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. Based on 2002-2004 fires reported to U.S. fire departments, when sprinklers cover the area of fire origin, they operate in 93% of all reported structure fires large enough to activate sprinklers. When they operate, they are effective 97% of the time, resulting in a combined effectiveness reliability of 90%. For most property uses, 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, the fire death rate per 1,000 reported structure fires is lower by at least 57% and the rate of property damage per reported structure fire is lower by one-third to two-thirds (34-68%). 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, 88% of reported structure fires have flame damage confined to the room of origin compared to 57% when no automatic extinguishing system is present. When sprinklers fail to operate, the reason most often (66% of failures) given is shutoff of the system before fire began.

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

Acknowledgements

The National Fire Protection Association thanks all the fire departments and state fire authorities who participate in the National Fire Incident Reporting System (NFIRS) and the annual NFPA fire experience survey. These firefighters are the original sources of the detailed data that make this analysis possible. Their contributions allow us to estimate the size of the fire problem.

We are also grateful to the U.S. Fire Administration for its work in developing, coordinating. and maintaining NFIRS.

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Performance and Reliability of Sprinklers

All statistics are based on fires reported in 2002-2004

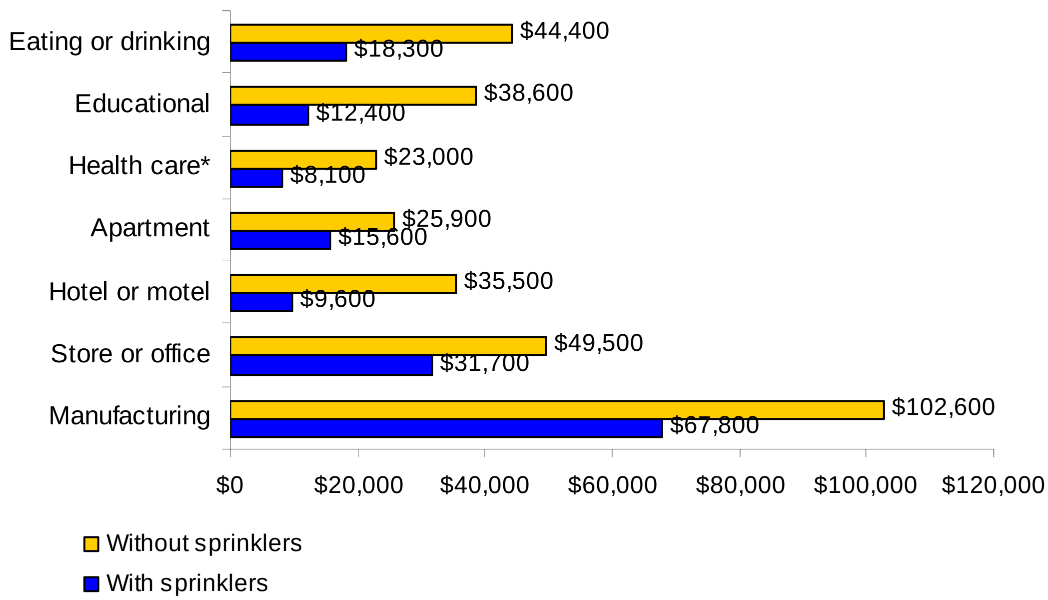
Sprinklers save lives and protect property from fires.

Compared to properties without automatic extinguishing systems

- The death rate per fire in sprinklered properties is lower by at least 57%.
- For most property uses, damage per fire is lower by one-third to two-thirds (34-68%) in sprinklered properties.

Flame damage was confined to the room of origin in 88% of fires in sprinklered properties vs. 57% in fires with no automatic extinguishing system.

Damage per Fire With and Without Sprinklers 2002-2004



* “Health care” refers only to facilities that care for the sick or the aged.

Sprinklers are reliable.

- In reported structure fires large enough to activate them, sprinklers operated in 93% of fires in sprinklered properties.
- Wet pipe sprinklers operated in 93% of these fires vs. 87% for dry pipe sprinklers.

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

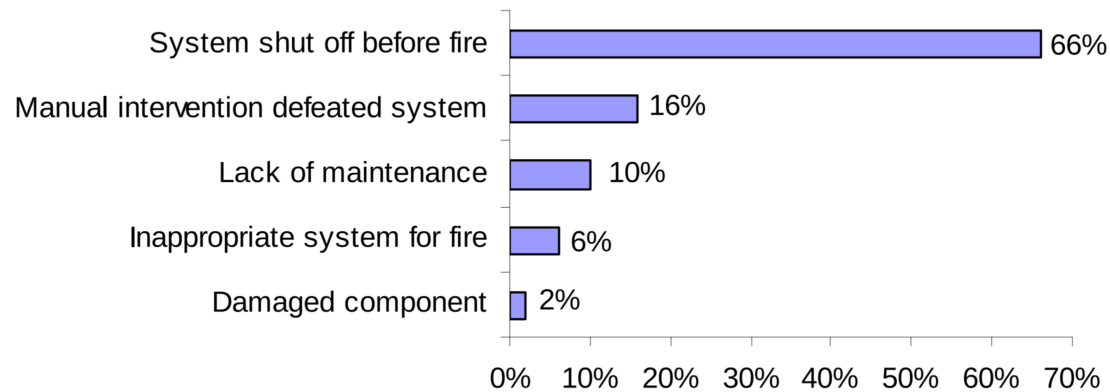
- When wet pipe sprinklers operated, 85% of reported fires involved only 1 or 2 sprinklers.
- For dry pipe sprinklers, 67% involved only 1 or 2 sprinklers.

Sprinklers are both reliable and effective.

- In reported structure fires large enough to activate them, sprinklers operated and were effective in 90% of fires in sprinklered properties.
- Wet pipe sprinklers operated and were effective in 91% of fires vs. 83% for dry pipe sprinklers.

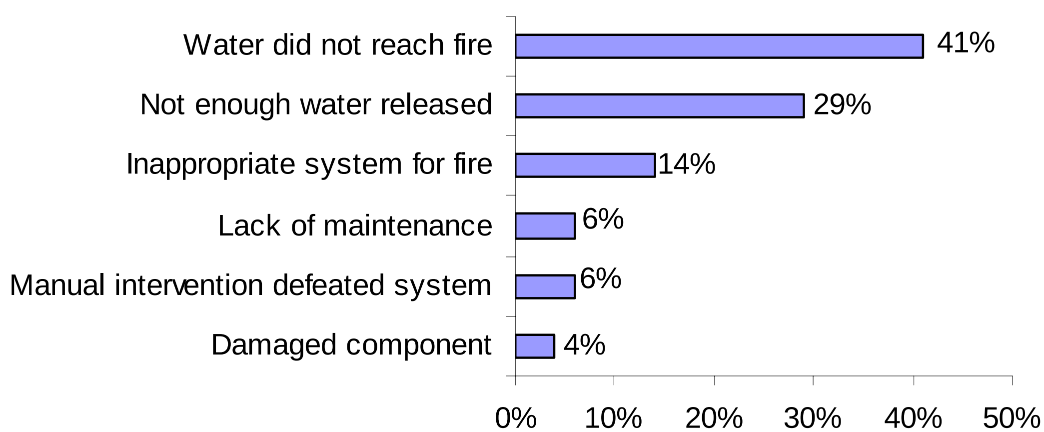
The graph below is based on the **7%** of fires in sprinklered properties in which the sprinkler should have operated but did not.

