

Comparison of the Life Safety Performance of Smoke Detectors and Sprinklers in Commercial, Industrial and Education Institution Housing

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Executive Summary

The intent of this project is to extend the research conducted from a previous project, *Performance of Smoke Detectors and Sprinklers in Residential and Health-Care Occupancies* (2010), to include commercial, industrial and educational occupancies to assess the relative role of smoke detectors and sprinklers. As a consequence, the important roles of smoke detectors and sprinklers to mitigate the casualties from fire are illustrated. The studies included in this presentation include statistical analyses of smoke detector and sprinkler performance from fire incident data and information from the literature.

The trend in all of the numerous recent research investigations is that smoke alarms and smoke detectors respond prior to quick response or ordinary sprinklers and thus have the capability of providing the earliest warning of a fire to building occupants. While responding later, sprinklers provide the complementary function of fire suppression to limit the development of hazardous conditions.

The comparison of performance determined from the analysis of fire incident data is based on several measures. One measure is the proportion of fires judged to be too small for activation of smoke detectors and sprinklers. A second measure is the casualty rate (fatal and non-fatal) in facilities protected with operating smoke detectors only, operating sprinklers only or both. A third measure is the average casualty severity (based on a ranking of 1 to 5, 1 being the least severe) in facilities protected with smoke detectors only, sprinklers only or both.

In addition, the research also involves collaboration with the Center for Campus Fire Safety (CCFS). As part of a joint effort between NEMA and CCFS, CCFS has collected fire incident data occurring on or near college and university US campuses including on and off-campus housing. The collaboration with CCFS is intended to provide an analysis of the data being collected by CCFS with the Campus Fire Data Reporting System, CFDRS. While potentially overlapping with some of the NFIRS data, the CCFS data allows for an in-depth review of fire incidents in buildings affiliated with college campuses.

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1. Introduction

Fire detection and suppression systems are installed in buildings to mitigate the threat due to fires. The purpose of this report is to compile results from previous studies and indicate the relative performance of smoke detectors and sprinklers in fire incidents in a wide range of occupancies in the U.S. In so doing, the important roles that smoke detectors and sprinklers provide in reducing the threat due to fire are illustrated.

Smoke detectors and sprinklers perform different fire safety functions. As expressed by Budnick, “*Automatic sprinklers have been used to confine the fire to the room of origin; detectors are installed to provide adequate warning to persons outside the room to ensure escape or rescue.*” [2]. Budnick also indicates “*While the rate of temperature rise and smoke production are both functions of the rate of fire growth, quantities of smoke sufficient to activate a smoke detector generally precede a gas temperature sufficient to activate a sprinkler.*” In 1984, Budnick projected that smoke detectors could reduce fatalities in residences by 50% and using both sprinklers and smoke detectors could reduce fatalities by 73% in residences.

Budnick’s observations reflect the key distinctions between the basic intent of smoke detectors and sprinklers. Smoke detectors are intended to provide early warning of fires. Sprinklers are intended to provide warning and control the development of a fire. Smoke detectors do not have the capability to control the fire except by alerting occupants at an early enough stage when manual suppression still might be feasible.

This report is similar to that of a previous project which addressed these issues in residential, commercial residential and institutional health-care occupancies [1]. The previous report presented observations from experimental programs and statistical analyses of fire incident data on the performance of sprinklers and smoke detectors. Given that the reviewed experimental data was from a broad range of occupancies, it is not repeated here.

The studies included in this report can be grouped into two categories based on the methodology followed. One category consists of statistical analyses of smoke detector and sprinkler performance from fire incident data reported in the literature. These statistical analyses were from sources in the open literature and also from an analysis by the research team of fire incident data from 2003 to 2010 included in the National Fire Incident Reporting Systems (NFIRS). The other category consists of an analysis conducted by the study team of fire incident data provided by the Center for Campus Fire Safety.

Numerous studies have been conducted to assess the performance of various fire protection components in buildings, including smoke detectors and sprinklers. Some of these studies have included comparisons of the smoke detectors and sprinklers and some have included stand-alone analyses of the performance of the individual protection systems.

The comparison of performance of smoke detectors and sprinklers used in this study is based on two principal measures:

- the proportion of fires judged to be too small for activation of the respective devices
- casualty rates (fatal and non-fatal)

The broad categories of “commercial” and “industrial” occupancies included in this project are defined using labels included in NFIRS. These designations are listed in Table 1. These designations were utilized in both the review of information in the open literature and also in the analysis of NFIRS data by the research team.

Table 1. Commercial and Industrial Occupancies included in this Project

<i>Commercial</i>	<i>Industrial</i>
Church, place of worship Restaurant or cafeteria Bar/tavern or nightclub Elementary school, kindergarten High school, junior high College, adult education Clinic, clinic-type infirmary Doctor/dentist office Prison or jail, not juvenile Rooming/boarding house Residential, board and care Food and beverage sales Household goods, sales, repairs Motor vehicle/boat sales/repairs Business office Laboratory/science laboratory	Electric-generating plant Manufacturing plant Warehouse

The scope of this project exploring the performance of smoke detectors and sprinklers in commercial and industrial occupancies

2. Literature Review: Previous Statistical Analyses

Only limited information is available in the open literature on the performance of sprinklers and smoke detectors in fire incidents in commercial and industrial occupancies. The available data is solely from NFPA's Fire Analysis and Research Division and addresses mostly 'big picture' topics, i.e. the data does not provide a detailed assessment of the performance of smoke detectors and sprinklers in the occupancies identified for this study.

Sprinklers were present in an appreciable number (though not majority) of fire incidents that occurred from 2005-2009 in commercial and industrial occupancies, as indicated in Table 2 [3].

Table 2. Presence of Sprinklers in Fire Incidents Occurring in Commercial and Industrial Occupancies [3]

Occupancy	Number of Incidents	% of Incidents in Occupancy Group
Public Assembly	3310	21
Education	2080	34
Detention and Correction	260	50
Mercantile and Office	4360	23
Manufacturing	2920	48
Storage	820	4
Total	13750	

In the reports by NFPA's Fire Analysis and Research Division, the performance of sprinklers is described using the following metrics:

- Proportion of fires where equipment operated
- Proportion of fires where equipment was judged to be effective
- Proportion of fires where fire is confined to room of origin
- Casualty rates with and without sprinklers
- Number of fires judged to be too small to activate equipment

Using these metrics, sprinkler system performance in the period from 2005-2009, for all types of sprinkler systems (wet-pipe, dry pipe, etc.) are summarized by the following statements.

- For fires that are “Not confined”, equipment operated in 96% of the incidents and were judged to be effective in 87% of the incidents in which sprinklers operated (i.e. 84% of the fire incidents where sprinklers were present).
- For fires confined to the room of origin, sprinklers operated in 35% of the incidents and were effective in 86% of the incidents in which sprinklers operated (i.e. 30% of the fire incidents where sprinklers were present).
- There is an estimated 85% reduction in civilian deaths in fire incidents where wet pipe sprinklers were present compared to non-sprinkler protected buildings (all occupancies).
- 15% of all structure fires were judged to be too small to operate automatic extinguishment equipment (7,190 of 46,530 incidents). In commercial and industrial occupancies, 23% of the fires were judged to be too small to operate automatic extinguishing equipment (4,510 of 19,820 incidents).

A profile of the fatalities that occurred in fire incidents in buildings with and without sprinkler operation is summarized in Table 3.

Table 3. Fatalities in 2005-2009 Structure Fires Reported in NFIRS [3]

Victim Characteristics	When wet pipe sprinklers operate	No automatic extinguishing equipment operates
Victim in area of origin	24 (intimate with ignition in 23/24 cases)	1470 (1110)
Intentional fire	1	390
Clothing on fire	6	210
Victim age 65+	15	820
Victim returned to fire, unable to act or acted irrationally	11	590

Data was also compiled to document the presence of automatic extinguishing systems and fire detection systems in office buildings over a 20 year period. The data from fires in office buildings is summarized in Table 4 [4]. The report does not provide any information on the type of detectors provided in the fire detection systems or on the performance of smoke detectors and sprinklers in the incidents.

