U.S. EXPERIENCE WITH SPRINKLERS AND OTHER AUTOMATIC FIRE EXTINGUISHING EQUIPMENT

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Abstract

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. When sprinklers cover the area of fire origin, they operate in 95% of all reported structure fires large enough to activate sprinklers. When they operate, they are effective 96% of the time, resulting in a combined performance of operating effectively in 91% of reported fires where sprinklers were present in the fire area and fire was large enough to activate sprinklers. When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported structure fires is lower by 80% for home fires, where most structure fire deaths occur, and the rate of property damage per reported structure fire is lower by 45-70% for most property uses. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 94% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present. When sprinklers fail to operate, the reason most often given (63% of failures) is shutoff of the system before fire began. (All statistics are based on 2003-2006 fires reported to U.S. fire departments, excluding buildings under construction.)

Keywords: fire sprinklers; fire statistics; automatic extinguishing systems; automatic suppression systems

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Executive Summary

Automatic sprinklers are highly effective and reliable elements of total system designs for fire protection in buildings. Sprinklers operate in 95% of all reported structure fires large enough to activate sprinklers. When they operate, they are effective 96% of the time, resulting in a combined performance of operating effectively in 91% of all reported fires where sprinklers were present in the fire area and fire was large enough to activate them. The combined performance for the more widely used wet pipe sprinklers is 92%, while for dry pipe sprinklers, the combined performance is only 77%. By comparison, combined performance is 58% for dry chemical systems, 84% for carbon dioxide systems, and 82% for foam systems. These most current statistics are based on 2003-2006 fires reported to U.S. fire departments, excluding buildings under construction and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area and after some recoding between failure and ineffectiveness based on reasons given.

When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported home structure fires is lower by 80% and the rate of property damage per reported structure fire is lower by 45-70% for most property uses. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 94% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present.

The previous statistics are all taken from 2003-2006 data. One sprinkler performance statistic that goes back to the introduction of automatic fire sprinklers is the following: NFPA has no record of a fire killing 3 or more people in a completely sprinklered building where the system was properly operating, except in an explosion or flash fire or where civilians or firefighters were killed while engaged in fire suppression operations.

Of reported 2006 structure fires in health care properties, an estimated 64% showed automatic extinguishing equipment present. In 2003-2006 health care structure fires, 93% of the automatic extinguishing equipment reported was sprinklers. The majority of 2006 reported structure fires in manufacturing properties (56%), cold storage warehouses (55%), hotels and motels (53%), and public assembly properties (51%) also showed automatic extinguishing equipment present. In 2003-2006, sprinklers accounted for more than 90% of the automatic extinguishing equipment present for each of these property use groups, except for public assembly, where most were dry chemical systems.

The few surveys that have been done of sprinkler usage in general, not limited to fires, have found usage levels much higher than the sprinkler presence percentages in fires for the same properties. Sprinklers apparently are still rare in many of the places where people are most exposed to fire, including educational properties, offices, most stores, and especially homes, where most fire deaths occur. There is considerable potential for expanded use of sprinklers to reduce the loss of life and property to fire.

When sprinklers fail to operate, the reason most often given (63% of failures) was shutoff of the system before fire began, as may occur in the course of routine inspection maintenance. Other leading reasons were lack of maintenance (14%), inappropriate system for the type of fire (11%), and manual

intervention that defeated the system (9%). Only 3% of sprinkler failures were attributed to component damage.

When sprinklers operate but are ineffective, the reason usually had to do with an insufficiency of water applied to the fire, either because water did not reach the fire (42% of cases of ineffective performance) or because not enough water was released (29%). Other leading reasons were inappropriate system for the type of fire (11%), lack of maintenance (3%), and manual intervention that defeated the system (3%). Only 3% of cases of sprinkler ineffectiveness were attributed to component damage.

When people die in fires despite the presence of operating sprinklers, it is often because they are close to the fire when it begins (85% of fatal victims in the area of origin and 34% with their clothing on fire when sprinklers operate, compared to 53% and 7% of fatal victims when no automatic extinguishing equipment was present) or because they had some severe vulnerabilities or limitations before fire began (44% of fatal victims when sprinklers operated were age 65 or older and 34% returned to fire after escaping, were unable to act, or acted irrationally when fatally injured, compared to 28% and 18% of fatal victims in general).

Table of Contents

Executive Summary	i
Table of Contents	iii
List of Tables	v
Fact Sheet	vii
Introduction	1
Presence of Sprinklers and Other Automatic Extinguishing Equipment	3
Automatic Extinguishing Equipment Type	9
Automatic Extinguishing Equipment Operational Reliability	13
Automatic Extinguishing Equipment Effectiveness	27
Other Issues	59
Concluding Points	65
Appendix A: How National Estimates Statistics Are Calculated	67
Appendix B: Sprinkler-Related Data Elements in NFIRS 5.0	75
Appendix C: Multiple-Death Fries in Fully Sprinklered Properties	77

List of Tables

Table 1. Percentage of Structure Fires Estimated to Have Occurred in Structures With Automatic Extinguishing Equipment 5

Table 2. Type of Automatic Extinguishing Equipment Reported as Percentage of All Structure Fires Where Equipment Was Present and of Known Type 11

Table 3. Automatic Extinguishing Equipment Operationality When Fire Was Large Enough to Activate Equipment 16

Table 4. Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire 21

Table A. Areas of Origin That Could Be Room Larger Than Sprinkler Design Area for the Space 28

Table B. Combined Sprinkler Performance vs. Sprinkler Success in Confining Fire to Room of Origin 30

Table C. Leading Areas of Origin for Non-Confined or Confined Fires in One- or Two-Family Dwellings 31

Table 5. Automatic Extinguishing Equipment Performance 37

Table 6. Automatic Extinguishing Equipment Effectiveness 42

Table 7. Extent of Flame Damage, for Sprinklers Present vs. Automatic Extinguishing Equipment Absent 47

Table 8. Number of Sprinklers Operating 48

Table 9. Sprinkler Effectiveness Related to Number of Sprinklers Operating 50

Table 10. Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire 51

Table 11. Estimated Reduction in Civilian Deaths per Thousand Fires Due to Wet Pipe Sprinklers 56

Table 12. Characteristics of Fatal Victims When Wet Pipe Sprinklers Operate vs. All Conditions 57

Table 13. Estimated Reduction in Average Direct Property Damage per Fire Due to Wet Pipe Sprinklers 58

Table D. Non-Fire Sprinkler Activations and Major Property Use Group 60

Table E. Non-Fire Sprinkler Activations by Likelihood of Water Release and Major Property Use Group 60

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U.S. Experience with Sprinklers

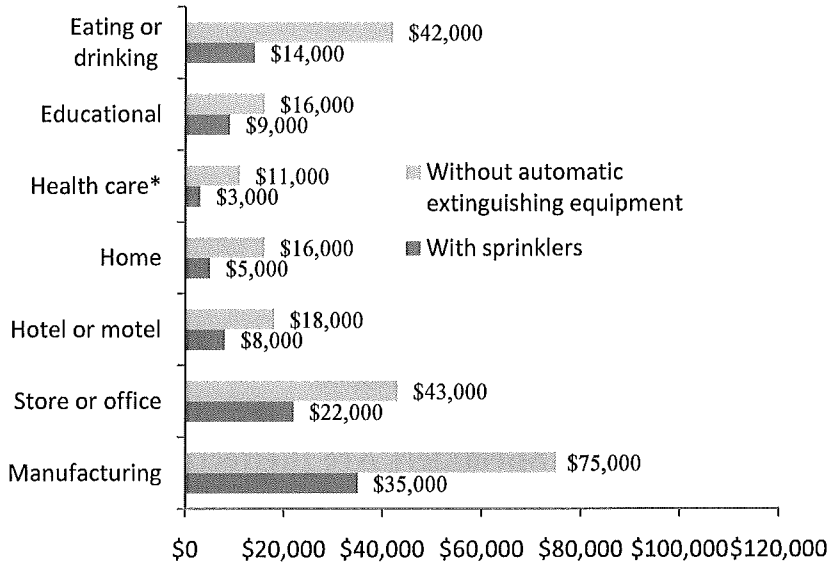
Sprinklers save lives and protect property from fires.

Compared to properties without automatic extinguishing equipment

- The death rate per fire in sprinklered homes is lower by 80%.
- For most property uses, damage per fire is lower by 45-70% in sprinklered properties.

Flame damage was confined to the room of origin in 94% of fires in sprinklered properties vs. 74% in fires with no automatic extinguishing equipment.

Damage per Fire With and Without Sprinklers, 2003-2006



*Health care refers only to hospitals, nursing homes, and clinics.

Sprinklers are reliable and effective.

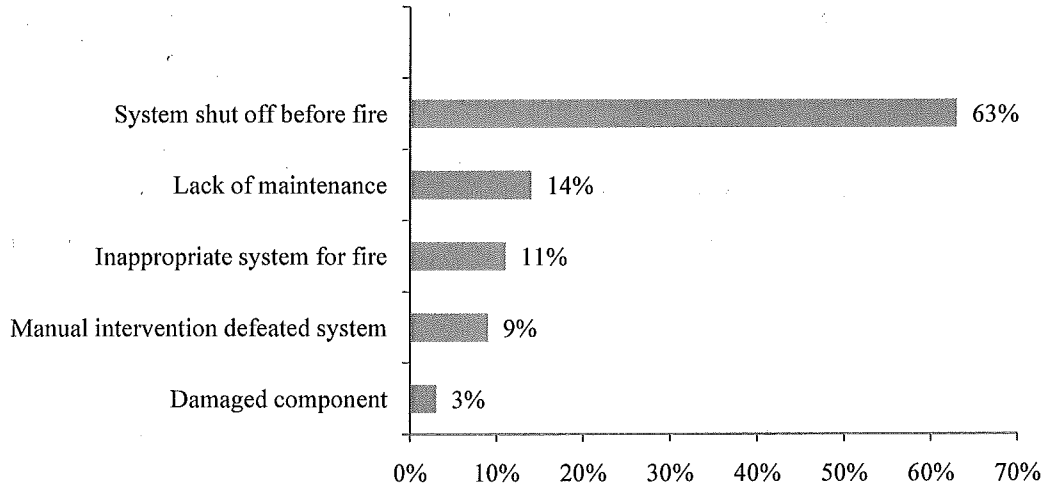
- In reported structure fires large enough to activate them, sprinklers operated in 95% of fires in sprinklered properties.
- Wet pipe sprinklers operated in 96% of these fires vs. 84% for dry pipe sprinklers.
- In reported structure fires large enough to activate them, sprinklers operated and were effective in 91% of fires in sprinklered properties.
- Wet pipe sprinklers operated and were effective in 92% of fires vs. 77% for dry pipe sprinklers.

NOTE: NFPA's Fire Sprinkler Initiative: Bringing Safety Home is a nationwide effort to encourage the use of home fire sprinklers and the adoption of fire sprinkler requirements for new construction. See www.firesprinklerinitiative.org.

Based on 2003-2006 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

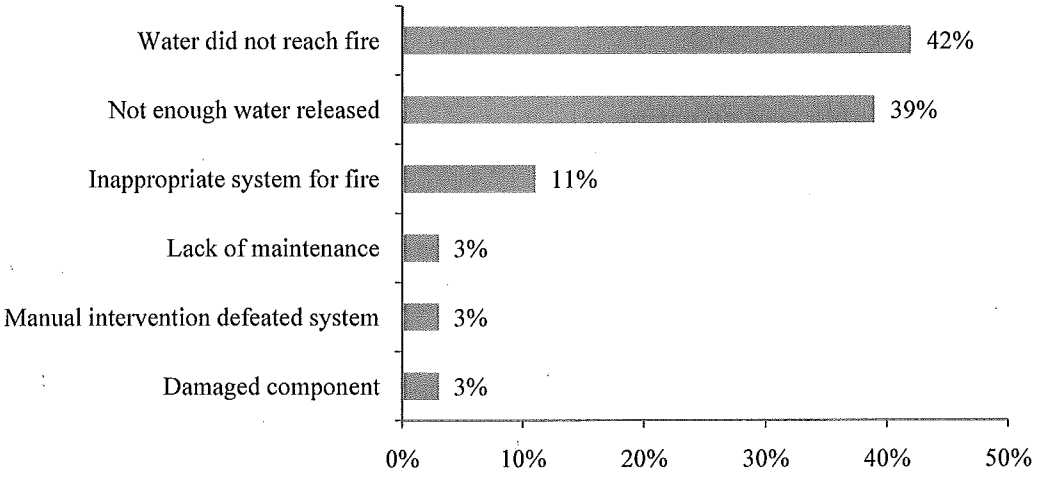
The graph below is based on the 5% of fires in sprinklered properties in which the sprinkler should have operated but did not.

Reasons When Sprinklers Fail to Operate
2003-2006



In fires where sprinklers operated, they were effective in 96% of the cases. The graph below is based on the other 4%, in which the sprinkler was ineffective.

Reasons When Sprinklers Are Ineffective
2003-2006



Usually only 1 or 2 sprinklers are required to control the fire.

- When wet pipe sprinklers operated, 88% of reported fires involved only 1 or 2 sprinklers.
- For dry pipe sprinklers, 73% involved only 1 or 2 sprinklers.

Based on 2003-2006 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

Introduction

There have been a number of changes related to automatic extinguishing equipment in the National Fire Incident Reporting System (NFIRS) since 1999. Here are some points to keep in mind when reading this report:

- Statistics by year on automatic extinguishing equipment present do not distinguish by type of equipment (and in particular do not distinguish sprinklers) because no such distinction was possible prior to 1999. There is a table for 2003-2006 on type of equipment present for reported fires where some type of automatic extinquishing equipment was present.

- In most tables, fires in buildings with reported structure status of under construction are excluded. No fire protection systems or features can be expected to perform as designed in a building that is still under construction.

- Statistics on reliability, effectiveness, and performance exclude partial systems as identified by reason for failure and ineffectiveness equal to equipment not in area of fire. Not all partial systems will be so identified, and the codes and standards for this equipment do not require coverage in all areas. For example, concealed spaces and exterior locations may not be required to have coverage.