Reasons When Sprinklers Fail to Operate
2002-2004



Sprinklers were effective 90% of the time. The graph below is based on the few fires in sprinklered properties in which the sprinkler was ineffective.

Reasons When Sprinklers Are Ineffective
2002-2004



Executive Summary

Automatic sprinklers are highly effective and reliable elements of total system designs for fire protection in buildings. Based on 2002-2004 fires reported to U.S. fire departments, excluding 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, sprinklers operate in 93% of all reported structure fires large enough to activate sprinklers. When they operate, they are effective 97% of the time, resulting in a combined performance reliability of 90%. The combined performance reliability for the more widely used wet pipe sprinklers is 91%, while for dry pipe sprinklers, the combined performance reliability is only 83%. By comparison, combined performance reliability is only 49% for dry chemical systems but is 90% for carbon dioxide systems.

For most property uses, 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, the fire death rate per 1,000 reported structure fires is lower by at least 57% and the rate of property damage per reported structure fire is lower by one-third to two-thirds (34-68%). 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, 89% of reported structure fires have flame damage confined to the room of origin compared to 57% when no automatic extinguishing system is present.

An estimated 64% of reported 2004 structure fires in health care properties showed automatic extinguishing systems present and 97% of the automatic extinguishing systems reported in health care structure fires were sprinklers. The majority (54% in 2004) of reported structure fires in manufacturing properties also showed automatic extinguishing systems present, with 92% of those systems being sprinklers.

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. On that basis, it is likely that sprinklers are now common in hotels and motels and in department stores. However, sprinklers apparently are still rare in many of the places where people are most exposed to fire, including educational properties, public assembly 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 (66% of failures) given is shutoff of the system before fire began, as may occur in the course of routine inspection maintenance. Other leading reasons are manual intervention that defeated the system (16%), lack of maintenance (10%), and inappropriate system for the type of fire (6%). Only 2% of sprinkler failures are attributed to component damage.

When sprinklers operate but are ineffective, the reason usually has to do with an insufficiency of water applied to the fire, either because water did not reach the fire (41% of cases of ineffective performance) or because not enough water was released (29%). Other leading reasons are inappropriate system for the type of fire (14%), lack of maintenance (6%), and manual intervention that defeated the system (6%). Only 4% of cases of sprinkler ineffectiveness are 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 (88% of fatal victims in the area of origin and 11% with their clothing on fire when sprinklers operate, compared to 55% and 3% of fatal victims in general) or because they had some severe vulnerabilities or limitations before fire began (66% of fatal victims age 65 or older and 17% unable to act when fatally injured when sprinklers operate, compared to 27% and 10% of fatal victims in general). When three or more people die in fires despite the presence of complete coverage, operational sprinklers, the reason is always participation in firefighting activities or, most often, explosions or flash fires (or a collision, like the World Trade Center incident, that has the same effect as an explosion).

Introduction

Prior to 1999, reported fire data coded in the National Fire Incident Reporting System (NFIRS) did not distinguish sprinklered properties from other properties. The only information provided was on the presence or absence of any type of automatic extinguishing system (AES), as well as limited information on system performance. See Appendix A for more details on the development of national estimates statistics from NFIRS and Appendix B for details on NFIRS data elements related to automatic extinguishing systems.

Several changes in 1999 need to be considered in extending the 1980-1998 timeline for AES presence provided in previous editions of this report.

- In NFIRS Version 5.0, there was no code for AES presence unknown during 1999 to 2003. During that period the U.S. Fire Administration advised that data reported as unknown should be converted to no AES present.* The rate of unknowns (all blanks) for nonconfined fires reported in NFIRS Version 5.0 was around 8-9% in 2003, which indicates there are many unknowns not coded with the default code of no AES, but that percentage is also only one-third to one-half the unknown rate with NFIRS Version 4.1 data. In 2004, the unknown rate rose only to 10%, which suggests a lag in the field in restoring and using the unknown code. This flaw in coding would be expected to artificially lower the estimated percentages of AES presence. As a minimum, this argues against any use of converted NFIRS Version 4.1 data.

- In NFIRS Version 5.0, there are new codes for confined fires of six types, all defined as confined in part or in whole by the enclosure in which fire began (e.g., chimney, furnace, cooking vessel). Fewer details are required for these, and specifically the sprinkler and AES data elements are not required. If these confined fires are included in the analysis and simply pooled with the nonconfined fires, the confined fires will have little influence on the estimate because too few of them have AES presence coded. If they are included but analyzed separately, the confined fires will contribute a component with much more uncertainty because the AES presence for a large number of confined fires will be based on the presence percentage in the few fires with that information coded (e.g., in 2002-2004, only 3% of confined fires had AES presence coded). However, confined fires are by definition less severe, and so excluding confined fires will result in higher estimates of average loss per fire.

With these points in mind, consider Table A, which compares 2002-2004 AES presence for several property classes, calculated in three different ways, to the 1998 AES presence estimates for the same property class.

The estimates that exclude confined fires tend to be slightly lower than the corresponding 1998 estimates. These lower estimates might be more accurate than the 1998 estimates (if the reduction primarily reflects the change in definition to exclude partial systems not in the area of the fire) or less accurate (if the miscoding of unknowns is driving the reduction). Also, note that a larger share

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

of confined fires show hard-wired detectors present, which could mean that the reporting of confined fires is biased toward properties with detection/alarm systems that provide automatic notification to fire departments or central stations. In other words, fires too small to need fire department help might be more likely to be reported anyway if reporting is automatic. Moreover, usage of automatic detection equipment with automatic notification might be expected to be correlated with use of other advanced fire protection, such as sprinklers or other automatic extinguishing systems. This hypothesis, while speculative, would provide another way in which reported confined fires could lead to over-estimation of the presence of automatic extinguishing system.

