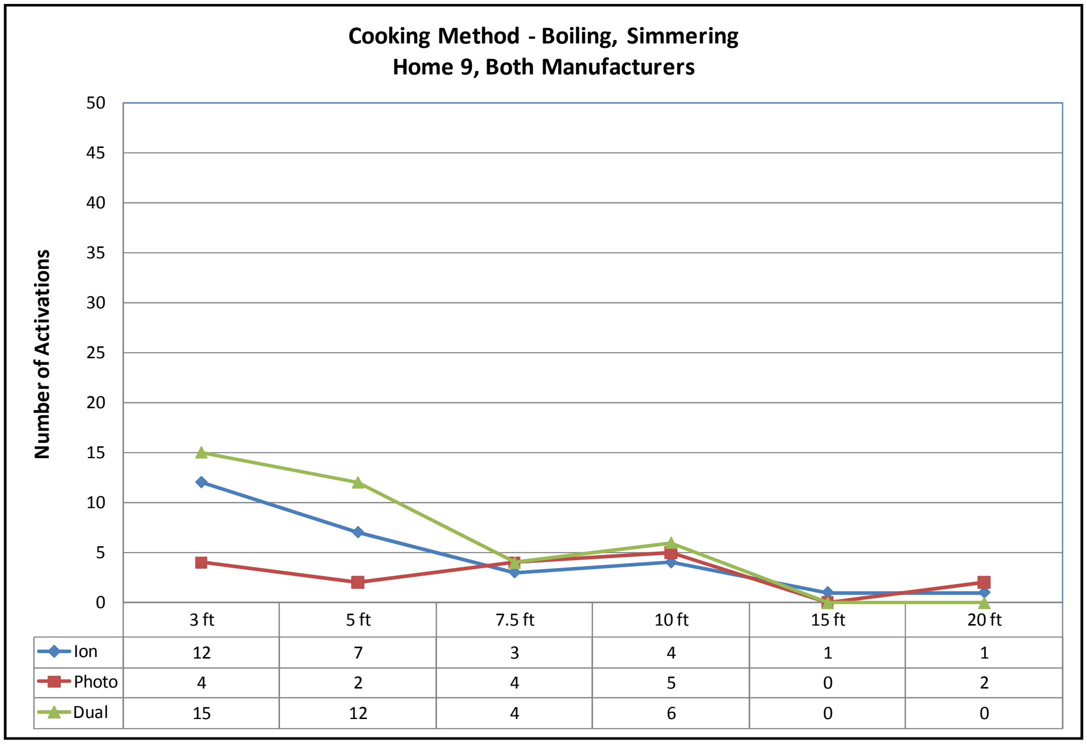


	Boiling, simmering	Baking	Sautéing, pan and stir frying	Toasting (including toaster oven)
Photo	19.8%	21.9%	24.5%	14.7%
Ion	32.6%	75.0%	38.5%	30.9%
Dual	43.0%	93.8%	51.0%	39.7%

Figure 32. Percent Activations vs. Cooking Method and Type of Smoke Alarm (Home 9)

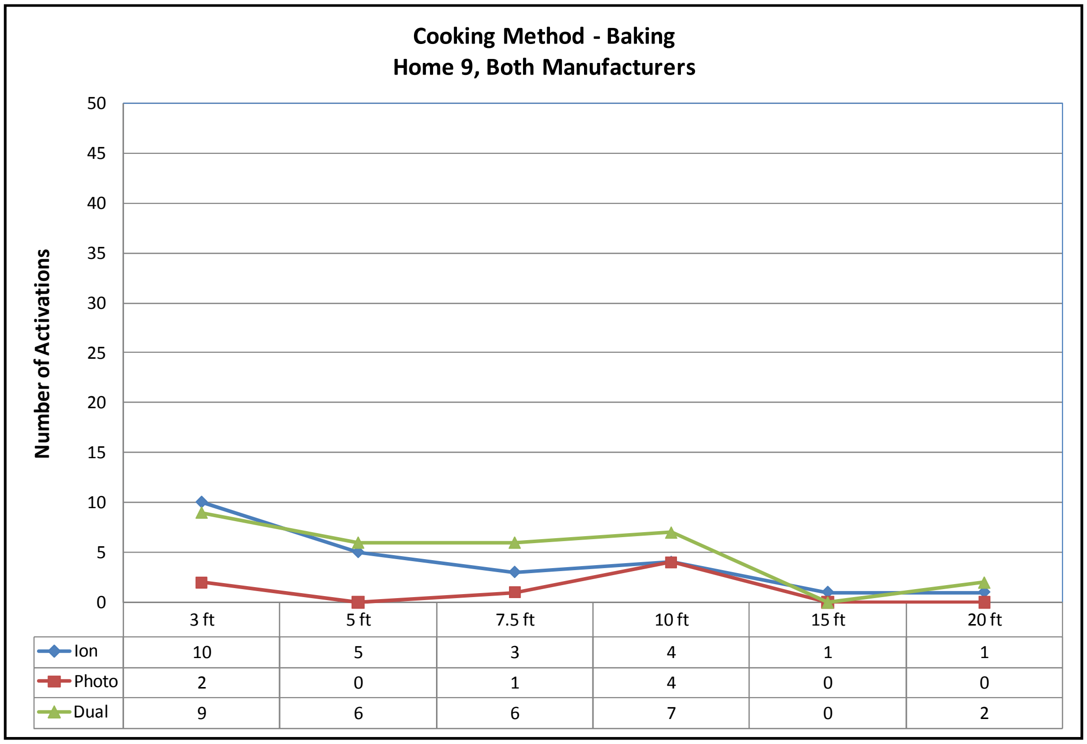
Figures 33, 34, 35, and 36 show the number of activations at each location for each cooking method. All the figures are similar, regardless of the cooking method. The dual-sensor and ionization smoke alarms at 3 feet had the most activations. The dual and ionization smoke alarms traces are similar regardless of the cooking method. For all smoke alarm types and regardless of cooking method, the number of activations decreased at 5 feet and then increased at 10 feet. After 10 feet, the number of activations decreased as the distance increased.

The photoelectric smoke alarms had fewer nuisance alarms than the other types of smoke alarms at 3 and 5 feet. The difference between the photoelectric and other types of smoke alarms was greater at 3 feet than at 5 feet. After 7.5 feet, the number of nuisance alarms was similar regardless of smoke alarm type.



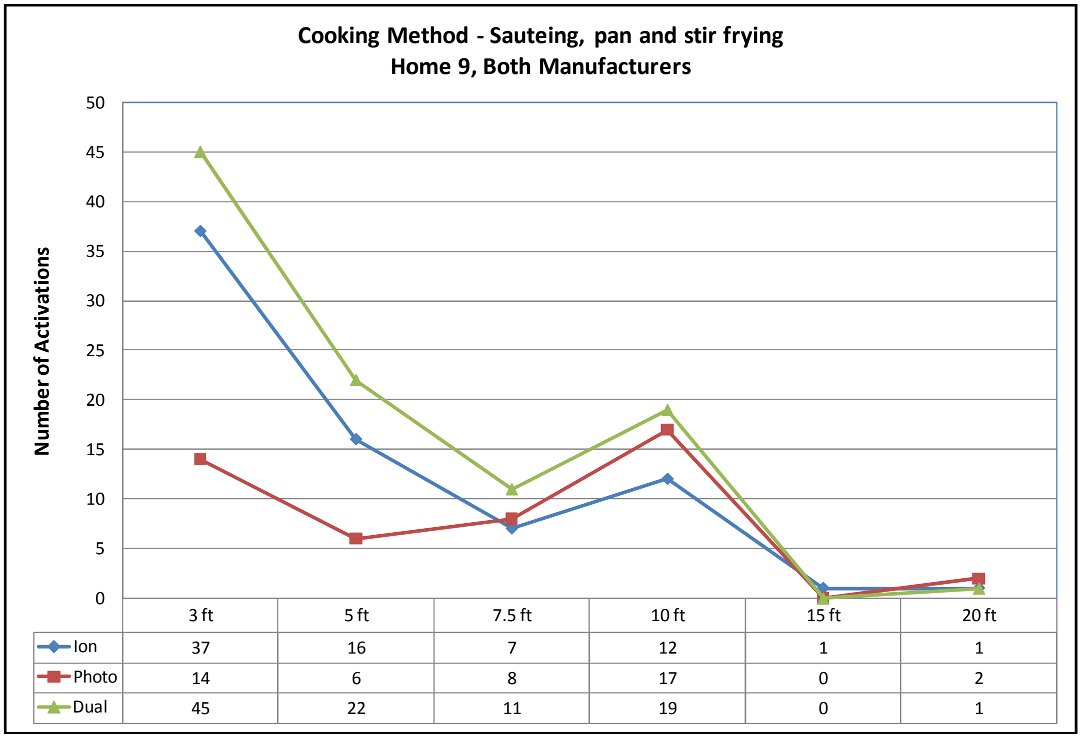
	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
Ion	12	7	3	4	1	1
Photo	4	2	4	5	0	2
Dual	15	12	4	6	0	0

Figure 33. Boiling, Simmering – Activations and Type of Smoke Alarm vs. Distance



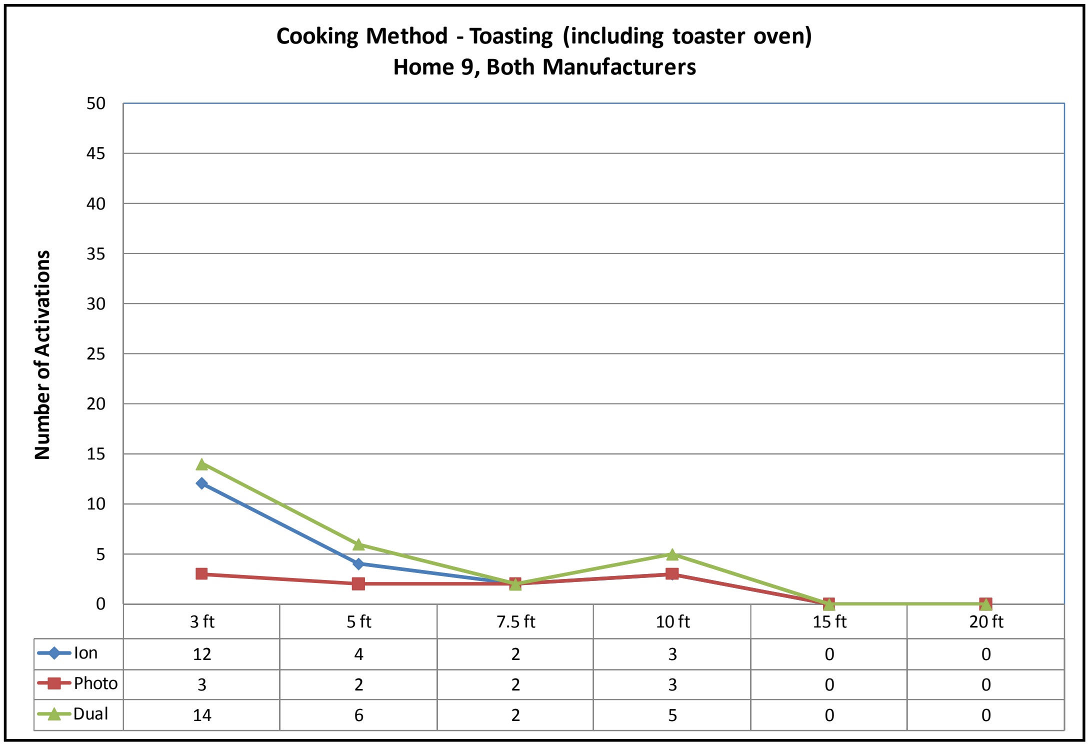
	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
Ion	10	5	3	4	1	1
Photo	2	0	1	4	0	0
Dual	9	6	6	7	0	2

Figure 34. Baking – Activations and Type of Smoke Alarm vs. Distance



	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
Ion	37	16	7	12	1	1
Photo	14	6	8	17	0	2
Dual	45	22	11	19	0	1

Figure 35. Sauteing, Pan and Stir Frying – Activations and Type of Smoke Alarm vs. Distance



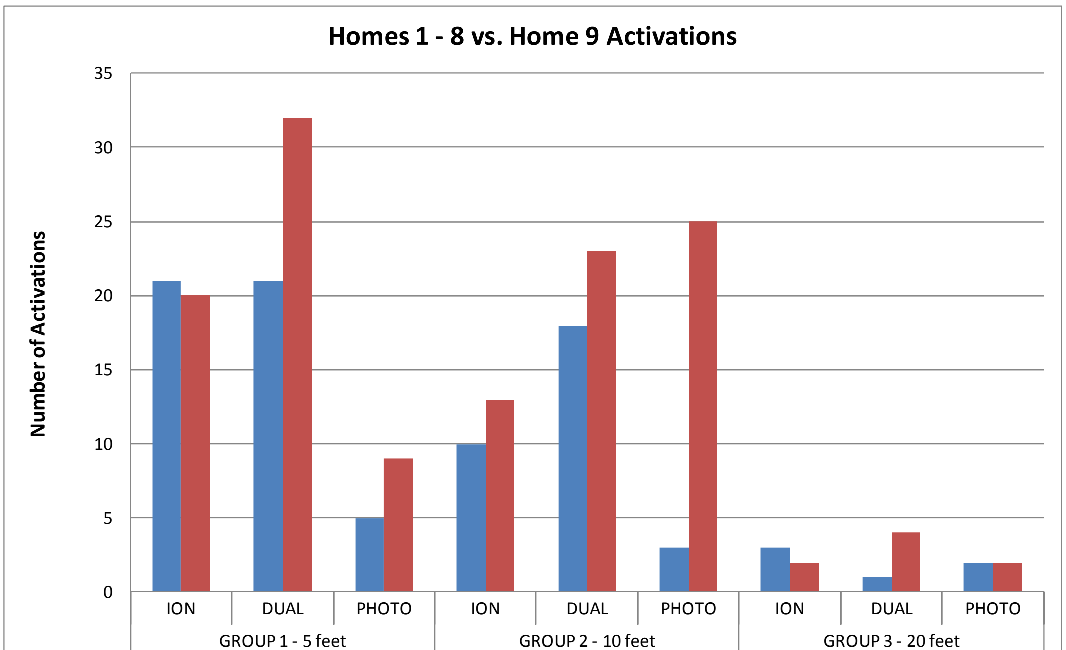
	3 ft	5 ft	7.5 ft	10 ft	15 ft	20 ft
Ion	12	4	2	3	0	0
Photo	3	2	2	3	0	0
Dual	14	6	2	5	0	0

Figure 36. Toasting – Activations and Type of Smoke Alarm vs. Distance

14.0 ANALYSIS OF DIFFERENCES (HOMES 1-8 VS. HOME 9)

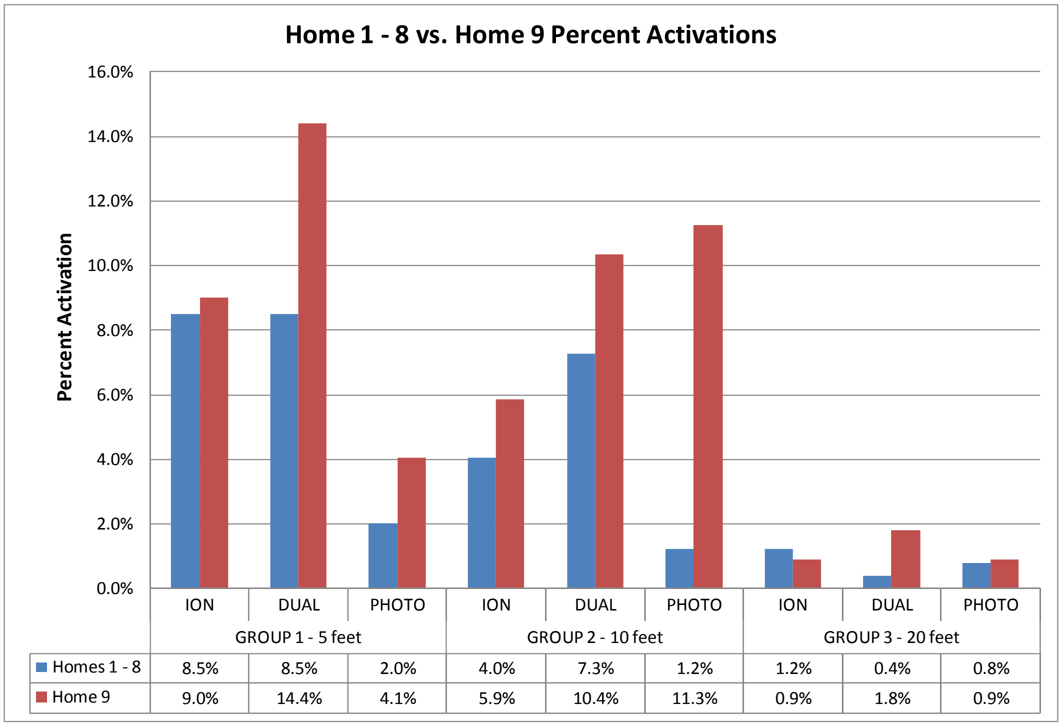
As shown in Section 10 Data Analysis (Home 9), there was a a distinguishable increase in smoke alarm activations at 10 feet, especially for activations associated with the photoelectric smoke alarms. This section will examine the differences between homes 1-8 and home 9 that may explain the increase in activations at 10 feet.

Figure 37 compares the number of smoke alarm activations for homes 1-8 and home 9 for different locations and types of smoke alarms. The number of cooking events for homes 1-8 and home 9 were similar at 247 and 222 (normalized), respectively. The percentage of activations involving photoelectric smoke alarms was about 10 percent higher at 10 feet for home 9 than for homes 1-8, as shown in Figure 38. At 5 feet, the percentage of activations for dual-sensor smoke alarms was about 6 percent higher for home 9 than for homes 1-8.