Table 4. Percentage of Sprinklers and Fire Detection Systems in Fire Incidents Occurring in Office Buildings [4]

Year of Fire Incident	High-Rise Buildings	Non-High-Rise Buildings	All Buildings
Automatic Extinguishing Equipment			
1986-1989	47	17	21
1989-1998	61	21	25
2003-2006 ¹	54	18	21
Fire Detection Equipment			
1986-1989	69	33	37
1989-1998	79	48	51
2003-2006	89	62	65

3. Statistical Analysis of NFIRS Data for this Study

An analysis of NFIRS data from fire incidents in commercial and industrial occupancies for the eight year period from 2003-2010 was conducted. A total of 55,846 fire incidents was identified in the database for this analysis. The number of fire incidents with smoke detectors or sprinklers and their performance in these two broad categories of occupancies is presented in Tables 5 and 6.

There were 477 fire casualties (fatal and non-fatal) that occurred in these 55,846 fire incidents, of the following types:²

1. Intimate with the fire, in the room of origin, and died or were injured from:
 - a. burns
 - b. smoke inhalation
 - c. combination of burns and smoke inhalation
2. Not intimate with the fire (i.e. not in the room of origin) and died or were injured from:
 - a. burns
 - b. smoke inhalation
 - c. combination of burns and smoke inhalation
3. No casualty resulted from the fire.

¹ Identified in this time period as “wet-pipe sprinkler”.

² Additional casualties were incurred with other symptoms, including those from falls, cuts, etc., though those were defined as being outside the scope of this project.

Table 5. Protection Equipment in Commercial Occupancies in Fire Incidents included in NFIRS Analysis, 2003-2010

Protection Equipment	Present	Operated	% Operated
None	12,571	-	-
Smoke Detectors Only	10,181	5304	52
Sprinklers Only	1,234	409	33
Smoke Detectors & Sprinklers			
smoke detectors	6,993	3873	55
sprinkler		1829	26
Total	30,979	-	-

Table 6. Protection Equipment in Industrial Occupancies in Fire Incidents included in NFIRS Analysis, 2003-2010

Protection Equipment	Present	Operated	% Operated
None	10758	-	-
Smoke Detectors Only	6108	3275	54
Sprinklers Only	1773	663	37
Smoke Detectors & Sprinklers			
smoke detectors	6308	3590	58
sprinkler		2054	33
Total	24,947		

The response of the smoke detectors in the fire incidents occurring in commercial and industrial occupancies is summarized in Table 7. The proportion of incidents where the fires were judged to be too small for operation of a smoke detector is determined qualitatively by the fire service individual tasked with completing the form. No engineering analysis of the fire scenario or the operational status of the smoke detector was conducted to assist in such an assessment. Similarly, the ‘failed to operate’ category reflects a judgment that the fire conditions were severe enough to cause a smoke detector to operate, though none operated. As with ‘fire too small’, no engineering analysis of the scenario or the detector was conducted to assist in this assessment.

Table 7. Smoke Detector Response in Commercial and Industrial Occupancies

Response	Non-sprinklered		Sprinklered	
	Number of incidents	%	Number of incidents	%
Commercial				
Fire too small to operate	2470	24	1923	28
Operated	5304	52	3873	55
Failed to operate	716	7	277	4
Undetermined or no answer	1691	17	923	13
Total	10181	100	6993	100
Industrial				
Fire too small to operate	1393	23	1545	24
Operated	3275	54	3651	58
Failed to operate	393	6	223	4
Undetermined or no answer	1044	17	889	14
Total	6108	100	6308	100

The proportion of fires judged to be too small is larger than that reported for residential, commercial and health-care occupancies in the previous report. The “too small” proportion is very similar for the four categories explored (commercial vs. industrial occupancies, sprinklered vs. non-sprinklered buildings), ranging from 23-28% of the total number of incidents. No reasons for smoke detectors that “failed to operate” are given in NFIRS. Some of these cases may be attributable to fire size, given that the assessment of the adequacy of fire size necessary for response is done subjectively by the individual completing the form for a particular incident.

Similarly, the response of sprinklers in the fire incidents occurring in commercial and industrial occupancies is summarized in Table 8. The proportion of incidents where the fires were judged to be too small for operation of a sprinkler are all less than 50%, which is less than that found in the case of commercial residential and health-care occupancies in the previous report [1]. The proportion of “too small” fires ranges from 26-43% in the occupancies included here, though it’s not clear why such a wide range exists. No reasons for why sprinklers “failed to operate” are given in NFIRS. Some of these cases may be attributable to fire size.

The observation of “fires too small” for cases where smoke detectors and sprinklers were both present and hence “side by side” is summarized in Table 9. As indicated in the table, the “fires too small” are appreciably greater for sprinklers than smoke detectors in both commercial and industrial occupancies.

Table 8. Sprinkler Response in Commercial and Industrial Occupancies

Response	No Smoke Detector		Smoke Detector Present	
	Number of incidents	%	Number of incidents	%
Commercial				
Fire too small to operate	526	43	3613	52
Operated	407	33	1804	26
Failed to operate	86	7	271	4
Undetermined or no answer	203	17	1244	18
Total	1222	100	6993	100
Industrial				
Fire too small to operate	686	39	2690	43
Operated	663	37	2054	33
Failed to operate	139	8	251	4
Undetermined or no answer	267	15	1290	20
Total	1773	99*	6285	100

- Total does not equal 100% due to round-off.

Table 9. Fire Too Small in Commercial and Industrial Occupancies with both Sprinklers and Smoke Detectors Present

	Smoke Detectors (% of Incidents)	Sprinklers (% of Incidents)
Commercial Occupancies	28	52
Industrial Occupancies	24	43

Considering that the entire NFIRS database for the years 2003-2010 only includes 477 casualties, the trends identified in this analysis cannot be considered to be highly robust, especially as these 477 are divided into several categories, depending on the performance of the protection equipment and nature of the casualty.

Of the 477 casualties included in the database, only 45 of those casualties included an injury of someone who was not intimate with the fire. As such, 91% of the casualties identified were intimate with the fire ignition. Also, virtually all of the casualties involved ambulatory adults, so no statistical analysis of the casualties by age or mobility status was merited. The dominance of adults in the database is not surprising given the occupancy categories that were included in this study.

The principal purpose of the analysis conducted in this study is to provide a detailed analysis of the role of smoke detectors and sprinklers in the commercial and industrial occupancies, with special emphasis on exploring the role of these two categories of fire protection equipment on reducing deaths and injuries from fire. Consequently, the analysis divides the fire incidents in the above occupancies into the following conditions:

1. Neither sprinklers nor smoke detectors were present
2. Non-sprinklered buildings, smoke detectors operated
3. Buildings without smoke detectors, sprinklers operated
4. Both sprinklers and smoke detectors provided and at least one operated

A distribution of the casualties experienced for the first three options of protection equipment is presented in Tables 10 and 11 for the two occupancy categories.³ As indicated in the two tables, the number of casualties experienced for any particular protection equipment provided is relatively small, especially for the casualties experienced by people not intimate with the fire. As such, casualty rates for the people not intimate with the fire will be determined for the entire group, independent of the nature of the casualty.

All of the detailed results from the analysis for the four¹ protection equipment options in the two occupancy groups are presented in the Appendix. The principal observations resulting from the analysis addressing the response of smoke detectors and sprinklers and the relationship between casualty rates and the performance of smoke detectors and sprinklers are presented in the remainder of this section.

³ The fourth option is not presented in Table 10 or 11 because some of the casualties occurred in fire incidents where both sprinklers and smoke detectors operated and hence would be counted twice.