Table A.
Percentage of Structure Fires with Automatic Extinguishing System Present

	2002-2004 Structure Fires Reported in NFIRS Version 5.0			
		Including Confined Fires		
Property Use	**Excluding Confined Fires**	**Excluding Unknown AES Performance**	**Unknown AES Performance Allocated Separately For Confined and Non-Confined Fires**	**1998 Reported Structure Fires**
Public assembly	29.6%	31.1%	46.4%	30.7%
(Eating or drinking establishment)	(39.6%)	(41.6%)	(55.9%)	(31.5%)
Educational	29.8%	29.7%	28.8%	25.3%
Health care	61.6%	62.1%	67.3%	74.3%
Residential	3.2%	3.2%	4.4%	3.1%
(One- or two-family dwelling)	(1.3%)	(1.3%)	(1.3%)	(0.7%)
(Apartment)	(8.1%)	(8.3%)	(11.3%)	(7.9%)
(Hotel or motel)	(40.5%)	(40.6%)	(43.1%)	(40.4%)
(Dormitory or barracks)	(33.2%)	(32.6%)	(28.0%)	(34.9%)
Store or office	20.9%	21.2%	26.7%	22.7%
(Food or beverage sales)	(28.3%)	(29.3%)	(39.7%)	(28.0%)
(Department store)	(40.8%)	(40.7%)	(39.4%)	(52.1%)
(Office building)	(23.7%)	(24.1%)	(30.0%)	(26.9%)
Manufacturing	53.7%	53.9%	56.4%	51.5%
Storage	2.9%	3.0%	4.0%	3.1%
(Warehouse excluding cold storage)	(30.7%)	(31.3%)	(38.9%)	(16.5%)
(Cold storage)	(51.4%)	(51.4%)	(51.4%)	(8.0%)
All structures	6.6%	6.8%	9.2%	7.2%

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, required for Table 1, 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. Therefore, no data from 1999-2001 is used in analyses in this report.

Source: NFIRS and NFPA survey.

The timeline for 1980-1998 showed a gradual but fairly steady increase in reported AES presence in nearly all property use classes. Therefore, the most credible timeline for years after 1998 would be one that showed continued increases. Columns 1 and 2 show many increases and some decreases (particularly for health care properties and for stores and offices). Column 3 shows a very similar pattern of which property uses had increases and which decreases, but some of its increases are much larger, with the net effect that column 3 shows an increase for all structures combined whereas columns 1 and 2 do not. The estimates that include the confined fires but without weighting them for their much higher rate of unknowns (column 2) differ little from the estimates that exclude confined fires (column 1). Also as expected, the estimates that include and weight the confined fires (column 3) are much more volatile, with some estimates falling well outside any reasonably likely range of values for their property classes (e.g., public assembly, which may also be skewed by the large number of confined cooking fires and the large percentage of AES systems that are not sprinklers). Because the weighted estimates are so volatile and the unweighted estimates with confined fires differ little from the estimates excluding confined fires, the estimates excluding confined fires seem to be the best choices to extend the timeline. None of the new estimates are close to the 1998 estimates for cold storage or for warehouse excluding cold storage.

Information on reasons for failure or ineffectiveness can be used to recode incidents for more accurate treatment of cases where sprinklers are not in the area of fire.

Prior to 1999, the coding of automatic extinguishing system performance in fires had the following choices:

NFIRS Version 4.1

1	Equipment operated
2	Equipment should have operated but did not
3	Equipment present, but fire too small to require operation
8	No equipment present in room or space of fire origin
9	Unclassified performance
0	Unknown performance

This data provided the only available basis for estimation of a statistic related to automatic extinguishing system operationality. NFPA estimated operationality as fires coded 1 (operated) divided by fires coded 1 or 2, thereby excluding fires deemed too small to activate an operational system. Such calculations produced the estimate of 16% non-operational for all structures combined, cited in older NFPA statistical reports on sprinklers.

This calculation has always had some serious limitations that reduce its validity as a best estimate of sprinkler operationality. First, it did not distinguish sprinklers from other types of systems, most notably the dry chemical systems widely used for hazard protection of commercial ranges. Second, there was anecdotal evidence to suggest that codes 1-3 were often recorded for partial-coverage systems that in fact had no coverage in the room or space of fire origin.

Beginning in 1999, the new NFIRS Version 5.0 separated "equipment operated" into "equipment operated and was effective" and "equipment operated and was not effective." For fires coded in NFIRS Version 4.1 as equipment operated, there was no way to determine effectiveness, and so all such entries were converted to unknown. Therefore, only fires reported directly in NFIRS Version 5.0 could be used. By itself, this change in coding had little impact on the estimate. The overall average for all buildings was now 18% non-operational instead of the previous 16%, essentially no change.

However, NFIRS Version 5.0 also included two new data elements which can be used to refine the estimates. First, type of equipment is now coded, which permits sprinklers to be separated from other extinguishing systems. Second, and more importantly, reasons for non-operation or ineffectiveness can now be identified, and these reasons confirmed the long-held suspicion that many partial systems were being coded incorrectly.

The coding of reasons 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. Here are the rules used for recoding:

<u>If Performance = Not Effective</u>

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

<u>If Performance = Failed to Operate</u>

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 Systems

Table 1 shows the percentage of reported nonconfined structure fires in which automatic extinguishing systems were present for each year in the ranges of 1980-1998 and 2002-2004. It is probably safe to say that health care facilities without automatic extinguishing systems are now a minority of all such facilities, even if one includes those that are unlicensed and those that were built under older, less demanding codes.

Automatic extinguishing systems also appear to be present in most manufacturing facilities. However, they still appear to be the exception, not the rule, in many property classes where large numbers of people are at risk – e.g., public assembly properties, schools, stores and offices (except department stores), apartment buildings, and dormitories and barracks. Of the properties shown, AES is least commonly seen in reported fires in one- or two-family dwellings.

Automatic extinguishing systems are reported in only 1% of fires in one- or two-family dwellings and only 8% of fires in apartments. Clearly, there is great potential for expanded use. The National Residential Fire Sprinkler Initiative of the U.S. Fire Administration reported in 2003 that no more than 2% of all new residences were then being protected with residential sprinkler systems.* This very low proportion of sprinkler-protected new residences suggests that sprinklers continue to have only a token presence in dwellings. The initiative hopes to increase interest in residential sprinkler systems among builders, developers, community officials, and especially homeowners.

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.

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.

*National Residential Fire Sprinkler Initiative, United States Fire Administration, Summary of Meeting, April 9-10 2003.

Table 1.
Percentage of Structure Fires Estimated to Have Occurred
in Structures With Automatic Extinguishing Systems
1980-1998 and 2002-2004, Excluding Non-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%)

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

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.

Source: NFIRS.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred
in Structures With Automatic Extinguishing Systems
1980-1998 and 2002-2004, Excluding Non-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
Public assembly	28.5%	30.0%	30.1%
(Eating or drinking establishment)	(38.9%)	(40.4%)	(39.4%)
Educational	28.9%	29.6%	30.7%
Health care*	60.3%	60.4%	63.8%
Residential	2.9%	3.3%	3.2%
(One- or two-family dwelling)	(1.3%)	(1.3%)	(1.3%)
(Apartment)	(8.1%)	(8.3%)	(7.9%)
(Hotel or motel)	(38.1%)	(40.6%)	(42.4%)
(Dormitory or barracks)	(27.1%)	(35.9%)	(36.5%)

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

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.

Source: NFIRS.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred
in Structures With Automatic Extinguishing Systems
1980-1998 and 2002-2004, Excluding Non-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%
(Food or beverage sales)	(14.0%)	(13.0%)	(13.8%)	(17.2%)	(16.9%)	(16.6%)	(20.1%)
(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%
(Food or beverage sales)	(22.2%)	(22.1%)	(23.4%)	(23.1%)	(23.6%)	(24.8%)	(21.8%)
(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.