	GROUP 1 - 5 feet			GROUP 2 - 10 feet			GROUP 3 - 20 feet		
	ION	DUAL	PHOTO	ION	DUAL	PHOTO	ION	DUAL	PHOTO
Home 1-8	21	21	5	10	18	3	3	1	2
Home 9	20	32	9	13	23	25	2	4	2

Figure 37. Activations (Homes 1-8 vs. Home 9)



	GROUP 1 - 5 feet			GROUP 2 - 10 feet			GROUP 3 - 20 feet		
	ION	DUAL	PHOTO	ION	DUAL	PHOTO	ION	DUAL	PHOTO
Homes 1 - 8	8.5%	8.5%	2.0%	4.0%	7.3%	1.2%	1.2%	0.4%	0.8%
Home 9	9.0%	14.4%	4.1%	5.9%	10.4%	11.3%	0.9%	1.8%	0.9%

Figure 38. Frequency of Activations (Homes 1-8 vs. Home 9)

The cooking method played a role in the number of smoke alarm activations. Figure 39 compares homes 1-8 and home 9 for the percentage of time that various cooking methods were used. In home 9, frying was used twice as often as for homes 1-8. In contrast, in homes 1-8, baking was recorded almost four times as often. Boiling and toasting were conducted in similar proportions for homes 1-8 and home 9. Home 9 had no cooking events involving deep frying. Homes 1-8 had a small percentage of deep frying cooking events, and these events typically resulted in smoke alarm activations for either the ionization or dual-sensor smoke alarms.

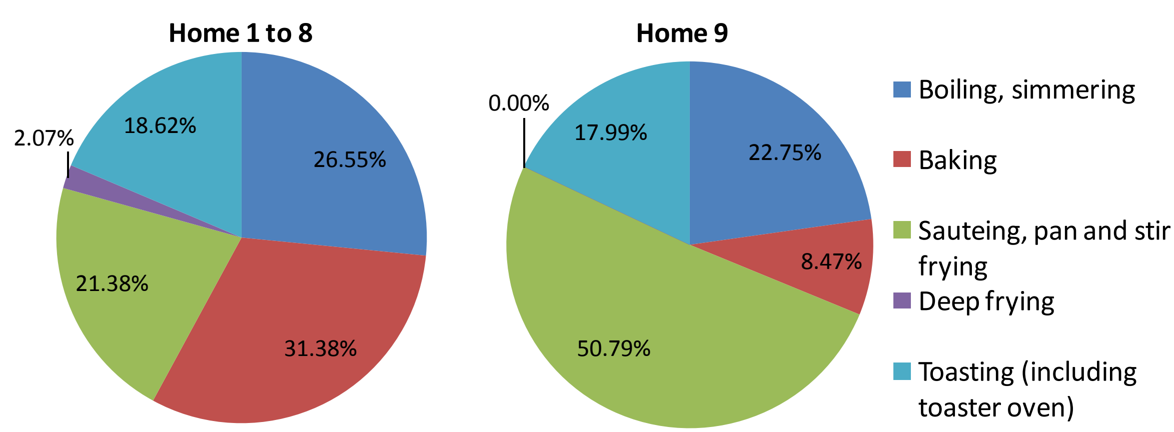


Figure 39. Percent Cooking Methods for Homes 1-8 vs. Home 9

Exhaust fan usage was different between homes 1-8 and home 9, excluding home 7 since it did not have an exhaust fan. Home 9 used the exhaust fan for 48 percent of the cooking events, whereas homes 1-8 used the exhaust fan for an average of 8.7 percent of the cooking events. For homes 1-8, usage of the exhaust fan ranged from 0 to 23 percent of the cooking events. An analysis of the number of detections versus when the fan was on or off cannot be conducted because fan usage was not a random act. Occupants who cook regularly may be predisposed to using the fan when cooking certain foods because past cooking events with the same food may have caused their smoke alarm to sound and prompted them to turn on the exhaust fan to prevent the smoke alarm from sounding.

There are many factors between home 9 and the other homes tested that could have influenced the effects seen in home 9 (where the number of nuisance detections increased after 5 feet and peaked at 10 feet before decreasing to near zero). Even though home 9 did more frying than any other type of cooking methods (and other homes), the increased nuisance alarms at 10 feet were affected by all cooking methods. The individual smoke alarm data for homes 1 to 8 did not reveal the same effects as seen in home 9, but this may be attributed to home layout, shorter test period, and/or the frequency and method of cooking.

One hypothesis as to the cause for the apparent increase in detections at 10 feet may be attributed to fan usage. Home 9 contained a 48 inch wide, double impeller overhead exhaust hood. The typical setting used on the exhaust hood was rated at 300 cubic feet minute (cfm). Rather than an increase in nuisance alarms at 10 feet, there may have been a decrease in the number of activations closer than 10 feet as a result of exhaust fan usage. Using the exhaust fan may have removed some of the cooking particles near the exhaust fan. The fan's effects on cooking particles may be proportionally related to the distance to the fan. The exhaust fan's flow most likely had little or no effect beyond 10 feet from the fan. An estimate in the number of nuisance activations that would have occurred in home 9 if the exhaust fan had not been used was generated using trend data from home 9 and homes 1 to 8. The results are shown in Figure 39. Several factors, including the percentage difference in activations between homes 1 to 8 and home 9, known activations in home 9, fan effects in home 9, and distance from the cooking appliance were used to estimate the number of activations within 10 feet. Caution should be used in generalizing the results shown in Figures 40 and 41a to 41c since no testing was conducted to validate the hypothesis or the method to calculate the estimated activations. Figures 41a to 41c show the individual smoke alarm types with the actual activations and estimated activations.

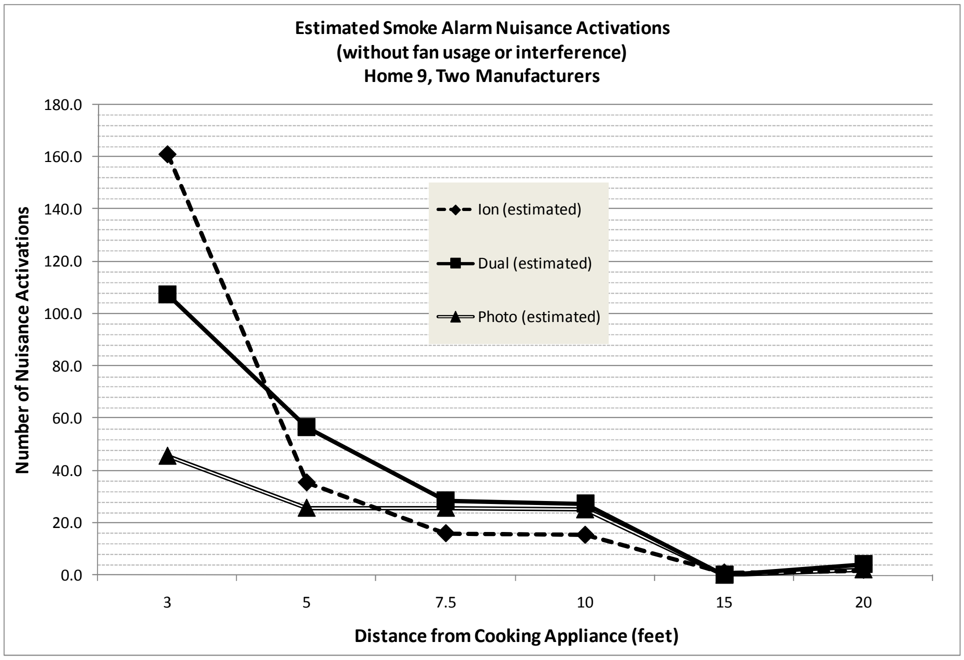


Figure 40. Estimated Activations for Home 9

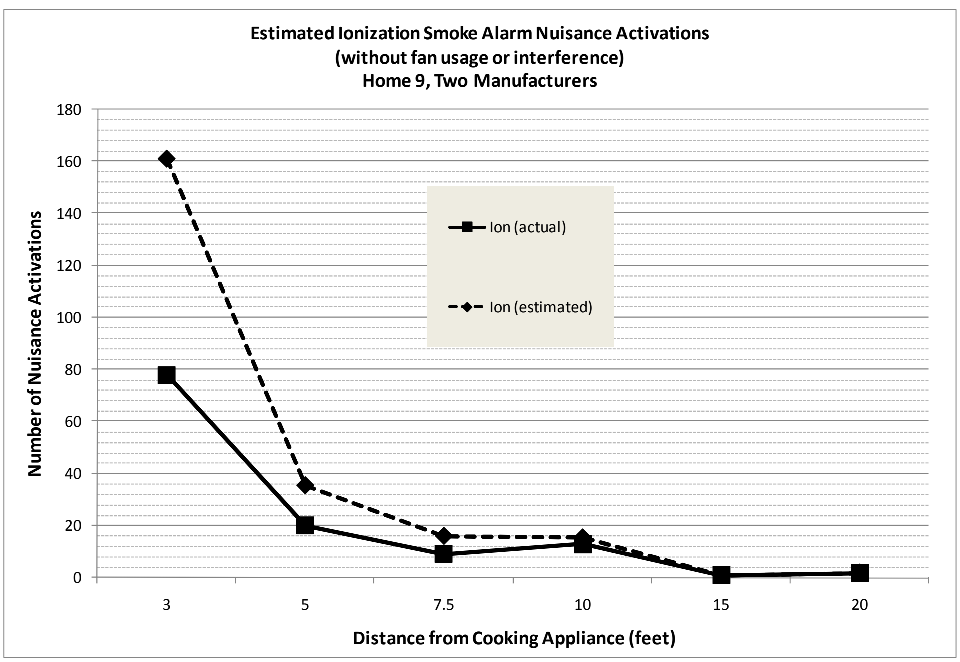


Figure 41a. Estimated Ionization Activations for Home 9

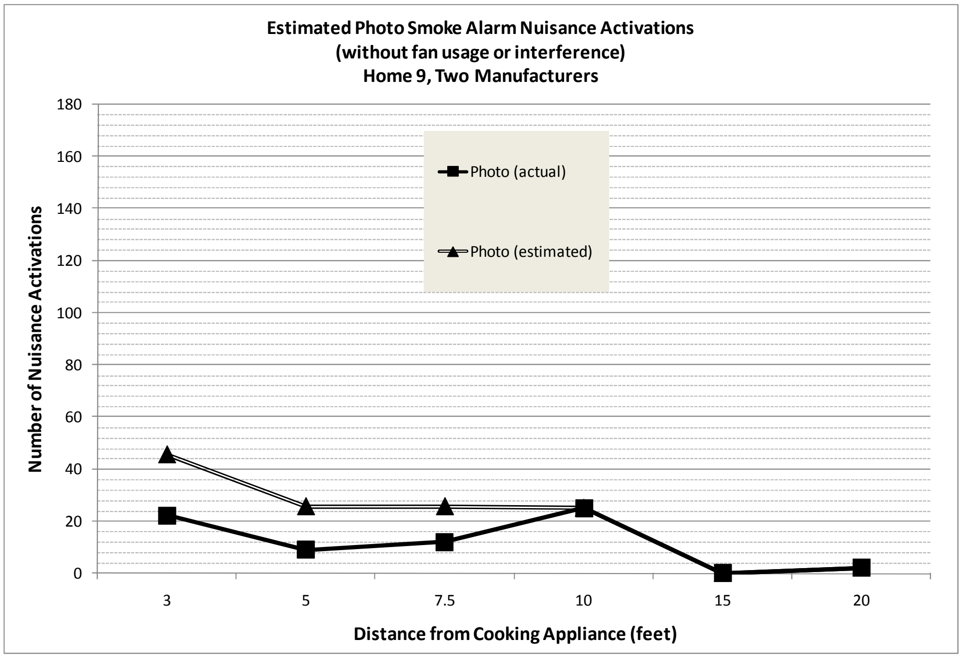


Figure 41b. Estimated Photoelectric Activations for Home 9

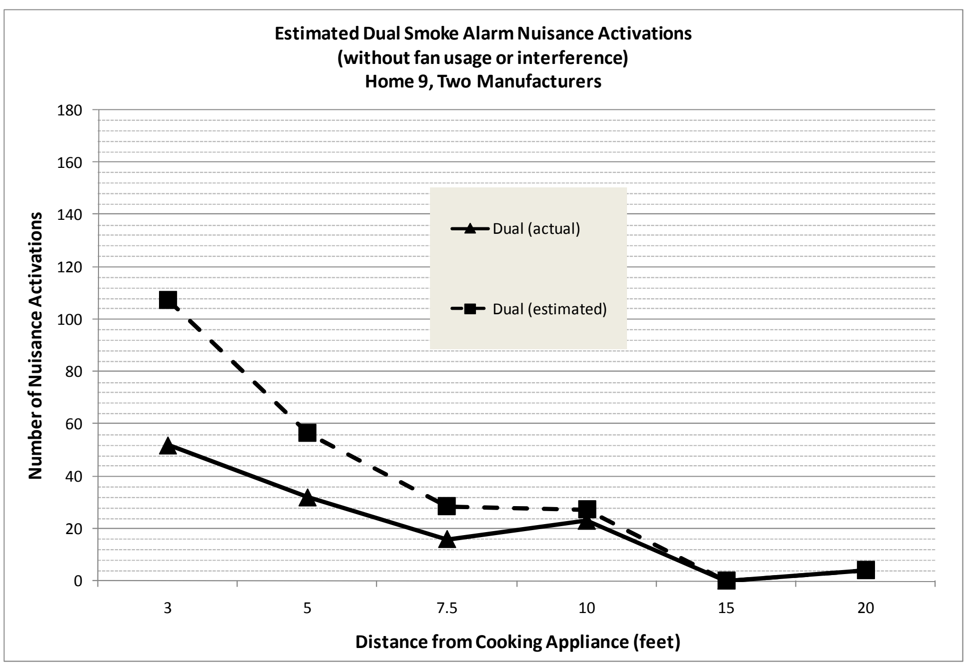
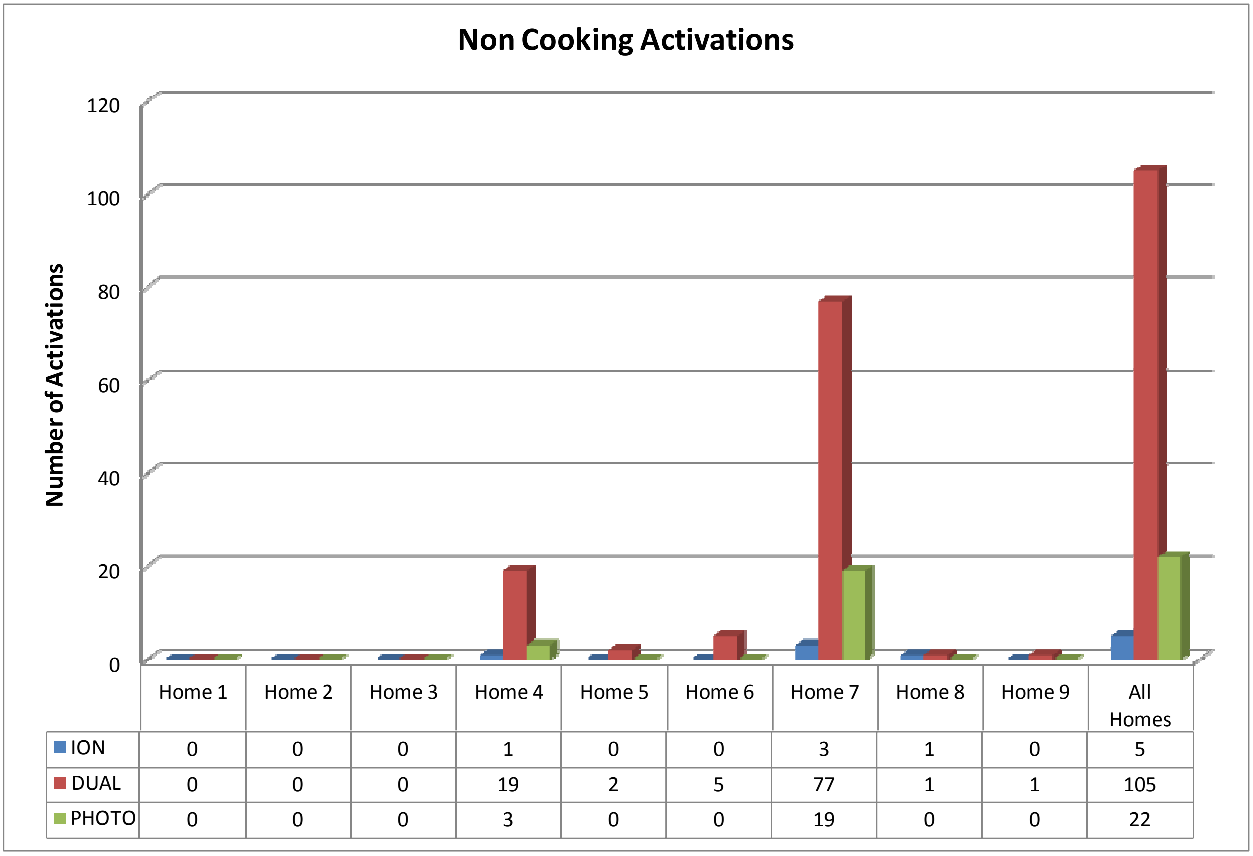