- There was no way to code automatic extinquishing equipment as unknown in NFIRS Version 5.0 during 1999 to 2003, although there was the option of leaving the field blank. During that period, the U.S. Fire Administration advised that unknowns should be reported as no equipment present.* This arrangement had the potential to severely understate the presence of automatic extinguishing equipment. However, the estimates for 2002 and 2003 are not substantially lower than either the pre-1999 estimates or the three years of estimates from 2004 and later. Therefore, this potential problem seems to have had little effect in practice.

- NFIRS Version 5.0 began in 1999, and participation grew slowly. The only statistics by year in this report are statistics on fraction of reported fires with automatic extinguishing equipment present, by property use group. Statistics for 1999-2001 are not shown because of low participation in NFIRS Version 5.0 in those years. Statistics for 2002 are shown but are not used in the other analyses.

In this analysis, information on reasons for failure or ineffectiveness is used to recode incidents for more accurate treatment of cases where sprinklers are not in the area of fire.
The coding of reasons for failure or ineffectiveness has been used in this analysis to recode system performance entries. Unknown reasons have been proportionally allocated to avoid the dubious alternative assumption that the coded performance is correct if no reason is given for the performance.

* U.S. Fire Administration, *NFIRS Coding Questions*, revised January 2, 2002, p.13.

Recoding rules used

If Performance =	Not Effective	
	And Reason =	Then Change to:
	System shut off	Performance = Failed to operate
	Not in area of fire	Presence = No; Performance not applicable

If Performance =	Failed to Operate	
	And Reason =	Then Change to:
	Not enough agent	Performance = Not effective
	Agent didn't reach fire	Performance = Not effective
	Not in area of fire	Presence = No; Performance not applicable

Note that this recoding will not address partial sprinkler systems where there were sprinklers in part or all of the fire area unless the system is ineffective because of fire spread to or from uncovered areas.

Presence of Sprinklers and Other Automatic Extinguishing Equipment

Table 1 shows the percentage of reported nonconfined and confined structure fires, excluding buildings under construction, in which automatic extinguishing equipment was present for each year in the ranges of 1980-1998 and 2002-2006. Confined fires are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reporting with most data fields not required and usually left blank.

The following properties consistently show a majority of reported fires in properties with automatic extinguishing equipment present from 2003 to 2006:

- Eating or drinking establishments
- Health care facilities
- Manufacturing facilities

Dormitories and barracks showed a jump in reported presence of automatic extinguishing equipment in 2006, which may reflect the influence of national campaigns to increase fire protection and fire safety on campuses.

The following properties where large numbers of people routinely are present typically show less than one-third of reported fires in properties with automatic extinguishing equipment present:

- Apartments
- Stores and offices

Educational properties have shown roughly one-third of reported fires in properties with automatic extinguishing equipment present in the most recent two years of 2005 and 2006. Public assembly properties showed over half of 2006 reported fires in properties with automatic extinguishing equipment present, but the percentages have been consistently below one-third for public assembly properties other than eating and drinking establishments.

Most fires in storage properties are not in warehouses but are in garages, barns, silos, and small outbuildings. It is these types of buildings that drive the very low percentage of reported fires with automatic extinguishing equipment in all storage properties combined.

In 2006, automatic extinguishing equipment was reported in only 1% of fires in one- or two-family dwellings and only 16% of fires in apartments. Clearly, there is great potential for expanded use.

The 2007 American Housing Survey included a question about sprinkler usage in homes.* The survey indicated 3.9% of occupied year-round housing units had sprinklers. Usage in occupied housing units by type of housing shows usage in dwellings lag behind usage in multi-unit buildings:

- 1.5% of single family detached dwellings,
- 1.9% of single family dwellings, whether detached or attached,
- 10.6% of all housing units in multi-unit buildings,

* *American Housing Survey 2007*, U.S. Department of Commerce and U.S. Department of Housing and Urban Development, September 2008, Table 1C-4, 2-4, and 2-25.

- 2.9% of housing units in buildings with 2-4 units,
- 5.8% of housing units in buildings with 5-9 units,
- 12.1% of housing units in buildings with 10-19 units,
- 16.3% of housing units in buildings with 20-49 units, and
- 27.3% of housing units in buildings with 50 or more units.

Sprinklers are in use in 13.0% of housing units in buildings that were constructed no more than four years ago. This is more than triple the percentage for all housing units. It also suggests a higher percentage of sprinkler usage in newly constructed dwellings – for which specific statistics were not provided in the published report – than previous estimates.

Sprinkler usage is higher in the West region than in other regions and lower in rural areas than in non-rural areas.

To underscore the principal finding, more than 1 million single family detached dwellings now have fire sprinklers.

The Home Fire Sprinkler Coalition, formed in 1996, developed a variety of educational materials about the benefits of home fire sprinklers. These materials address common questions and misconceptions. They may be accessed through their web site http://www.homefiresprinkler.org.

Because sprinkler systems are so demonstrably effective, they can make a major contribution to fire protection in any property. The 2006 editions of NFPA 101®, *Life Safety Code*; NFPA 1, *Uniform Fire Code*, and NFPA 5000®, *Building Construction and Safety Code*, require sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs. The 2009 edition of the *International Residential Code*, effective in January 2011, also added requirements for sprinklers in one- or two-family dwellings. This protection can be expected to increase in areas that adopt and follow these revised codes.

In 2009, NFPA launched the Fire Sprinkler Initiative: Bringing Safety Home. Its aim is to encourage the adoption of requirements for automatic fire sprinklers in new one- and two-family homes. Materials and resources for advocates of this goal are available on the initiative's website, www.firesprinklerinitiative.org.

Outside the limited data on facilities that have fires, we know very little about the extent of usage of sprinklers or other automatic extinguishing systems in buildings in general, overall or for any specific property class. Surveys of such usage are quite rare.

In general, the extent of usage of sprinklers in any property class will be considerably higher than the percentage of fires occurring in sprinklered properties in that property class. As with detection/ alarm systems and all other fire protection features, in property classes where sprinklers are not required, they will tend to go first into the properties that can afford them most, not the high-risk fire-prone properties that would benefit most from their presence.

Table 1.
Percentage of Structure Fires Estimated to Have Occurred in Structures With Automatic Extinguishing Equipment 1980-1998 and 2002-2006, Including Non-Confined and Confined Fires In and After 2002

Property Use	1980	1981	1982	1983	1984	1985	1986
Public assembly	12.2%	12.3%	13.5%	14.3%	14.6%	15.6%	15.9%
(Eating or drinking establishment)	(14.3%)	(14.6%)	(16.4%)	(17.4%)	(17.7%)	(19.0%)	(18.7%)
Educational	13.0%	13.6%	12.6%	13.1%	14.1%	16.4%	15.0%
Health care*	50.1%	50.6%	51.1%	51.1%	51.1%	58.1%	61.5%
Residential	0.9%	1.2%	1.0%	0.9%	1.2%	1.4%	1.7%
(One- or two-family dwelling)	(0.2%)	(0.2%)	(0.2%)	(0.2%)	(0.2%)	(0.4%)	(0.5%)
(Apartment)	(3.2%)	(4.4%)	(3.8%)	(3.3%)	(4.1%)	(4.2%)	(4.5%)
(Hotel and motel)	(11.5%)	(14.8%)	(16.7%)	(15.2%)	(17.6%)	(19.0%)	(23.4%)
(Dormitory or barracks)	(16.5%)	(19.5%)	(12.1%)	(15.6%)	(15.2%)	(22.8%)	(17.2%)

Property Use	1987	1988	1989	1990	1991	1992	1993
Public assembly	17.9%	18.5%	19.2%	20.1%	19.8%	20.9%	21.2%
(Eating or drinking establishment)	(21.8%)	(22.1%)	(22.7%)	(23.8%)	(23.2%)	(24.9%)	(24.9%)
Educational	16.4%	17.0%	17.2%	18.9%	18.1%	19.0%	21.5%
Health care*	63.5%	62.3%	64.3%	66.1%	66.1%	67.9%	70.1%
Residential	1.7%	2.4%	2.4%	2.6%	2.5%	2.7%	2.6%
(One- or two-family dwelling)	(0.4%)	(0.9%)	(0.8%)	(0.8%)	(0.8%)	(0.7%)	(0.7%)
(Apartment)	(4.5%)	(6.0%)	(5.9%)	(5.9%)	(6.1%)	(6.9%)	(6.6%)
(Hotel or motel)	(24.9%)	(29.0%)	(30.1%)	(31.7%)	(30.6%)	(31.6%)	(32.1%)
(Dormitory or barracks)	(22.0%)	(21.3%)	(21.7%)	(28.7%)	(21.3%)	(22.2%)	(24.1%)

* Nursing home, hospital, or clinic.

Notes: These are structure fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on non-confined structure fires reported in Version 5.0 of NFIRS. Single-year estimates are unstable and unreliable in 1999-2001 because of the small number of fires reported with AES presence known and in NFIRS Version 5.0 in those years. After 1998, buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred in Structures With Automatic Extinguishing Equipment 1980-1998 and 2002-2006, Including Non-Confined and Confined Fires In and After 2002

Property Use	1994	1995	1996	1997	1998
Public assembly	22.6%	24.2%	24.5%	25.6%	30.7%
(Eating or drinking establishment)	(26.3%)	(28.9%)	(28.7%)	(30.6%)	(31.5%)
Educational	23.6%	22.7%	21.9%	25.9%	25.3%
Health care*	69.9%	70.3%	71.1%	72.9%	74.3%
Residential	2.5%	2.2%	2.6%	3.0%	3.1%
(One- or two-family dwelling)	(0.7%)	(0.4%)	(0.6%)	(0.7%)	(0.7%)
(Apartment)	(6.3%)	(5.6%)	(6.8%)	(7.7%)	(7.9%)
(Hotel or motel)	(31.9%)	(32.3%)	(34.6%)	(34.0%)	(40.4%)
(Dormitory or barracks)	(24.7%)	(31.6%)	(25.9%)	(28.4%)	(34.9%)

Property Use	2002	2003	2004	2005	2006
Public assembly	45.9%	45.9%	47.9%	45.9%	51.3%
(Eating or drinking establishment)	(56.2%)	(57.0%)	(55.1%)	(56.2%)	(61.1%)
Educational	28.2%	29.5%	29.3%	33.3%	34.0%
Health care*	69.3%	66.9%	64.1%	65.4%	64.1%
Residential	3.9%	4.6%	4.6%	5.1%	6.3%
(One- or two-family dwelling)	(1.2%)	(1.5%)	(1.2%)	(1.1%)	(1.2%)
(Apartment)	(9.3%)	(13.0%)	(12.1%)	(12.7%)	(16.4%)
(Hotel or motel)	(53.9%)	(39.1%)	(40.2%)	(46.4%)	(53.3%)
(Dormitory or barracks)	(23.0%)	(25.3%)	(40.1%)	(46.8%)	(58.1%)

*Nursing home, hospital, or clinic..

Notes: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on data reported in Version 5.0 of NFIRS. Single-year estimates are unstable and unreliable in 1999-2001 because of the small number of fires reported with AES presence known and in NFIRS Version 5.0 in those years. After 1998, buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred
in Structures With Automatic Extinguishing Equipment
1980-1998 and 2002-2006, Including Non-Confined and Confined Fires In and After 2002

Property Use	1980	1981	1982	1983	1984	1985	1986
Store or office	11.9%	12.4%	12.2%	12.9%	13.7%	14.6%	15.9%
(Department store)	(47.2%)	(48.2%)	(44.1%)	(41.4%)	(39.2%)	(42.8%)	(46.7%)
(Office building)	(9.9%)	(11.3%)	(12.8%)	(12.7%)	(14.3%)	(16.2%)	(15.9%)
Manufacturing	44.9%	44.2%	42.1%	44.6%	44.8%	46.5%	47.7%
Storage facilities	2.0%	1.6%	1.8%	2.1%	2.5%	3.0%	2.9%
(Warehouse excluding cold storage)	(10.0%)	(7.9%)	(8.1%)	(9.2%)	(10.5%)	(13.1%)	(12.9%)
(Cold storage)	(8.2%)	(13.4%)	(10.3%)	(0.0%)	(21.2%)	(19.4%)	(7.3%)
All structures*	4.0%	4.1%	4.0%	3.9%	4.3%	5.0%	5.2%

Property Use	1987	1988	1989	1990	1991	1992	1993
Store or office	18.4%	18.8%	19.7%	19.6%	19.2%	20.3%	20.6%
(Department store)	(49.8%)	(54.0%)	(52.5%)	(50.5%)	(49.1%)	(54.2%)	(55.5%)
(Office building)	(19.3%)	(20.1%)	(21.1%)	(22.8%)	(22.0%)	(24.1%)	(25.4%)
Manufacturing facilities	49.1%	48.5%	49.0%	49.3%	48.9%	48.6%	50.1%
Storage facilities	2.9%	2.5%	3.3%	3.2%	3.0%	2.8%	3.0%
(Warehouse excluding cold storage)	(13.7%)	(12.2%)	(14.1%)	(14.6%)	(13.2%)	(13.3%)	(14.4%)
(Cold storage)	(27.5%)	(27.8%)	(24.5%)	(0.0%)	(19.5%)	(21.1%)	(11.4%)
All structures*	5.6%	5.7%	5.9%	6.1%	6.0%	6.1%	6.1%

* "All structures" include some property uses not listed individually.

Notes: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on data reported in Version 5.0 of NFIRS. Single-year estimates are unstable and unreliable in 1999-2001 because of the small number of fires reported with AES presence known and in NFIRS Version 5.0 in those years. After 1999, buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred in Structures With Automatic Extinguishing Equipment
1980-1998 and 2002-2006, Including Non-Confined and Confined Fires In and After 2002

Property Use	1994	1995	1996	1997	1998
Store or office	20.9%	20.1%	21.1%	22.2%	22.7%
(Department store)	(50.5%)	(49.5%)	(52.7%)	(53.0%)	(52.1%)
(Office building)	(23.9%)	(25.3%)	(25.4%)	(25.5%)	(26.9%)
Manufacturing facilities	48.5%	50.1%	50.7%	51.2%	51.5%
Storage facilities	2.8%	2.7%	2.8%	3.2%	3.1%
(Warehouse excluding cold storage)	(14.5%)	(13.9%)	(15.0%)	(15.9%)	(16.5%)
(Cold storage)	(25.5%)	(22.7%)	(17.1%)	(8.3%)	(8.0%)
All structures*	6.1%	5.8%	6.3%	7.1%	7.2%

Property Use	2002	2003	2004	2005	2006
Store or office	24.9%	27.2%	27.8%	30.4%	30.1%
(Department store)	(29.9%)	(40.5%)	(36.1%)	(51.5%)	(40.9%)
(Office building)	(29.9%)	(34.8%)	(25.5%)	(27.7%)	(25.1%)
Manufacturing facilities	57.1%	56.8%	56.0%	55.8%	56.1%
Storage facilities	3.9%	4.1%	4.2%	3.2%	4.3%
(Warehouse excluding cold storage)	(38.6%)	(40.0%)	(39.0%)	(36.9%)	(36.6%)
(Cold storage)	(46.7%)	(50.0%)	(60.0%)	(30.4%)	(55.0%)
All structures*	8.5%	9.4%	9.7%	9.6%	10.8%

* "All structures" include some property uses not listed individually.