Table 10. Casualties in Fire Incidents in Commercial Occupancies, 2003-2010⁴

Casualty Symptom	None	Non-sprinklered buildings, smoke detectors operated	Buildings without smoke detection, sprinklers operated
A	18	26	1
B	9	12	0
C	31	9	1
D	8	11	0
E	1	0	0
F	1	0	0

Legend for casualty symptoms:
Intimate with the fire, in the room of origin, and died or were injured from:
A. burns
B. smoke inhalation
C. combination of burns and smoke inhalation
Not intimate with the fire (i.e. not in the room of origin) and died or were injured from:
D. burns
E. smoke inhalation
F. combination of burns and smoke inhalation

Table 11. Casualties in Fire Incidents in Industrial Occupancies, 2003-2010

Casualty Symptom	None	Non-sprinklered buildings, smoke detectors operated	Buildings without smoke detection, sprinklers operated
A	40	9	5
B	15	1	3
C	38	1	9
D	4	1	1
E	0	0	0
F	4	0	1

Legend for casualty symptoms:
Intimate with the fire, in the room of origin, and died or were injured from:
A. burns
B. smoke inhalation
C. combination of burns and smoke inhalation
Not intimate with the fire (i.e. not in the room of origin) and died or were injured from:
D. burns
E. smoke inhalation
F. combination of burns and smoke inhalation

⁴ This table shows that with sprinklers the incidence of casualties was consistently lower for categories A, B, C, and D. The lack of difference in the number of casualties for Categories E and F involving smoke in non-intimate conditions (where smoke detectors would be expected to provide a distinct benefit) may be attributed to the lack of casualties in these categories.

The performance of smoke detectors and sprinklers is labeled in NFIRS as ‘operated’, ‘fire too small’ or ‘failed to operate’. Sprinklers had sub-categories for the ‘operated’ label of being effective or ineffective, but those sub-categories are not addressed in this report.

A summary of the casualty rates (in terms of casualties per 100 fire incidents) is presented in Figures 1-3 for commercial occupancies where smoke detectors or sprinklers operated. As a baseline for comparison purposes, an overall casualty rate of 0.54 casualties per 100 fire incidents was experienced in fire incidents without any protection equipment being present for commercial occupancies. The casualty rates in fire incidents in commercial occupancies with operating protection equipment are at least 10% less than the baseline casualty rate when no protection equipment is provided. For many of the casualty symptoms, the rate is at least 50% less than the baseline rate. Casualty rates for those occupants not intimate with ignition are approximately 20% of the baseline rate when protection equipment operates.

The review of casualty rates relative to the performance of fire protection systems should be done keeping in mind the following:

- Information on when or how the casualty was incurred is not available via NFIRS. Some of the reported casualties could have occurred during the ignition process itself in which case a detection or sprinkler system is unable to prevent the casualty.
- Information is not available on the fire scenario, i.e. did the fire smolder for an extended period of time, was the fire a fast-growing fire, etc.
- Information is not available on the size of the room of origin or of the overall building.

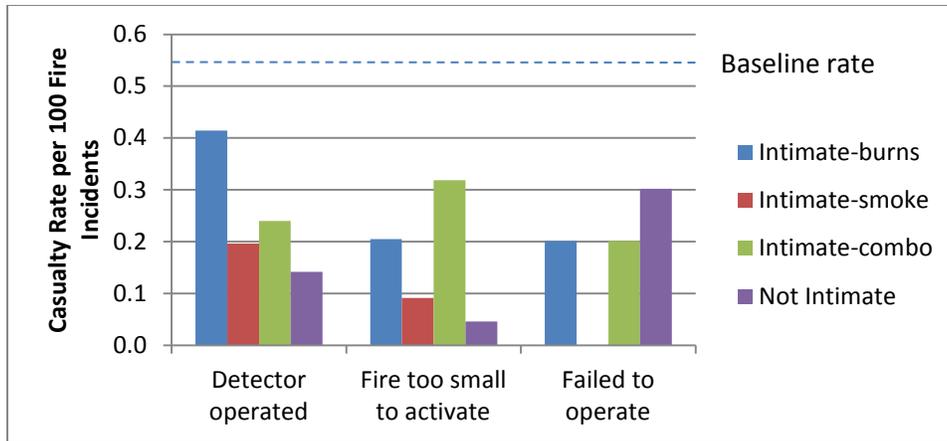


Figure 1. Casualty Rates in Unsprinklered Commercial Occupancies vs. Smoke Detector Operation

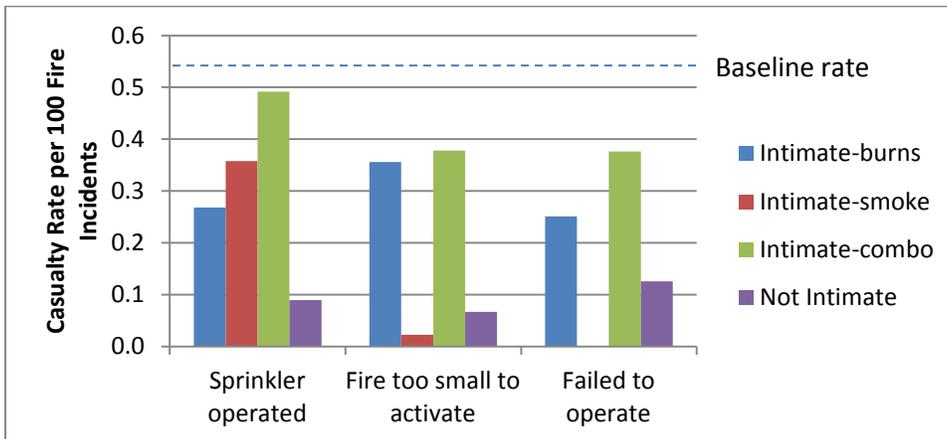


Figure 2. Casualty Rates in Sprinklered Commercial Occupancies without Smoke Detection vs. Sprinkler Operation

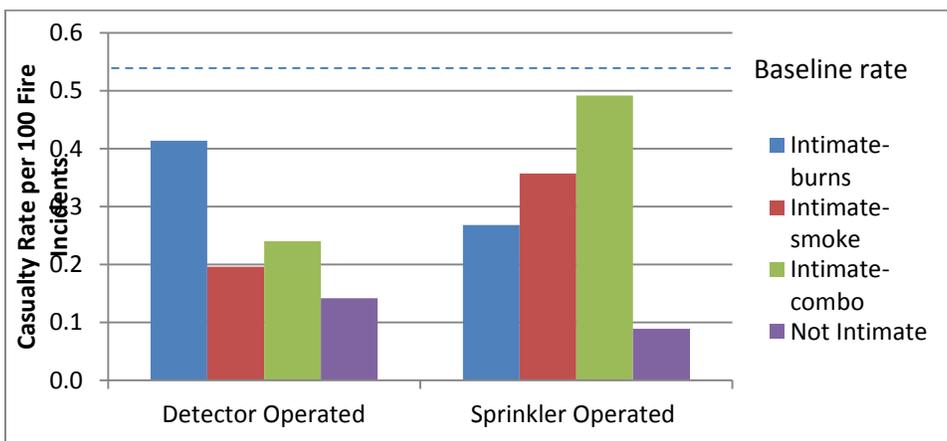


Figure 3. Casualty Rates in Sprinklered Commercial Occupancies vs. Operating Protection Equipment

A summary of the casualty rates for industrial occupancies is presented in Figures 4-6 where smoke detectors or sprinklers operated. The baseline casualty rate for fire incidents in industrial occupancies without any protection equipment being present is 0.94 casualties per 100 fire incidents.

As indicated in Figures 4-6, the casualty rates when smoke detectors or sprinklers operate is less than the baseline rate except for those occupants intimate with ignition who sustained burns and smoke inhalation in fires where sprinklers operated. In the fires with operating smoke detectors, the casualty rate is reduced by two-thirds for burn casualties and by a factor of 30 for all others, including those occupants not intimate with ignition. As in commercial occupancies, the casualty rates for occupants not intimate with ignition are significantly reduced from the baseline rate when protection equipment operates.