Figure 41c. Estimated Dual Activations for Home 9

15.0 NON-COOKING ACTIVATIONS

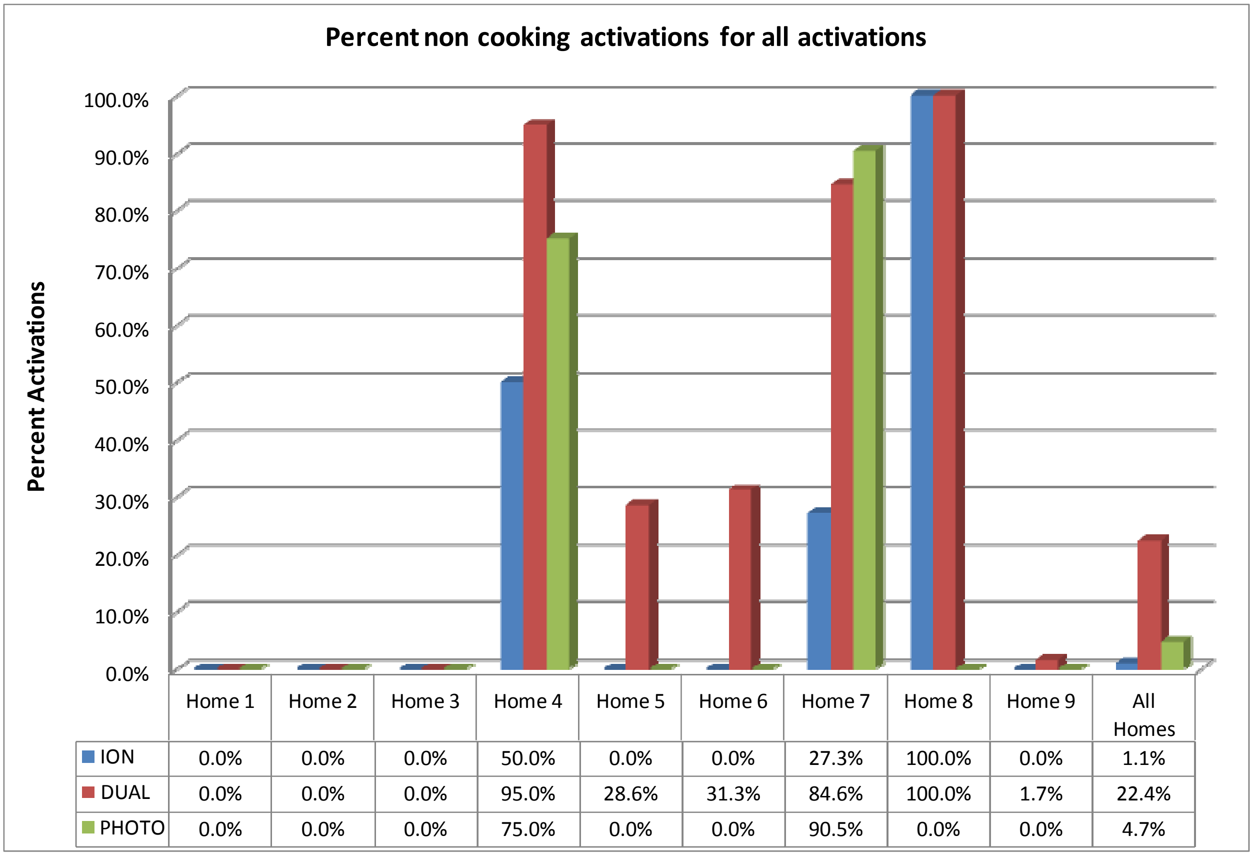
Most homes tested typically had very few non-cooking nuisance alarms. Homes 4 and 7 had a greater number of non-cooking activations, as shown in Figure 42. The majority of these activations involved dual-sensor and photoelectric smoke alarms. The non-cooking activations for home 4 were mainly from the smoke alarms at 20 feet. After the installation, it was observed that the alarms at 20 feet were placed within several feet of a heating and air conditioning return vent. The data showed a pattern of activations when the heating system turned on in the evening/night, when the temperature dropped. Figure 43 shows the percentage of non-cooking activations for all activations recorded for a particulate sensor type and home

For home 7, the location of the 20-foot smoke alarms was in the living room, which contained a ceiling fan. Factors that may have contributed to the number of unwanted activations included use of the ceiling fan and use of the home's front door (which led directly to the living room). In addition, one of the occupants was a smoker, which also may have contributed to the number of activations.



	Home 1	Home 2	Home 3	Home 4	Home 5	Home 6	Home 7	Home 8	Home 9	All Homes
ION	0	0	0	1	0	0	3	1	0	5
DUAL	0	0	0	19	2	5	77	1	1	105
PHOTO	0	0	0	3	0	0	19	0	0	22

Figure 42. Non-Cooking Activations



	Home 1	Home 2	Home 3	Home 4	Home 5	Home 6	Home 7	Home 8	Home 9	All Homes
ION	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	27.3%	100.0%	0.0%	1.1%
DUAL	0.0%	0.0%	0.0%	95.0%	28.6%	31.3%	84.6%	100.0%	1.7%	22.4%
PHOTO	0.0%	0.0%	0.0%	75.0%	0.0%	0.0%	90.5%	0.0%	0.0%	4.7%

Figure 43. Percentage of Non-Cooking Activations

16.0 CONCLUSIONS

CPSC staff initiated a study to investigate nuisance alarms from cooking. The study measured the number and rate of nuisance alarms generated by ionization, photoelectric, and dual-sensor smoke alarms during cooking activities. This information helped to determine the effect of an alarm location relative to the main cooking appliance in the kitchen and to various cooking routines, such as cooking methods, foods prepared, and mealtimes. In this study, CPSC staff installed smoke alarms in nine different homes for a period of approximately 30 days. The sample size of homes tested was limited and may not be representative of homes or cooking behaviors of the U.S. population in general.

The CPSC staff tests found that any smoke alarm placed too close to a cooking source caused nuisance alarms. The type of food cooked and the cooking method used influenced the number of nuisance alarms. For home 9, baking produced a higher percentage of nuisance alarms for ionization and dual-sensor smoke alarms. This type of cooking typically produces large quantities of small particles when the oven door is opened. However, all smoke alarm types that were less than 10 ft. to 15 ft. from the cooking appliance were susceptible to nuisance alarms, regardless of the cooking method used.

Dinnertime produced almost twice the number of smoke alarm activations as other meal times. This was expected since, typically, there are greater amounts of food cooked and cooking times tend to be longer at dinnertime.

Regardless of the smoke alarm type, placing the smoke alarm at least 10 to 15 feet from the main cooking appliance reduced the number of nuisance alarms. For smoke alarms placed closer than 10 to 15 feet to a cooking appliance, photoelectric smoke alarms produced the fewest number of nuisance alarms during CPSC staff tests, and photoelectric types also had the least variation in performance for the two manufacturers tested. For these tests, the performance of dual-sensor and ionization smoke alarms varied between manufacturers in sensitivity to cooking particles when installed within 10 to 15 feet of a cooking appliance.

Additional research on a larger sample size may be necessary to achieve a more accurate representation of the general population. Factors in an expanded research effort could include additional cooking behaviors, various kitchen configurations (e.g., different ceiling heights), exhaust fan usage, and additional smoke alarm locations. An evaluation of the effects of exhaust fan usage should include an investigation of whether the exhaust fan affects nuisance alarms at various distances from the cooking appliance. Additional research may also be necessary to evaluate the effectiveness of a hush feature on smoke alarms to determine if occupants will disable a smoke alarm that nuisance alarms frequently by removing the power source instead of using the hush feature. It is significant to note that the CPSC staff study did not evaluate the effectiveness of smoke alarms at various locations from the cooking source with regard to cooking fires. It would be important to examine the effects of smoke alarm location on detecting a cooking fire and minimizing nuisance alarms.

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17.0 REFERENCES

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APPENDIX A - DATA COLLECTED FROM INDIVIDUAL HOMES

A.1 Test Home 1

The home was built in 1998. The home is a single-family home that has a family room, dining room, and bathroom adjacent to the kitchen. The front foyer hallway also leads into the kitchen. There is an open floor plan between the kitchen and the family room. Figure A.1-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave, toaster oven, coffee maker, steamer, and dishwasher. The stove and oven use natural gas. The overhead exhaust fan is vented to the outside.

The household is a family of four, the parents and their two children. One parent works outside the home. The test period was extended one week to compensate for the approximate one week the family was on vacation away from home. The testing period was from the end of May to the beginning of July 2008. There were no non-cooking activations during the time period when the family was on vacation.

Home 1 had 56 cooking events during a 34-day period. The number of dinner and breakfast cooking events was about the same. Lunch produced half the number of cooking events. A smoke alarm activation at 20 feet from the main cooking appliance was accompanied by activations of the smoke alarms closer to the cooking appliance. The majority of the activations were during dinnertime cooking. Figure A.1-1 shows the distribution of the cooking events during different mealtimes. The exhaust fan was used for 3.6 percent of the cooking events, which did not appear to have a large effect on the number of activations.

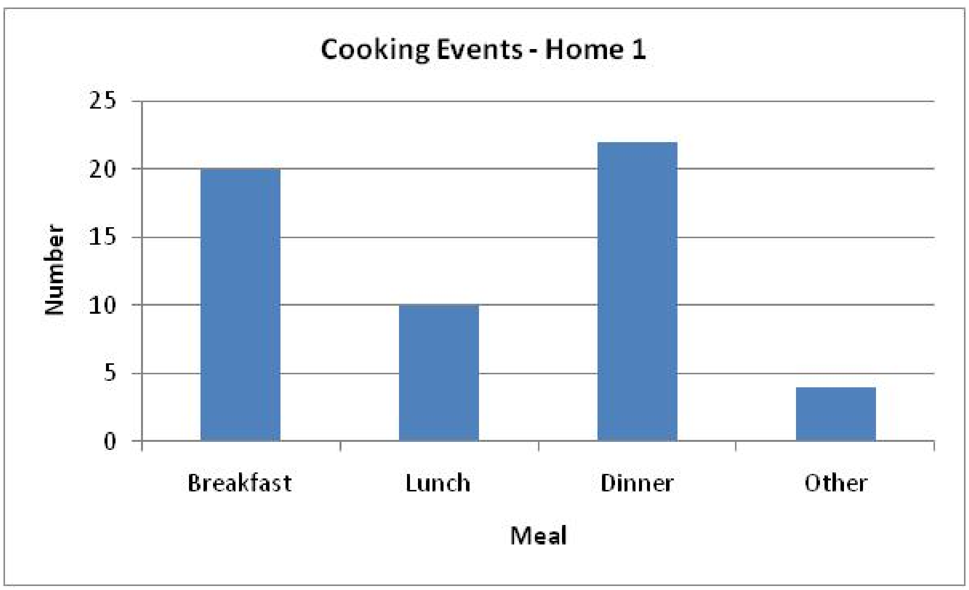


Figure A.1-1 Distribution of Cooking Events (Home 1)

The first group of smoke alarms (group 1) was located approximately 5 feet horizontally from and perpendicular to the front of the stove; group 1 smoke alarms were approximately in the center of the kitchen. The second group of smoke alarms (group 2) was located approximately 10 feet horizontally from and perpendicular to the front of the stove; group 2 smoke alarms were located above the eating/sitting area in the kitchen. The third group of smoke alarms (group 3) was located approximately 20 feet horizontally from the front of the stove. The smoke alarms were placed at a slight angle from the perpendicular because of the limited ceiling space in the kitchen. The smoke alarms were mounted at the entrance to the dining room, adjacent to the kitchen. Table A.1-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer A were used in home 1.

Table A.1-1 Smoke Alarm Placement (Manufacturer A)

Smoke Alarm Group	Left	Center	Right
1	I	P	D
2	D	P	I
3	I	P	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D – Dual-sensor smoke alarm

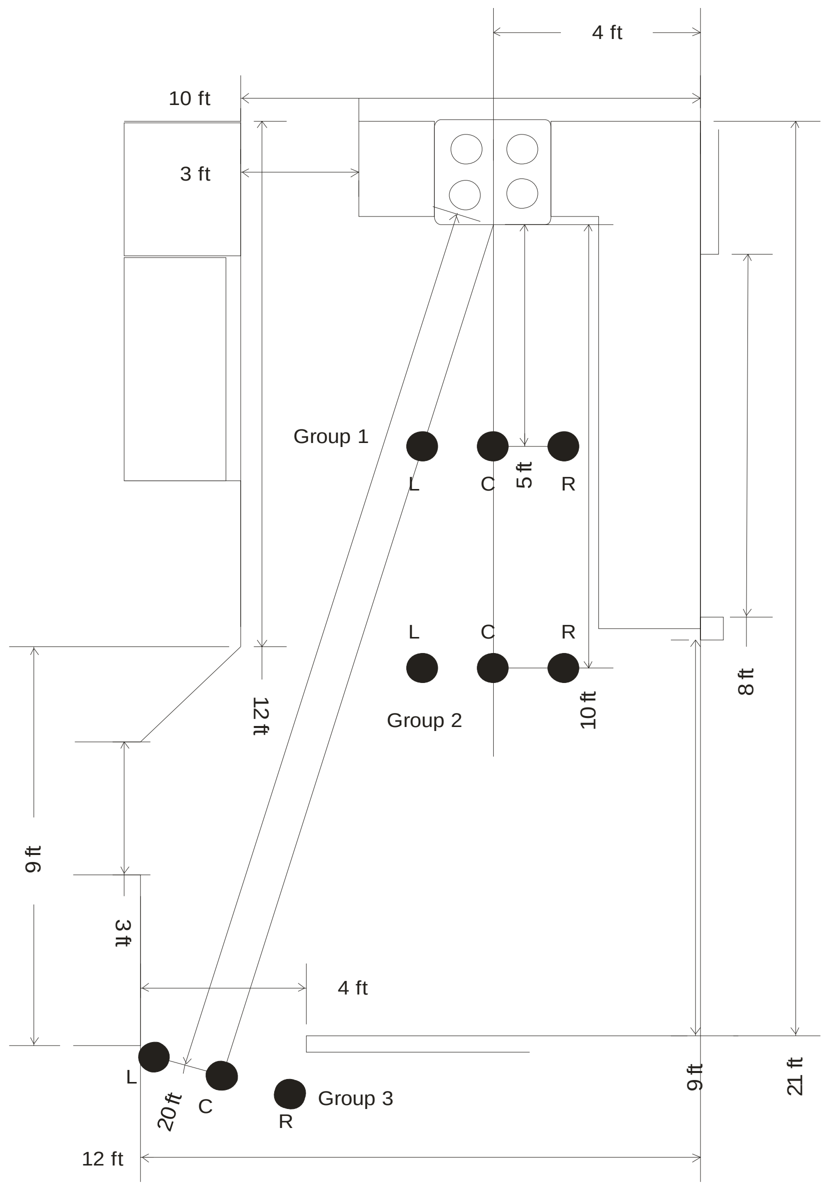
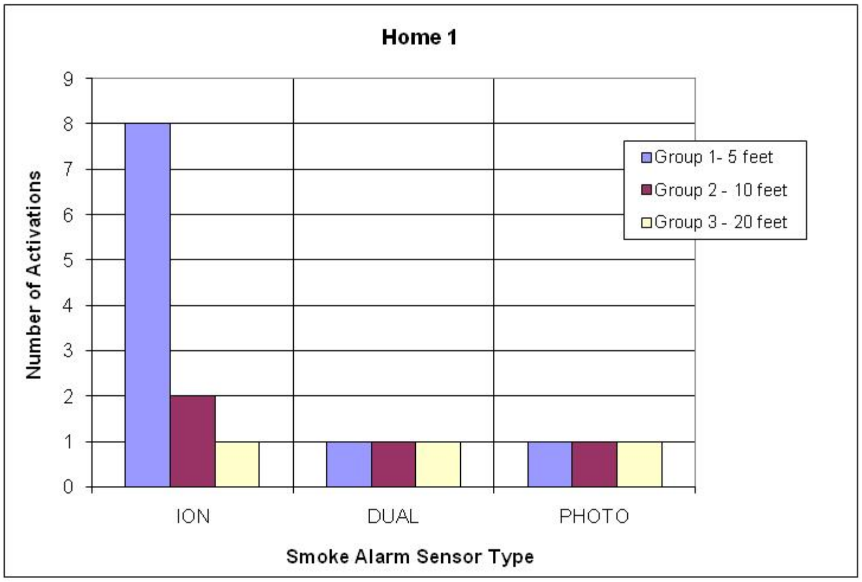


Figure A.1-2 Floor Layout for Test Home 1

Test home 1 had a total of 17 activations during the test period. Group 1 had a total of 11 activations; the ionization had eight activations, the photoelectric had two activations, and the dual-sensor had one activation. Group 2 had three activations; each smoke alarm had a single activation to the same cooking event. Group 3 had three activations; each smoke alarm had a single activation (in response to the same cooking event that caused activation of the group 2 alarms).



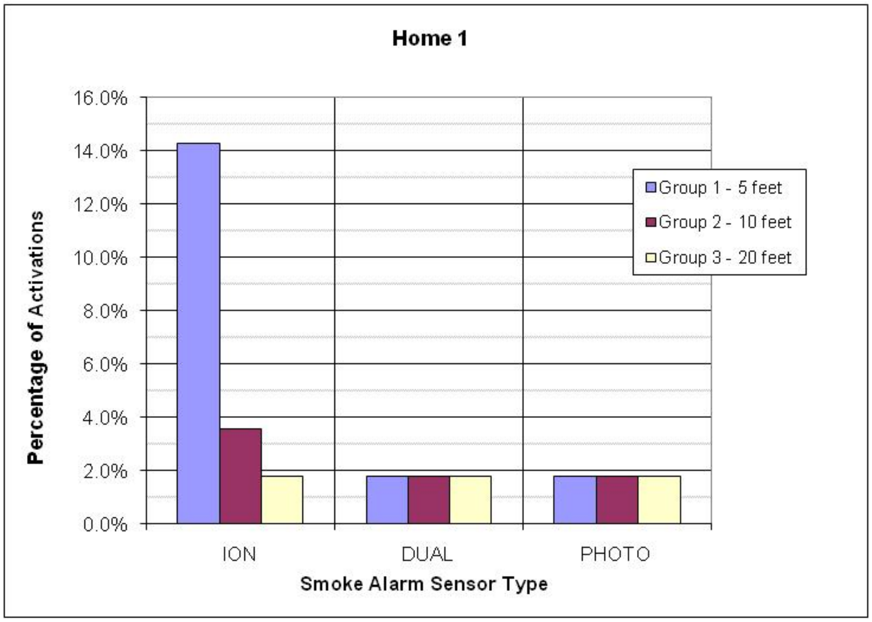


Figure A.1-3 Number and Percent of Activations from Cooking

A.2 Test Home 2

The home was built in 1988. The home is a single-family home that has a family room, dining room, and breakfast nook adjacent to the kitchen. The front foyer hallway also leads into the kitchen. There is an open floor plan between the kitchen and the family room and breakfast nook. Figure A.2-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a free-standing gas stove/oven located in the center of the kitchen. The stove and oven use propane. The kitchen has a microwave oven, coffee maker, and dishwasher. The overhead exhaust fan is vented to the outside.