Notes: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on data reported in Version 5.0 of NFIRS. Single-year estimates are unstable and unreliable in 1999-2001 because of the small number of fires reported with AES presence known and in NFIRS Version 5.0 in those years. After 1999, buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Automatic Extinguishing Equipment Type

In reported fires, most automatic extinguishing equipment is recorded as sprinklers, and most sprinklers are wet pipe sprinklers.
Table 2 shows the percentage of non-confined and confined fires, excluding buildings under construction, by type of automatic extinguishing equipment for each of the major property groups and some subgroups. Confined fires are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reported with most data fields ot required and usually left blank. Percentage calculations are based only on fires where automatic extinguishing equipment presence and type were known and reported. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started.

Some type of sprinkler system was present in 79% of 2006 fires where automatic extinguishing equipment was present. Wet pipe sprinkler systems accounted for 70% of all systems and so out-numbered dry pipe systems by roughly 10-to-1.

The major property class with the largest share for dry pipe sprinklers was storage, where dry pipe sprinklers accounted for 21% of the systems cited. Cold storage was the only property class for which dry pipe sprinklers constituted a majority (in this case, 65%) of systems cited.

The last report analyzed only non-confined fires, while this report includes confined fires in the analysis. This change adds a large number of confined cooking fires to the database, which explains the shift from sprinklers (88% of equipment in the last report, 79% in this report) to other equipment and especially to dry chemical equipment (7% of equipment in the last report and 13% in this report).

For public assembly properties, there was a 38% to 62% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 43% of the systems present. Combining these results with the earlier tables, one can see that less than one-third of reported fires in public assembly properties had sprinklers present in the area of fire. Eating or drinking establishments (the dominant part of public assembly) had a 27% to 73% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 41% of total systems in eating or drinking establishments, nearly twice the share for all sprinklers combined.

It would be useful to have a better sense of what kind of equipment is coded as "other special hazard systems." There are some types of automatic suppression equipment that would not fit into any of the defined categories, such as equipment using wet chemicals. It is also possible that some fires will be coded as other special hazard system when they really involved automatic extinguishing equipment of one of the defined types. The category also could be used for some devices that are not automatic and so should not be coded as automatic extinguishing equipment present.

Public assembly properties, especially eating and drinking establishments, have the highest percentages for both dry chemical systems (43% and 50%, respectively) and other special hazard systems (10% and 11%, respectively). Roughly ten years ago, the applicable standards for eating and drinking establishments required that dry chemical systems be replaced by wet chemical systems, but there is no category labeled for wet chemical systems. It seems likely that some wet chemical systems

will be coded as other special hazard systems and some will be coded as dry chemical systems, the latter being the well-defined equipment type closets to a wet chemical system.

Some insight into what is being coded under "other special hazard systems" comes from a check of uncoded narratives for the three restaurant fires in recent years in Minnesota where such equipment was reported. (The narratives on these fires were part of a data set provided for a special analysis, which is described on pp. 60-61.) One fire involved a wet chemical system, and another involved an undefined hood system, which could have involved dry or wet chemical agents. The third fire involved use of portable extinguisher and should not have been coded as automatic extinguishing equipment present.

Table 2.
Type of Automatic Extinguishing Equipment Reported as Percentage of All Structure Fires Where Equipment Was Present and of Known Type, by Property Use
2003-2006 Confined and Non-Confined Fires

Property Use	All sprinklers	Wet pipe sprinklers	Dry pipe sprinklers	Other sprinklers*
Public assembly	38%	32%	2%	3%
(Eating or drinking establishment)	(27%)	(22%)	(2%)	(4%)
Educational	88%	78%	6%	4%
Health care**	93%	80%	12%	1%
Residential	95%	86%	6%	2%
(Home)	(95%)	(87%)	(6%)	(2%)
(One- or two-family dwelling)	(82%)	(74%)	(4%)	(4%)
(Apartment)	(96%)	(88%)	(6%)	(2%)
(Hotel or motel)	(95%)	(87%)	(4%)	(4%)
(Dormitory or barracks)	(93%)	(77%)	(15%)	(1%)
Store or office	75%	66%	7%	2%
(Department store)	(94%)	(84%)	(9%)	(1%)
(Office building)	(99%)	(87%)	(10%)	(1%)
Manufacturing	91%	79%	10%	3%
Storage	97%	74%	21%	2%
(Warehouse excluding cold storage)	(99%)	(81%)	(17%)	(1%)
(Cold storage)	(100%)	(35%)	(65%)	(0%)
All structures***	79%	70%	7%	3%

* Includes deluge and pre-action sprinkler systems and may include sprinklers of unknown or unreported type.

** Nursing home, hospital, or clinic.

*** Includes some property uses that are not shown separately.

Note: These are based on structure fires reported to U.S. municipal fire departments in NFIRS Version 5.0 and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Row totals are shown in the left column, and sums may not equal totals because of rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 2. (Continued)
Type of Automatic Extinguishing Equipment Reported as Percentage of All Structure Fires Where Systems Were Present and of Known Type, by Property Use
2003-2006 Non-Confined and Confined Fires

Property Use	All systems other than sprinklers	Dry chemical system*	Carbon dioxide (CO2) system	Halogen type system*	Foam system	Other special hazard system*
Public assembly	62%	43%	3%	3%	4%	10%
(Eating or drinking establishment)	(73%)	(50%)	(3%)	(3%)	(5%)	(11%)
Educational	12%	9%	0%	0%	1%	1%
Health care**	7%	5%	1%	0%	0%	1%
Residential	5%	3%	0%	0%	0%	2%
(Home)	(5%)	(3%)	(0%)	(0%)	(0%)	(2%)
(One- or two-family dwelling)	(18%)	(6%)	(0%)	(0%)	(0%)	(12%)
(Apartment)	(4%)	(3%)	(0%)	(0%)	(0%)	(1%)
(Hotel or motel)	(5%)	(2%)	(0%)	(0%)	(0%)	(3%)
(Dormitory or barracks)	(7%)	(5%)	(0%)	(0%)	(0%)	(2%)
Store or office	25%	15%	3%	1%	3%	4%
(Department store)	(6%)	(5%)	(0%)	(0%)	(0%)	(0%)
(Office building)	(1%)	(1%)	(0%)	(1%)	(0%)	(0%)
Manufacturing	9%	2%	5%	0%	1%	2%
Storage	3%	1%	0%	0%	0%	2%
(Warehouse excluding cold storage)	(1%)	(0%)	(0%)	(0%)	(0%)	(0%)
(Cold storage)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
All structures***	21%	13%	2%	1%	2%	4%

* "Halogen type system" includes non-halogenated suppression systems that operate on the same principle. "Other special hazard system" may include automatic extinguishing systems that are known not to be sprinklers but otherwise are of unknown or unreported type. "Dry chemical system" may include wet chemical systems, because there is no category designated for wet chemical systems.

** Nursing home, hospital, or clinic.

*** Includes some property uses that are not shown separately.

Note: These are based on structure fires reported to U.S. municipal fire departments in NFIRS Version 5.0 and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Row totals are shown in the left column, and sums may not equal totals because of rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Building under construction are excluded.

Source: NFIRS and NFPA survey.

Automatic Extinguishing Equipment Operational Reliability

Table 3 shows the percentage of non-confined and confined structure fires, excluding buildings under construction, where automatic extinguishing equipment failed to operate, after removal from the data set of incidents with partial systems not in area of fire, for:

- All sprinklers
- Wet pipe sprinklers
- Dry pipe sprinklers
- Dry chemical systems,
- Carbon dioxide systems, and
- Foam systems.

Property use classes are shown only if they accounted for at least 90 raw fire incidents in 2003-2006, before scaling up and before allocation of unknowns. However, confined fires usually have these details unreported, and so their few fires with details reported will be weighted far more heavily, after allocation of unknowns, than will non-confined fires. Halogen type systems were not reported in enough fires to support any separate analysis, even for all structures combined.

Sprinklers in the area of fire failed to operate in only 5% of reported structure fires large enough to activate sprinklers.
Failure rates are equal to 100% minus the percentage of systems that operated, which is the percentage shown in Table 3. The other estimated failure rates corresponding to percentage operating rates shown in Table 3 are:

- 4% for wet pipe sprinklers,
- 16% for dry pipe sprinklers,
- 29% for dry chemical systems,
- 12% for carbon dioxide systems, and
- 3% for foam systems.

For major property classes and sprinklers, the estimated failure rates range from a low of 2% for residential properties to a high of 21% for storage properties. For storage properties, the estimated failure rates are 15% for wet pipe sprinklers and 49% for dry pipe sprinklers.

The majority of sprinkler failures occurred because the system was shut off.
Table 4 provides the percentages of reasons for failure, after recoding, by type of automatic extinguishing system and property use. Other or unclassified reason for failure is treated as an unknown and allocated.

For all types of sprinklers combined:

- 63% of failures to operate were attributed to the equipment being shut off,
- 14% were because of lack of maintenance,
- 11% were because the equipment was inappropriate for the type of fire,
- 9% were because manual intervention defeated the equipment, and
- 3% were because a component was damaged.

If manual intervention occurs before fire begins, one would expect that to be coded as system shut off before fire. If manual intervention occurs after sprinklers operate, one would expect that to constitute ineffective performance, not failure to operate. What is left is manual intervention after fire begins but before sprinklers operate, but we do not know whether that is the only condition associated with this coding.

Only 3% were because of a failing of the equipment rather than a failing of the people who designed, selected, maintained, and operated the equipment. If these human failings could be eliminated, the overall sprinkler failure rate would drop from the estimated 5% of reported fires to less than 0.2%. That is the kind of sprinkler failure rate reported by Marryatt* for Australia and New Zealand, where high standards of maintenance are reportedly commonplace.

The likelihood of failures due to system being shut off can be greatly reduced through the use of programs that put highly noticeable tags on systems shut off for testing and maintenance. Valve supervision using a tamper switch connected to a central alarm monitoring station can also be helpful.

Training can sharply reduce the likelihood of three other causes of failure – system defeating due to manual intervention, lack of maintenance, and installation of the wrong system for the hazard.

If the failure rate percentages (calculated as 100% minus the percentages of cases where equipment operated, taken from Table 3A) are multiplied by the percentage of failures due to a particular reason, (taken from Table 4A), the results are rates of failure due to particular reason. The following are combinations of property use groups and failure reasons for which the failure rate due to that reason was at least 1% for that property use group.

- In 19% (= 89% of 22%) of warehouse fires (with sprinklers and fire large enough to activate a sprinkler), sprinklers failed due to system shut off.
- In 18% (= 85% of 21%) of total storage fires, sprinklers failed due to system shut off.
- In 7% (= 81% of 9%) of hotel or motel fires, sprinklers failed due to inappropriate system.
- In 5% (= 76% of 7%) of one- or two-family dwelling fires, sprinklers failed due to system shut off.
- In 5% (= 64% of 7%) of manufacturing facility fires, sprinklers failed due to system shut off.
- In 3% (= 63% of 5%) of total structure fires, sprinklers failed due to system shut off.
- In 3% (= 48% of 7%) of educational property fires, sprinklers failed due to system shut off.
- In 3% (= 60% of 5%) of office building fires, sprinklers failed due to system shut off.
- In 2% (= 61% of 4%) of store or office fires, sprinklers failed due to system shut off.
- In 2% (= 62% of 4%) of public assembly fires, sprinklers failed due to system shut off.
- In 2% (= 33% of 7%) of educational property fires, sprinklers failed due to manual intervention defeating the system.
- In 2% (= 60% of 3%) of eating or drinking establishment fires, sprinklers failed due to system shut off.

*H.W. Marryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand*, 1886-1986, 2nd edition, Victoria, Australia: Australian Fire Protection Association, 1988.

- In 2% (= 32% of 5%) of office building fires, sprinklers failed due to manual intervention defeating the system.
- In 1% (= 21% of 7%) of manufacturing facility fires, sprinklers failed due to lack of maintenance.
- In 1% (= 29% of 4%) of health care facility fires, sprinklers failed due to manual intervention defeating system.
- In 1% (= 6% of 21%) of total storage fires, sprinklers failed due to component damage.
- In 1% (= 16% of 7%) of one- or two-family dwelling fires, sprinklers failed due to component damage.
- In 1% (= 5% of 22%) of warehouse fires, sprinklers failed due to component damage.
- In 1% (= 65% of 2%) of home fires, sprinklers failed due to system shut off.
- In 1% (= 11% of 9%) of hotel or motel fires, sprinklers failed due to manual intervention defeating the system.
- In 1% (= 24% of 4%) of health care facility fires, sprinklers failed due to system shut off.

Table 3.
Automatic Extinguishing Equipment Operationality
When Fire Was Large Enough to Activate Equipment, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

A. All Sprinklers

Property Use	Percent where system operated
Public assembly	96%
(Eating or drinking establishment)	(97%)
Educational	93%
Health care**	96%
Residential	98%
(Home)	(98%)
(One- or two-family dwelling)	(93%)
(Apartment)	(99%)
(Hotel or motel)	(91%)
(Dormitory or barracks)	(99%)
Store or office	96%
(Department store)	(97%)
(Office building)	(95%)
Manufacturing	93%
Storage	79%
(Warehouse excluding cold storage)	(78%)
All structures***	95%

* Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. All percentages have a basis of at least 90 raw incidents submitted to NFIRS.