Source: NFIRS.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred
in Structures With Automatic Extinguishing Systems
1980-1998 and 2002-2004, Excluding Non-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%
(Food or beverage sales)	(25.9%)	(25.1%)	(26.8%)	(27.9%)	(28.0%)
(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
Store or office	20.2%	21.1%	21.2%
(Food or beverage sales)	(30.1%)	(27.5%)	(27.8%)
(Department store)	(41.0%)	(40.5%)	(41.0%)
(Office building)	(23.4%)	(24.4%)	(23.3%)
Manufacturing facilities	56.2%	51.4%	53.7%
Storage facilities	2.7%	2.9%	3.1%
(Warehouse excluding cold storage)	(30.6%)	(29.6%)	(31.9%)
(Cold storage)	(46.7%)	(50.0%)	(60.0%)
All structures*	6.3%	6.8%	6.8%

* "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.

Source: NFIRS.

Automatic Extinguishing System Type

In reported fires, most automatic extinguishing systems are sprinklers and most sprinklers are wet pipe sprinklers.
Table 2 shows the percentage of fires by type of automatic extinguishing system for each of the major property groups and some subgroups. Percentage calculations are based only on fires where automatic extinguishing system presence and type were known and reported.

Some type of sprinkler system was present in 88% of all structure fires where an automatic extinguishing system was present. Wet pipe sprinkler systems accounted for 77% of all systems and so out-numbered dry pipe systems by more than 8-to-1 and outnumbered all other types of sprinklers by nearly 30-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, 72%) of systems cited.

For public assembly properties, there was a 56% to 44% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 32% of the systems present. Eating or drinking establishments (the dominant part of public assembly) had a 44% to 56% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 41% of total systems in eating or drinking establishments, nearly the same share as all sprinklers combined.

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.

For property classes other than public assembly, sprinklers account for most of the reported systems.

Table 2.
Type of Automatic Extinguishing System Reported as Percentage of All Structure Fires Where Systems Were Present and of Known Type, by Property Use 2002-2004 Non-Confined Fires

Property Use	All sprinklers	Wet pipe sprinklers	Dry pipe sprinklers	Other sprinklers*
Public assembly	56%	47%	6%	3%
(Eating or drinking establishment)	(44%)	(36%)	(4%)	(4%)
Educational	94%	85%	8%	2%
Health care**	97%	84%	11%	2%
Residential	96%	87%	6%	3%
(One- or two-family dwelling)	(88%)	(81%)	(4%)	(3%)
(Apartment)	(96%)	(88%)	(6%)	(2%)
(Hotel or motel)	(96%)	(87%)	(7%)	(2%)
(Dormitory or barracks)	(96%)	(88%)	(3%)	(5%)
Store or office	89%	78%	8%	2%
(Office building)	(97%)	(87%)	(8%)	(3%)
Manufacturing	92%	77%	12%	3%
Storage	97%	75%	21%	1%
(Warehouse excluding cold storage)	(98%)	(82%)	(15%)	(2%)
(Cold storage)	(100%)	(28%)	(72%)	(0%)
All structures***	88%	77%	9%	3%

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

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

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

Note: These are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 2. (Continued)
Type of Automatic Extinguishing System Reported as Percentage of All Structure Fires Where Systems Were Present and of Known Type, by Property Use
2002-2004 Non-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	44%	32%	2%	1%	2%	7%
(Eating or drinking establishment)	(56%)	(41%)	(3%)	(2%)	(2%)	(9%)
Educational	6%	4%	0%	0%	0%	1%
Health care**	3%	2%	0%	0%	0%	1%
Residential	4%	2%	0%	0%	0%	0%
(One- or two-family dwelling)	(12%)	(6%)	(1%)	(0%)	(0%)	(6%)
(Apartment)	(4%)	(2%)	(0%)	(0%)	(0%)	(2%)
(Hotel or motel)	(4%)	(2%)	(0%)	(0%)	(0%)	(1%)
(Dormitory or barracks)	(4%)	(2%)	(1%)	(0%)	(0%)	(2%)
Store or office	11%	8%	0%	1%	0%	1%
(Office building)	(3%)	(1%)	(0%)	(1%)	(0%)	(0%)
Manufacturing	8%	1%	4%	0%	0%	2%
Storage	3%	1%	0%	1%	0%	1%
(Warehouse excluding cold storage)	(2%)	(0%)	(0%)	(1%)	(0%)	(1%)
(Cold storage)	(0%)	(0%)	(0%)	0%)	(0%)	(0%)
All structures***	12%	7%	1%	1%	0%	2%

* "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.

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

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

Note: These are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Automatic Extinguishing System Operational Reliability

Table 3 shows the percentage of non-confined structure fires where automatic extinguishing systems 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, and
- Carbon dioxide systems.

Table 3 also shows the number of fires that formed the basis for the calculation, excluding fires too small to activate a system and excluding cases of failure or ineffective performance because of no sprinklers in the fire area (which should have been coded as sprinkler not present), by property use and type of automatic extinguishing system. The numbers of fires are 3-year totals and are not the sample size numbers but include scaling up to national estimates. Property use classes are shown only if they accounted for at least 300 fires in 3 years for all sprinklers or wetpipe sprinklers, or for at least 200 fires for dry pipe sprinklers, dry chemical systems, or carbon dioxide systems. Foam systems and 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 fail to operate in 7% of reported structure fires large enough to activate sprinklers.
The other estimated failure rates shown in Table 3 are:

- 7% for wet pipe sprinklers,
- 13% for dry pipe sprinklers,
- 23% for dry chemical systems, and
- 5% for carbon dioxide systems

For major property classes and sprinklers, the estimated failure rates range from a low of 4% for residential properties to a high of 20% for storage properties. For storage properties, the estimated failure rates are 17% for wet pipe sprinklers and 26% 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.

For all sprinklers:

- 66% of failures to operate were attributed to the system being shut off,
- 16% were because manual intervention defeated the system,
- 10% were because of lack of maintenance,
- 6% were because the system was inappropriate for the type of fire, and
- 2% 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.

In other words, only 2% 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 7% 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.

Health care facilities (41%), hotels and motels (32%), educational properties (27%), and stores and offices (26%) had the highest percentages for defeating of sprinklers by manual intervention as the reason for failure to operate.

Warehouses excluding cold storage and eating or drinking establishments are the property uses reporting the highest percentages for system component damage as the reason for sprinkler failure (both 10%). Component damage in warehouses could include forklifts damaging exposed sprinklers.

For all structures, lack of maintenance has its highest percentages of failure reasons for dry chemical systems (51%) and dry pipe sprinklers (23%). The highest failure rates due to lack of maintenance are also for dry chemical systems (12%) and dry pipe sprinklers (3%).

Dry chemical systems had the highest percentage for wrong system for type of fire as the reason for failure, when all structures were considered together (16%). Whenever any property changes, there needs to be a review of the appropriateness and adequacy of its built-in fire protection. A change in cooking style, for example, could lead to more use of frying or an expanded cooking surface. Any such change has direct and potentially significant implications for the design and selection of automatic extinguishing systems, including a dry chemical system for the cooking surfaces.