The household is a family of two with no children. Both adults work outside the home. The test period was from the end of May to the end of June 2008.

Home 2 had 27 cooking events during a 36 day period. The number of lunch and breakfast cooking events were about the same. Dinner produced the majority of the cooking events. Figure A.2-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was used for 22.2 percent of the cooking events, which did not appear to have a great effect on the number of activations.

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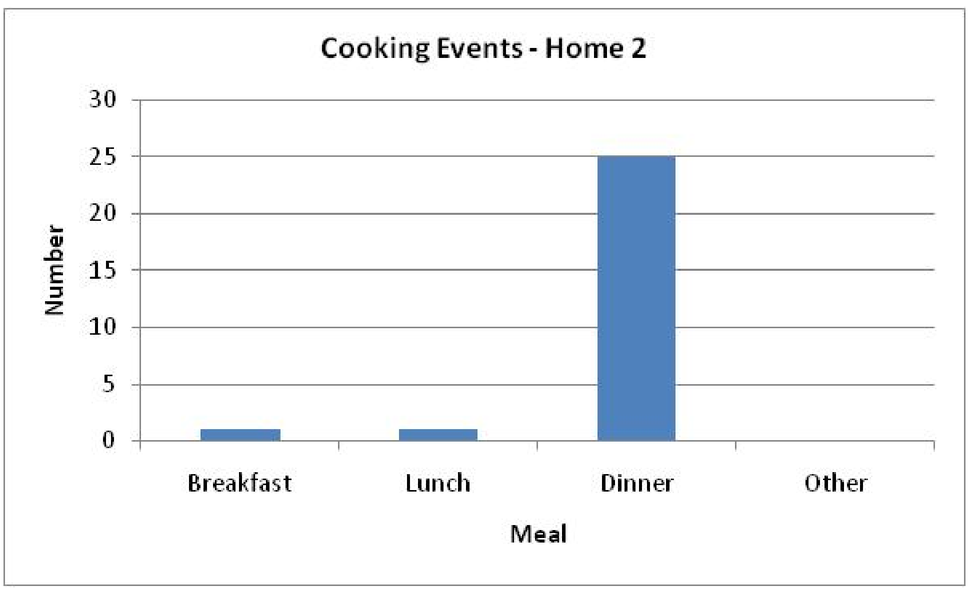


Figure A.2-1 Distribution of Cooking Events (Home 2)

The stove was located in the middle of the kitchen. The smoke alarm groups were placed in the direction leading toward the family room, which allowed enough ceiling space for the farthest smoke alarm group at 20 feet. Group 1 smoke alarms were located approximately 5 feet horizontally from and perpendicular to the side of the stove. Group 2 smoke alarms were located approximately 10 feet horizontally from and perpendicular to the side of the stove (which placed them just outside of the kitchen area and into the family room). Group 2 smoke alarms were located above a countertop eating/sitting area. Group 3 smoke alarms were located approximately 20 feet horizontally from the side of the stove. The smoke alarms were approximately in the center of the family room. The kitchen ceiling contains exposed beams which extended perpendicular to the direction of travel of cooking particles from the main cooking appliance to the smoke alarm groups. The cross section of the beams was approximately 8 inches x 8 inches. Table A.2-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer A were used in home 2.

Table A.2-1 Smoke Alarm Placement (Manufacturer A)

Smoke Alarm Group	Left	Center	Right
1	I	P	D
2	D	P	I
3	P	I	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D – Dual-sensor smoke alarm

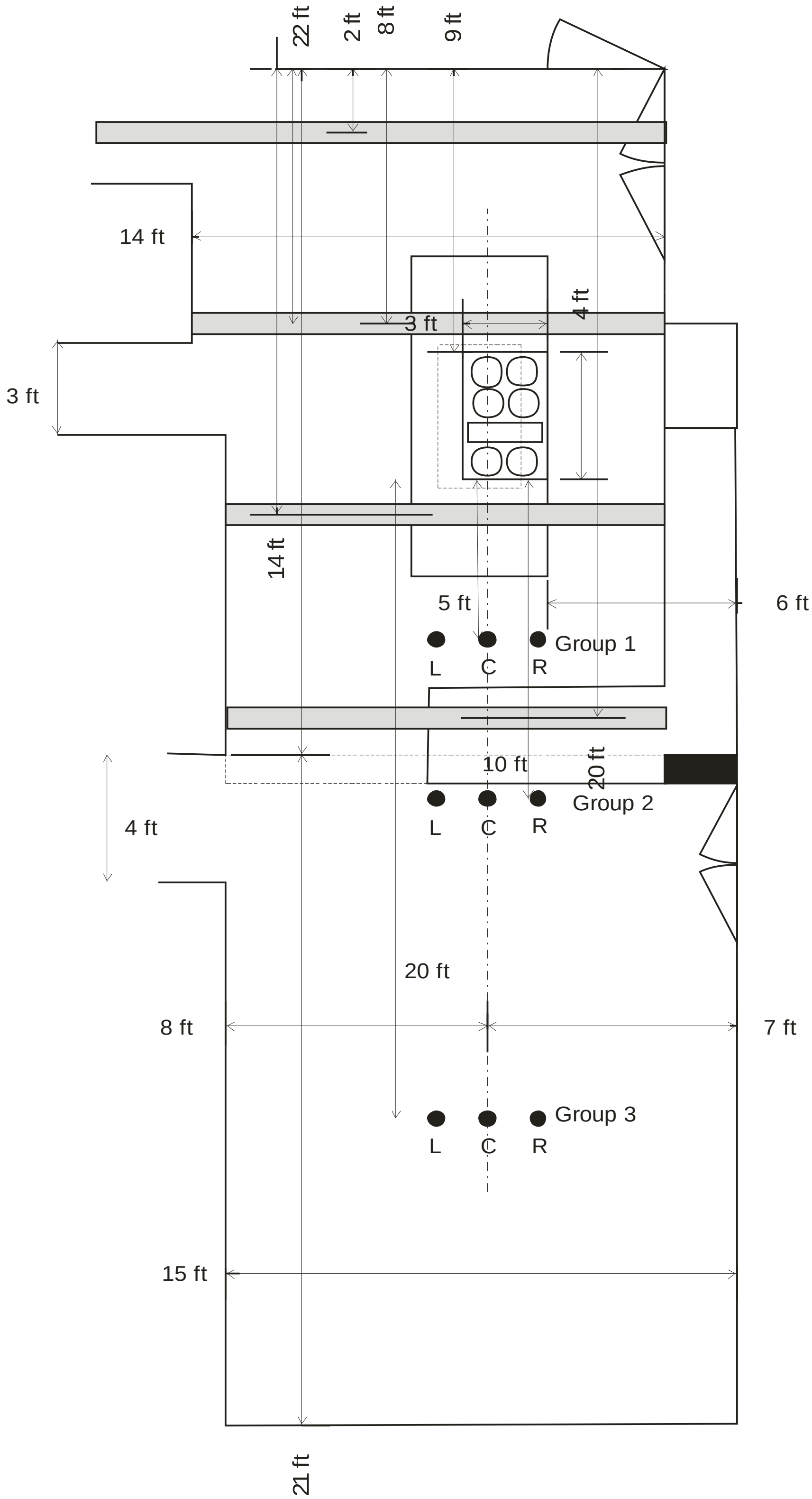
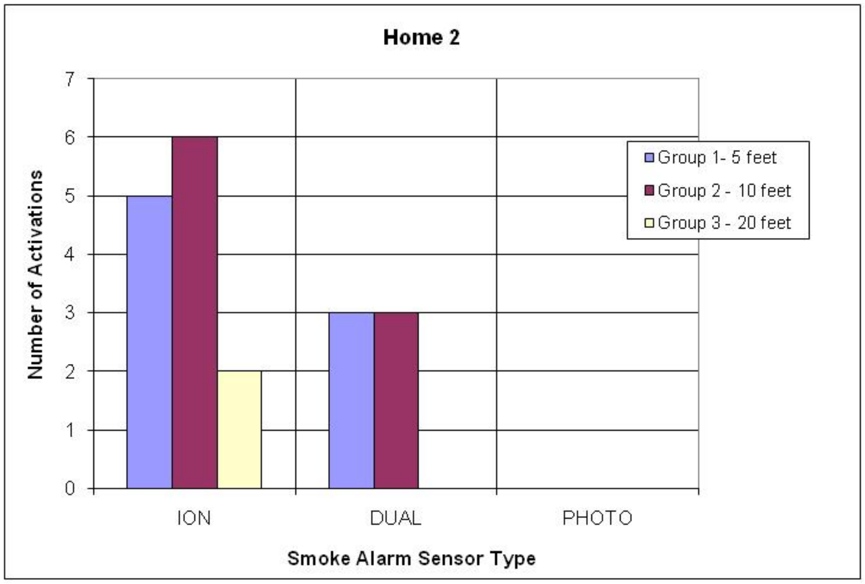


Figure A.2-2 Floor Layout for Test Home 2

Test home 2 had a total of 19 activations during the test period. Group 1 had eight activations, five of which involved the ionization smoke alarm. The other three activations involved the dual-sensor smoke alarm. Group 2 had a total of nine activations, six involving the ionization smoke alarm and three involving the dual-sensor smoke alarm. Group 3 had two activations, both of which involved the ionization smoke alarm. There were no activations of photoelectric smoke alarms at any location.



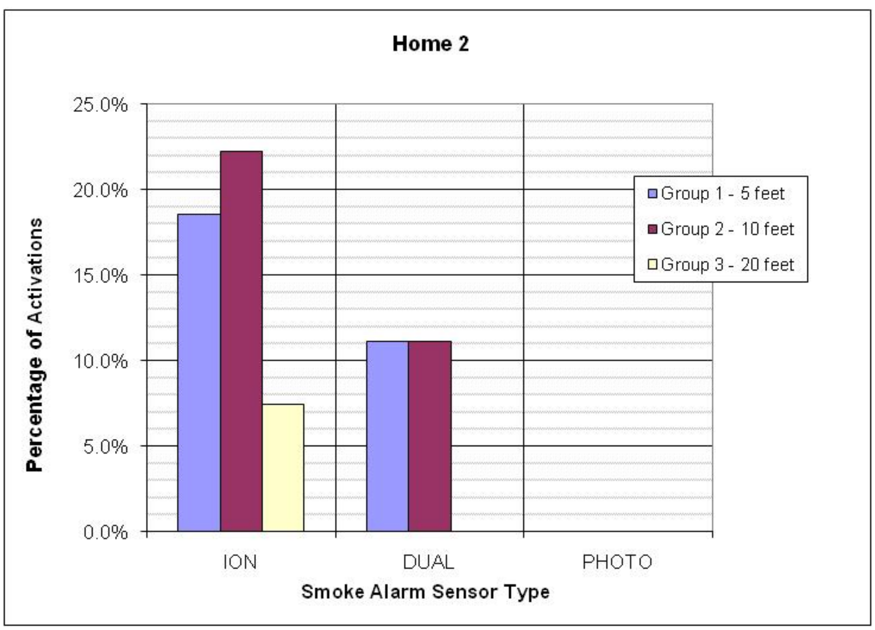


Figure A.2-3 Number and Percent of Activations from Cooking

A.3 Test Home 3

The home was built in 1979. The home is a single-family home that has a family room, a hallway, and bathroom adjacent to the kitchen. The front foyer hallway leads into the kitchen. The kitchen is a closed floor plan between the kitchen and the family room. Figure A.3-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave oven, toaster oven, coffee maker, steamer, and dishwasher. The stove and oven are electric. The overhead exhaust fan is vented to the outside.

The household is a family of two adults. One adult works outside the home, and the other adult is retired.

Home 3 had 27 cooking events during a 31-day period. The number of dinner, lunch, and breakfast cooking events varied. Dinner produced the most cooking events followed by breakfast and then lunch. Figure A.3-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was not used during any of the cooking events.

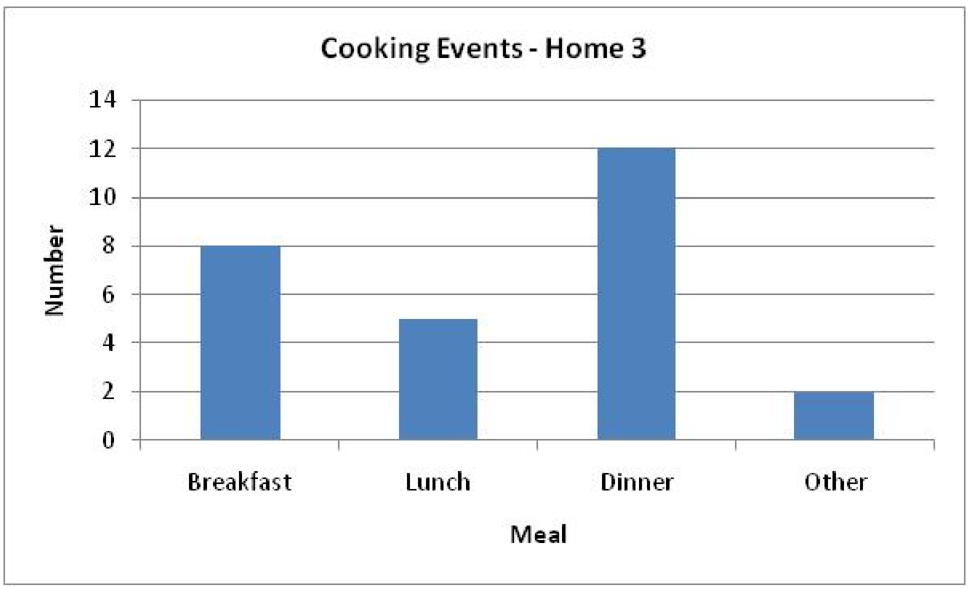


Figure A.3-1 Distribution of Cooking Events (Home 3)

Group 1 smoke alarms were located approximately 5 feet horizontally from and perpendicular to the front of the stove (approximately in the center of the kitchen). Group 2 smoke alarms were located approximately 10 feet horizontally from and perpendicular to the front of the stove, which placed the alarms in the hallway to the foyer. The spacing between the smoke alarms had to be decreased slightly because of the 3-foot width limitation of the hallway. Group 3 smoke alarms were located approximately 20 feet horizontally from the front of the stove. The smoke alarms were placed in the foyer near the front entrance door. Table A.3-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer A were used in home 3.

Table A.3-1 Smoke Alarm Placement (Manufacturer A)

Smoke Alarm Group	Left	Center	Right
1	I	P	D
2	D	P	I
3	D	I	P

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D– Dual-sensor smoke alarm

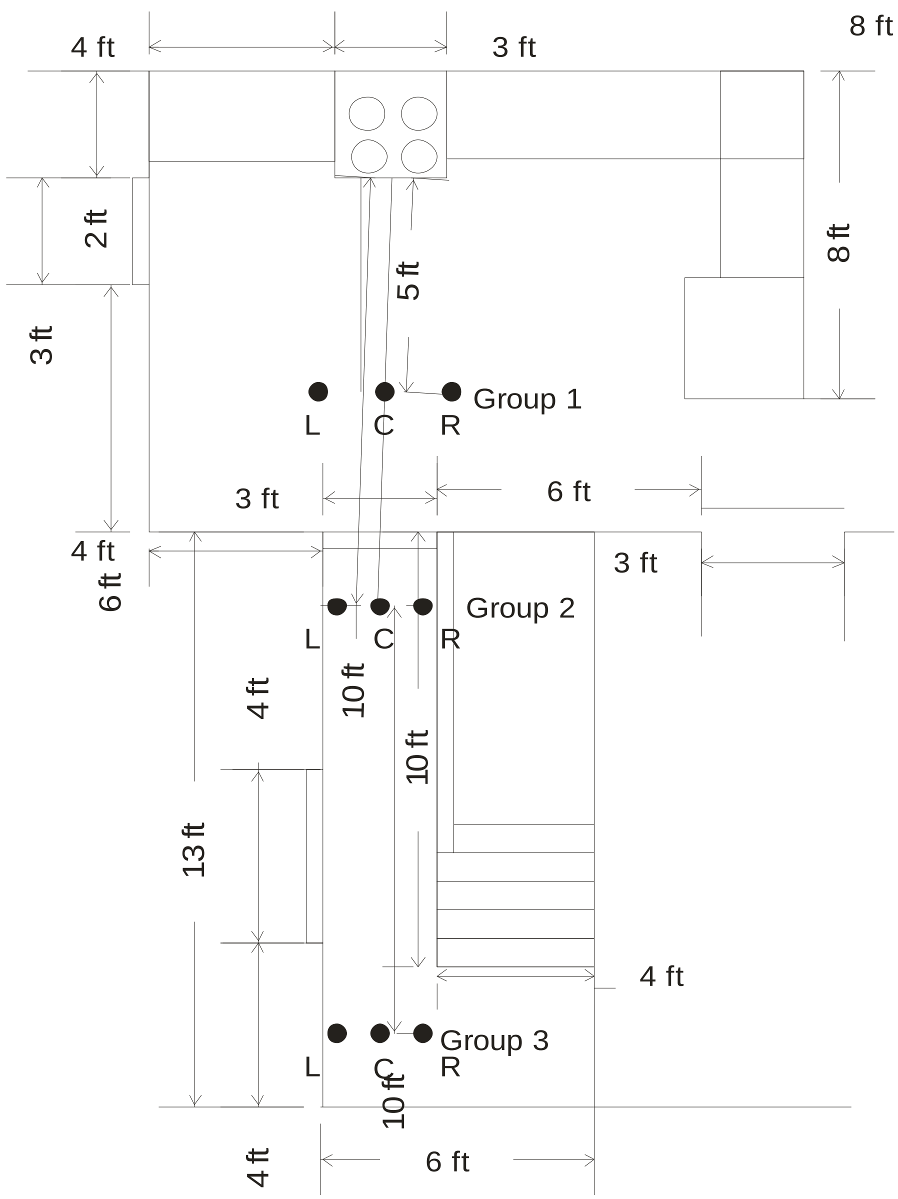
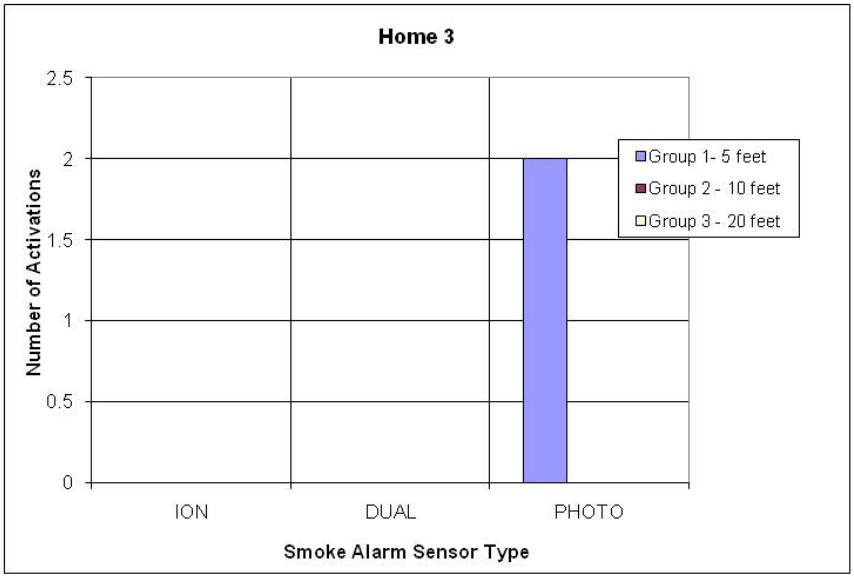


Figure A.3-2 Floor Layout for Test Home 3

Test home 3 had a total of two activations during the test period. The two activations involved the group 1 photoelectric smoke alarm. One activation was caused by browning meats, and the other activation was caused by browning sausage and onions.