** Nursing home, hospital, or clinic.

*** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Operationality
When Fire Was Large Enough to Activate Equipment, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Percent where system operated
Public assembly	97%
(Eating or drinking establishment)	(97%)
Educational	96%
Health care**	96%
Residential	99%
(Home)	(98%)
(One- or two-family dwelling)	(93%)
(Apartment)	(99%)
(Hotel or motel)	(90%)
(Dormitory or barracks)	(99%)
Store or office	96%
(Department store)	(96%)
(Office building)	(96%)
Manufacturing	93%
Storage	85%
(Warehouse excluding cold storage)	(85%)
All structures**	96%

* Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. All percentages have a basis of at least 90 raw incidents submitted to NFIRS.

** Nursing home, hospital, or clinic.

*** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Operationality in Structure Fires When Fire Was Large Enough to Activate Equipment, by Property Use 2003-2006 Non-Confined and Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Percent where system operated
Residential	99%
Store or office	93%
Manufacturing	90%
Storage	51%
All structures**	84%

* Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. All percentages have a basis of at least 90 raw incidents submitted to NFIRS.

** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Operationality in Structure Fires When Fire Was Large Enough to Activate Equipment, by Property Use 2003-2006 Non-Confined and Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Percent where system operated
Public assembly	67%
(Eating or drinking establishment)	(67%)
Residential	93%
Store or office	71%
All structures**	71%

* Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. The "number of fires" is a national estimate that is roughly twice the number of fires in the database. All percentages have a basis of at least 90 raw incidents submitted to NFIRS.

** Includes some properties not listed separately above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Operationality in Structure Fires When Fire Was Large Enough to Activate Equipment, by Property Use 2003-2006 Non-Confined and Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Percent where system operated
Manufacturing	99%
All structures**	88%

F. Foam Systems Only

Property Use	Percent where system operated
All structures	97%

* Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. The "number of fires" is a national estimate that is roughly twice the number of fires in the database. All percentages have a basis of at least 90 raw incidents submitted to NFIRS.

** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 4.
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

A. All Sprinklers

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
Public assembly	62%	11%	7%	16%	3%	100%
(Eating or drinking establishment)	(60%)	(19%)	(0%)	(21%)	(0%)	(100%)
Educational	48%	0%	10%	33%	10%	100%
Health care*	24%	22%	20%	29%	5%	100%
Residential	34%	8%	40%	14%	5%	100%
(Home)	(65%)	(6%)	(6%)	(10%)	(13%)	(100%)
(One- or two-family dwelling)	(76%)	(0%)	(0%)	(8%)	(16%)	(100%)
(Apartment)	(44%)	(17%)	(18%)	(13%)	(7%)	(100%)
(Hotel or motel)	(6%)	(2%)	(81%)	(11%)	(0%)	(100%)
(Dormitory or barracks)	(71%)	(0%)	(0%)	(29%)	(0%)	(100%)
Store or office	61%	18%	6%	22%	0%	100%
(Office building)	(60%)	(0%)	(7%)	(32%)	(0%)	(100%)
Manufacturing	64%	21%	4%	8%	3%	100%
Storage	85%	5%	3%	2%	6%	100%
(Warehouse excluding cold storage)	(89%)	(5%)	(0%)	(2%)	(5%)	(100%)
All structures**	63%	14%	11%	9%	3%	100%

* Nursing home, hospital, or clinic.

** Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
Public assembly	70%	11%	5%	13%	0%	100%
(Eating or drinking establishment)	(67%)	(15%)	(0%)	(18%)	(0%)	(100%)
Educational	43%	0%	19%	38%	0%	100%
Health care*	26%	23%	22%	24%	5%	100%
Residential	50%	11%	11%	21%	7%	100%
(Home)	(65%)	(6%)	(6%)	(10%)	(13%)	(100%)
(One- or two-family dwelling)	(76%)	(0%)	(0%)	(8%)	(16%)	(100%)
(Apartment)	(44%)	(17%)	(18%)	(13%)	(7%)	(100%)
(Hotel or motel)	(6%)	(0%)	(81%)	(12%)	(0%)	(100%)
(Dormitory or barracks)	(63%)	(0%)	(0%)	(37%)	(0%)	(100%)
Store or office	69%	8%	2%	20%	0%	100%
(Office building)	(71%)	(0%)	(0%)	(29%)	(0%)	(100%)
Manufacturing	60%	25%	5%	7%	3%	100%
Storage	85%	2%	5%	4%	4%	100%
(Warehouse excluding cold storage)	(91%)	(2%)	(0%)	(3%)	(4%)	(100%)
All structures**	59%	16%	13%	10%	2%	100%

* Nursing home, hospital, or clinic..

** Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
Residential	0%	42%	58%	0%	0%	100%
Store or office	21%	33%	25%	21%	0%	100%
Manufacturing	84%	5%	0%	11%	0%	100%
Storage	86%	7%	0%	0%	7%	100%
All structures*	80%	7%	3%	5%	4%	100%

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
Public assembly (Eating or drinking establishment)	15% (15%)	79% (79%)	2% (3%)	3% (3%)	1% (2%)	100% (100%)
Residential	0%	100%	0%	0%	0%	100%
Store or office	2%	83%	4%	4%	6%	100%
All structures*	12%	82%	2%	2%	2%	100%

* Includes some properties not listed separately above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
Manufacturing	0%	0%	0%	0%	100%	100%
All structures*	6%	90%	0%	0%	4%	100%

F. Foam Systems Only

Property Use	System shut off	Lack of maintenance	Inappropriate system for type of fire	Manual intervention defeated system	System component damaged	Total
All structures	26%	24%	26%	24%	0%	100%

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Automatic Extinguishing Equipment Effectiveness

A number of approaches can be and have been used to quantify the effectiveness and value of sprinklers and other automatic extinguishing systems. These approaches may be grouped into the following three types:

- Qualitative judgments as "effective" or "satisfactory" by fire investigators or others completing incident reports;
- Reduction in life loss per fire or property loss per fire; and
- Reduction in the likelihood of large fire size or severity, such as fire spread beyond room of origin, multiple deaths, or large property loss.

Percentage of Structure Fires Where Sprinklers or Other Automatic Extinguishing Equipment Were Effective

For sprinklers that operated, their performance was deemed effective for 96% of the time. For all confined or non-confined fires large enough to activate sprinklers, excluding buildings under construction, sprinklers operated and were effective 91% of the time. Table 5 provides the full distribution for operated and effective, operated but not effective, fire too small to activate equipment, and failed to operate, by property class and by type of automatic extinguishing equipment. This is the only table that provides statistics on the shares of fires that are too small to activate equipment. Most reported non-confined and confined fires (62% for all structures) are too small to activate sprinklers. Less than half (44%) of reported fires were too small to activate carbon dioxide systems in the area of the fire.

Table 6 indicates "effectiveness" – the term used here for the proportion of non-confined and confined fires with operating sprinklers that have effective performance – and "combined performance" – the term used here for the percentage of fires (non-confined or confined and large enough to activate equipment) for which the system operates and is effective. The combined performance is equal to reliability times effectiveness and is probably the most useful and appropriate summary statistic for systems.

Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) is calculated from Table 5 as [column 1 + column 2] divided by [column 1 + column 2 + column 4]. Combined performance is calculated from Table 5 as [column 1] divided by [column 1 + column 2 + column 4].

For sprinklers that operated, effectiveness was uniformly high in all property classes. Effectiveness was higher for wet pipe sprinklers (97% for all structures) than for dry pipe sprinklers (91%). Effectiveness was much lower for dry chemical systems (81% for all structures) and for foam systems (84% for all structures) than for any other automatic extinguishing system analyzed.

Combined performance was 91% for all sprinklers, 92% for wet pipe sprinklers, and 77% for dry pipe sprinklers, all measured for all property types combined. Combined performance was 84% for carbon dioxide systems, 58% for dry chemical systems, and 82% for foam systems.

A disadvantage of measuring automatic extinguishing equipment effectiveness by judgments made in incident reports is the ambiguity and subjectivity of the criterion of "effective," which has never been precisely defined, let alone supported by an operational assessment protocol that could be executed consistently by different people. Also, confined fires usually have these details unreported, and so their few fires with details reported will be weighted far more heavily, after allocation of unknowns, than will non-confined fires.

Effectiveness should be measured relative to the design objectives for a particular system. For most rooms in most properties, sprinklers are designed to confine fire to the room of origin. Some properties have some very large rooms in which the sprinkler installation is designed to confine fire to a design area that is much smaller than the entire room. These rooms could include large assembly areas; sales, showroom, or performance areas; and storage areas.

Table A shows that percentage of fires, by property use, begin in rooms that *could* be large enough to have a design area smaller than the entire room. Many of these rooms will not be that large. All these rooms combined do not account for a majority of fires in any type of property, and only warehouses have more than about one-fifth of their fires in such rooms.

Table A. Areas of Origin That Could Be Room Larger Than Sprinkler Design Area for the Space, for Buildings Not Under Construction and With Sprinklers in Fire Area Percentage of 2003-2006 Structure Fires Reported to U.S. Fire Departments (Excluding Fires Reported as Confined Fires)

Property Use	Large Assembly Area (At Least 100 People)	Sales, Showroom or Performance Area	Storage Room, Area, Tank or Bin	Shipping, Receiving or Loading Area	Unclassified Storage Area	All Areas Combined
Eating or drinking Establishments	2.0%	0.4%	2.9%	0.3%	2.4%	8.1%
Public assembly excluding eating or drinking establishments	7.0%	1.9%	2.8%	0.4%	2.7%	14.8%
Educational	3.2%	0.8%	1.4%	0.1%	1.6%	7.1%
Health care*	0.0%	0.0%	1.3%	0.2%	0.6%	2.1%
Home*	0.0%	0.0%	0.7%	0.1%	0.7%	1.5%
Hotel or motel	1.6%	0.1%	0.5%	0.1%	1.0%	3.2%
Dormitory or barracks	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%
Store or office	0.1%	10.0%	3.9%	3.7%	3.7%	21.4%
Manufacturing	0.1%	0.0%	3.6%	3.2%	2.3%	9.2%
Warehouse excluding cold storage	0.0%	0.6%	8.1%	19.5%	15.6%	43.8%

* Health care consists of hospitals, clinics, and nursing homes. Home includes dwellings, apartments, and manufactured homes.

Note: Percentages sum left to right and may not equal totals because of rounding. These are based on structure fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Statistics exclude fires reported as confined fires, buildings under construction, and fires with sprinklers not in fire area reported as reason for failure or ineffectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Sprinklers are designed to confine a fire to the room of origin or the design fire area, whichever is smaller. Therefore, the benefits of sprinklers will tend to come in the following scenarios:

- A fire that would otherwise have spread beyond the room of fire origin will be confined to the room of origin, resulting in a smaller fire-damaged area and less property damage.

- A fire that would otherwise have grown larger than the design fire area in a room larger than that area will be confined to the design fire area, resulting in a smaller fire-damaged area and less property damage.

- A fire will be confined to an area smaller than the room or the design fire area, even though that degree of success goes beyond the performance assured by the design, resulting in a smaller fire-damaged area and less property damage.

Table 7 provides direct measurement of sprinkler effect involving the first scenario. For all structures combined, 74% have flame damage confined to room of origin when there is no automatic extinguishing equipment present. This rises to 94% of fires with flame damage confined to room of origin when any type of sprinkler is present.

As noted, for most rooms in most properties, effective performance is indicated by confinement of fire to the room of origin. For the few rooms where the design area is smaller than the room, a sprinkler system can be ineffective in terms of confining fire to the design area but still be successful in confining fire to the larger room of origin. Therefore, one might expect the percentage of fires with flame confined to room of origin to be slightly larger than the combined performance (operating effectively) for any given property use. Table B shows this is usually the case.

Effectiveness cannot be expected when fires begin in uncovered areas.

At one extreme, no standard for any type of automatic extinguishing equipment includes concealed wall spaces in required coverage. At the other extreme, a dry chemical range hood system is designed only for control of range fires. Even other kitchen fires cannot be expected to be controlled by a hazard-specific system like this, let alone fires starting in any other part of the building.

In between is NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*. Certain areas of fire origin that account for small shares of fire deaths, such as bathrooms, are excluded from the coverage requirements of NFPA 13D. A bathroom fire cannot be fairly used to evaluate sprinkler performance relative to objectives.

In this report, the analysis excludes fires where there were no sprinklers in the fire area. These fires will be a mix of fires where the fire area was not a coverage area under the applicable standard and other fires where the area of fire origin should have been covered, indicating a partial installation not compliant with the standard.

Table B. Combined Sprinkler Performance vs. Sprinkler Success in Confining Fire to Room of Origin, by Property Use Group

Property Use	Combined Performance	Percentage of Fires with Flame Damage Confined to Room of Origin
Public assembly	90%	96%
(Eating or drinking establishment)	(90%)	(94%)
Educational	91%	97%
Health care*	94%	99%
Residential	96%	96%
(Home)	(97%)	(95%)
(One- or two-family dwelling)	(89%)	(83%)
(Apartment)	(98%)	(97%)
(Hotel or motel)	(90%)	(97%)
(Dormitory or barracks)	(91%)	(96%)
Store or office	95%	93%
(Office building)	(94%)	(95%)
Manufacturing	85%	87%
Storage	77%	79%
(Warehouse excluding cold storage)	(76%)	(78%)
All structures**	91%	94%

* Nursing home, hospital or clinic

** Includes some properties not separately listed above.

Source: Tables 6 and 7.

Table C shows the leading areas of fire origin for one- and two-family dwelling fires coded as sprinklers present but failed or ineffective because of no sprinkler in the fire area. Percentage shares for all dwelling fires, regardless of sprinkler status are also included for comparison.

Concealed spaces and other structural areas, external areas, garages, and attics account for half of the fires where sprinklers are present but not in the fire area. These same areas accounted for only one-fifth of fires in dwellings in general.

Dry pipe sprinkler systems tend to have more sprinklers operating than wet pipe sprinkler systems.

Table 8A shows the number of sprinklers operating by type of sprinkler system. Five or fewer heads operated in 97% of the wet pipe system activations and 87% of the dry pipe system activations.