*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.

Table 3.
Automatic Extinguishing System Operationality
When Fire Was Large Enough to Activate System, by Property Use
2002-2004 Non-Confined Structure Fires

A. All Sprinklers

Property Use	Percent where systems failed to operate	Based on number of fires*
Public assembly	7%	800
(Eating or drinking establishment)	(8%)	(500)
Educational	11%	300
Health care**	8%	500
Residential	4%	3,600
(Apartment)	(3%)	(2,500)
(Hotel or motel)	(4%)	(500)
Store or office	6%	1,600
Manufacturing	7%	2,300
Storage	20%	500
(Warehouse excluding cold storage)	(19%)	(300)
All structures***	7%	10,100

* Percentages are based on estimated total 2002-2004 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.

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

*** 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.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing System Operationality
When Fire Was Large Enough to Activate System, by Property Use
2002-2004 Non-Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Percent where systems failed to operate	Based on number of fires*
Public assembly	8%	600
(Eating or drinking establishment)	(9%)	(400)
Educational	8%	300
Health care**	7%	400
Residential	4%	3,400
(Apartment)	(3%)	(2,300)
(Hotel or motel)	(3%)	(500)
Store or office	5%	1,400
Manufacturing	6%	1,900
Storage	17%	400
(Warehouse excluding cold storage)	(10%)	(300)
All structures**	7%	8,800

* Percentages are based on estimated total 2002-2004 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.

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

*** 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.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing System Operationality in Structure Fires When Fire Was Large Enough to Activate System, by Property Use 2002-2004 Non-Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Percent where systems failed to operate	Based on number of fires*
Residential	4%	200
Store or office	9%	200
Manufacturing	16%	300
Storage	26%	300
All structures**	13%	1,000

* Percentages are based on estimated total 2002-2004 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.

** 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.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing System Operationality in Structure Fires
When Fire Was Large Enough to Activate System, by Property Use
2002-2004 Non-Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Percent where systems failed to operate	Based on number of fires*
Public assembly	28%	600
(Eating or drinking establishment)	(29%)	(600)
Residential	0%	300
Store or office	16%	300
All structures**	23%	1,000

* Percentages are based on estimated total 2002-2004 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.

** 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.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing System Operationality in Structure Fires
When Fire Was Large Enough to Activate System, by Property Use
2002-2004 Non-Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Percent where systems failed to operate	Based on number of fires*
Manufacturing	4%	200
All structures**	5%	300

* Percentages are based on estimated total 2002-2004 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.

** 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.

Source: NFIRS and NFPA survey.

Table 4.
Reasons for Failure to Operate When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-Confined Structure Fires

A. All Sprinklers

Property Use	System shut off	Manual intervention defeated system	Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Public assembly	58%	17%	13%	5%	7%	100%
(Eating or drinking establishment)	(57%)	(16%)	(17%)	(0%)	(10%)	(100%)
Educational	73%	27%	0%	0%	0%	100%
Health care*	20%	41%	10%	29%	0%	100%
Residential	64%	18%	10%	6%	2%	100%
(Apartment)	(58%)	(15%)	(18%)	(9%)	(0%)	(100%)
(Hotel or motel)	(52%)	(32%)	(0%)	(16%)	(0%)	(100%)
Store or office	51%	26%	17%	6%	0%	100%
Manufacturer	74%	11%	10%	3%	2%	100%
Storage	75%	6%	9%	5%	5%	100%
(Warehouse excluding cold storage)	(76%)	(5%)	(10%)	(0%)	(10%)	(100%)
All structures**	66%	16%	10%	6%	2%	100%

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

** Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	System shut off	Manual intervention defeated system	Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Public assembly	55%	18%	13%	6%	7%	100%
(Eating or drinking establishment)	(57%)	(16%)	(17%)	(0%)	(10%)	(100%)
Educational	77%	23%	0%	0%	0%	100%
Health care*	25%	25%	12%	38%	0%	100%
Residential	64%	19%	10%	4%	2%	100%
(Apartment)	(56%)	(16%)	(19%)	(9%)	(0%)	(100%)
(Hotel or motel)	(62%)	(38%)	(0%)	(0%)	(0%)	(100%)
Store or office	63%	30%	4%	4%	0%	100%
Manufacturing	68%	15%	10%	4%	2%	100%
Storage	81%	8%	0%	7%	4%	100%
(Warehouse excluding cold storage)	(86%)	(7%)	(0%)	(0%)	(7%)	(100%)
All structures**	67%	17%	7%	6%	2%	100%

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

** Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	System shut off	Manual intervention defeated system	` Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Residential	50%	0%	0%	50%	0%	100%
Store or office	0%	0%	78%	22%	0%	100%
Manufacturing	90%	0%	10%	0%	0%	100%
Storage	58%	0%	32%	0%	10%	100%
All structures*	60%	8%	23%	5%	3%	100%

* Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	System shut off	Manual intervention defeated system	Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Public assembly	11%	15%	54%	18%	3%	100%
(Eating or drinking establishment)	(11%)	(15%)	(54%)	(18%)	(3%)	(100%)
Residential	NA	NA	NA	NA	NA	NA
Store or office	0%	0%	42%	19%	39%	100%
All structures*	10%	17%	51%	16%	6%	100%

* Includes some properties not listed separately above.

NA – Not applicable because there were no reported cases of failure with fire in the coverage area.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-Confined Structure Fires

E. Carbon Dioxide Systems Only

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

* Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Automatic Extinguishing System 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 AES Were Effective

Operating sprinklers were deemed effective 97% of the time and overall, in fires large enough to activate sprinklers, sprinklers were effective 90% of the time.
Table 5 provides the full distribution for operated and effective, operated but not effective, fire too small to activate system, and failed to operate, by property class and by type of automatic extinguishing system. This is the only table that provides statistics on the shares of fires that are too small to activate system. The majority of reported non-confined fires (55% for all structures) are too small to activate sprinklers (and this would be even more true for fires reported as confined fires). Only 22% of reported fires were too small to activate carbon dioxide systems in the area of the fire.

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

Effectiveness reliability 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).

Combined performance reliability is calculated by multiplying effectiveness reliability (column 1 of Table 6) by operational reliability (100% minus column 1 in Table 3).

Effectiveness reliability was uniformly high for sprinklers in all property classes. Effectiveness reliability was slightly higher for wet pipe sprinklers (97% for all structures) than for dry pipe sprinklers (95%). Effectiveness reliability was much lower (64% for all structures) for dry chemical systems than for any other automatic extinguishing system analyzed.

Combined performance reliability was 90% for all sprinklers, 91% for wet pipe sprinklers, and 83% for dry pipe sprinklers, all measured for all structures. Combined performance reliability was also 90% for carbon dioxide systems but only 49% for dry chemical systems.

A disadvantage of measuring AES 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.