Further insights into the roles of smoke detectors and sprinklers can be provided by assessing the severity of the casualties incurred by the building occupants. The NFIRS manual notes [5]:

1. Minor. The patient is not in danger of death or permanent disability. Immediate medical care is unnecessary.
2. Moderate. Little danger of death or permanent disability. Quick medical care is advisable.
3. Severe. The situation is potentially life threatening if the condition remains uncontrolled. Immediate medical care is necessary even though body processes may still be functioning and vital signs normal.
4. Life threatening. Death is imminent; body processes and vital signs are not normal. Immediate medical care is necessary. Includes cases such as severe hemorrhaging, severe multiple trauma, and multiple internal injuries.
5. Death

The effect of the performance of smoke detectors and sprinklers on the average severity of casualties incurred in commercial occupancies is presented in Figure 7. As indicated in the figure, when smoke detectors and sprinklers operated, the casualty severities are at their lowest level.⁵ The low apparent average casualty severity for sprinklers having operated and ineffective is because there were no cases with this condition.

⁵ The lack of a bar in Figure 7 for sprinklers 'operated and ineffective' is because there were no casualties in fire incidents in this category.

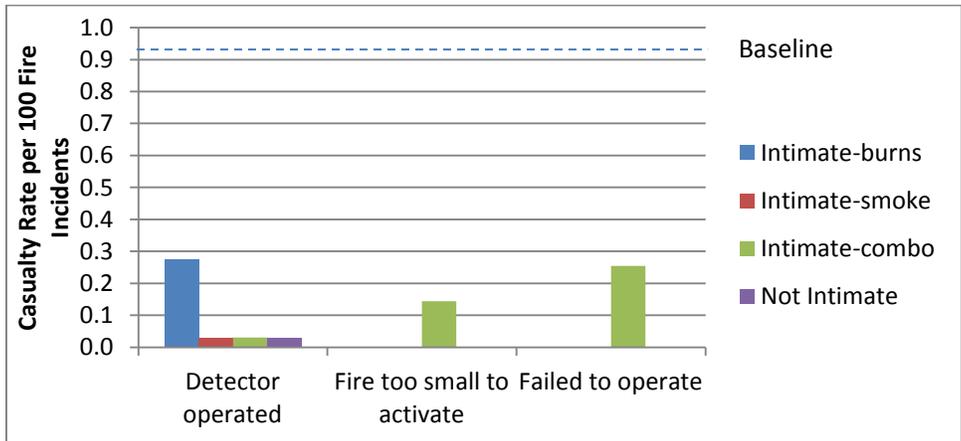


Figure 4. Casualty Rates in Unsprinklered Industrial Occupancies vs. Smoke Detector Operation

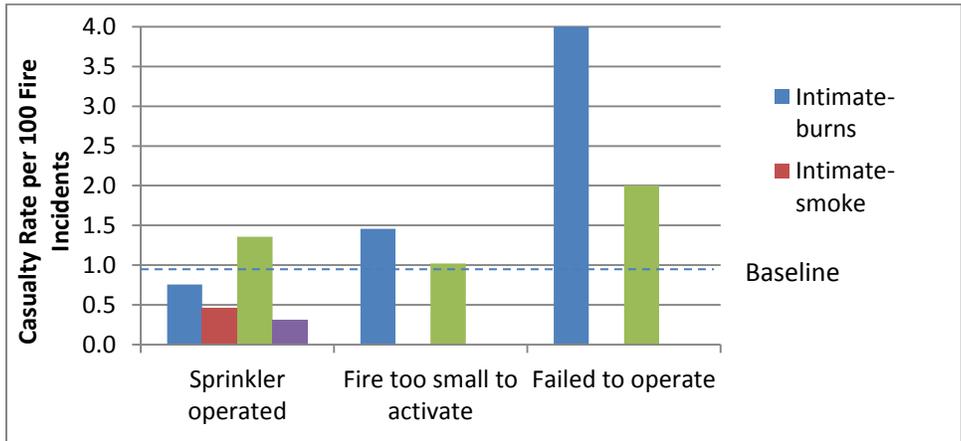


Figure 5. Casualty Rates in Sprinklered Industrial Occupancies without Smoke Detection vs. Sprinkler Operation

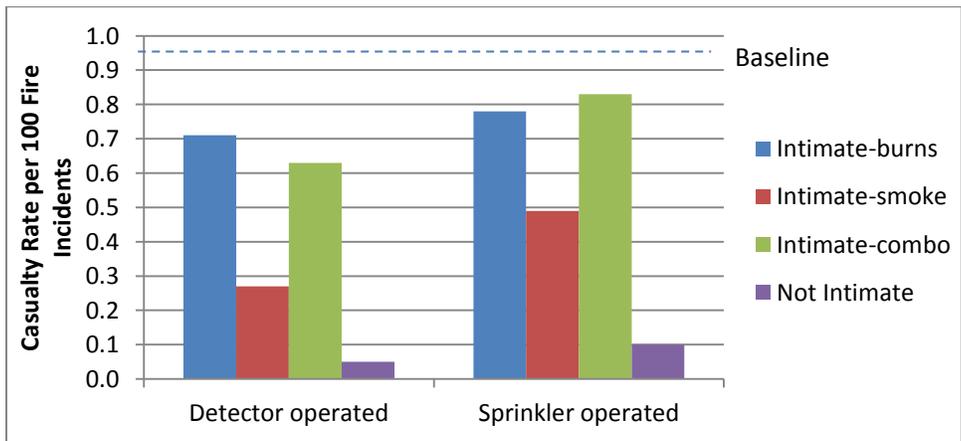


Figure 6. Casualty Rates in Sprinklered Commercial Occupancies vs. Operating Protection Equipment

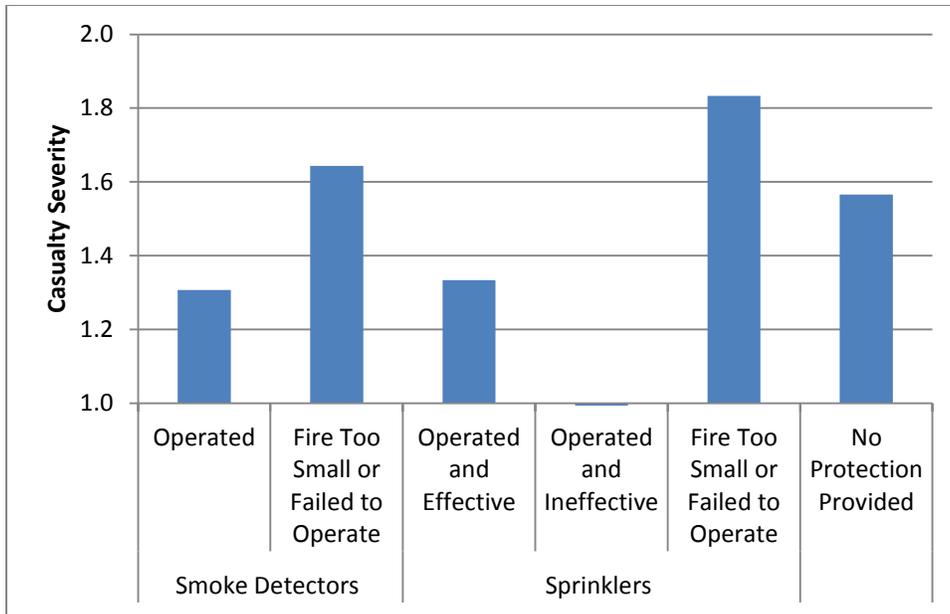


Figure 7. Average Casualty Severities in Commercial Occupancies

The effect of the performance of smoke detectors and sprinklers on the average severity of casualties incurred in industrial occupancies is presented in Figure 8. Again, the lowest average casualty severity is associated with fire incidents in which a smoke detector operates. Low casualty severities are also found in those incidents where effective sprinkler operation was observed.