Dry-pipe systems are much more likely to open more than one sprinkler than wet pipe systems (43% vs. 24% of fires). The likely reason is the designed time delay in tripping the dry pipe

Table C. Leading Areas of Origin for Non-Confined or Confined Fires in One- or Two-Family Dwellings, Excluding Buildings Under Construction 2003-2006 Structure Fires Reported to U.S. Fire Departments

Area of Origin	Wet Pipe Sprinklers Present But Not in Fire Area, Which Is Reason for Failure or Ineffectiveness	All Fires
Kitchen	37%	32%
Attic or concealed space above top story	8%	3%
Wall assembly or concealed space	8%	3%
Garage*	7%	3%
Crawl space or substructure space	6%	2%
Exterior balcony or unenclosed porch	5%	2%
Courtyard, terrace or patio	5%	1%
Unclassified area of origin	3%	4%
Living room, family room, or den	3%	6%
Unclassified storage area	3%	1%
Other area of origin	15%	43%
Total	100%	100%

* Excludes garages coded as separate building.

Source: NFIRS and NFPA survey.

valve and passing water through the piping to the opened sprinklers. The delay permits fire to spread, which can mean a larger fire, requiring and causing more sprinklers to activate.

Wet pipe sprinkler systems tend to have more sprinklers operating in fires in manufacturing facilities or warehouses than in other properties.
Table 8B shows the number of wet pipe sprinklers operating by property use group. In warehouses or manufacturing facilities respectively, 69-70% of the fires in properties with operating wet pipe sprinklers had two or fewer sprinklers operating, which means 30-31% of the fires in properties had at least three sprinklers operating. Similarly, 90-91% had five or fewer sprinklers operating, which means 9-10% had at least six sprinklers operating. By contrast, in public assembly properties and stores and offices, 87% of fires in properties had two or fewer sprinklers operating, which means only 13% of fires in properties had at least three sprinklers operating. Similarly, 94-95% had five or fewer sprinklers operating, which means only 5-6% had at least six sprinklers operating.

Effectiveness declines when more sprinklers operate.
When more than 1-2 sprinklers have to operate, this is often taken as an indication of less than ideal performance. Table 9 shows that the percentage of fires where performance is deemed not effective increases as the number of wet pipe sprinklers operating increases, rising from 3% of fires when one sprinkler opens to 29% when more than 10 sprinklers open.

Most cases of sprinkler ineffectiveness were because water did not reach the fire (42%) or because not enough water was released (39%).

Table 10 provides distributions of reasons for ineffectiveness, by property class and type of automatic extinguishing equipment. In addition to the two reasons cited, sprinkler ineffectiveness for all structures was attributed to inappropriate equipment for the type of fire (11%), lack of maintenance (3%), defeating due to manual intervention (3%), and damage to a system component (3%).

The lead reason of water not reaching the fire can arise in several different ways. One is shielded fires such as rack storage in a property with ceiling sprinklers only. Another is fire spread above exposed sprinklers, through unsprinklered concealed spaces, or via exterior surfaces. Another reason would be a deep-seated fire in bulk storage. A different kind of problem would be droplet sizes that are too small to penetrate the buoyant fire plume and reach the seat of the fire.

Insufficient water may be released if there are problems with the system's water supply. This reason for ineffectiveness can also overlap with other reasons, such as inappropriate equipment (if, for example, the hazard has changed under the equipment and now requires a higher water flow density than is provided by the now inappropriate equipment) and defeating by manual intervention (if, for example, the sprinklers are turned off prematurely so that insufficient water reaches the fire). Insufficient water also could be a factor if a flash fire or a fire with several points of origin overwhelms the system or if an explosion reduces the water flow but does not cause complete system failure.

Reasons for ineffectiveness are different for wet pipe sprinklers and dry pipe sprinklers, with dry pipe sprinklers having 53% of cases attributed to not enough water released compared to 36% for wet pipe sprinklers. Because the design of dry pipe sprinklers assures a delayed release of water, it is not surprising that when such systems are ineffective, an insufficiency of water is usually involved. The relative importance of insufficient agent release is also greater for dry chemical systems.

Even a well-maintained, complete, appropriate system is not a guarantee. It requires the support of a well-considered integrated design for all the other elements of the building's fire protection. Unsatisfactory sprinkler performance can result from an inadequate water supply or faulty building construction. More broadly, unsatisfactory fire protection performance can occur if the building's design does not address all five elements of an integrated system – slowing the growth of fire, automatic detection, automatic suppression, confining the fire, and occupant evacuation.

Sprinkler Reduction in Loss of Life in Fire

For 2003-2006 home fires, the death rate per 100 fires was 80% lower with wet pipe sprinklers than with no automatic extinguishing equipment.
Table 11 shows fire death rate reductions for various property use groups. The estimated reduction was 87% for one- or two-family dwellings and 65% for apartments.

Most property groups average too few deaths per year in sprinklered properties to produce stable statistical comparisons. Only apartments and property use groups that include apartments – such

as homes and all residential properties – averaged at least 5 projected deaths per year in sprinklered properties.

For the other property use groups, statistical comparisons tend to show either a zero death rate in sprinklered properties or a misleadingly high death rate in sprinklered properties, based on the random occurrence of one or two fatal fires. A zero death rate for sprinklered properties was estimated for public assembly properties, eating or drinking establishment, educational properties, stores and offices, and office properties. Health care properties and hotels and motels both have a high percentage of fires in sprinklered properties, but not so high that the death rate estimates for non-sprinklered properties become statistically unstable. They show 80% and 74% reductions, respectively, with wet pipe sprinklers.

The exceptions are manufacturing facilities and warehouses. Manufacturing facilities show a small reduction in an already low death rate, while warehouses show no reduction. Warehouses illustrate the statistical problem. Total fire deaths in sprinklered warehouses in 2003-2006 are estimated from projections based on only three fatal incidents. The most severe, accounting for 64% of the total, was an explosion in a fireworks warehouse that killed three people. Sprinklers cannot save people killed in an initial explosion even if the explosion does not knock out the sprinklers, as can easily happen. The second most severe, accounting for 21% of the total, was an intentional fire using flammable liquids as accelerants. That fire killed two people, and there were few details. In particular, we cannot tell from the coded records whether either or both of the victims might have been the arsonists, killed early in the fire before sprinklers could activate, or whether the area of origin – an unclassified storage area – might have been outside the range of the sprinklers, which if true should have excluded the incident as no sprinklers in initial fire area. The last fatal fire was in a building under major renovation. The analysis excludes buildings under construction, but buildings under major renovation can present the same challenge to fire protection, depending on the scale of the renovation and the location of the fire origin.

For most properties other than homes, the value of sprinklers can be more clearly seen and more appropriately measured by their success in preventing catastrophic multiple-death incidents.

NFPA has no record of a fire killing 3 or more people in a completely sprinklered building where the system was properly operating, except in an explosion or flash fire or where civilians or firefighters were killed while engaged in fire suppression operations.
For decades, this statement – phrased in terms of sprinkler ability to prevent a defined class of severe outcomes – had been NFPA's principal statistic measuring sprinkler effectiveness. Appendix C lists the incidents with 3 or more deaths in a completely sprinklered building where the system was properly operating after 1970. Each is marked by type of exception, either explosion or flash fire, which is the most common exception, or firefighting.

And because explosions, flash fires, and industrial fire brigades are rarely found outside mercantile and industrial properties and associated storage facilities, the following statement is also true:

> NFPA has no record of a fire killing more than two people in a completely sprinklered public assembly, educational, institutional, or residential building where the system was properly operating.

The statement says it excludes systems that were not "properly operating." Nearly all the systems that were present in multiple-death fires but not properly operating have been systems damaged by explosions. An exception, where poor installation or maintenance was involved, was a 1990 Alabama board and care facility fire where the water supply was insufficient to support the sprinklers.

A December 2000 assisted living facility fire in Pennsylvania, which is not on the list, illustrates some of the challenges with this kind of measure of sprinkler effectiveness. Smoking materials ignited a sofa bed. The resulting fire spread to other combustibles in the room, then into the adjacent hallway. There was no explosion or flash fire, and there was no firefighting by the three victims, each over 80 years old. The three victims were fatally injured in three different locations, none of them in the room of origin. Their injuries involved both smoke inhalation and burns. These facts all imply a fire large enough to activate an operational sprinkler system in the area. The fire department report is silent on both coverage and operation of the system, indicating only that it was not effective. There is one report that sprinkler coverage did not include the room of fire origin, but it is not a primary report. What is known about this incident challenges the long-standing NFPA statement about sprinkler effectiveness in preventing major loss of life, but there are questions about the incident that no sources seem able to answer, and because the most likely answers (partial system or system shut off when fire occurred) would remove the fire from the Appendix C list, the incident does not appear in Appendix C, and the NFPA statement has not been modified.

There are dangers in statements that rely on all-or-nothing statistics. Until 1980, the exception for industrial brigades or employees engaged in firefighting was not needed because a multiple-death fire under those circumstances had not occurred. Until 1981, a separate, broader statement on hotels and motels could be used and sometimes was, because NFPA had no record of a fatal fire involving *any* number of deaths in fully sprinklered hotels or motels. In fact, though, it was only a matter of time before these exceptions had to be listed because sprinklers cannot expect to exclude all deaths under these circumstances. Similarly, it is remotely possible that a multiple-death fire will eventually occur in a fully sprinklered property involving a fire that develops in combustibles located in concealed spaces not protected by sprinklers. Many things would have to go wrong with the rest of the building's fire protection for this to happen, but it does represent a scenario where perfect sprinkler success cannot be expected, even if the performance to date has been perfect.

Moving away from large-loss incidents, the factors that make fatal injury possible even when sprinklers are present and operate would include those shown in Table 12:

- Victims who act irrationally, who return to the fire after safely escaping, or who are unable to act to save themselves, such as people who are bedridden or under restraint;

- Victims whose clothing is on fire, who can sustain a fatal fire injury from a fire too small to activate sprinklers, or more generally, victims so close to the fire as to be deemed "intimate with ignition," a victim condition no longer shown in the data but most closely approximated by victim in area of fire origin (who constituted 85% of fatal victims when sprinklers operated vs. 53% of total victims); and

- Victims who are or may be unusually vulnerable to fire effects, such as older adults, age 65 or older (who constituted 44% of fatal victims when sprinklers operated vs. 28% of total victims).

Sprinkler Reduction in Loss of Property in Fire

For most property uses, the property damage rate per reported structure fire is 45-70% lower when wet pipe sprinklers are present in structures that are not under construction, after excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area.
Table 13 shows smaller reductions for one- or two-family dwellings (22%) and warehouses (16%).

Estimates for one- or two-family dwellings and the property use groups that include dwellings – homes and all residential properties – exclude a reported $100 million loss in one California dwelling fire, which appears to be a badly miscoded fire loss, based on other available details on the property. Even so, only 1% of reported dwelling fires involve sprinklered properties, which means any loss estimate for sprinklered dwelling fires will tend to be statistically unstable.

The warehouse situation is a fairer indication of the limitations of sprinklers but also of the limitations of these statistical comparisons. About one-sixth of the 2003-2006 estimate of total direct property damage in warehouses with wet pipe sprinklers, excluding buildings under construction and sprinklers not in fire area, comes from projections from three fires each involving at least $5 million in loss and collectively involving $18 million in damage. All three incidents are also included in NFPA's Fire Incident Data Organization database, which provides a check on the NFIRS details and additional details not shown in NFIRS. One incident involved a deep-seated fire in palletized goods, and a second incident involved in-rack sprinklers that were blocked from the fire by the racks. The last incident was the only one where sprinklers were deemed ineffective, and the FIDO records indicated the fuel load was too great for the capacity of the sprinkler system.

At the same time, there is reason to believe that sprinklers are more common in warehouses that are larger and have higher values per square foot. If true, this will mean that fires of comparable physical size will involve higher property damage totals in sprinklered warehouses than in unsprinklered warehouses. That fact would mean that the average loss per fire in unsprinklered warehouses will be lower than the average loss would have been in sprinklered warehouses in the absence of sprinklers. And that means the use of average loss in unsprinklered warehouses as a proxy for average loss in sprinklered warehouses in the absence of sprinklers, as is done in this analysis, will produce a misleadingly low baseline for comparison and so a misleadingly low estimated reduction.

Generalizing from the warehouse analysis and the long-standing NFPA statement about sprinkler effectiveness in preventing catastrophic multiple death fires, one can say that sprinklers cannot be expected to prevent large loss if the large loss was attributable to partial coverage, explosion or flash fire, system shutoff, or the loss of the system before or early in the fire to collapse or collision. However, there are other circumstances that also can lead to a large loss:

- Sprinkler design may not be appropriate to the hazard being protected. In the simplest form, the contents may be capable of supporting a larger, more intense fire than the sprinkler system can handle. The problem may be insufficient sprinkler density or insufficient water flow, which in turn may reflect the system's design, its age and maintenance, or its supporting water supply. Unlike explosions and flash fires, fire loads can be addressed by appropriate design, installation, maintenance, and operation. And although the effectiveness statement could be phrased to require a fully code-compliant installation, fire incident reports rarely have enough detail to confirm code compliance, and large property-loss fires are less likely than large life-loss fires to receive the detailed fire investigations that could confirm such details.

- The nature or configuration of contents may be sufficient to create a large loss even when sprinkler performance is deemed fully successful. Some bulk goods can shield a deep-seated fire from sprinklers. Rack storage may shield fires from ceiling sprinklers, although in-rack sprinklers should be sufficient to address such problems. High-piled stock may block sprinklers or even permit fire spread on the tops of contents above the sprinklers. And some areas – such as clean rooms – have contents so sensitive and valuable that even a small fire can produce a large financial loss.

- A fire with a sufficient number of different points of origin can overwhelm any sprinkler system. This could also be an exception to the life-saving effectiveness statement, although it has not been found to be the deciding factor in any multiple-death fire to date. It has been the deciding factor for at least one large-loss fire. Multiple points of origin can occur deliberately in an arson fire, but they can occur unintentionally or naturally, as when an outside fire spreads to numerous entry points in and on a building.

Table 5.
Automatic Extinguishing Equipment Performance, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

A. All Sprinklers

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
Public assembly	29%	2%	68%	1%
(Eating or drinking establishment)	(42%)	(3%)	(53%)	(2%)
Educational	12%	0%	87%	1%
Health care*	17%	0%	82%	1%
Residential	40%	1%	59%	1%
(Home)	(43%)	(1%)	(56%)	(1%)
(One- or two-family dwelling)	(39%)	(1%)	(57%)	(3%)
(Apartment)	(44%)	(1%)	(55%)	(0%)
(Hotel or motel)	(31%)	(0%)	(65%)	(3%)
(Dormitory or barracks)	(30%)	(3%)	(67%)	(0%)
Store or office	38%	0%	60%	2%
(Office building)	(26%)	(0%)	(72%)	(1%)
Manufacturing	44%	4%	49%	4%
Storage	43%	1%	44%	12%
(Warehouse excluding cold storage)	(48%)	(1%)	(37%)	(14%)
All structures**	35%	1%	62%	2%

* Nursing home, hospital, or clinic.