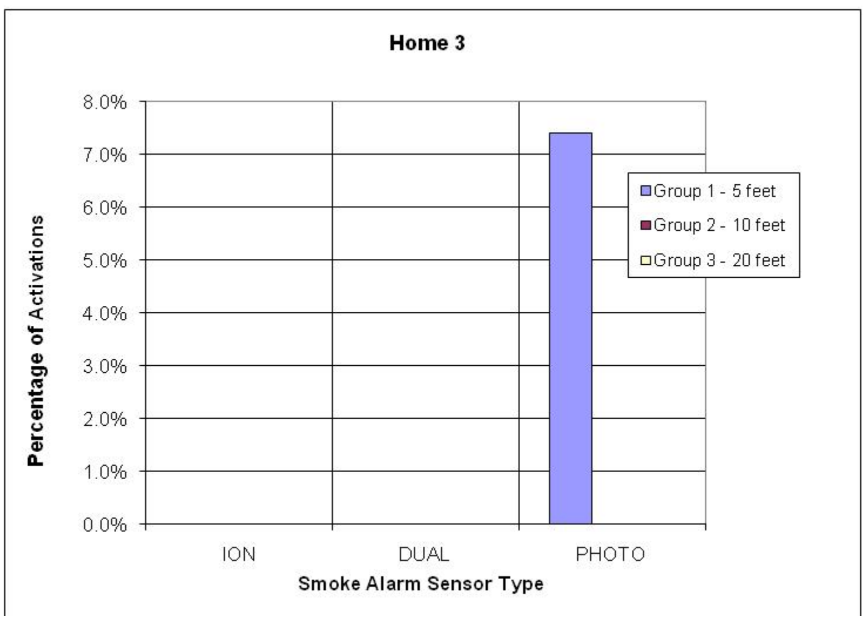


Figure A.3-3 Number and Percent of Activations from Cooking

A.4 Test Home 4

The home was built in 1926. The home is a single-family home that has a dining room adjacent to the kitchen. This home has a closed floor plan. The kitchen was built as an addition to the home in 1930. Figure A.4-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave oven, toaster, coffee maker, steamer, and dishwasher. The stove and oven use natural gas. The stove/oven was located in the corner of the room. The overhead exhaust fan was vented to the outside. The kitchen also had a ceiling fan in the center of room.

The household is a family of three, two adults and one child. Both parents worked outside the home.

Home 4 had 33 cooking events during a 33-day period. The number of dinner and breakfast cooking events was about the same. There were no recorded cooking events during lunchtime. Figure A.4-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was used for 9.1 percent of the cooking events, which did not appear to have a great effect on the number of activations. The ceiling fan was not used during any of the cooking events.

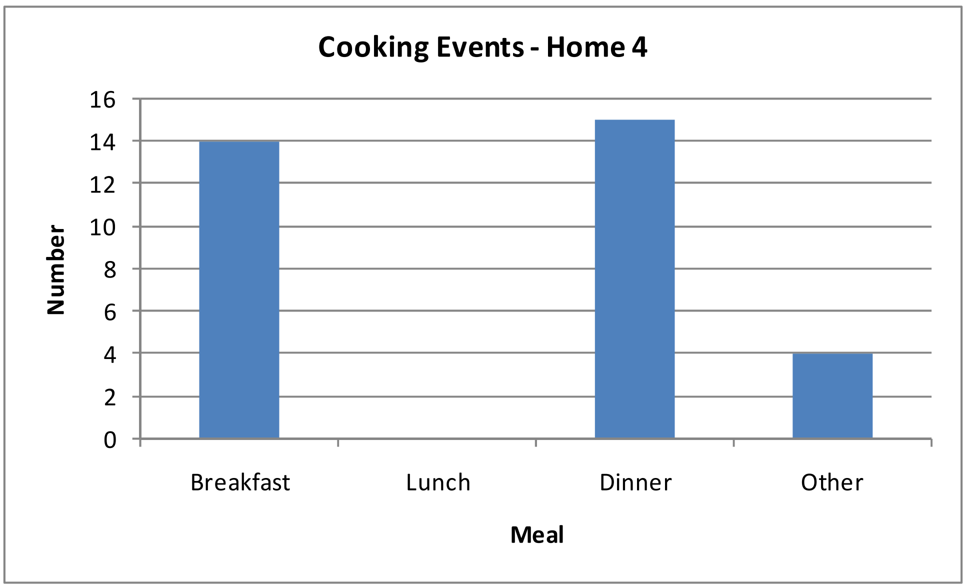


Figure A.4-1 Distribution of Cooking Events (Home 4)

Group 1 smoke alarms were located approximately 5 feet from the front of the stove leading toward the dining room. Group 2 smoke alarms had a choice of being located either in the hallway in line with group 1 or within the kitchen. The choice was to place group 2 within the kitchen. Group 2 was located approximately 10 feet horizontally from and perpendicular to the front of the stove, in close proximity to the ceiling fan. Group 3 smoke alarms were located approximately 20 feet horizontally from the stove, in the dining room. It was noticed later (after the testing was completed) that the group 3 smoke alarms were placed near an intake register on the upper portion of an adjacent wall. Table A.4-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer B were used in home 4.

Table A.4-1 Smoke Alarm Placement (Manufacturer B)

Smoke Alarm Group	Left	Center	Right
1	D	I	P
2	D	P	I
3	I	P	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D – Dual-sensor smoke alarm

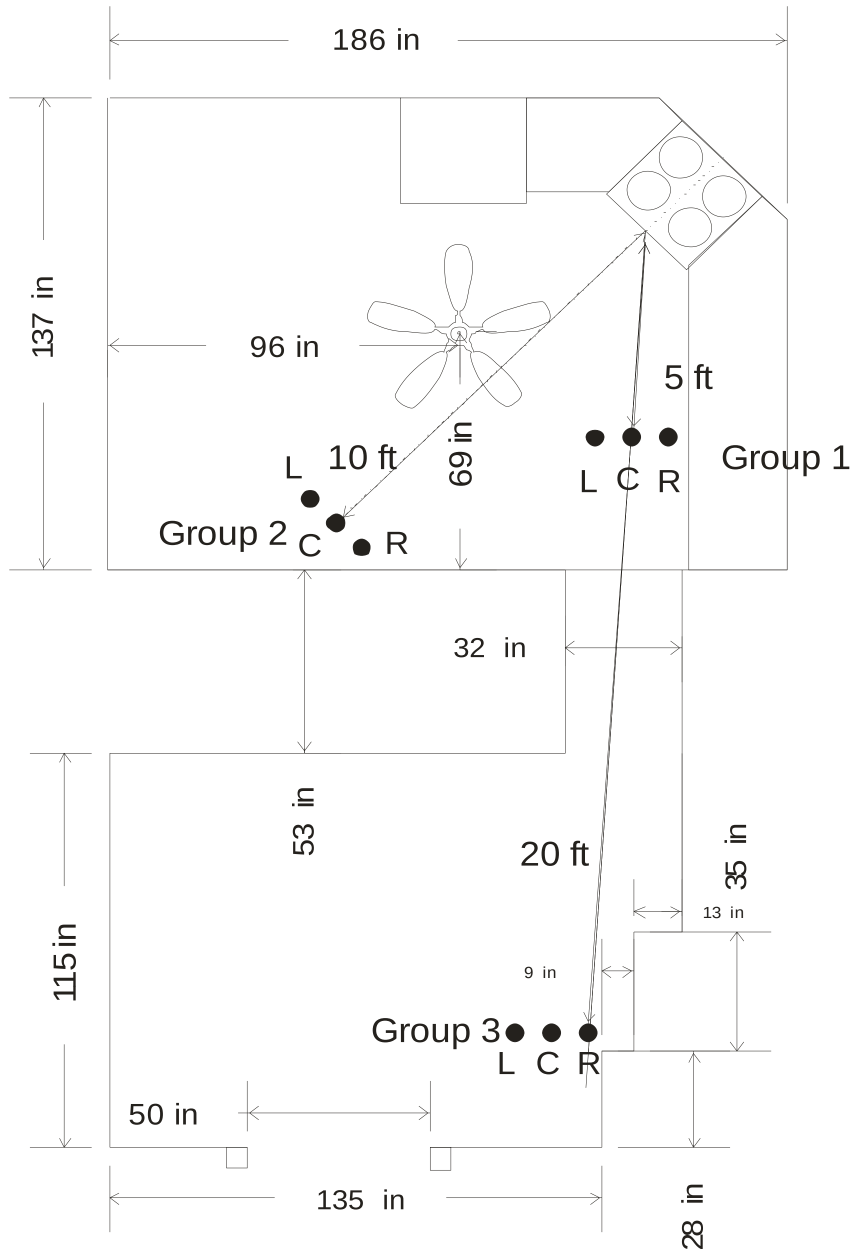
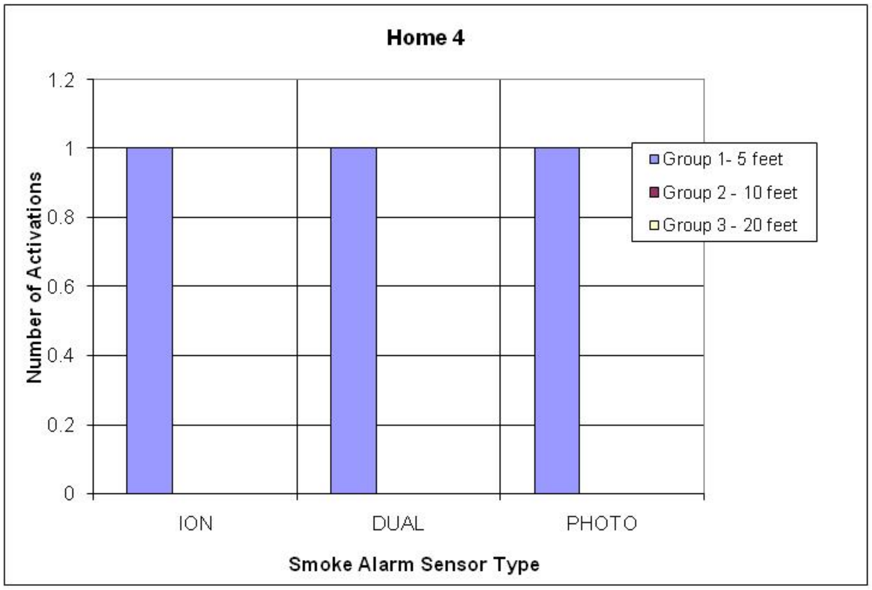


Figure A.4-2 Floor Layout for Test Home 4

Test home 4 had a total of three activations during the test period. All the activations involved group 1 smoke alarms. Each group 1 smoke alarm had a single activation associated with one dinnertime cooking event of frying fish and boiling beans and corn. The activations were most likely caused by frying fish.



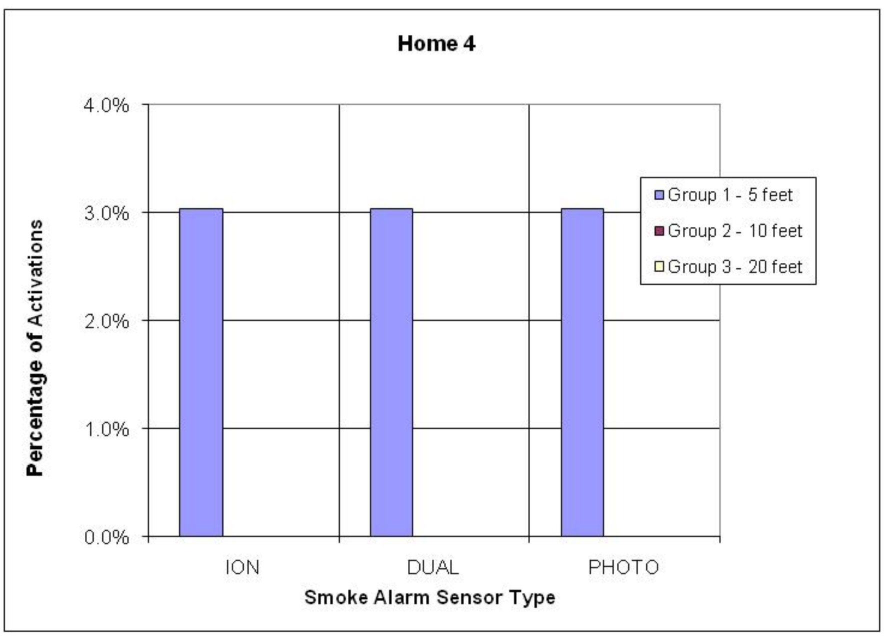


Figure A.4-3 Number and Percent of Activations from Cooking

A.5 Test Home 5

The home was built in 1964. The home is a single-family home that has a dining room adjacent to the kitchen. There is an open floor plan between the kitchen and the dining room. Figure A.5-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding gas stove/oven, microwave oven, toaster, steamer, and dishwasher. The overhead exhaust fan was a recirculating type. The kitchen also had a ceiling fan in the center of the room.

The household is a family of three, two adults and a child. One parent worked full-time outside the home, and the other parent worked part-time outside the home. At the time of the testing, the part-time parent was at home on bed rest because of her pregnancy.

Home 5 had 19 cooking events during a 35-day period. The number of dinner, lunch, and breakfast cooking events varied. Dinner had the most cooking events, followed by lunch, and then breakfast. Figure A.5-1 shows the distribution of cooking events for the different mealtimes. The exhaust fan was not used during any of the cooking events.

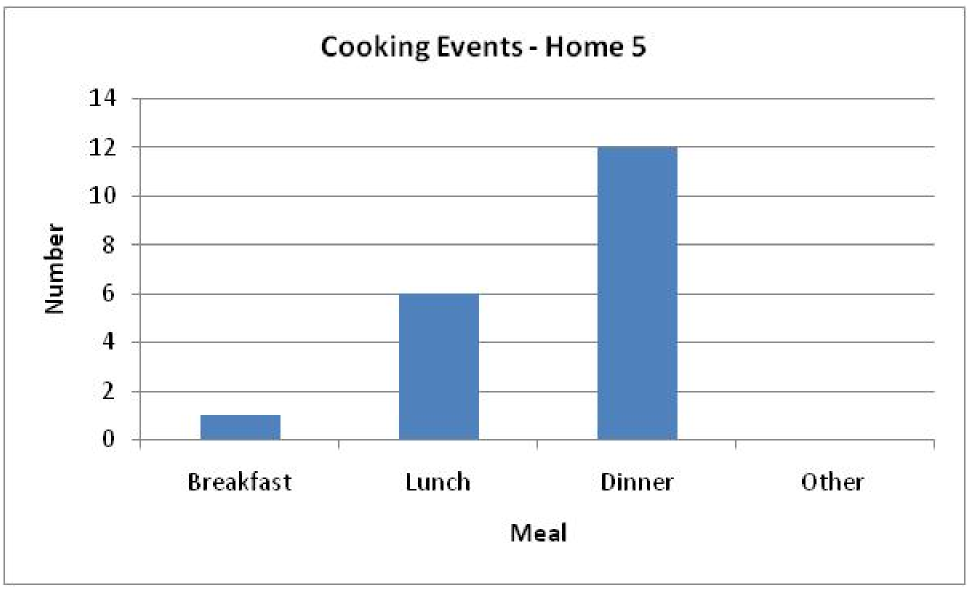


Figure A.5-1 Distribution of Cooking Events (Home 5)

Group 1 smoke alarms were located approximately 5 feet horizontally from and perpendicular to the front of the stove. Group 2 smoke alarms were located approximately 10 feet horizontally from and perpendicular to the front of the stove (in the dining room adjacent to the kitchen). Since the ceiling space from the kitchen to the farthest dining room wall was less than 20 feet, group 3 smoke alarms were placed in the living room. Group 3 smoke alarms were located approximately 20 feet, measured by the shortest path horizontally along the ceiling from the stove. Table A.5-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer B were used in home 5.