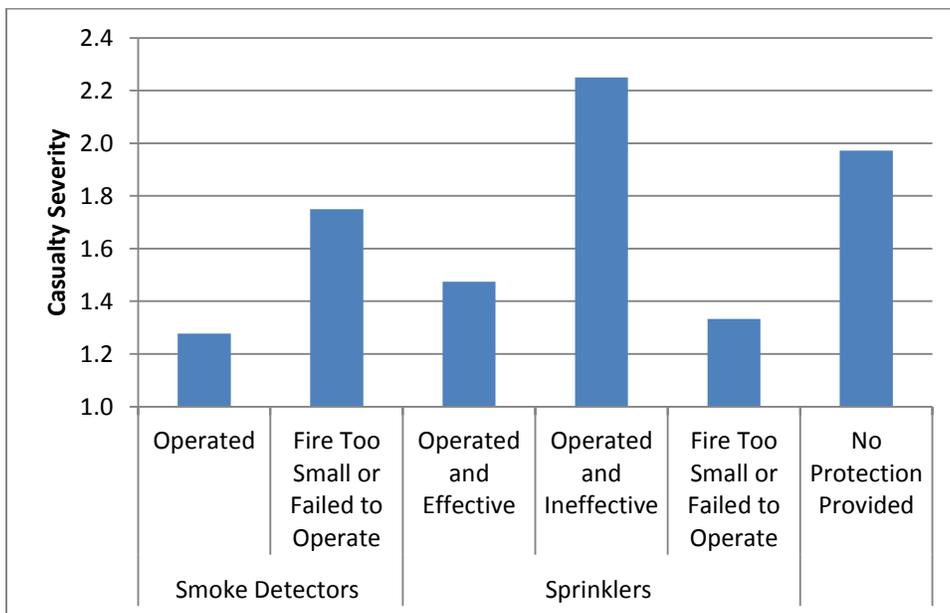


Figure 8. Average Casualty Severities in Industrial Occupancies

In addition to the averages reported in Figures 7 and 8, the maximum severity (fatality) noted for each category is noteworthy. Fatalities did occur for many of the categories. The cases where the maximum severity was a non-fatal consequence were associated with the following conditions:

- Fires too small in both commercial and industrial occupancies
- Sprinklers operated and were effective in both commercial and industrial occupancies
- Operated smoke detectors in industrial occupancies

The proportion of fire incidents that smoke detectors responded to in commercial occupancies is presented in Figure 9. Similarly, the distribution of casualties in fire incidents in commercial occupancies relative to the response of smoke detectors is presented in the same figure. Smoke detectors were noted as ‘failing’ to operate in about 6% of the fire incidents and in 5% of the casualties, as judged by the individual completing the NFIRS form. The distribution of casualty symptoms relative to the response of smoke detectors and sprinklers in commercial occupancies is presented in Figures 8 and 9.

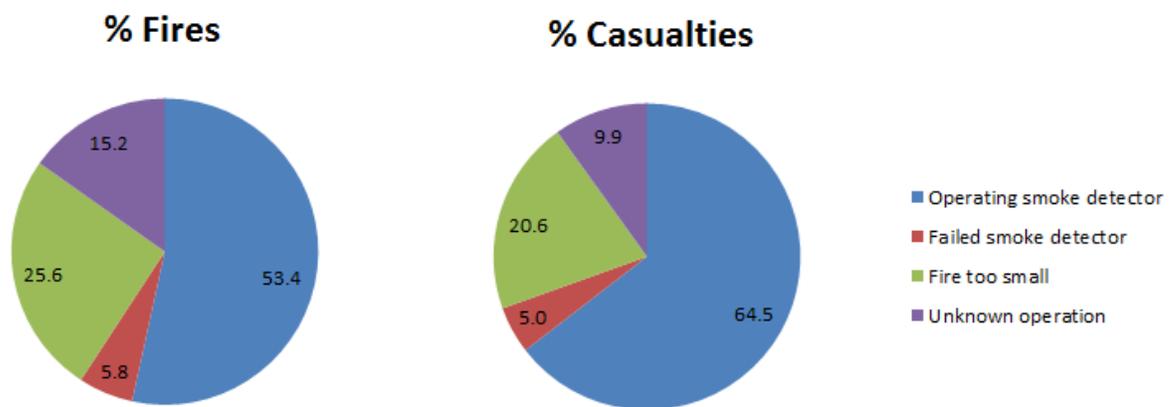


Figure 9. Performance of Smoke Detectors in Fire Incidents in Commercial Occupancies

In Figure 10, the effect of smoke detector performance is indicated in the fire incidents in commercial occupancies, both as a proportion of the number of fire incidents and the number of casualties. The 36% proportion of incidents where occupants respond to an alarm provided by a smoke detector is disappointing. This is significantly less than that observed from the previous study [1] for residential occupancies, where occupants

responded to an alarm from a smoke detector in 86% of the incidents. This difference may be attributable to differences in how individuals respond to alarms in their residence as compared to the workplace or other commercial venues.

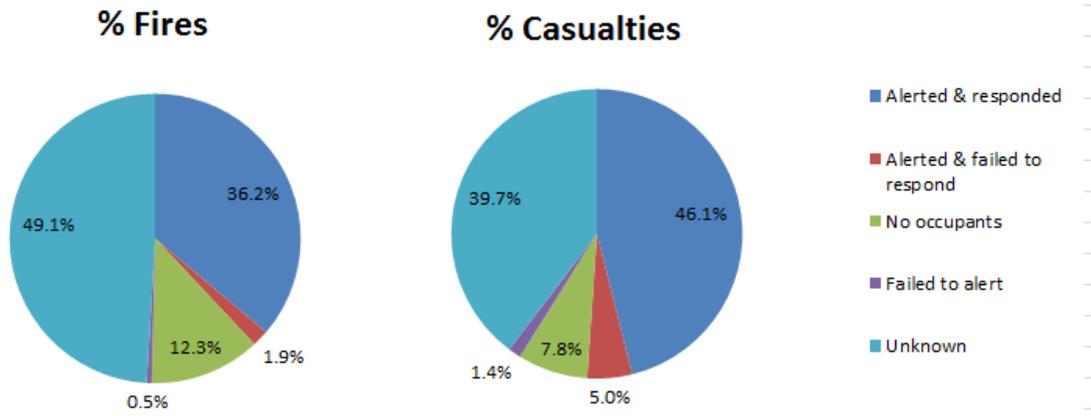


Figure 10. Proportion of Casualties by Performance of Sprinklers in Fire Incidents in Commercial Occupancies

The proportion of fire incidents that smoke detectors responded to in industrial occupancies is presented in Figure 11. The distribution of casualties in fire incidents in industrial occupancies relative to the response of smoke detectors is presented in the same figure. Smoke detectors were noted as ‘failing’ to operate in about 5% of the fire incidents and approximately 3% of the casualties, as judged by the individual completing the NFIRS form.

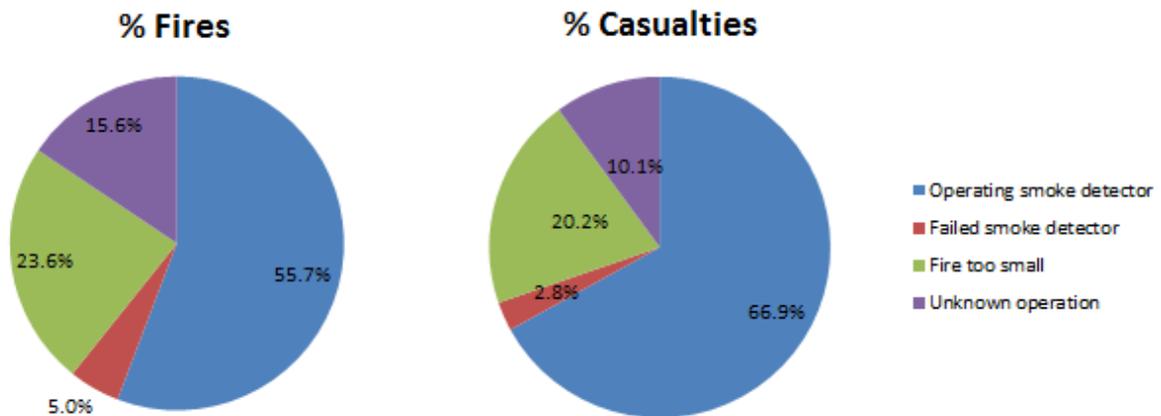


Figure 11. Performance of Smoke Detectors in Fire Incidents in Industrial Occupancies

The effect of smoke detector performance in industrial occupancies is presented in Figure 12, both as a proportion of the number of fire incidents and the number of casualties. As was noted for commercial occupancies, occupants respond rate to alarms from smoke detector operation in only 39% of the fire incidents.