** Includes some properties not separately listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude structure fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operate but ineffective if the reason for failure or ineffectiveness is not enough agent or agent did not reach fire. Rows sum to 100% except for rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing Equipment Performance, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
Public assembly	27%	1%	71%	1%
(Eating or drinking establishment)	(42%)	(1%)	(55%)	(2%)
Educational	12%	0%	87%	1%
Health care*	18%	0%	81%	1%
Residential	42%	1%	57%	1%
(Home)	(45%)	(0%)	(54%)	(1%)
(One or two-family dwelling)	(40%)	(2%)	(55%)	(3%)
(Apartment)	(46%)	(0%)	(53%)	(0%)
(Hotel or motel)	(29%)	(0%)	(67%)	(3%)
(Dormitory or barracks)	(34%)	(3%)	(62%)	(0%)
Store or office	37%	0%	61%	1%
(Office building)	(29%)	(0%)	(70%)	(1%)
Manufacturing	43%	4%	49%	3%
Storage	47%	1%	43%	9%
(Warehouse excluding cold storage)	(51%)	(2%)	(39%)	(9%)
All structures**	36%	1%	61%	2%

* Nursing home, hospital, or clinic.

** Includes some properties not separately listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude structure fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operate but ineffective if the reason for failure or ineffectiveness is not enough agent or agent did not reach fire. Rows sum to 100% except for rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing Equipment Performance, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
Residential	13%	3%	84%	0%
Store or office	40%	0%	56%	3%
Manufacturing	46%	2%	47%	5%
Storage	26%	1%	47%	26%
All structures*	24%	2%	69%	5%

* Includes some properties not separately listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude structure fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off, unclassified or unknown. Fires are recoded from failed to operate but ineffective if the reason for failure or ineffectiveness is not enough agent or agent did not reach fire. Rows sum to 100% except for rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing Equipment Performance, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
Public assembly	18%	5%	66%	11%
(Eating or drinking establishment)	(18%)	(6%)	(65%)	(11%)
Residential	43%	2%	51%	4%
(Apartment)	(60%)	(2%)	(38%)	(0%)
Store or office	20%	9%	59%	12%
All structures*	21%	5%	64%	10%

* Includes some properties not separately listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude structure fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off, unclassified or unknown. Fires are recoded from failed to operate but ineffective if the reason for failure or ineffectiveness is not enough agent or agent did not reach fire. Rows sum to 100% except for rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 5 . (Continued)
Automatic Extinguishing Equipment Performance, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
Manufacturing	90%	6%	3%	1%
All structures*	47%	2%	44%	7%

F. Foam Systems Only

Property Use	Operated and effective	Operated and not effective	Fire too small to activate system	Failed to operate
All structures*	33%	6%	60%	1%

* Includes some properties not separately listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude structure fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off, unclassified or unknown. Fires are recoded from failed to operate but ineffective if the reason for failure or ineffectiveness is not enough agent or agent did not reach fire. Rows sum to 100% except for rounding error. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 6.
Automatic Extinguishing Equipment Effectiveness, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

A. All Sprinklers

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
Public assembly	94%	90%
(Eating or drinking establishment)	(93%)	(90%)
Educational	98%	91%
Health care*	99%	94%
Residential	98%	96%
(Home)	(98%)	(97%)
(One- or two-family dwelling)	(96%)	(89%)
(Apartment)	(98%)	(98%)
(Hotel or motel)	(99%)	(90%)
(Dormitory or barracks)	(92%)	(91%)
Store or office	99%	95%
(Office building)	(99%)	(94%)
Manufacturing	91%	85%
Storage	97%	77%
(Warehouse excluding cold storage)	(97%)	(76%)
All structures**	96%	91%

* Nursing home, hospital, or clinic.

** Includes some properties not separately listed above.

Note: Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) equals the sum of columns 1 and 2 divided by the sum of columns 1, 2, and 4 in Table 5. Combined performance equals column 1 divided by the sum of columns 1, 2, and 4. All figures are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 6. (Continued)
Automatic Extinguishing Equipment Effectiveness, by Property Use
2003-2006 Non-Confined or Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
Public assembly	97%	94%
(Eating or drinking establishment)	(97%)	(93%)
Educational	99%	94%
Health care*	99%	95%
Residential	99%	97%
(Home)	(99%)	(98%)
(One- or two-family dwelling)	(96%)	(89%)
(Apartment)	(100%)	(99%)
(Hotel or motel)	(99%)	(90%)
(Dormitory or barracks)	(92%)	(91%)
Store or office	99%	95%
(Office building)	(99%)	(95%)
Manufacturing	91%	85%
Storage	98%	83%
(Warehouse excluding cold storage)	(97%)	(83%)
All structures**	97%	92%

* Nursing home, hospital, or clinic.

** Includes some properties not separately listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) equals the sum of columns 1 and 2 divided by the sum of columns 1, 2, and 4 in Table 5. Combined performance equals column 1 divided by the sum of columns 1, 2, and 4. Percentages in column 1 are calculated from corresponding part of Table 5 as (column 1)/(column 1 and column 2). Percentages in column 2 are calculated as (column 1) times [100% - (Table 3, column 1)] from the corresponding part of Table 3. All figures are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 6. (Continued)
Automatic Extinguishing Equipment Effectiveness, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
Residential	82%	81%
Store or office	99%	92%
Manufacturing	96%	86%
Storage	96%	48%
All structures*	91%	77%

* Includes some properties not separately listed above.

Note: Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) equals the sum of columns 1 and 2 divided by the sum of columns 1, 2, and 4 in Table 5. Combined performance equals column 1 divided by the sum of columns 1, 2, and 4. Percentages in column 1 are calculated from corresponding part of Table 5 as (column 1)/(column 1 and column 2). Percentages in column 2 are calculated as (column 1) times [100% - (Table 3, column 1)] from the corresponding part of Table 3. All figures are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 6. (Continued)
Automatic Extinguishing Equipment Effectiveness, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
Public assembly	78%	52%
(Eating or drinking establishment)	(76%)	(51%)
Residential	95%	88%
(Apartment)	(97%)	(97%)
Store or office	69%	49%
All structures*	81%	58%

* Includes some properties not separately listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) equals the sum of columns 1 and 2 divided by the sum of columns 1, 2, and 4 in Table 5. Combined performance equals column 1 divided by the sum of columns 1, 2, and 4. Percentages in column 1 are calculated from corresponding part of Table 5 as (column 1)/(column 1 and column 2). Percentages in column 2 are calculated as (column 1) times [100% - (Table 3, column 1)] from the corresponding part of Table 3. All figures are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 6. (Continued)
Automatic Extinguishing Equipment Effectiveness, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
Manufacturing	94%	93%
All structures*	95%	84%

F. Foam Systems Only

Property Use	Effectiveness (for systems that operated)	Combined performance (for all systems that were present)
All structures*	84%	82%

* Includes some properties not separately listed above.

Note: Effectiveness is calculated from Table 5 by dividing the percentage of fires where systems operated and were effective by the percentage of fires where systems operated, whether or not they were effective (column 1 divided by the sum of columns 1 and 2 in Table 5). Reliability (of operation) equals the sum of columns 1 and 2 divided by the sum of columns 1, 2, and 4 in Table 5. Combined performance equals column 1 divided by the sum of columns 1, 2, and 4. Percentages in column 1 are calculated from corresponding part of Table 5 as (column 1)/(column 1 and column 2). Percentages in column 2 are calculated as (column 1) times [100% - (Table 3, column 1)] from the corresponding part of Table 3. All figures are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with AES operation unknown and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 7.
Extent of Flame Damage,
for Sprinklers Present vs. Automatic Extinguishing Equipment Absent
2003-2006 Non-Confined and Confined Structure Fires

	Percentage of fires confined to room of origin excluding structures under construction and sprinklers not in fire area	
Property Use	**With no automatic extinguishing equipment**	**With sprinklers of any type**
Public assembly	78%	96%
(Eating or drinking establishment)	(77%)	(94%)
Educational	91%	97%
Health care*	91%	99%
Residential	76%	96%
(Home)	(77%)	(95%)
(One- or two-family dwelling)	(71%)	(83%)
(Apartment)	(89%)	(97%)
(Hotel or motel)	(87%)	(97%)
(Dormitory or barracks)	(93%)	(96%)
Store or office	72%	93%
(Department store)	(74%)	(92%)
(Office building)	(78%)	(95%)
Manufacturing	69%	87%
Storage	32%	79%
(Warehouse excluding cold storage)	(51%)	(78%)
All structures**	74%	94%

* Nursing home hospital, or clinic.

** Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Calculations exclude fires with unknown or unreported extent of flame damage. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.

Table 8.
Number of Sprinklers Operating
2003-2006 Non-Confined and Confined Structure Fires

A. By Type of Sprinkler

Number of Sprinklers Operating	Percentage of structure fires where that many sprinklers operated			
	Wet pipe	Dry pipe	Other type sprinkler	All sprinklers
1	76%	57%	45%	74%
2 or fewer	88%	73%	50%	86%
3 or fewer	92%	78%	65%	90%
4 or fewer	95%	84%	87%	94%
5 or fewer	97%	87%	89%	96%
6 or fewer	98%	89%	96%	97%
7 or fewer	98%	89%	97%	97%
8 or fewer	98%	89%	97%	98%
9 or fewer	98%	89%	97%	98%
10 or fewer	99%	91%	99%	98%
20 or fewer	99%	93%	100%	99%

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 8.
Number of Wet-Pipe Sprinklers Operating
2003-2006 Non-Confined and Confined Structure Fires

B. By Property Use Group

Number of Sprinklers Operating	Percentage of structure fires where that many wet pipe sprinklers operated				
	Public assembly	Home	Store or office	Manufacturing facility	Warehouse excluding cold storage
1	71%	91%	66%	49%	46%
2 or fewer	87%	97%	87%	69%	70%
3 or fewer	90%	98%	90%	79%	74%
4 or fewer	94%	99%	93%	86%	77%
5 or fewer	95%	99%	94%	90%	91%
6 or fewer	97%	99%	96%	93%	93%
7 or fewer	97%	99%	97%	94%	94%
8 or fewer	99%	100%	97%	95%	94%
9 or fewer	99%	100%	97%	95%	95%
10 or fewer	99%	100%	98%	96%	95%
20 or fewer	100%	100%	98%	99%	97%

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 9.
Sprinkler Effectiveness Related to Number of Sprinklers Operating 2003-2006 Non-Confined and Confined Structure Fires

	Percent of structure fires where sprinklers are effective			
		Wet Pipe		
Number of Sprinklers Operating	All sprinklers All structures	All structures	Manufacturing facility	Warehouse excluding cold storage
1	96%	97%	91%	97%
2	94%	95%	91%	100%
3 to 5	90%	92%	90%	98%
6 to 10	89%	89%	85%	82%
More than 10	78%	71%	69%	94%
Total	95%	96%	90%	97%

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 10.
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined and Confined Structure Fires

A. All Sprinklers

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
Public assembly	49%	41%	6%	0%	4%	0%	100%
(Eating or drinking establishment)	(57%)	(36%)	(7%)	(0%)	(0%)	(0%)	(100%)
Educational	50%	50%	0%	0%	0%	0%	100%
Health care*	40%	47%	0%	13%	0%	0%	100%
Residential	44%	38%	6%	5%	0%	7%	100%
(Home)	(69%)	(9%)	(5%)	(7%)	(0%)	(11%)	(100%)
(One- or two-family dwelling)	(25%)	(25%)	(0%)	(25%)	(0%)	(25%)	(100%)
(Apartment)	(85%)	(2%)	(7%)	(0%)	(0%)	(6%)	(100%)
(Hotel or motel)	(54%)	(0%)	(0%)	(46%)	(0%)	(0%)	(100%)
(Dormitory or barracks)	(0%)	(100%)	(0%)	(0%)	(0%)	(0%)	(100%)
Store or office	45%	32%	13%	0%	10%	0%	100%
(Office building)	(0%)	(45%)	(55%)	(0%)	(0%)	(0%)	(100%)
Manufacturing	45%	39%	5%	4%	7%	0%	100%
Storage	60%	20%	0%	0%	20%	0%	100%
(Warehouse excluding cold storage)	(75%)	(0%)	(0%)	(0%)	(25%)	(0%)	(100%)
All structures**	42%	39%	11%	3%	3%	3%	100%

NA – Not applicable because no reported cases of ineffective performance with known reason.

* Only facilities that care for the sick or the aged.

** Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 10. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
Public assembly	55%	24%	12%	0%	9%	0%	100%
(Eating or drinking establishment)	(65%)	(17%)	(17%)	(0%)	(0%)	(0%)	(100%)
Educational	50%	50%	0%	0%	0%	0%	100%
Health care*	72%	28%	0%	0%	0%	0%	100%
Residential	14%	64%	8%	4%	0%	9%	100%
(Home)	(24%)	(17%)	(13%)	(17%)	(0%)	(29%)	(100%)
(One- or two-family dwelling)	(25%)	(25%)	(0%)	(25%)	(0%)	(25%)	(100%)
(Apartment)	(23%)	(0%)	(40%)	(0%)	(0%)	(36%)	(100%)
(Hotel or motel)	(100%)	(0%)	(0%)	(0%)	(0%)	(0%)	(100%)
(Dormitory or barracks)	(0%)	(100%)	(0%)	(0%)	(0%)	(0%)	(100%)
Store or office	50%	24%	15%	0%	11%	0%	100%
(Office building)	(0%)	(45%)	(55%)	(0%)	(0%)	(0%)	(100%)
Manufacturing	48%	35%	6%	4%	6%	0%	100%
Storage	50%	0%	0%	0%	50%	0%	100%
(Warehouse Excluding cold storage)	(50%)	(0%)	(0%)	(0%)	(50%)	(0%)	(100%)
All structures**	41%	36%	14%	2%	3%	3%	100%

NA – Not applicable because no reported cases of ineffective performance with known reason.