Effectiveness should be measured relative to the design objectives for a particular system. For example, a sprinkler system that complies with NFPA 13, *Standard for the Installation of Sprinkler Systems*, is designed to confine fire to a design fire area, typically 1,500 square feet. However, incident reports may be completed by people who do not know the design objective for the system or cannot measure the fire outcome in the objective's terms.

Because it is not clear what is achieved with effective performance, it also is not clear what tangible benefit is derived from sprinklers. These measures do not support cost-benefit analyses as well as measures in the form of reductions in loss per fire.

Dry pipe sprinkler systems tend to have more sprinklers operating than wet pipe sprinkler systems.
Table 7 shows the number of sprinklers operating by type of sprinkler system. Five or fewer heads operated in 95% of the wet pipe system activations and 86% of the dry pipe system activations.

Dry-pipe systems are much more likely to open more than one sprinkler than wet pipe systems (50% vs. 29% of fires). The likely reason is the designed time delay in tripping the dry pipe 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.

Effectiveness reliability declines when more sprinklers operate.
When more than 1-2 sprinklers operate, this is often taken as an indication of less than ideal performance. Table 8 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 22% when more than 10 sprinklers open.

Most cases of sprinkler ineffectiveness were because water did not reach the fire (41%) or because not enough water was released (29%).
Table 9 provides distributions of reasons for ineffectiveness, by property class and type of automatic extinguishing system. In addition to the two reasons cited, sprinkler ineffectiveness for all structures was attributed to an inappropriate system for the type of fire (14%), lack of maintenance (6%), defeating due to manual intervention (6%), and damage to a system component (4%).

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 can 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 system (if, for example, the hazard has changed under the system and now requires a higher water flow density than is provided by the now inappropriate system) 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 one of the reasons that could be cited 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.

Storage properties probably provide the most opportunities for major changes in the hazard associated with the space, and so it is not surprising that inappropriate system was the only reason for ineffectiveness cited for sprinklers in storage properties. Apartments are one of the only properties where sprinkler ineffectiveness was attributed to system component damage. There have been anecdotal reports of apartment residents hanging clothes on sprinklers or sprinkler piping; the cited damage may arise from errors like this.

Reasons for ineffectiveness are quite different for wet pipe sprinklers and dry pipe sprinklers, with dry pipe sprinklers having 86% of cases attributed to not enough water released. 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 Rate per Fire

For most property uses, the fire death rate per 1,000 reported structure fires is at least 57% lower when 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 10 shows that the percent reduction in fire death rate in 2002 to 2004 was 57% for apartments, the property class with the most deaths for analysis in both sprinklered and unsprinklered properties.

Educational properties show no decrease in fire death rates because there were no deaths in either sprinklered or unsprinklered properties. In fact, all of these calculations are based on a very small number of reported fire deaths.

If the basic risk is low, the results may be very sensitive to the effects of one major fire. For example, Table 10 seems to show sprinklers as totally effective in protecting life safety in public assembly properties. However, if the calculation had included the year 1980, statistical projection of the 26 deaths in the 1980 Stouffer's Inn conference center fire in New York would have raised the total estimated number of deaths per year in sprinklered public assembly properties several times. Yet that property had sprinklers only in a stairway, a corridor length away from the origin of the fire, so the high death toll in that fire said little or nothing about the value of sprinklers. Also, the 2003 Station nightclub fire is not included in the NFIRS database; if it were, the average of deaths per 100 fires for unsprinklered public assembly properties would be much higher.

The calculations shown include only non-confined fires reported to fire departments. Sprinklers will control many fires before the fire department is notified, which can paradoxically appear to raise the death rate per thousand fires for the fires that remain to be handled by the fire department. On the other hand, sprinklered properties may tend to be better built and better maintained in terms of all other fire safety and fire protection features. This point alone will tend to mean that sprinklers will receive some credit for life savings that are actually produced by the whole integrated system of balanced fire protection in which sprinklers are an essential part but not the only part.

One and two-family dwellings also are not shown because they reported too few fires in sprinklered properties. If provided, that data would have shown a 100% reduction in fire death rate, but there are a large number of dwelling fire fatalities with automatic extinguishing systems of unknown type present. Because nearly all automatic extinguishing systems in dwellings are sprinklers, one might suppose that many of these unknown systems are also sprinklers, which could wipe out the estimated fire death rate reduction effect of sprinklers in dwellings. However, the only one of these incidents with details in NFPA's major fires database showed the "unknown-type automatic extinguishing system" to be garden hoses (according to news accounts). This suggests that perhaps all of the "unknown type" systems are in fact not automatic systems at all, in which case the original calculation of a 100% fire death rate reduction would be unchanged.

Analysts at the National Institute of Standards and Technology (NIST) conducted an analysis of the estimated impact of sprinklers on home fires and associated losses, using laboratory test data, estimates from panels of fire researchers, and statistics on the relative frequency of various fire scenarios and of the proximity of victims to those fires. Table 11 summarizes those results for one- and two-family dwellings. The key result is a 63-69% reduction in the death rate per thousand fires if sprinklers are added to dwellings that do or do not already have smoke alarms, respectively.

Note that the NIST analysis shows how sprinklers and smoke alarms both have an essential role to play in providing life safety from fires in homes. If smoke alarms are introduced first (which is the way most people would do it), the NIST study estimates fire death rates would fall by 52%. Adding sprinklers would further reduce by 63% the 48% of the original death rate that remains, producing a 30% reduction relative to that original death rate, or a total reduction of 82%. Or, if sprinklers were introduced first, the original death rate would be estimated to fall by 69%. Then adding smoke alarms would reduce by 42% the 31% of the original death rate that remained, producing a 13% reduction relative to that original death rate, for the same total reduction of 82%. What this means is that sprinklers will save many people who would not be saved by smoke alarms, and smoke alarms will save many people who would not be saved by sprinklers.

This analysis can be restructured in the following very simplified form. When Ruegg and Fuller performed their analysis, they were using fire experience from the early 1980's. In 1981, say, there were 5,400 home fire deaths, and their analysis would have predicted that sprinklers and smoke alarms could lower that figure to about 1,100. The 4,300 death reduction would have consisted of a combination of about 2,500 lives saved by completing the process of putting smoke alarms in all homes and 1,800 more lives saved by installing sprinklers. As of 2004, the home fire death toll had fallen by 2,200 from the 1981 figure, with much of the decline probably due to the steady growth in smoke alarm use. Meanwhile, the potential of home sprinklers still remains largely untapped.

For most property uses, the property damage rate per reported structure fire is one-third to two-thirds (34-68%) lower when 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 12 shows only public assembly properties falling outside this range of percent reductions in loss rates. Most of the three-year total of property damage in public assembly properties came in one casino fire, which is discussed more below.

The screening of fires with partial sprinkler systems is done using the sprinkler failure reason code for sprinklers not in area of fire. Note that this code does not identify all fires that begin in unsprinklered areas or spread from sprinklered to unsprinklered areas before sprinkler activation.