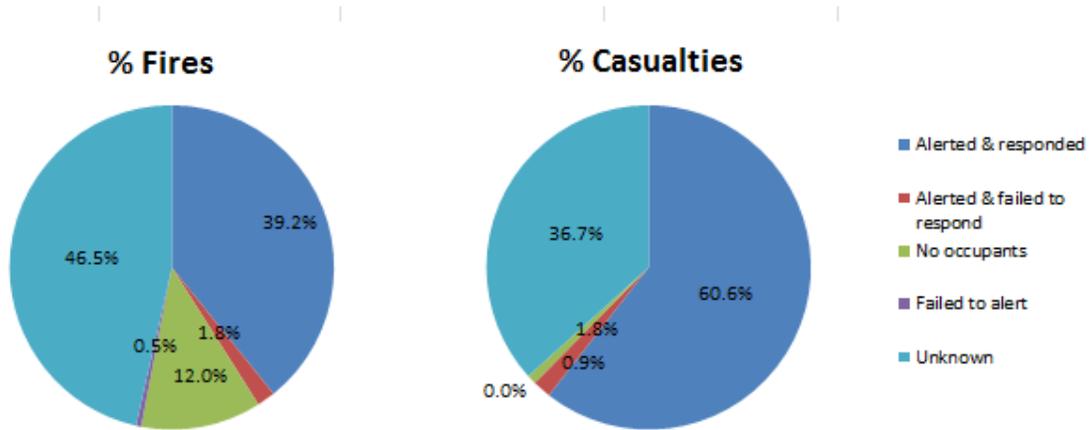


Figure 12. Proportion of Casualties by Performance of Sprinklers in Fire Incidents in Industrial Occupancies

Fires judged to be too small for smoke detector and sprinkler operation was used in the previous report [1] as a surrogate measure of their relative sensitivity. A summary of the casualty rates in such fires from this study are provided in Table 12. The fact that fewer fires are judged to be too small for smoke detector operation than for sprinklers reflects the fact that smoke detectors are capable of responding to smaller fires than sprinklers. Those fires which are “too small” for smoke detector or sprinkler response still pose a significant hazard, as indicated in casualty rates (fatal and non-fatal) in such fires.

Table 12. Casualty Rates for Fires Judged Too Small for Operation

Occupancy	Too Small for Smoke Detector	Too Small for Sprinkler	Ratio: Sprinkler/Smoke Detector
Commercial	0.66	0.80	1.2
Industrial	0.18	1.42	7.9

4. Analysis of Campus Fire Data Reporting System

The Center for Campus Fire Safety (CCFS) provided data from fire incidents collected by CCFS. Campus safety officials submitted forms to CCFS to document fire incidents that occurred on college campuses or in off-campus buildings associated with the college or university. The forms requested much of the same data as in NFIRS, albeit with some differences in the forms from the NFIRS forms. The part of the form pertaining to detection and suppression systems are provided as Figure 13.

Data from 978 fire incidents occurring during 2007-2012 were reported by campus safety officers to CCFS. The data in these fire incidents was reviewed by CCFS staff for completeness and was confirmed to have consistent information. Of those 978 incidents, 827 included an entry related to the presence of protection equipment. A summary of the information received is provided in Tables 13 and 14.

A summary of the responses of detection and suppression equipment in the incidents collected by CCFS is presented in Figure 14. The fires deemed to be “too small” for detectors was less than 10% while the proportion was almost 50% for suppression systems.

In the 827 incidents from CCFS which indicated the presence (or absence) of detection and suppression equipment, there were seven total casualties for a rate of 0.86 casualties/100 fire incidents. Given the small number of casualties, a detailed analysis of the situations involving these casualties was not conducted. As a general overview of the individual cases:

- For the three casualties with sprinklers present, sprinklers were reported as having operated and were effective in the incident that had one casualty. The fire was judged to be “too small” for sprinklers to activate in the two fire incidents that resulted in the other two casualties.
- For the six casualties with detectors present, detectors operated and occupants responded in incidents involving four of the casualties. Detector response was not reported in the other incidents involving the other two casualties.

DETECTION

Present of Detectors: None Present (if you checked none, proceed to Automatic Extinguishing Systems)

Detector Type: (choose one) Carbon Monoxide Combo Smoke & Heat Combo Smoke & Carbon Monoxide Heat More than one type
 Other Pull Station, Local Pull Station, Supervised Smoke, Ion Smoke, Photo Smoke, Ion & Photo
 Sprinkler,waterflow detection, Suppression System Folw/Activation Undetermined

Detector Power Supply: Battery only, Hardwire only, Plug-in, Hardwire with battery, Plug-in with battery Mechanical
 Multiple detectors and power supplies, Other, Undetermined Fire Alarm System

Detector Operation: Failed to operate correctly (Complete "Detector Failure Reason" below) Fire too small to activate
 Occupant witness event prior to alarm Operated (Complete " Detector Effectiveness" below) Undetermined

Detector Effectiveness: Alerted Occupants, occupants responded Alerted occupants, occupants failed to respond Failed to alert occupants
 There were no occupants Undetermined

Detector Failure Reason: Battery discharged or dead Battery missing or disconnected Defective Improper installation or placement
 Lack of maintenance, includes not cleaning Other Power failure, shutoff or disconnected Pull Station, Disabled
 Pull Station, Failed to Operate Undetermined

AUTOMATIC EXTINGUISHER SYSTEMS

Presence of Automatic Extinguishing System: (if none, proceed to Fire Extinguishers) None Present Present, Undetermined

Type of Automatic Extinguishing System: Carbon dioxide (Co2) Dry chemical Dry-pipe sprinkler Foam Halogen type Other sprinkler system
 Other special hazard system Undetermined Wet-pipe sprinkler

Number of sprinkler heads operating: _____

Operation of Automatic Extinguishing System: Failed to operate (Complete " Reason for Automatic Extinguishing System Failure" below) Fire too small to activate
 Operated/effective Operated/not effective Other Undetermined

Reason for Automatic Extinguishing System Failure: Agent discharged but did not read fire Fire not in area protected Lack of maintenance
 Manual intervention Not enough agent discharged System components damaged System shut off Wrong type of system
 Undetermined Other

Figure 13. CCFS Form for Data on Detection and Suppression System Performance

Table 13. Protection Equipment in Campus Fire Incidents

Protection	Number of Incidents	Number of Casualties
Both detector & sprinkler	277	2
Detector only	286	4
Sprinkler only	11	1
Neither	239	0

Table 14. Type of Detection Equipment Provided in Campus Fire Incidents

Type	Number of Incidents
Combination smoke and CO	2
Combination smoke and heat	17
Heat	7
More than one type present	35
Pull station, supervised	2
Smoke, both ionization and photoelectric	16
Smoke, ionization	34
Smoke, photoelectric	173
Sprinkler, water flow detection	2
Undetermined	40
No entry ¹	235

¹ No entry refers to the case that detection equipment was identified as being present, but not details of the equipment were provided.