* Only facilities that care for the sick or the aged.

** Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Fires are excluded if reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 10. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
Residential	81%	10%	0%	9%	0%	0%	100%
Store or office	0%	100%	0%	0%	0%	0%	100%
Manufacturing	28%	43%	0%	0%	29%	0%	100%
Storage	49%	51%	0%	0%	0%	0%	100%
All structures*	39%	53%	0%	5%	2%	0%	100%

* Includes some properties not listed separately above..

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 10. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
Public assembly	72%	19%	2%	4%	2%	0%	100%
(Eating or drinking establishment)	(68%)	(23%)	(3%)	(4%)	(3%)	(0%)	(100%)
Residential	23%	65%	0%	0%	12%	0%	100%
(Apartment)	(23%)	(65%)	(0%)	(0%)	(12%)	(0%)	(100%)
Store or office	77%	13%	7%	4%	0%	0%	100%
All structures*	72%	19%	3%	3%	2%	0%	100%

* Includes some properties not listed separately above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category for wet chemical systems. Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 10. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use
2003-2006 Non-Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
Manufacturing	33%	67%	0%	0%	0%	0%	100%
All structures*	49%	51%	0%	0%	0%	0%	100%

F. Foam Systems Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	Lack of maintenance	Manual intervention defeated system	System component damaged	Total
All structures*	10%	13%	0%	73%	4%	0%	100%

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 11.
Estimated Reduction in Civilian Deaths per Thousand Fires Due to Wet Pipe Sprinklers, by Property Use 2003-2006 Non-Confined and Confined Structure Fires

Property Use	Without AES	With sprinklers	Percent reduction
Public assembly	0.6*	0.0	100%
(Eating or drinking establishment)	(0.6)*	(0.0)	(100%)
Educational	0.0	0.0	NA
Health care**	7.9	1.6	80%
Residential	7.7	1.8	77%
(Home)	(7.7)	(1.5)	(80%)
(One- or two-family dwelling)	(9.1)	(1.2)	(87%)
(Apartment)	(4.3)	(1.5)	(65%)
(Hotel or motel)	(4.8)	(1.3)	(74%)
Store or office	0.9	0.0	100%
(Office building)	(0.4)	(0.0)	(100%)
Manufacturing	1.1	0.9	33%
(Warehouse excluding cold storage)	1.6	11.7	No reduction

AES – Automatic extinguishing equipment

NA – Not applicable because both death rates are estimated as zero.

* The Station nightclub fire is not included in the NFIRS database. If it were, the estimates for public assembly without automatic extinguishing equipment and for eating or drinking establishments without automatic extinguishing equipment would be much higher.

**Nursing home, hospital, or clinic.

Note: These are national estimates of structure fires reported to U.S. municipal fire departments, based on fires reported in NFIRS Version 5.0, and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with sprinkler status unknown or unreported, partial sprinkler systems not in fire area, and structures under construction; and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.

Table 12.
Characteristics of Fatal Victims
When Wet Pipe Sprinklers Operate vs. All Conditions
2003-2006 Non-Confined and Confined Structure Fires

Victim Characteristic	Percent of fire fatalities: When sprinklers operate, excluding sprinklers not in fire area	Percent of fire fatalities: No automatic extinguishing equipment
Victim in area of fire origin, whether or not involved in fire origin	85%	53%
Clothing on fire, whether or not while escaping	34%	7%
Victim age 65 or older	44%	28%
Victim returned to fire, unable to act, or acted irrationally	34%	18%

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Table 13.
Estimated Reduction in Average Direct Property Damage per Fire When Wet Pipe Sprinklers Are Present, by Property Use 2003-2006 Non-Confined and Confined Structure Fires

Property Use	Without AES	With sprinkler	Percent reduction
Public assembly	$36,000	$17,000	52%
(Eating or drinking establishment)	($42,000)	($14,000)	(67%)
Educational	$16,000	$9,000	46%
Health care*	$11,000	$3,000	70%
Residential	$16,000	$6,000	63%
(Home)	($16,000)	($5,000)	(71%)
(One- or two-family dwelling)	($18,000)	($14,000)	(22%)
(Apartment)	($10,000)	($4,000)	(61%)
(Hotel or motel)	($18,000)	($8,000)	(57%)
Store or office	$43,000	$22,000	48%
(Office building)	($32,000)	($17,000)	(48%)
Manufacturing	$75,000	$35,000	54%
(Warehouse excluding cold storage)	($102,000)	($86,000)	(16%)

AES – Automatic extinguishing equipment

*.Nursing home, hospital, or clinic.

Note: These are national estimates of structure fires reported to U.S. municipal fire departments, based on fires reported in NFIRS Version 5.0, and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures exclude fires with sprinkler status unknown or unreported, partial sprinkler systems not in fire area, and structures under construction; and reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Direct property damage is estimated to the nearest thousand dollars and has not been adjusted for inflation. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Source: NFIRS and NFPA survey.

Other Issues

Much of the resistance to wider use of sprinklers stems from a cluster of concerns that are not so much issues as myths. Most Americans have had little contact with sprinkler systems outside of their portrayal in movies and television shows, where sprinklers all too often are portrayed inaccurately. For instance, activation by common heat sources, activation of all sprinklers if any one is activated, even drowning or swimming in the water released by sprinklers, all have been portrayed in film versions of sprinklers.

Water Damage from Sprinklers in the Absence of Fire

Sprinkler systems are carefully designed to activate early in a real fire but not to activate in a non-fire situation. Each sprinkler reacts only to the fire conditions in its area. Water release in a fire is generally much less than would occur if the fire department had to suppress the fire, because later action means more fire, which means more water is needed. According to a 15-year study done in Scottsdale, Arizona, on average, a fire sprinkler will use 25 gallons of water per minute to control a home fire as compared to the estimated 250 gallons used by firefighters.*

Unintentional release of water in a non-fire activation of a sprinkler appears to be less likely and much less damaging, according to the best available evidence, than is unintentional water release involving other parts of a building's plumbing and water supply, which tend to be both more frequent and more costly per incident.** Maryatt's study of sprinklers in Australia and New Zealand found water damage from non-fire accidental discharges added only 25% to the fire losses suffered by sprinklered buildings.*** If sprinklers reduced average fire loss by only 20%, then combined fire and water damage in fire and non-fire incidents would be unchanged. (A 20% reduction means the sprinklered fire loss is 80% of the unsprinklered fire loss. Adding 25% for water damage adds 25% of 80%, which is 20%. 80%+20%=100%.) As previously noted, however, sprinklers reduce average fire loss by much more than 20%.

Another set of estimates have recently become available for water damage from sprinkler systems in the absence of fire. Jennifer Flynn analyzed the number of reported emergency responses in 2003 by U.S. fire department where the reason for the response was either (a) non-fire unintentional sprinkler activation or (b) non-fire sprinkler activation from a malfunction or failure of the system. The year 2003 was the last one for which the public release file of NFIRS included non-fire incidents (because the complete file grew too large for practical storage for release in and after 2004), and earlier years involved less participation in NFIRS Version 5.0 and so a narrower base for statistical analysis. Four property use groups accounted for nearly three-fourths of the reported non-fire sprinkler incidents. See Table D.

*Home Fire Sprinkler Coalition, *Automatic Sprinklers, A 15-Year Study, Scottsdale, Arizona*, available at http://www.homefiresprinkler.org/hfsc.html.

**Walter W. Maybee, "A Brief History of Fire Protection in the United States, Atomic Energy Commission, 1947-1975", paper presented to the NFPA Fall Meeting, 1978. Paper is not limited to or focused on power plants and like facilities.

***H.W. Marryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986*, 2nd edition, Victoria, Australia: Australian Fire Protection Association, 1988, p. 435.

Table D. Non-Fire Sprinkler Activations by Major Property Use Group, 2003

Property Use	Reported incidents	
Commercial properties (public assembly, stores and offices)	15,900	(36%)
Manufacturing facilities	6,800	(15%)
Homes (one- or two-family dwellings, apartments)	4,700	(11%)
Warehouses excluding cold storage	4,100	(9%)
Other property use groups	12,500	(28%)
Total	44,000	(100%)

Note: Projections from NFIRS to national estimates are based on non-fire emergency responses estimated by Michael Karter from the 2003 Fire Loss Experience Survey.

Source: Unpublished analysis by Jennifer D. Flynn, NFPA Fire Analysis and Research Division, January 2008.

Table E. Non-Fire Sprinkler Activations by Likelihood of Water Release and Major Property Use Group

Type of Activation (Based on :)	Commercial properties (726 incidents)	Manufacturing facilities (206 incidents)	Homes (292 incidents)	Warehouses excluding cold storage (165 incidents)
No Water Released	50%	55%	50%	50%
Definitely no water released except dry pipe system charging or release to drain or outside	(45%)	(48%)	(46%)	(44%)
Activation with no mention of water flow outside system	(5%)	(7%)	(4%)	(6%)
Possibly Water Released	50%	45%	50%	50%
Break or damage to component	(29%)	(30%)	(27%)	(38%)
Activation with mention of water flow release outside system	(8%)	(4%)	(14%)	(5%)
Leak	(5%)	(2%)	(2%)	(1%)
Freezing	(7%)	(6%)	(6%)	(6%)
Nearby heat	(2%)	(2%)	(1%)	(1%)
Total	100%	100%	100%	100%
Confirmed water release outside system	16%	7%	21%	12%

Source: Analysis of uncoded narratives from reported incidents in Austin (TX), Minnesota, and Massachusetts.

"Activation" need not involve any water damage or any release of water outside the sprinkler system but inside the building. To estimate the fraction of incidents where water is released, an exploratory data analysis was conducted on the uncoded narratives for one year of non-fire sprinkler incidents from Austin, TX (thanks to Karyl Kinsey) and the states of Minnesota and Massachusetts (thanks to Nora Gierok and Derryl Dion). Table E shows the results, separating incidents confirmed as no water outside the system and, among incidents where water release was possible, those with water release outside the system confirmed.

If the confirmed water release percentages shown in Table E are applied to the non-fire sprinkler incidents in Table D, and the resulting water-damage incidents are compared to the 2003-2006 annual average number of fires where sprinklers were present in the same properties, then one can obtain a basis for comparison. Non-fire sprinkler incidents with confirmed water release outside the system, as a percentage of fire incidents where sprinklers operated, were as follows:

- 34% for commercial properties,
- 13% for manufacturing facilities,
- 5% for homes, and
- 25% for warehouses excluding cold storage.

While the NFIRS reports do not include any estimates of dollar damage, only a handful of incidents mentioned extensive water damage. It seems likely that the average damage per non-fire sprinkler incident is considerably less than the average damage per fire incident in sprinklered properties. Even without any such adjustment, the percentages above are comparable to the estimates from Marryatt cited earlier.

Also, the Minnesota and Massachusetts incidents that dominate the combined data base probably reflect a bigger problem with freezing conditions than is true for the country as a whole. Roughly half of the commercial property confirmed water release incidents and roughly half of the warehouse incidents involved either freezing as a cited factor or a month of occurrence during December to February. Therefore, these two percentages would probably be somewhat lower if data with representative weather conditions were available.

Whatever the actual rate for these incidents, many of them can be readily prevented by better design or safer practices. Common factors in component breaks are:

- Exposure to freezing conditions,
- Damage from forklifts or other large vehicles,
- Misuse of sprinklers, notably their use as hangers or as a base for anchoring hangers,
- Damage by construction or similar workers,
- Vandalism or horseplay in the vicinity of sprinklers, and
- Damage from impact by large doors.

Non-fire activations can also be prevented by better design or safer practices. Common factors in such activations are:

- Proximity to very high levels of ambient heat, like that produced by certain manufacturing processes,

- Testing or maintenance not conducted according to standard, resulting in water surge or alarm activation.

Do People Want Sprinklers?

In surveys, many people say they do not want sprinklers. The question is why. The answer is often some type of misinformation, like the ones related to water damage, already discussed.

One myth has to do with aesthetics. Again, when people outside the fire community think of sprinklers, they may think of the exposed pipe and sprinkler arrays that are common in some large manufacturing facilities. Inconspicuously mounted sprinklers, which are already common in offices and hotels and are available for homes, need to be better publicized.

Another myth has to do with the risk of death, serious injury or significant property damage in fire. This was the principal reason cited by people without smoke alarms 30 years ago, when most people still did not have smoke alarms, to explain why they did not have smoke alarms. If sprinklers are an excellent solution to a problem you (wrongly) think you do not have, then that would naturally reduce your interest in sprinklers and your sense of their value.

The one legitimate concern is cost. Sprinklers are not inexpensive, although their effectiveness, documented earlier, means most people will find them cost-effective. This often can be incorporated into reduced insurance costs, allowing the systems to pay for themselves over an extended period of time.

A 2008 study, conducted by Newport Partners under sponsorship of the Fire Protection Research Foundation, developed comprehensive and all-inclusive cost estimates for 30 diverse new-house plans in 10 communities.* Cost per sprinklered square foot ranged from $0.38 to $3.66, with an average (mean) of $1.61 and a median of $1.42. Variables associated with higher cost systems included:

- Extension use of copper piping instead of CPVC or PEX plastic;
- On-site water supply (such as well water) instead of municipal water supply;
- Local requirements to sprinkler areas, like garages or attics, where coverage is not required under NFPA 13D;
- Local sprinkler ordinances in effect for less than five years, or too brief a time for market acceptance, increased competition, and resulting lower prices to take hold; and
- Local sprinkler permit fees that are higher than the norm.

Many people are not aware how much the cost of sprinkler systems and the cost of installing them have been reduced in recent years as a result of continued innovation

* Newport Partners, *Home Fire Sprinkler Cost Assessment – Final Report*, Fire Protection Research Foundation, Quincy, MA, September 2008, pp. iv and 6.

in the industry. When people say they are not interested in sprinklers for cost reasons, they may well be reacting to an inflated notion of those costs.