Table A.5-1 Smoke Alarm Placement (Manufacturer B)

Smoke Alarm Group	Left	Center	Right
1	P	I	D
2	D	P	I
3	P	I	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D– Dual-sensor smoke alarm

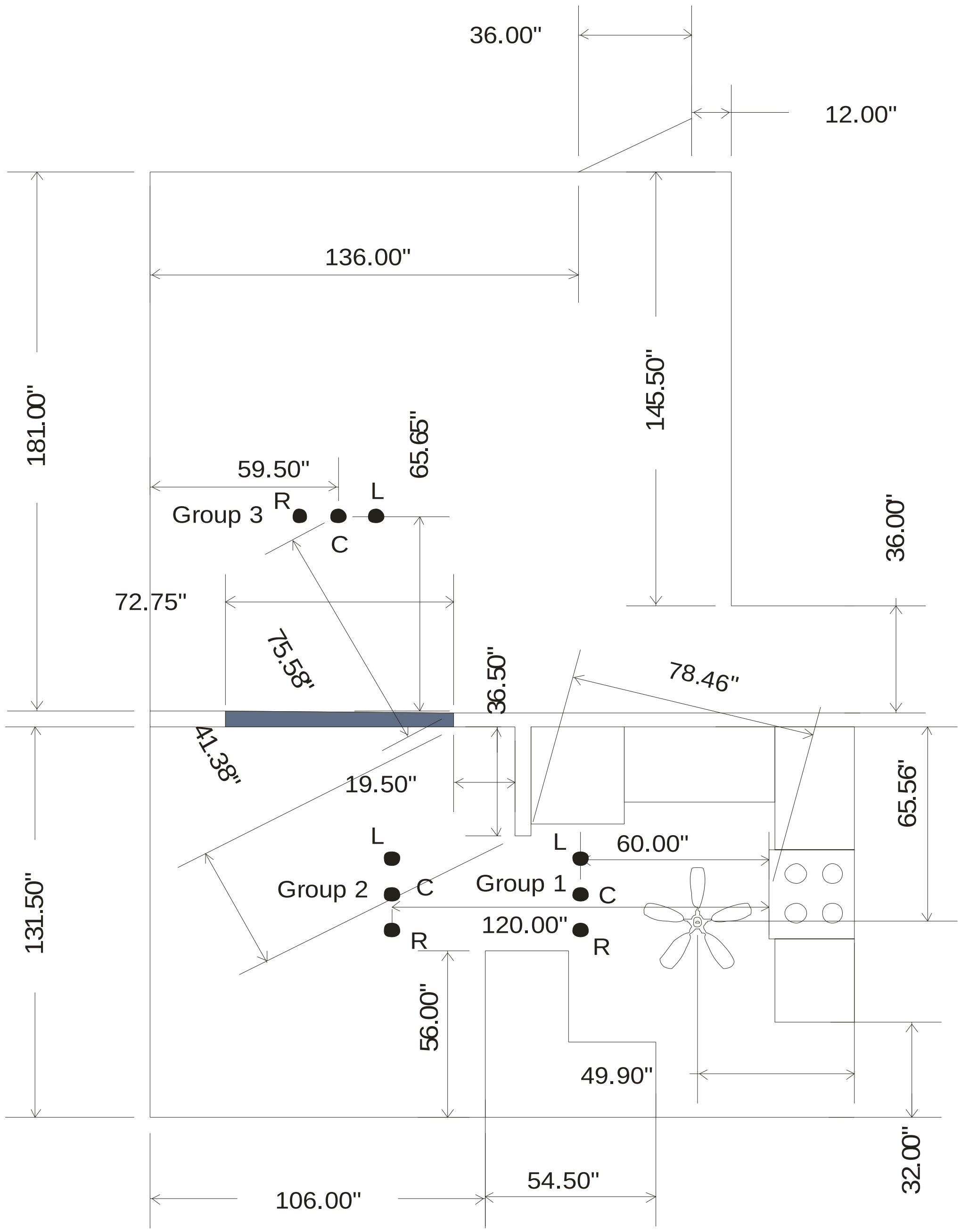
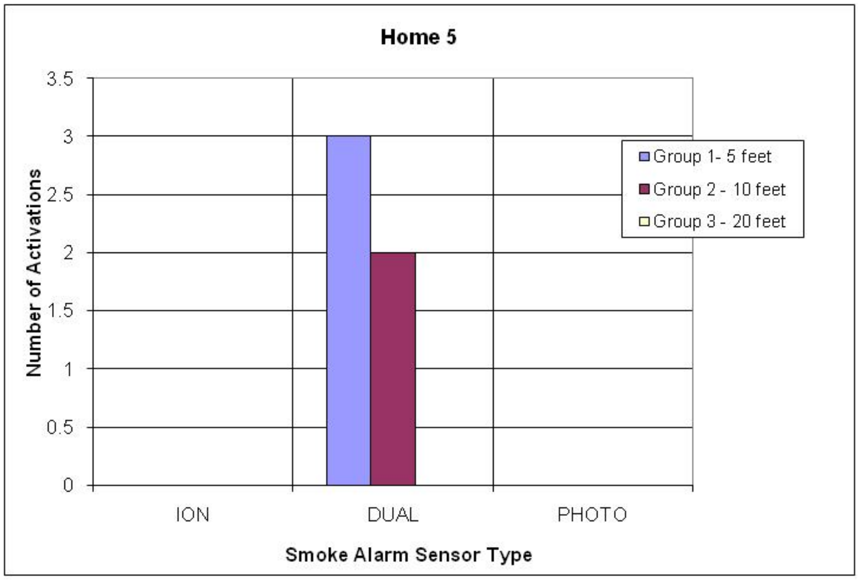


Figure A.5-2 Floor Layout for Test Home 5

Test home 5 had a total of five activations during the test period. All the activations involved the dual-sensor smoke alarms in groups 1 and 2. Group 1 had three activations, two of which occurred during separate dinnertime cooking events (steaming rice and baking chicken breasts, and boiling tortellini and toasting garlic bread in the oven). The other group 1 activation occurred during a lunchtime cooking event of toasting a bagel in the toaster.

There were two group 2 dual-sensor smoke alarm activations. One occurred during a breakfast cooking event (frying eggs on the stove). The other occurred in response to the same cooking event that activated a group 1 alarm (steaming rice and baking chicken breasts in the oven).



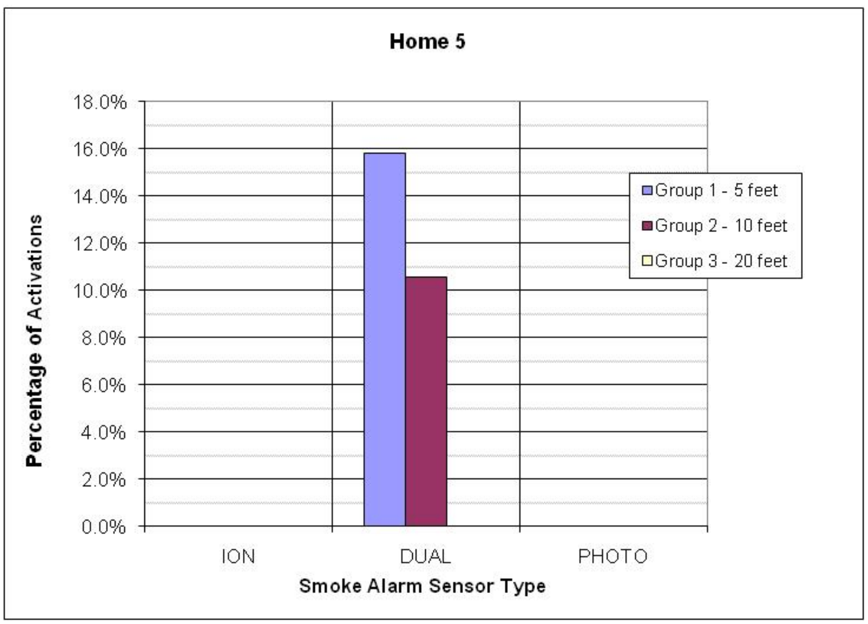


Figure A.5-3 Number and Percent of Activations from Cooking

A.6 Test Home 6

The home was built in 1985. The home is a single-family home that has a family room, dining room, and hallway adjacent to the kitchen. The front foyer hallway leads into the kitchen. There is an open floor plan between the kitchen and the family room. Figure A.6-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave oven, toaster oven, coffee maker, and dishwasher. The stove/oven uses natural gas. The overhead exhaust fan is vented to the outside.

During the test period, there were three adults and one child in the household (including a niece between 19 and 30 years old, who was staying in the home at the time). Both parents work outside the home.

Home 6 had 55 cooking events during a 40-day period. The number of dinnertime and breakfast cooking events was about the same. Lunch produced a quarter of the number of cooking events as either dinner or breakfast. Figure A.6-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was used for 10.9 percent of the cooking events, which did not appear to have a great effect on the number of activations.

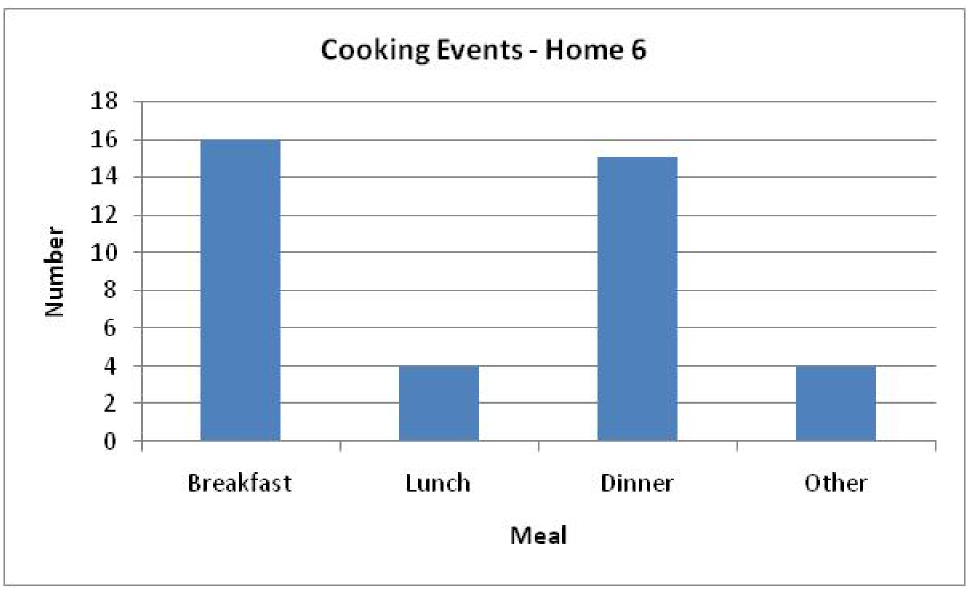


Figure A.6-1 Distribution of Cooking Events (Home 6)

Group 1 smoke alarms were located approximately 5 feet from the front of the stove. Group 2 smoke alarms were located approximately 10 feet from the front of the stove, in line with the group 1 alarms. Group 3 smoke alarms were located approximately 20 feet horizontally from the front of the stove, in the hallway to the foyer. The smoke alarms were placed at a slight angle from the center line of groups 1 and 2 to avoid the heating and cooling intake register. It was noticed after the test period that group 3 alarms would be unlikely to activate from cooking because of a ceiling height change between the kitchen, family room, and hallway. Although the ceiling height of the kitchen and hallway were the same, the family room in between had a cathedral ceiling. Any cooking particles that traveled from the kitchen to the family room would likely be trapped along the higher ceiling and would not travel back down to the ceiling in the hallway, with the group 3 smoke alarms. Table A.6-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer B were used in home 6.

Table A.6-1 Smoke Alarm Placement (Manufacturer B)

Smoke Alarm Group	Left	Center	Right
1	I	P	D
2	P	D	I
3	I	P	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D– Dual-sensor smoke alarm

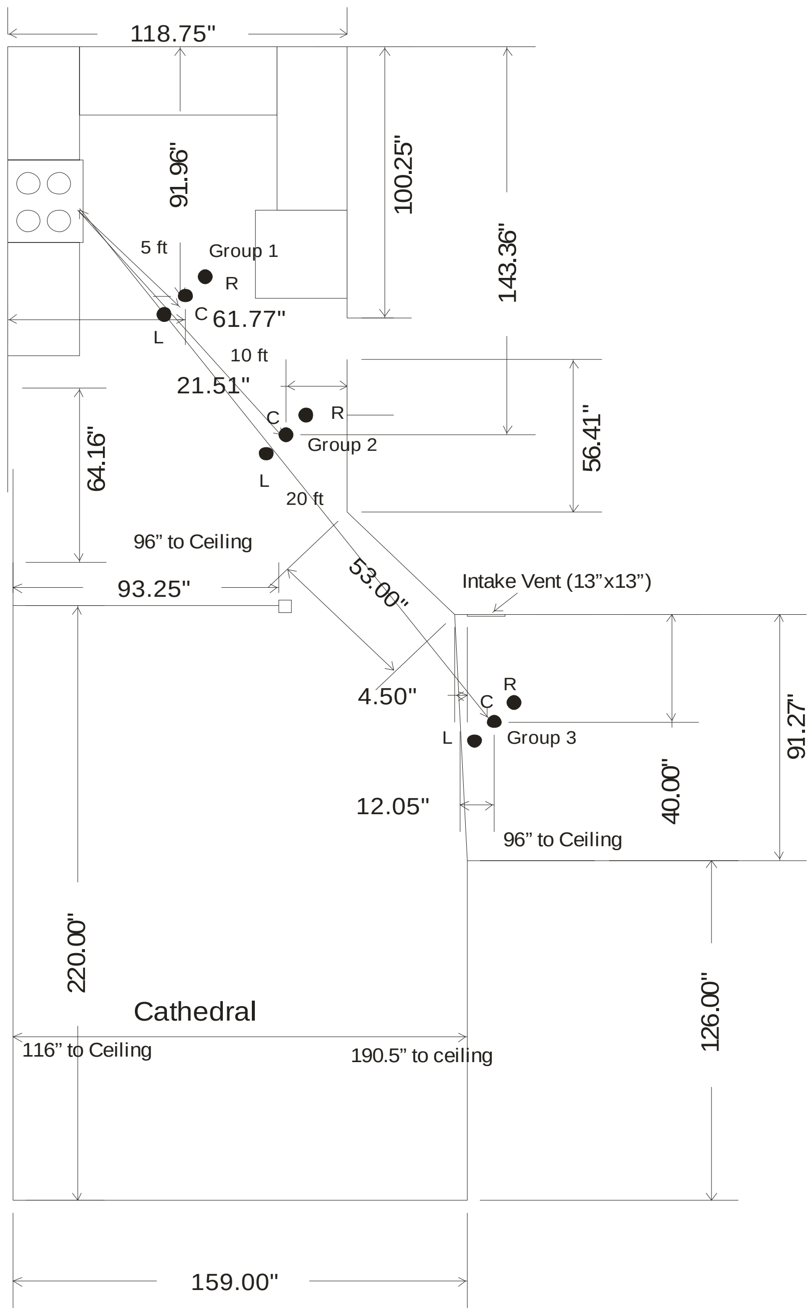
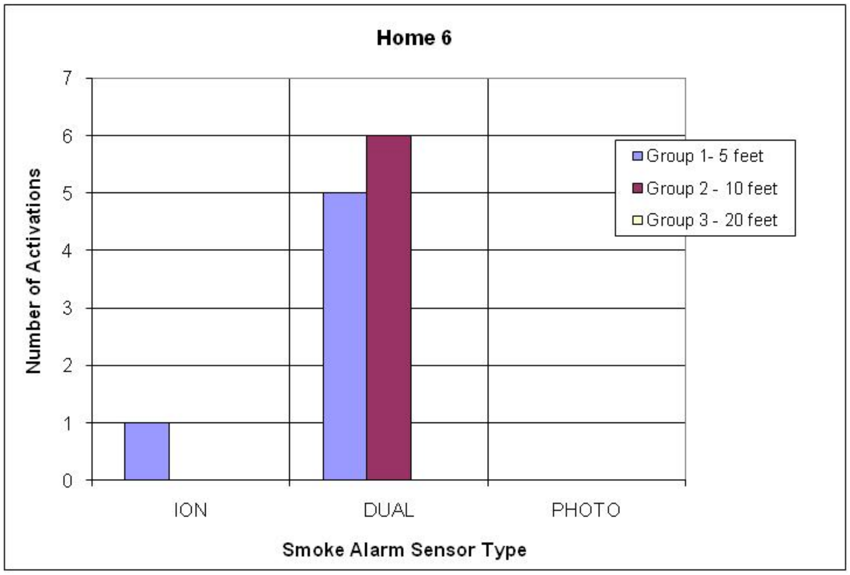


Figure A.6-2 Floor Layout for Test Home 6

Test home 6 had a total of 12 activations during the test period. Group 1 had six activations – one involving the ionization smoke alarm and five involving the dual-sensor smoke alarm. Group 2 had six activations, all of which involved the dual-sensor smoke alarm. All the activations appeared to have been caused by cooking events associated with the toaster or oven. The activations occurred during all three mealtimes (breakfast, lunchtime, and dinnertime). There were no activations of the photoelectric smoke alarms (groups 1, 2, and 3) during the test period.