For example, five of the highest-loss warehouse fires, accounting for roughly one-third of total warehouse fire damage in sprinklered properties, involved fires that began in loading areas (In decreasing order of magnitude of loss, they were a 2003 fire in New York, a 2002 fire in Montana, a 2002 fire in New York, a 2003 fire in Indiana, and a 2004 fire in Ohio.) The two of these five fires with highest loss are also in NFPA's major fires database. Both had outdoor loading areas; one loading area was definitely outside sprinkler coverage, and the other was not reported. It is possible that all five incidents began outside sprinkler coverage.

The three largest reported 2002-2004 fire losses in sprinklered structures of any type (excluding partial systems that could be identified and screened out) were in two manufacturing properties and a casino. NFPA has major-fire records on two of the three. The largest manufacturing fire loss (2002 in Illinois) involved a system shut off before fire began and had a loss that appears to have been double counted in the NFIRS record. (NFPA's figure for combined structure and contents loss was entered in total in each of the structure and contents fields in NFIRS.)

The other manufacturing fire loss of $25 million (2002 in South Dakota) is not in NFPA records, which normally capture all losses of $5 million or more. A keystroke error could easily add a zero or two to the end of a much smaller loss amount, and the NFIRS records show no contents loss and no contents value for the property, with no reported information on fire spread or building size, and no reported information on sprinkler performance. There is in other words, no incident report information confirming the magnitude of the loss, and the absence of contents loss and value make the large structure loss and value, combined with a structure status of open and operating, appear suspect.

The casino fire (2003 in Nevada) is in NFPA's major fires database, but NFPA was never able to obtain confirmation of the loss amount or the incident details from the fire department. News accounts quote fire officials as supporting the $15 million loss estimate and also quoted them as saying a grease fire had spread above the sprinklers before the sprinklers activated. However, the NFIRS report describes the item first ignited as unknown and provides no coded reason for sprinkler ineffectiveness.

The point here is not to dismiss all large losses in sprinklered properties but to illustrate how much the calculations depend on a small number of major losses and to point out that the more we are able to screen data to make appropriate exclusions, the larger the estimated impact of sprinklers becomes. The best estimate of the overall impact of sprinklers on loss rates per fire is therefore the range of loss rate reductions obtained for major property classes with enough fires for meaningful analysis and a relatively low sensitivity to individual large losses. These property classes lead to the range of one-third to one-half loss rate reductions obtained from residential, store and office, and manufacturing properties.

The advantages of loss per fire measures include the ability to support cost-benefit analyses and a more direct and understandable measure of sprinkler that means something even to non-technical people – lives saved and money saved.

A major disadvantage is sensitivity to a small number of very serious fires. For example, an explosion can disable a sprinkler system and lead to a very large, deadly, and costly fire, but its serious consequences are not a reflection on sprinkler performance, because sprinklers are not designed to operate in such conditions. The same is true of fires outside the coverage area of a partial sprinkler system if such fires are incorrectly recorded under sprinkler present. The sensitivity to one or two serious fires is a problem when there are only a small amount of data to work with, as is true for deaths in most property classes.

One- and two-family dwellings account for a very large share of total reported structure fires but have a sprinkler presence of about 1%. This means any calculation of deaths per 1,000 fires or property loss per fire for a property group including but not limited to dwellings – such as all homes, all residential properties, or all structures – will be dominated by dwellings for unsprinklered properties but barely affected by dwellings for sprinklered properties. Because it is also true that dwellings have a high rate of deaths per 1,000 fires and a low rate of property loss per fire, relative to other properties, the net result is that a simple comparison of loss rates for all structures in sprinklered vs. unsprinklered properties will be misleadingly favorable for deaths and misleadingly unfavorable for property damage, in both cases because the very low sprinkler presence in dwellings leads to an implicit comparison of loss rates in unsprinklered dwellings to loss rates in sprinklered properties that are not homes. For this reason, none of the loss per fire tables show a line for all structures.

Another problem with assessment of sprinklers using loss per fire measures is that sprinklers – like any new technology or home feature – will tend to be obtained first by more affluent households that can more easily afford sprinklers. Statistically, affluent households tend to have a lower rate of deaths per 1,000 fires, but because their homes and possessions are worth more, they may have higher average property loss per fire even if the fires they have are on average no larger in physical size. This is another way in which loss per fire measures can look misleadingly favorable for deaths and misleadingly unfavorable for property damage if the percent usage of sprinklers is quite low for the property class, as it is for dwellings.

Sprinkler Reduction in Likelihood of Multiple-Death, Large-Loss or Other Severe Fire

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 are the most common exceptions, 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 hope 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.

If one attempts to construct an analogous statement about sprinkler effectiveness in preventing large losses of property to fire, most major fires would be covered by a similar statement. That is, 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 can lead to a large loss, and they prevent the crafting of a simple statement of effectiveness.

- 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.

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 13:

- Victims 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 88% of fatal victims when sprinklers operated vs. 55% 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 66% of fatal victims when sprinklers operated vs. 27% of total victims).

Measures of likelihood of very large or severe fires have the advantage that they are not sensitive to the actual severity of the most severe fires because any fire more severe than the threshold is treated the same as any other qualifying fires. They have the disadvantage that the measure of success is harder to use in a cost-benefit analysis and harder for non-technical people to appreciate. Also, such measures may appear to understate the value of systems by giving no credit for their ability to produce marginal reductions in fire loss, such as saving lives in what would have been one-death fires.

When complete-coverage sprinklers are present in structures that are not under construction, 89% of reported structure fires have flame damage confined to the room of origin, compared to 57% when no automatic extinguishing system is present.
Table 14 provides these statistics as well as corresponding statistics for various property classes. Every property class, except for one- and two-family dwellings, shows a major change in the percentage of fires confined to room of origin.

Table 5.
Automatic Extinguishing System Performance, by Property Use
2002-2004 Non-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	35%	4%	59%	3%
(Eating or drinking establishment)	(37%)	(5%)	(55%)	(4%)
Educational	20%	0%	78%	2%
Health care*	21%	1%	76%	2%
Residential	47%	1%	50%	2%
(Apartment)	(54%)	(1%)	(44%)	(2%)
(Hotel or motel)	(37%)	(1%)	(61%)	(1%)
Store or office	37%	1%	60%	2%
Manufacturing	47%	3%	46%	4%
Storage	45%	2%	41%	11%
(Warehouse excluding cold storage)	(50%)	(0%)	(38%)	(12%)
All structures**	40%	1%	55%	3%

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

** Includes some properties not separately listed above.

Note: Percentages are based on 2002-2004 non-confined 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. 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.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing System Performance, by Property Use
2002-2004 Non-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	36%	3%	59%	3%
(Eating or drinking establishment)	(38%)	(3%)	(55%)	(4%)
Educational	20%	0%	78%	2%
Health care*	23%	0%	75%	2%
Residential	48%	1%	49%	2%
(Apartment)	(54%)	(1%)	(43%)	(2%)
(Hotel or motel)	(37%)	(1%)	(60%)	(1%)
Store or office	37%	1%	60%	2%
Manufacturing	47%	2%	47%	3%
Storage	46%	3%	41%	10%
(Warehouse excluding cold storage)	(49%)	(3%)	(38%)	(10%)
All structures**	41%	1%	55%	3%

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

** Includes some properties not separately listed above.

Note: Percentages are based on 2002-2004 non-confined 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. 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.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing System Performance, by Property Use
2002-2004 Non-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	39%	1%	59%	1%
Store or office	34%	0%	62%	3%
Manufacturing	44%	2%	45%	9%
Storage	40%	3%	42%	15%
All structures*	35%	2%	58%	5%

* Includes some properties not separately listed above.