A 1977 survey done for the U.S. Fire Administration, back when only 22% of U.S. homes had smoke alarms, found that 74% of households with smoke alarms were very concerned about fire compared to only 45% of households that had no smoke alarms and no intention of obtaining smoke alarms. For households without smoke alarms, whether or not they intended to obtain smoke alarms, the leading reason cited for not having obtained one was no perception of need (don't need one – 16%; no interest in one – 16%) and the second leading reason was cost (too expensive – 23%; not worth the money – 1%). These are the same reasons, in the same order, cited today by people not intending to obtain home fire sprinklers today.*

In survey after survey, we find that people's perceptions and reasoning align for consistency with their actions. It is impossible today to believe that a large segment of the public once objected to smoke alarms on the basis of cost, but early in their adoption, it was true. The more people learn about home fire sprinklers, the more they are attracted to them, and there is no reason to expect this trend to stop.

In fact, there is evidence that many homeowners are getting past these dated perceptions and moving on to more fact-based and positive views of home fire sprinklers. The Home Fire Sprinkler Coalition sponsored a December 2005 survey by Harris Interactive®.** Among the findings were that 45% of homeowners considered a sprinklered home more desirable than an unsprinklered home, that 69% believe a fire sprinkler system increases the value of a home, that 38% say they would be more likely to purchase a new home with sprinklers than one without, and that 43% would be more likely to have home fire sprinklers installed if the cost could be included in the mortgage. These read like the emerging perceptions of a nation that sees value for the cost of home fire sprinklers and sees ways to handle that cost within their home-buying budget.

* Based on 2007 slide presentation of results of NAHB National Survey, conducted August 14-16, 2006, by Public Opinion Strategies, #06811.

** See a summary of findings in a press release at http://www.homefiresprinkler.org/release/HarrisPoll.html.

Concluding Points

1. Fire sprinklers are highly effective elements of total system designs for fire protection in buildings. When wet pipe sprinklers are present excluding structures under construction and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the chances of dying if a home fire occurs are reduced by 80%, and the average property loss per fire is cut by 45-70% for most property classes, compared to reported fires where no automatic extinguishing equipment is present.

2. Excluding fires too small to activate a sprinkler and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, sprinklers operated in 95% of reported structure fires and operated effectively in 91% of fires. Two-thirds (63%) of the failures occurred because the system had been shut off.

3. There are certain fire situations where even a complete sprinkler system will have limited impact: (a) Explosions and flash fires that may overpower the system; (b) Fires that begin very close to a person (e.g., clothing ignition) or unusually sensitive and expensive property (e.g., an art gallery) where fatal injury or substantial property loss can occur before sprinklers can react; and (c) Fires that originate in unsprinklered areas (e.g., concealed wall spaces) or adjacent properties (e.g., exposure fires), which may grow to unmanageable size outside the range of the sprinkler system. These situations can arise when (a) sprinkler standards are based on design fires less severe than explosions or flash fires, as is normally the case; (b) sprinkler objectives are defined in terms of a design fire area larger than the distance implied by a victim intimate with ignition; or (c) sprinkler standards exclude certain potential areas of fire origin from their definition of complete coverage, which is typically but not always the case.

4. Sprinkler systems are so effective that it can be tempting to overstate just how effective they are. For example, some sprinkler proponents have focused too narrowly on the reliability of the components of the sprinkler system itself. If this were the only concern in sprinkler performance, then there would be little reason for concern at all, but human error is a relevant problem.

On the other hand, some people, concerned that sprinklers will be treated as a panacea to the detriment of other essential elements of fire protection, have treated human errors as intrinsic to sprinkler performance. In fact, all forms of active and passive fire protection tend to show more problems with human error than with intrinsic mechanical or electrical reliability.

It is important for all concerned parties to (a) distinguish between human and mechanical problems because they require different strategies; (b) include both as concerns to be addressed when deciding when and how to install, maintain, and rely on sprinklers and other automatic extinguishing systems; (c) strive to use performance analysis in assessing any other element of fire protection; and (d) remember that the different elements of fire protection support and reinforce one another and so must always be designed and considered as a system.

5. Because sprinkler systems are sophisticated enough to require competent fire protection engineering and function best in buildings where there is a complete integrated system of fire protection, it is especially important that proper procedures be used in the installation and maintenance of sprinkler systems. This means careful adherence to the relevant standards: NFPA 13, *Standard for the Installation of Sprinkler Systems*; NFPA 13D, *Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes*; NFPA 13R, *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height*; and NFPA 25, *Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems*.

6. Because sprinkler systems are so demonstrably effective, they can make a major contribution to fire protection in any property. The 2006 editions of NFPA 101®, *Life Safety Code*; NFPA 1, *Uniform Fire Code*, and NFPA 5000®, *Building Construction and Safety Code*, require sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs. The 2009 edition of the *International Residential Code*, effective in January 2011, also added requirements for sprinklers in one- or two-family dwellings. This protection can be expected to increase in areas that adopt and follow these revised codes.

Appendix A.
How National Estimates Statistics Are Calculated

The statistics in this analysis are estimates derived from the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and the National Fire Protection Association's (NFPA's) annual survey of U.S. fire departments. NFIRS is a voluntary system by which participating fire departments report detailed factors about the fires to which they respond. Roughly two-thirds of U.S. fire departments participate, although not all of these departments provide data every year. Fires reported to federal or state fire departments or industrial fire brigades are not included in these estimates.

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

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

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

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

The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities have fewer people protected per department and are less likely to respond to the survey. A larger number must be

surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did respond are truly representative of fire departments their size.) On the other hand, large city departments are so few in number and protect such a large proportion of the total U.S. population that it makes sense to survey all of them. Most respond, resulting in excellent precision for their part of the final estimate.

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

Projecting NFIRS to National Estimates

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

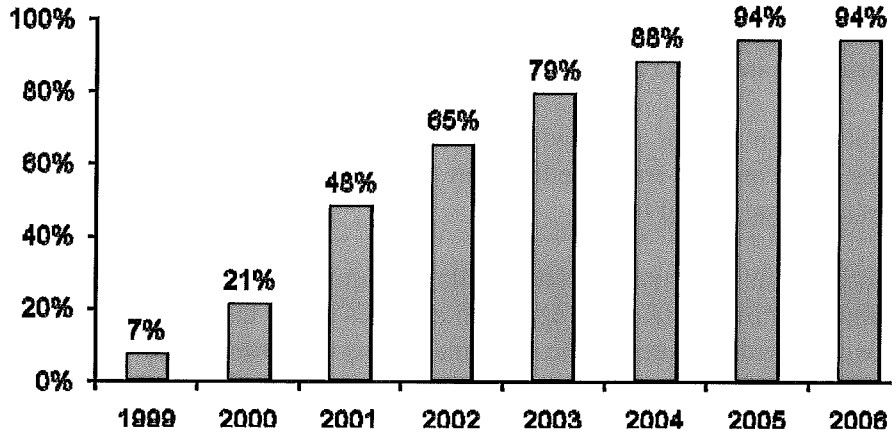
Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific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

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

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

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

Figure 1. Fires Originally Collected in NFIRS 5.0 by Year



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

NFPA survey projections
NFIRS totals (Version 5.0)

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

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

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

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

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

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

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

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

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

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

31. Water-caused short circuit arc;
32. Short-circuit arc from mechanical damage;

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

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

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

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

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

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

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

The downside of this approach is that heat sources that are truly a different type of open flame or smoking material are erroneously assigned to other categories. The grouping "smoking materials" includes codes 61-63 (cigarettes, pipes or cigars, and heat from

undetermined smoking material, with a proportional share of the code 60s and true unknown data.

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

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

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

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

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

Code Grouping	EII Code	NFIRS definitions
Central heat	132	Furnace or central heating unit
	133	Boiler (power, process or heating)
Fixed or portable space heater	131	Furnace, local heating unit, built-in
	123	Fireplace with insert or stove
	124	Heating stove
	141	Heater, excluding catalytic and oil-filled
	142	Catalytic heater
	143	Oil-filled heater
Fireplace or chimney	121	Fireplace, masonry
	122	Fireplace, factory-built

	125	Chimney connector or vent connector
	126	Chimney – brick, stone or masonry
	127	Chimney-metal, including stovepipe or flue
Wiring, switch or outlet	210	Unclassified electrical wiring
	211	Electrical power or utility line
	212	Electrical service supply wires from utility
	214	Wiring from meter box to circuit breaker
	216	Electrical branch circuit
	217	Outlet, receptacle
	218	Wall switch
Power switch gear or overcurrent protection device	215	Panel board, switch board, circuit breaker board
	219	Ground fault interrupter
	222	Overcurrent, disconnect equipment
	227	Surge protector
Lamp, bulb or lighting	230	Unclassified lamp or lighting
	231	Lamp-tabletop, floor or desk
	232	Lantern or flashlight
	233	Incandescent lighting fixture
	234	Fluorescent light fixture or ballast
	235	Halogen light fixture or lamp
	236	Sodium or mercury vapor light fixture or lamp
	237	Work or trouble light
	238	Light bulb
	241	Nightlight
	242	Decorative lights – line voltage
	243	Decorative or landscape lighting – low voltage
	244	Sign
Cord or plug	260	Unclassified cord or plug
	261	Power cord or plug, detachable from appliance
	262	Power cord or plug- permanently attached
	263	Extension cord

Torch, burner or soldering iron	331	Welding torch
	332	Cutting torch
	333	Burner, including Bunsen burners
	334	Soldering equipment
Portable cooking or warming equipment	631	Coffee maker or teapot
	632	Food warmer or hot plate
	633	Kettle
	634	Popcorn popper
	635	Pressure cooker or canner
	636	Slow cooker
	637	Toaster, toaster oven, counter-top broiler
	638	Waffle iron, griddle
	639	Wok, frying pan, skillet
	641	Breadmaking machine

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

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

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

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

Appendix B
Data Elements in NFIRS 5.0 Related to Automatic Extinguishing Systems

M1. Presence of Automatic Extinguishment System

This is to be coded based on whether a system was or was not present in the area of fire and is designed to extinguish the fire that developed. (The latter condition might exclude, for example, a range hood dry chemical extinguishing system from being considered if the fire began in a toaster.)

Codes:

N	None Present
1	Present
U	Undetermined (restored to coding in 2004)

M2. Type of Automatic Extinguishment System

If multiple systems are present, this is to be coded in terms of the (presumably) one system designed to protect the hazard where the fire started. This is a required field if the fire began within the designed range of the system. It is not clear whether questions might arise over a system that is not located in the area of fire origin but has the area of fire origin within its designed range; this has to do with the interpretation of the "area" of fire origin.

Codes:

1	Wet pipe sprinkler
2	Dry pipe sprinkler
3	Other sprinkler system
4	Dry chemical system
5	Foam system
6	Halogen type system
7	Carbon dioxide system
0	Other special hazard system
U	Undetermined

M3. Automatic Extinguishment System Operation

This is designed to capture the "operation and effectiveness" of the system relative to area of fire origin. It is also said to provide information on the "reliability" of the system. The instructions say that "effective" does not necessarily mean complete extinguishment but does mean containment and control until the fire department can complete extinguishment.

Codes:

1 System operated and was effective
2 System operated and was not effective
3 Fire too small to activate the system
4 System did not operate
0 Other
U Undetermined

M4. Number of Sprinklers Operating
The instructions say this is not an indication of the effectiveness of the sprinkler system. The instructions do not explicitly indicate whether this data element is relevant if the automatic extinguishment system is not a sprinkler system (as indicated in M2). The actual number is recorded in the blank provided; there are no codes.

M5. Automatic Extinguishment System Failure Reason
This is designed to capture the (one) reason why the system "failed to operate or did not operate properly." The instructions also say that this data element provides information on the "effectiveness" of the equipment. It is not clear whether this is to be completed if the system operated properly but was not effective.

Text shown in brackets is text shown in the instructions but not on the form. Note that for code 4, the phrase "wrong" is replaced by "inappropriate" in the instructions; the latter term is more precise and appropriate, although it is possible for the type of fire to be unexpected in a given occupancy.

Codes:

1 System shut off
2 Not enough agent discharged [to control the fire]
3 Agent discharged but did not reach [the] fire
4 Wrong type of system [Inappropriate system for the type of fire]
5 Fire not in area protected [by the system]
6 System components damaged
7 Lack of maintenance [including corrosion or heads painted]
8 Manual intervention [defeated the system]
0 Other _____ [Other reason system not effective]
U Undetermined

Appendix C
Multiple-Death Fires in Fully Sprinklered Properties
(Excluding Incidents Where Sprinklers Were Not Operational at Time of Fire)
1971-Present

Month and Year	Property Use	State	Deaths*	Explosion or flash fire	Firefighting
December 1971	Chemical manufacturer	New York	3	X	
April 1975	Metal recycling plant	Oregon	3 (1)	X	X
January 1976	Aerosol packaging plant	Indiana	5	X	
November 1976	Gum factory	New York	6	X	
June 1979	Ink manufacturer	California	3	X	
March 1980	Paper products warehouse	Idaho	5 (3)		X
July 1980	Metal products manufacturer	New York	11	X	
October 1981	Aerosol packaging plant	Massachusetts	5	X	
September 1982	Textile mill	North Carolina	4 (4)		X
July 1983	Supermarket	Florida	5	X	
December 1983	Vehicle parts repair	New York	7 (5)	X	
December 1984	Recycle steam plant	Ohio	3	X	
February 1985	Furniture manufacturer	Virginia	4	X	
December 1985	Shopping mall	California	4	X	
April 1986	Industrial park	California	9	X	
February 1993	Office complex	New York	6	X	
April 1995	Office building	Oklahoma	168	X	
November 1997	Toy manufacturer	California	4	X	
February 1999	Chemical manufacturer	Pennsylvania	5	X	
February 1999	Iron foundry	Massachusetts	3	X	
February 2001	Particleboard manufacturer	Pennsylvania	3	X	
May 2002	Rubber reclamation manufacturer	Mississippi	5	X	
February 2003	Insulation products manufacturer	Kentucky	7	X	
July 2003	Fireworks warehouse	Texas	3	X	
April 2004	Plastic products manufacturer	Illinois	5	X	

X – Indicates whether explosion or flash fire and/or firefighting was the factor that allowed multiple deaths in spite of the presence of operational sprinklers with complete coverage.

* "Multiple-death fires are here defined as fires with 3 or more civilian or firefighter deaths. Numbers in parentheses indicate the number of firefighter deaths in the total. The 9/11 attack on the World Trade Center involved an initial flash fire from the ignited jet fuel, but it is excluded here because the impact of the airplanes rendered the sprinklers non-operational before fire began.