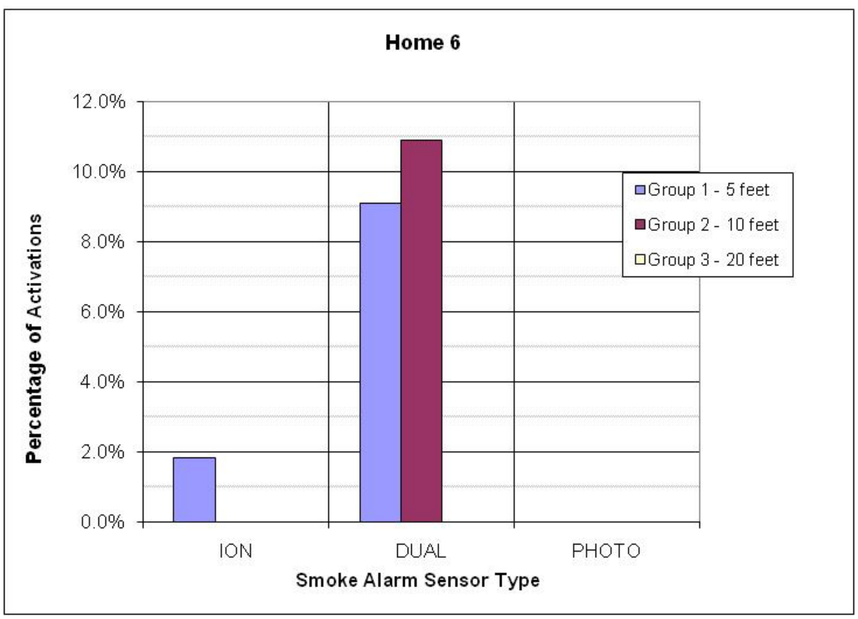


Figure A.6-3 Number and Percent of Activations from Cooking

A.7 Test Home 7

The home was built in 1952. The home is a single-family home that has a living room and dining room adjacent to the kitchen. Figure A.7-3 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave oven, toaster, toaster oven, and coffee maker. The stove/oven uses natural gas. There is no exhaust fan in the kitchen, but there is a window adjacent to the stove that may be used for venting.

The household is a family of four, the parents and two children. Both parents work outside the home.

Home 7 had 17 cooking events during a 39 day period. The number of lunchtime and breakfast cooking events was about the same. Dinnertime produced the most cooking events. Figure A.7-1 shows the distribution of the cooking events for the different mealtimes.

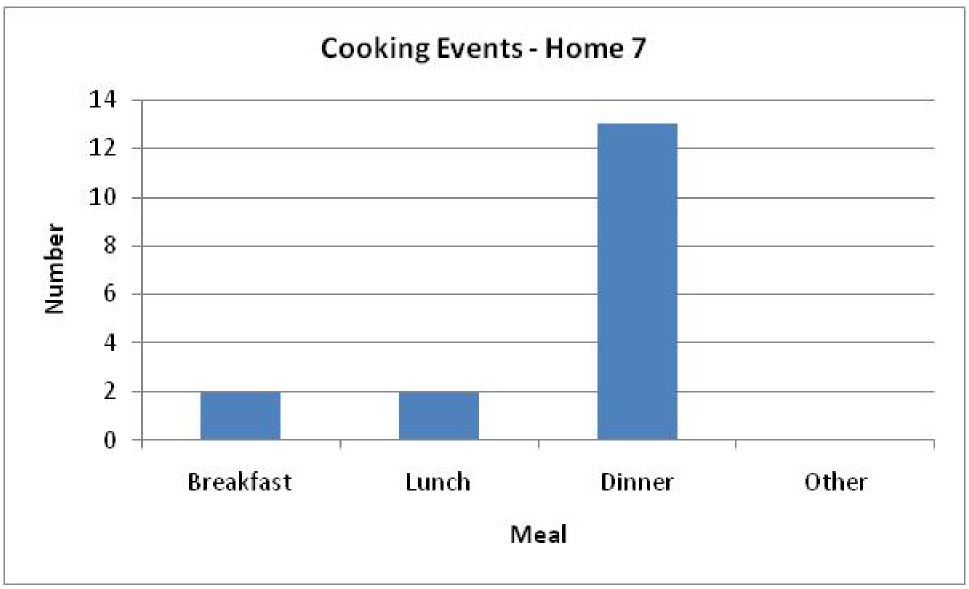


Figure A.7-1 Distribution of Cooking Events (Home 7)

Group 1 smoke alarms were located approximately 5 feet horizontally from the front of the stove. Group 2 smoke alarms were located approximately 10 feet from the front of the stove, which was near the entrance to the living room. Group 3 smoke alarms were located approximately 20 feet horizontally from the front of the stove, which placed the smoke alarms in the living room. The home's front door entrance led into the living room, and there was a ceiling fan in the middle of the room. Table A.7-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer A were used in home 7.

Table A.7-1 Smoke Alarm Placement (Manufacturer A)

Smoke Alarm Group	Left	Center	Right
1	I	P	D
2	D	P	I
3	I	P	D

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D– Dual-sensor smoke alarm

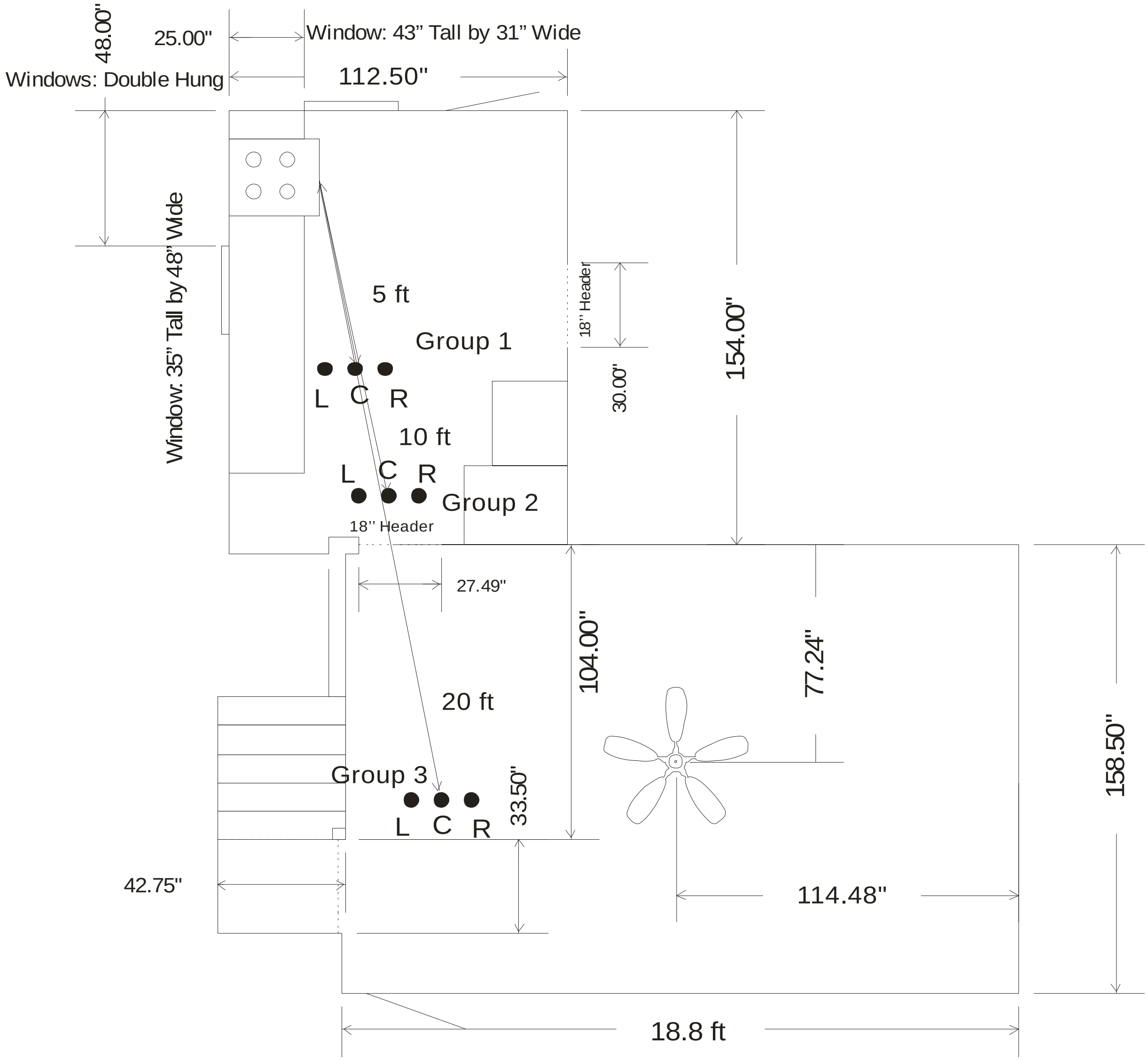
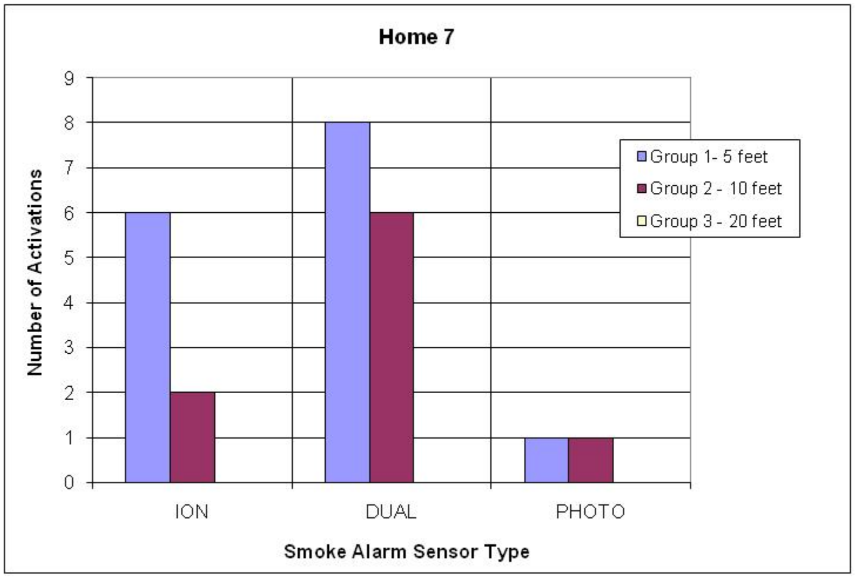


Figure A.7-2 Floor Layout for Test Home 7

Test home 7 had a total of 24 activations during the test period. Group 1 had 15 activations – six involving the ionization smoke alarms, one involving the photoelectric smoke alarm, and eight involving the dual-sensor smoke alarm. Group 2 had nine activations – two involving the ionization smoke alarm, one involving the photoelectric smoke alarm, and six involving the dual-sensor smoke alarm. There were no activations involving the group 3 smoke alarms.



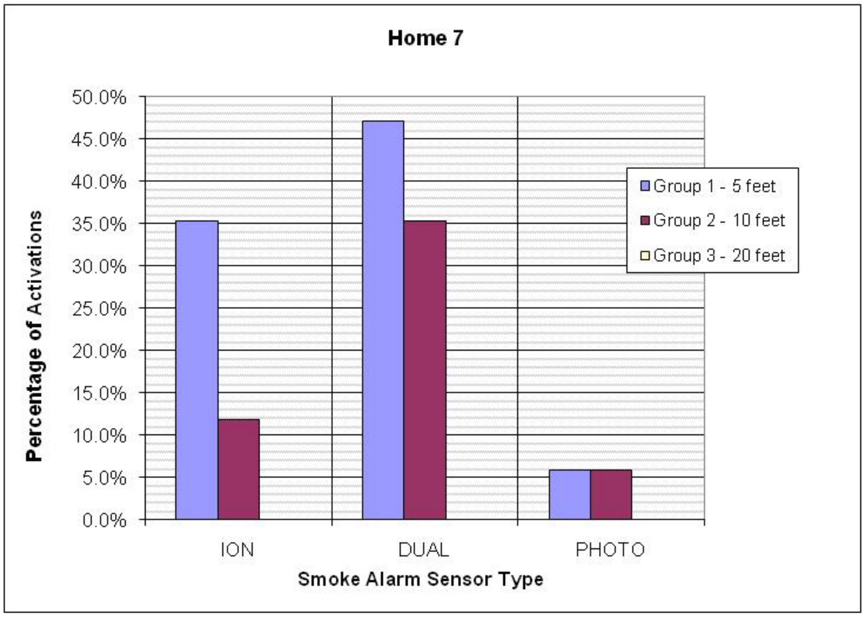


Figure A.7-3 Number and Percent of Activations from Cooking

A.8 Test Home 8

The home was built in 1986. The home is a multi-family home with a hallway adjacent to the kitchen. The front foyer hallway leads into the kitchen. There is a pass-through above the sink from the kitchen to the family room. Figure A.8-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a freestanding stove/oven, microwave oven, toaster, and dishwasher. The stove/oven is electric. The overhead exhaust fan is vented to the outside.

The household is a family of two, an adult and a teenager. The adult works outside the home.

Home 8 had 13 cooking events during a 28-day period. Most of the cooking events occurred at dinnertime, followed by lunchtime and then breakfast. Figure A.8-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was used for 23.1 percent of the cooking events, which did not appear to have a great effect on the number of activations.

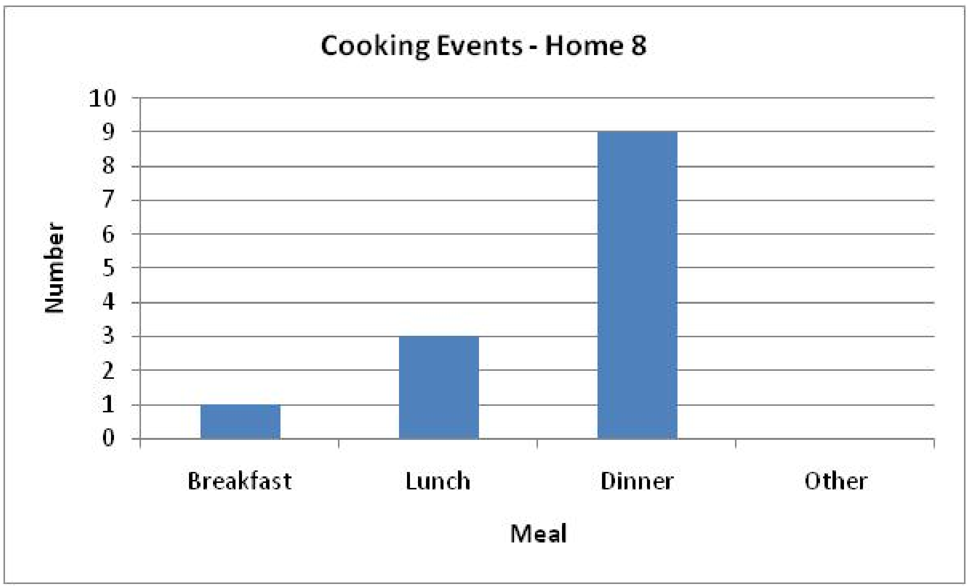


Figure A.8-1 Distribution of Cooking Events (Home 8)

Because the ceiling of home 8 had a textured surface to which foam adhesive would not adhere, the smoke alarms were mounted on walls, just below the junction with the ceiling. Group 1 smoke alarms were located approximately 5 feet horizontally from the front of the stove, above some kitchen cabinets. Group 2 smoke alarms were located approximately 10 feet horizontally from the front of the stove. Group 3 smoke alarms were located approximately 20 feet from the front of the stove on the bulkhead of the hallway leading into the family room. Table A.8-1 lists the locations and placement of the smoke alarms. Smoke alarms from manufacturer A were used in home 8.

Table A.8-1 Smoke Alarm Placement (Manufacturer A)

Smoke Alarm Group	Left	Center	Right
1	D	I	P
2	I	D	P
3	D	I	P

I – Ionization smoke alarm
P – Photoelectric smoke alarm
D – Dual-sensor smoke alarm

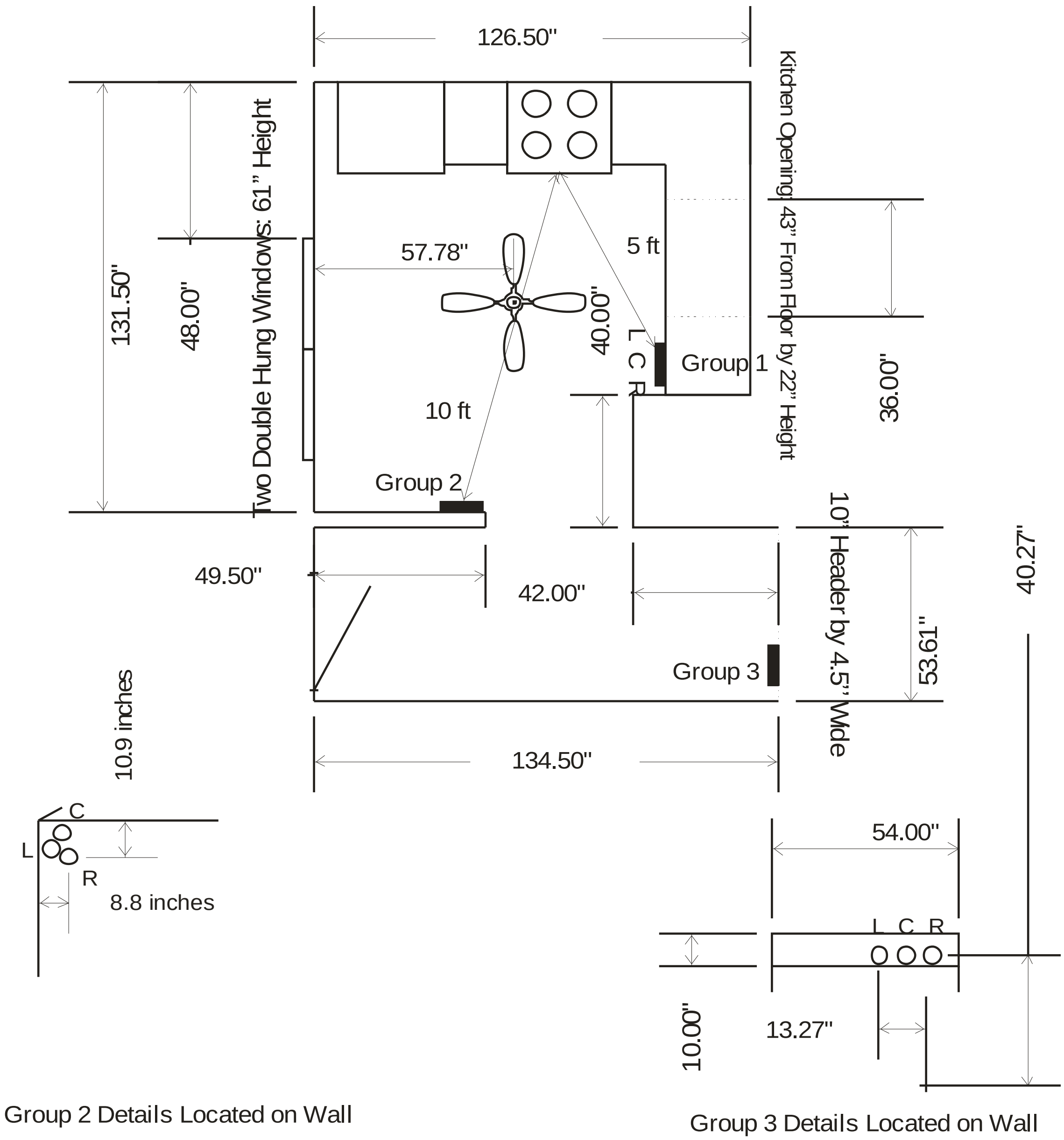
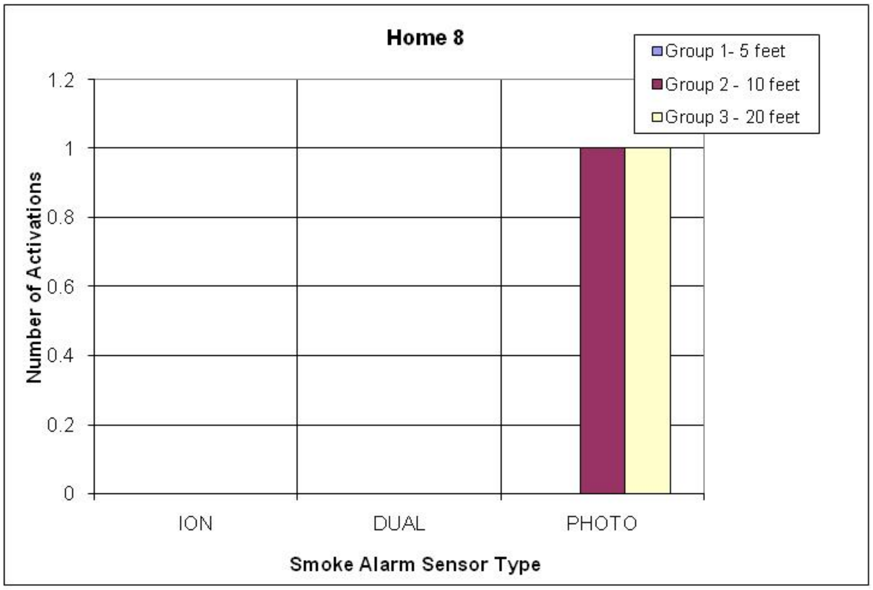