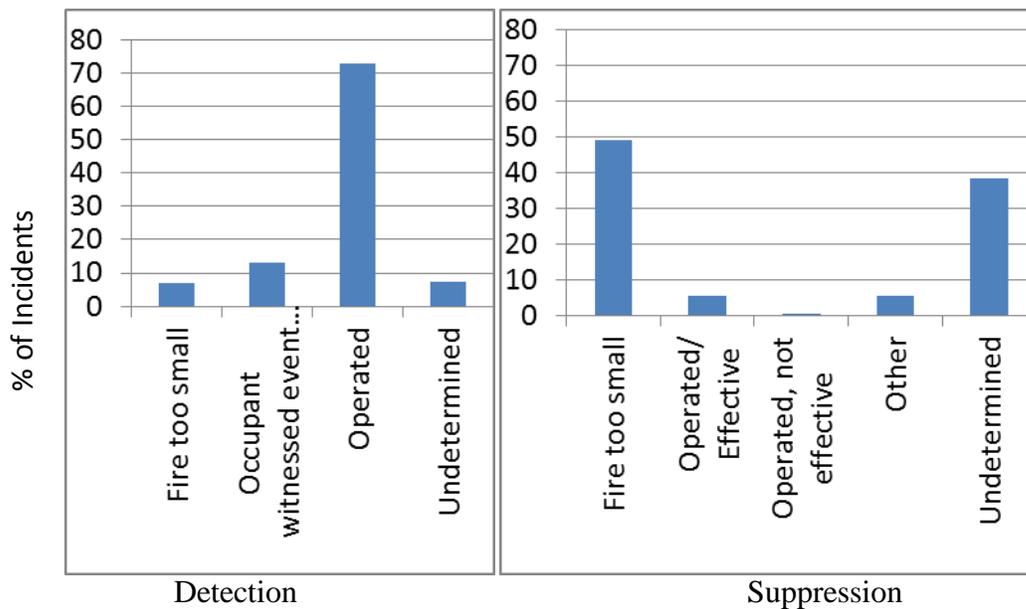


Figure 14. Performance of Detection and Suppression Systems in Campus Fires

In Figure 15, the effect of smoke detector performance is indicated in the fire incidents included in the CCFS database. Occupants responded to an alarm provided by a smoke detector in 86% of the fire incidents, almost identical to the proportion seen in residential occupancies.

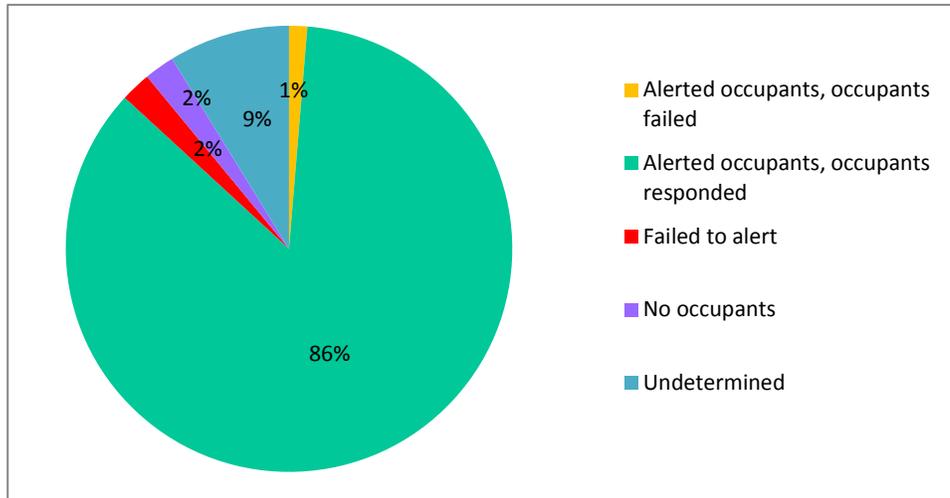


Figure 15. Performance of Smoke Detectors in Fire Incidents in Campus Environments

5. Summary

The relative role of smoke alarms and sprinklers has been demonstrated in commercial and industrial occupancies. The trend in identified previous studies of smoke alarms responding prior to quick response or ordinary sprinklers is repeated in this study indicating the smoke detectors provide the earliest warning of a fire to building occupants. While responding later, sprinklers provide the additional function of fire suppression to limit the development of hazardous conditions.

This project conducted an analysis of NFIRS fire incident data during the period of 2003-2010. In the resulting database, there were 477 fire casualties (fatal and non-fatal) which incurred in 55,846 fire incidents.

The principal purpose of the analysis conducted in this study was to provide a detailed analysis of the role of smoke detectors and sprinklers in the commercial and industrial occupancies, with special emphasis on exploring the role of these two categories of fire protection equipment on reducing deaths and injuries from fire. Consequently, the analysis divided the fire incidents in the above occupancies into the following conditions:

1. Neither sprinklers nor smoke detection was provided
2. Non-sprinklered buildings with operational smoke detection
3. Fully-sprinklered buildings without smoke detection
4. Fully-sprinklered buildings with operational smoke detection

The benefits of smoke detectors and sprinklers in commercial and industrial occupancies are indicated through the reduced casualty rates and casualty severities in fire incidents where smoke detectors or sprinklers operated. In commercial occupancies, the casualty rates with operating protection equipment are at least 10% less than the baseline casualty rate when no protection equipment is provided and in some cases were reduced by more than half. Similarly, in industrial occupancies, in fires with operating smoke detectors, the casualty rate is reduced by two-thirds for burn casualties and by a factor of 30 for all others, including those occupants not intimate with ignition.

Again, the lowest average casualty severity is associated with fire incidents in which a smoke detector operates. Low casualty severities are also found in those incidents where effective sprinkler operation was observed.

In less than 40% of fire incidents in both commercial and industrial occupancies did occupants respond to the alarm resulting from an activated smoke detector. This suggests that work is needed to understand why a minority of building occupants are responding to alarm signals in commercial and industrial occupancies.

Fires judged to be too small for smoke detector and sprinkler operation was used in the previous report [1] as a surrogate measure of their relative sensitivity. As in the previous studies, the fewer number of fires judged to be too small for smoke detector operation than for sprinklers reflects the fact that smoke detectors are capable of responding to smaller fires than sprinklers. Those fires which are “too small” for smoke detector or sprinkler response still pose a significant hazard, as indicated in casualty rates (fatal and non-fatal) in such fires.

6. References

1. Milke, J.A., Campanella, A.J., Childers, Cathleen T. and Wright, Brittany D., “Performance of Smoke Detectors and Sprinklers in Residential and Health-Care Occupancies,” for National Electrical Manufacturers Association, Department of Fire Protection Engineering, University of Maryland, May 14, 2010.

2. Budnick, Edward K., 1984, "Estimating Effectiveness of State-of-the-Art Detectors and Automatic Sprinklers on Life Safety in Residential Occupancies," Fire Technology, Vol. 20, No. 3, August.
3. Hall, John R., Jr., 2011, "US Experience with Sprinklers and Other Automatic Fire Extinguishing Equipment, Quincy, MA: NFPA, May.
4. Hall, John R., Jr., 2009, "High-Rise Building Fires," Quincy, MA: NFPA, June.
5. NFIRS, 2008, "National Fire Incident Reporting System 5.0," Emmitsburg, MD: National Fire Data Center, US Fire Administration, FEMA.

Appendix: Results from Analysis of NFIRS Data

Legend

Symptom	Scenario
A	Intimate with fire - Primary symptom = smoke inhalation
B	Intimate with fire - Primary symptom = Combination
C	Intimate with fire - Primary symptom = Burns
D	Not Intimate with fire - Primary symptom = smoke inhalation
E	Not Intimate with fire - Primary symptom = Combination
F	Not Intimate with fire - Primary symptom = Burns
G	No Casualty (Note: Cannot provide detailed information on

Non-sprinklered Commercial, No Smoke Detectors: Casualty Profile

Symptom	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	18	16	2	17	1
B	9	7	1	8	1
C	31	27	1	29	1
D	8	6	2	8	0
E	1	1	0	1	0
F	1	1	0	1	0
G	12503	N/A	N/A	N/A	N/A
Total	12571	58	6	64	3

Non-sprinklered Industrial, No Smoke Detectors: Casualty Profile

	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	40	40	0	38	2
B	15	15	0	14	1
C	38	36	2	37	1
D	4	4	0	4	0
E	0	0	0	0	0
F	4	4	0	4	0
G	10657	N/A	N/A	N/A	N/A
Total	10758	99	2	97	4

Non-sprinklered with Smoke Detectors in Commercial: Casualty Profile.

	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	31	26	1	27	0
B	14	11	1	12	0
C	21	19	3	20	2
D	14	7	1	8	0
E	0	0	0	0	0
F	0	0	0	0	0
G	10101	N/A	N/A	N/A	N/A
Total	10181	63	6	67	2

Non-sprinklered with Smoke Detectors in Commercial: Smoke Detector Performance

	Total	1-Too Small to Activate	2-Detector Operated	3-Failed to operate	Unknown	Null
A	31	1	26	2	2	0
B	14	0	12	0	2	0
C	21	6	9	1	5	0
D	14	0	11	2	1	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	10101	2463	5246	711	1681	0
Total	10181	2470	5304	716	1691	0

	Total	1 Alerted occup, occup respond	2- Alerted occup, occup failed	3- no occup	4- failed to alert occup	U- Undetermined	Null
A	31	20	1	0	0	5	5
B	14	3	0	9	0	0	2
C	21	7	0	2	0	0	12
D	14	10	0	0	1	0	3
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0
G	10101	3377	166	1377	54	271	4856
Total	10181	3417	167	1388	55	276	4878

Non-sprinklered with Smoke Detectors in Industrial: Casualty Profile

		Age		Impaired	
	Total	Adult	Child	Ambulatory	Otherwise Impaired
A	9	9	0	9	0
B	2	2	0	2	0
C	6	4	1	5	0
D	1	1	0	1	0
E	0	0	0	0	0
F	0	0	0	0	0
G	6090	N/A	N/A	N/A	N/A
Total	6108	16	1	17	0

Non-sprinklered with Smoke Detectors in Industrial: Smoke Detector Performance

	Total	1-Too Small to Activate	2-Detector Operated	3-Failed to operate	Unknown	Null
A	9	0	9	0	0	0
B	2	0	1	0	1	0
C	6	2	1	1	2	0
D	1	0	1	0	0	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	6090	1391	3263	392	1044	0
Total	6108	1393	3275	393	1047	0

	Total	1 Alerted occup, occup respond	2- Alerted occup, occup failed	3- no occup	4- failed to alert occup	U- Undetermined	Null
A	9	9	0	0	0	0	0
B	2	1	0	0	0	0	1
C	6	1	0	0	0	0	5
D	1	1	0	0	0	0	0
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0
G	6090	2125	90	857	29	161	2828
Total	6108	2137	90	857	29	161	2834

Sprinklers and Smoke Detectors in Commercial: Casualty Profile

		Age		Impaired	
	Total	Adult	Child	Ambulatory	Otherwise Impaired
A	21	19	2	21	0
B	10	8	2	10	0
C	25	24	1	25	0
D	5	5	0	5	0
E	0	0	0	0	0
F	0	0	0	0	0
G	6932	N/A	N/A	N/A	N/A
Total	6993	56	5	61	0

Sprinklers and Smoke Detectors in Commercial: Smoke Detector Performance

	Total	1-Too Small to Activate	2-Detector Operated	3-Failed to operate	Unknown	Null
A	21	8	12	0	1	0
B	10	4	6	0	0	3
C	25	8	13	1	3	0
D	5	2	2	1	0	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	6932	1901	3840	275	916	0
Total	6993	1923	3873	277	920	3

	Total	1 Alerted occup, occup respond	2- Alerted occup, occup failed	3- no occup	4- failed to alert occup	U- Undetermined	Null
A	21	8	1	0	1	3	8
B	10	4	2	0	0	0	4
C	25	11	3	0	0	1	10
D	5	2	0	0	0	0	3
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0
G	6932	2773	145	732	38	133	3111
Total	6993	2798	151	732	39	137	3136

Sprinklers and Smoke Detectors in Commercial: Sprinkler Performance

	Total	1-Operated and Effective	2-Operated and Not Effective	3-Fire too small to activate	4-Failed to operate	Undetermined	Null	0-Other
A	21	3	2	12	1	1	2	0
B	10	8	0	1	0	0	1	0
C	25	10	0	14	0	1	0	0
D	5	2	0	2	1	0	0	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	6932	1716	88	3584	269	416	828	31
Total	6993	1739	90	3613	271	418	831	31

Sprinklers and Smoke Detectors in Industrial: Casualty Profile

	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	45	45	0	21	0
B	12	12	0	6	0
C	32	31	1	13	1
D	2	2	0	0	0
E	0	0	0	0	0
F	0	0	0	0	0
G	6217	N/A	N/A	N/A	N/A
Total	6308	90	1	40	1

Sprinklers and Smoke Detectors in Industrial: Smoke Detector Performance

	Total	1-Too Small to Activate	2-Detector Operated	3-Failed to operate	Unknown	Null
A	45	13	26	2	4	0
B	12	0	10	0	2	0
C	32	7	23	0	2	0
D	2	0	2	0	0	0
E	0	0	0	0	0	0
F	0	0	0	0	0	0
G	6217	1525	3590	221	881	0
Total	6308	1545	3651	223	889	0

	Total	1 Alerted occup, occup respond	2- Alerted occup, occup failed	3- no occup	4- failed to alert occup	U- Undetermined	Null
A	45	25	1	0	0	0	19
B	12	9	0	0	0	2	1
C	32	18	1	1	0	2	10
D	2	2	0	0	0	0	0
E	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0
G	6217	2677	135	631	35	125	2614
Total	6308	2731	137	632	35	129	2644

Sprinklers and Smoke Detectors in Industrial: Sprinkler Performance

	Total	1-Operated and Effective	2-Operated and Not Effective	3-Fire too small to activate	4-Failed to operate	Undetermined	Null	0-Other
A	45	16	0	23	2	1	3	0
B	12	6	4	0	1	0	1	0
C	32	15	2	8	0	1	6	0
D	2	2	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	6217	1905	104	2659	248	324	954	23

Sprinklers only in Commercial: Casualty Profile

	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	4	3	2	3	1
B	0	0	0	0	0
C	4	3	2	3	1
D	1	1	1	0	1
E	0	0	0	0	0
F	0	0	0	0	0
G	1225	N/A	N/A	N/A	N/A
Total	1234	7	5	6	3

Sprinklers only in Commercial: Sprinkler Performance

	Total	1-Operated and Effective	2-Operated and Not Effective	3-Fire too small to activate	4-Failed to operate	Undetermined	Null	0-Other
A	4	1	0	3	0	0	0	0
B	0	0	0	0	0	0	0	0
C	4	1	0	1	2	0	0	0
D	1	0	0	0	0	0	1	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	1225	382	25	522	84	23	189	10
Total	1234	384	25	526	86	23	190	10

Sprinklers only in Industrial: Casualty Profile

	Total	Age		Impaired	
		Adult	Child	Ambulatory	Otherwise Impaired
A	23	22	1	23	0
B	3	3	0	3	0
C	19	19	0	19	0
D	1	1	0	1	0
E	0	0	0	0	0
F	3	0	0	0	0
G	1724	N/A	N/A	N/A	N/A
Total	1773	45	1	46	0

Sprinklers only in Industrial: Sprinkler Performance

	Total	1-Operated and Effective	2-Operated and Not Effective	3-Fire too small to activate	4-Failed to operate	Undetermined	Null	0-Other
A	23	3	2	10	6	0	2	0
B	3	3	0	0	0	0	0	0
C	19	7	2	7	3	0	0	0
D	1	1	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0
F	3	0	1	0	2	0	0	0
G	1724	613	31	669	139	27	238	7
Total	1773	627	36	686	150	27	240	7