Figure A.8-2 Floor Layout for Test Home 8

Test home 8 had a total of two activations during the test period. Both activations involved photoelectric smoke alarms (one from group 2 and one from group 3), which responded to the same cooking event. The cooking event that resulted in smoke alarm activation was grilling chicken on a portable indoor grill. The location of the counter-top grill is unknown.



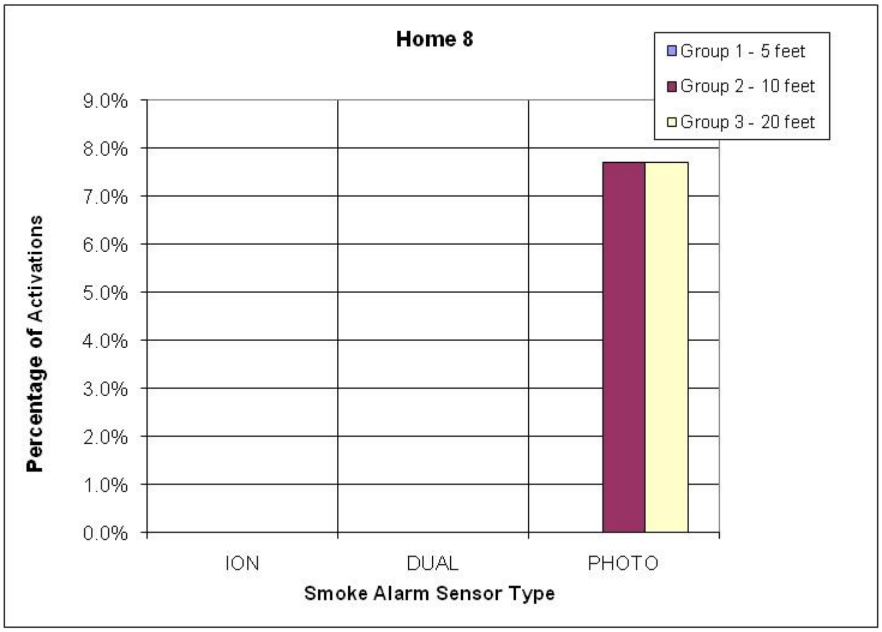


Figure A.8-3 Number and Percent of Activations from Cooking

A.9 Test Home 9

The home was built in 2000. The home is a single-family home that has a family room, dining room, and hallway adjacent to the kitchen. The front foyer hallway also leads into the kitchen. There is an open floor plan between the kitchen and the family room and front foyer. Figure A.9-2 shows a diagram of the kitchen layout and smoke alarm group locations. The kitchen has a free-standing stove/oven, microwave oven, toaster oven, coffee maker, steamer, and dishwasher. The stove/oven uses natural gas. The overhead exhaust fan vented to the outside.

The household is a family of six, the parents and four children. Both parents work outside the home. Two of the children are infants.

Home 9 had 111 cooking events during the 56-day test period. The number of dinnertime and breakfast cooking events was about the same. Lunchtime produced the fewest number of cooking events. Figure A.9-1 shows the distribution of the cooking events for the different mealtimes. The exhaust fan was used for 48 percent of the cooking events, which appeared to have a great effect on the number of activations for the smoke alarms closer than 10 feet.

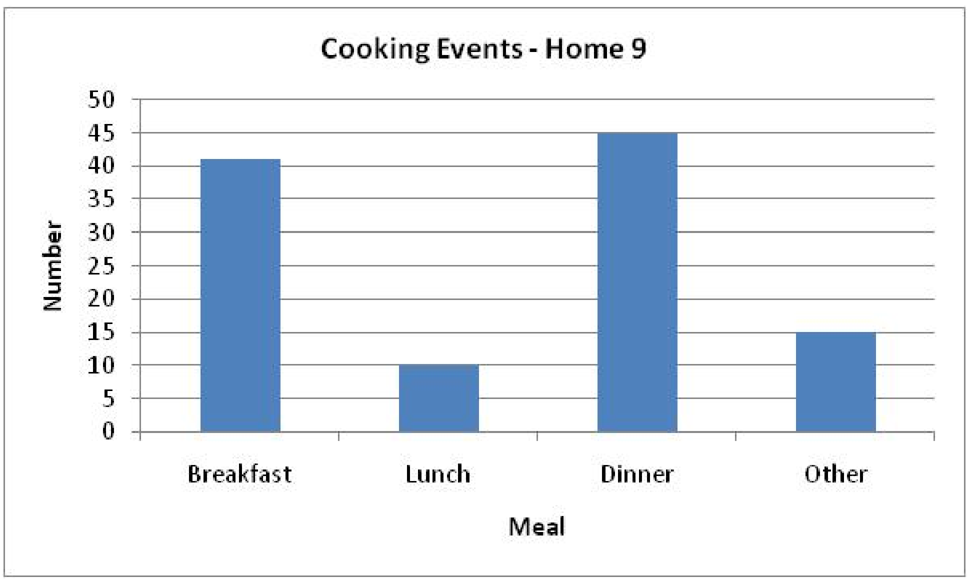


Figure A.9-1 Distribution of Cooking Events (Home 9)

Six groups of smoke alarms were installed in Home 9. Each group was located horizontally from and perpendicular to the front of the stove: group 0 at 3 feet, group 1 at 5 feet, group 1b at 7.5 feet, group 2 at 10 feet, group 2b at 15 feet, and group 3 at approximately 20 feet. Table A.9-1 lists the locations and placement of the smoke alarms for each manufacturer. Smoke alarms from both manufacturer A and manufacturer B were used in home 9.

Table A.9-1 Smoke Alarm Placement (Manufacturers A and B)

Smoke Alarm Group	Furthest Left	Middle Left	Left	Right	Middle Right	Furthest Right
0	I-A	P-B	P-A	D-B	D-A	I-B
1	D-A	D-B	P-B	I-B	I-A	P-A
1b	P-B	D-B	D-A	I-A	P-A	I-B
2	P-B	I-B	D-B	D-A	I-A	P-A
2b	I-A	P-B	P-A	D-A	I-B	D-B
3	P-A	P-B	D-B	I-A	D-A	I-B

A – Manufacturer A
B – Manufacturer B
I – Ionization smoke alarm
P – Photoelectric smoke alarm
D – Dual-sensor smoke alarm

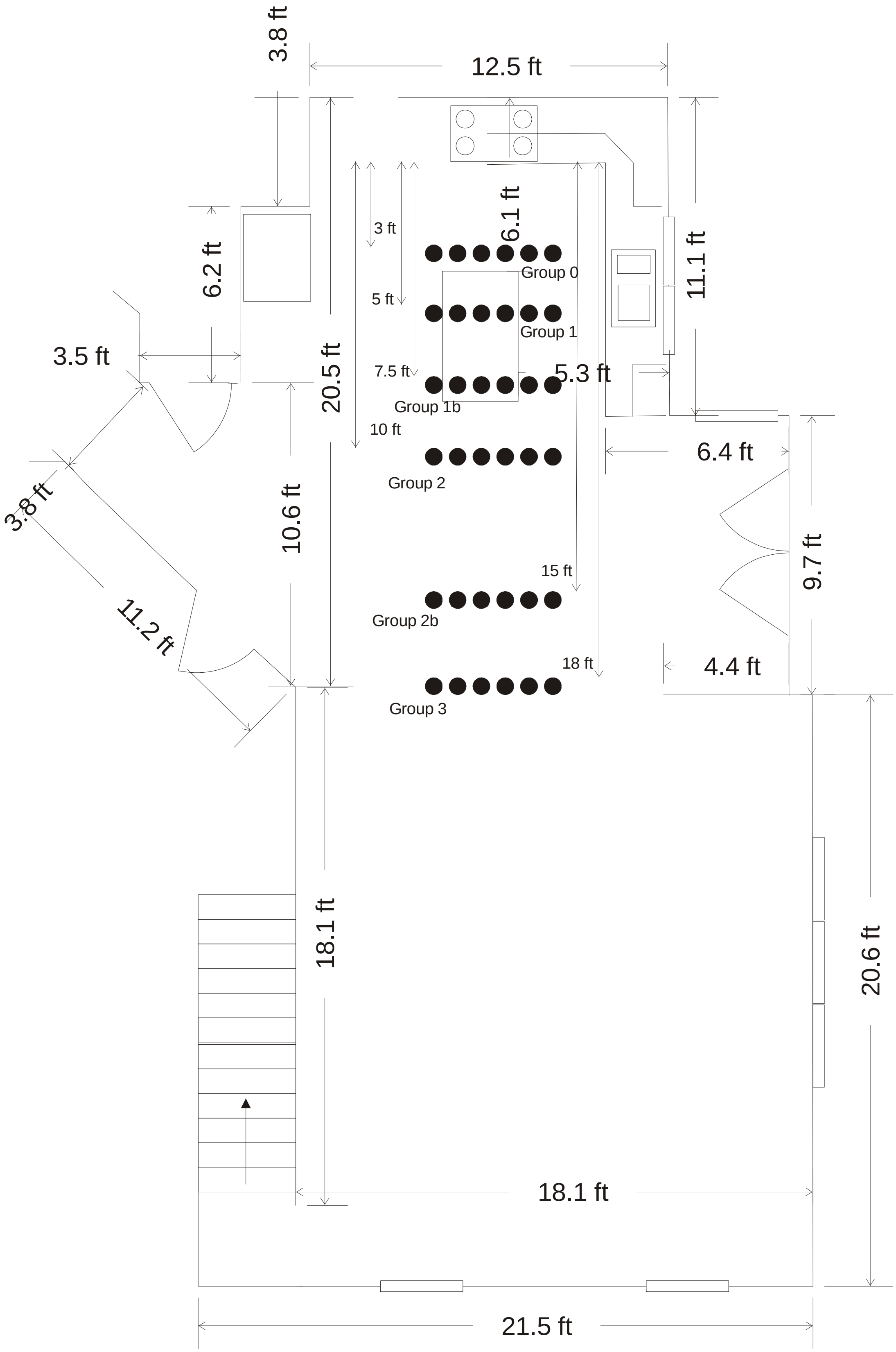


Figure A.9-2 Floor Layout for Test Home 9

Test home 9 had a total of 320 activations during the test period. Group 0 at 3 feet had 198 activations: manufacturers A and B ionization smoke alarms had 78 activations, manufacturers A and B photoelectric smoke alarms had 22 activations, and manufacturers A and B dual-sensor smoke alarms had 98 activations as shown in Figure A.9-3. Group 1 at 5 feet had a total of 61 activations: manufacturers A and B ionization smoke alarms had 20 activations, manufacturers A and B photoelectric smoke alarms had 9 activations, and manufacturers A and B dual-sensor smoke alarms had 32 activations. Group 1b at 7.5 feet had a total of 37 activations: manufacturers A and B ionization smoke alarms had 9 activations, manufacturers A and B photoelectric smoke alarms had 12 activations, and manufacturers A and B dual-sensor smoke alarms had 16 activations. Group 2 at 10 feet had a total of 61 activations: manufacturers A and B ionization smoke alarms had 13 activations, manufacturers A and B photoelectric smoke alarms had 25 activations, and manufacturers A and B dual-sensor smoke alarms had 23 activations. Group 2b at 15 feet had a total of one activation: manufacturer A ionization smoke alarm had 1 activation. Group 3 at 20 feet had a total of 8 activations: manufacturers A and B ionization smoke alarms each had one activation, manufacturer A photoelectric smoke alarms had 2 activations, and manufacturer B dual-sensor smoke alarm had four activations.

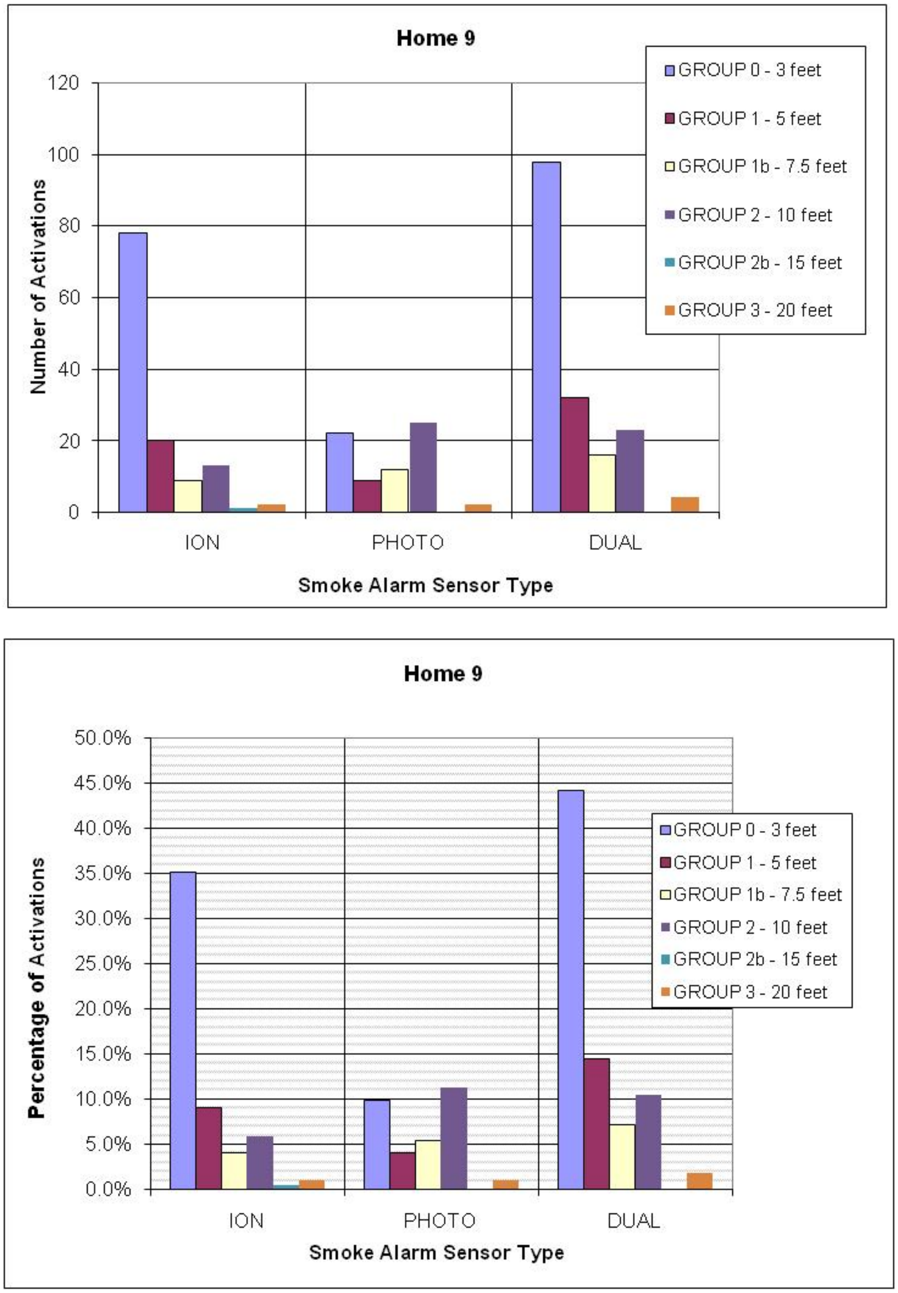


Figure A.9-3 Number and Percent of Activations from Cooking