Note: Percentages are based on 2002-2004 non-confined 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. 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.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Automatic Extinguishing System Performance, by Property Use
2002-2004 Non-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	20%	16%	50%	14%
(Eating or drinking establishment)	(20%)	(15%)	(49%)	(15%)
Residential	60%	10%	29%	0%
Store or office	21%	16%	56%	7%
All structures*	26%	15%	48%	12%

* Includes some properties not separately listed above.

Note: Percentages are based on 2002-2004 non-confined 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. 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.

Source: NFIRS and NFPA survey.

Table 5 . (Continued)
Automatic Extinguishing System Performance, by Property Use
2002-2004 Non-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%	3%	3%	4%
All structures*	71%	4%	22%	4%

* Includes some properties not separately listed above.

Note: Percentages are based on 2002-2004 non-confined 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. 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.

Source: NFIRS and NFPA survey.

Table 6.
Automatic Extinguishing System Effectiveness, by Property Use
2002-2004 Non-Confined Structure Fires

A. All Sprinklers

Property Use	Effectiveness reliability (for systems that operated)	Combined performance effectiveness (for all systems that were present)
Public assembly	91%	84%
(Eating or drinking establishment)	(89%)	(81%)
Educational	100%	89%
Health care*	98%	90%
Residential	98%	94%
(Apartment)	(98%)	(96%)
(Hotel or motel)	(97%)	(94%)
Store or office	98%	92%
Manufacturing	95%	88%
Storage	95%	77%
(Warehouse excluding cold storage)	(100%)	(81%)
All structures**	97%	90%

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

** Includes some properties not separately listed above.

Note: 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 2002-2004 non-confined 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. 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 6. (Continued)
Automatic Extinguishing System Effectiveness, by Property Use
2002-2004 Non-Confined Structure Fires

B. Wet Pipe Sprinklers Only

Property Use	Effectiveness reliability (for systems that operated)	Combined performance effectiveness (for all systems that were present)
Public assembly	93%	86%
(Eating or drinking establishment)	(93%)	(85%)
Educational	100%	92%
Health care*	98%	91%
Residential	99%	94%
(Apartment)	(98%)	(96%)
(Hotel or motel)	(97%)	(94%)
Store or office	98%	93%
Manufacturing	95%	89%
Storage	93%	77%
(Warehouse excluding cold storage)	(94%)	(79%)
All structures**	97%	91%

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

** Includes some properties not separately listed above.

Note: 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 2002-2004 non-confined 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. 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 6. (Continued)
Automatic Extinguishing System Effectiveness, by Property Use
2002-2004 Non-Confined Structure Fires

C. Dry Pipe Sprinklers Only

Property Use	Effectiveness reliability (for systems that operated)	Combined performance effectiveness (for all systems that were present)
Residential	97%	94%
Store or office	100%	91%
Manufacturing	95%	80%
Storage	93%	69%
All structures*	95%	83%

* Includes some properties not separately listed above.

Note: 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 2002-2004 non-confined 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. 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.

Table 6. (Continued)
Automatic Extinguishing System Effectiveness, by Property Use
2002-2004 Non-Confined Structure Fires

D. Dry Chemical Systems Only

Property Use	Effectiveness reliability (for systems that operated)	Combined performance effectiveness (for all systems that were present)
Public assembly	57%	41%
(Eating or drinking establishment)	(57%)	(40%)
Residential	85%	85%
Store or office	57%	48%
All structures*	64%	49%

* Includes some properties not separately listed above.

Note: 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 2002-2004 non-confined 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. 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.

Table 6. (Continued)
Automatic Extinguishing System Effectiveness, by Property Use
2002-2004 Non-Confined Structure Fires

E. Carbon Dioxide Systems Only

Property Use	Effectiveness reliability (for systems that operated)	Combined performance effectiveness (for all systems that were present)
Manufacturing	97%	93%
All structures*	95%	90%

* Includes some properties not separately listed above.

Note: 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 2002-2004 non-confined 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. 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.

Table 7.
Number of Sprinklers Operating
2002-2004 Non-Confined Structure Fires

	Percentage of Structure Fires Where That Many Sprinklers Operated		
Number of Sprinklers Operating	**Wet pipe**	**Dry pipe**	**Other type sprinkler**
1	71%	50%	53%
2 or fewer	85%	67%	68%
3 or fewer	90%	75%	79%
4 or fewer	93%	82%	85%
5 or fewer	95%	86%	86%
6 or fewer	96%	89%	88%
7 or fewer	97%	89%	91%
8 or fewer	97%	89%	93%
9 or fewer	97%	92%	94%
10 or fewer	98%	93%	96%

Note: Percentages are based on 2002-2004 non-confined 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. 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.
Sprinkler Effectiveness Reliability Related to
Number of Sprinklers Operating
2002-2004 Non-Confined Structure Fires

Number of Sprinklers Operating	Percent of structure fires where sprinklers were effective
1	97%
2	94%
3	94%
4	93%
5	93%
6 to 10	83%
More than 10	78%
Total	95%

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 9.
Reasons for Ineffectiveness When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 Non-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	36%	37%	12%	0%	15%	0%	100%
(Eating or drinking establishment)	(37%)	(35%)	(12%)	(0%)	(16%)	(0%)	(100%)
Educational	NA	NA	NA	NA	NA	NA	NA
Health care*	32%	68%	0%	0%	0%	0%	100%
Residential	46%	18%	15%	7%	0%	14%	100%
(Apartment)	(37%)	(24%)	(20%)	(0%)	(0%)	(19%)	(100%)
(Hotel or motel)	(71%)	(0%)	(0%)	(29%)	(0%)	(0%)	(100%)
Store or office	79%	0%	21%	0%	0%	0%	100%
Manufacturing	38%	30%	12%	10%	10%	0%	100%
Storage	0%	50%	50%	0%	0%	0%	100%
(Warehouse excluding cold storage)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)
All structures**	41%	29%	14%	6%	6%	4%	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 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 9. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 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	43%	37%	21%	0%	0%	0%	100%
(Eating or drinking establishment)	(44%)	(35%)	(21%)	(0%)	(0%)	(0%)	(100%)
Educational	NA	NA	NA	NA	NA	NA	NA
Health care*	50%	50%	0%	0%	0%	0%	100%
Residential	53%	12%	18%	0%	0%	17%	100%
(Apartment)	(41%)	(15%)	(22%)	(0%)	(0%)	(21%)	(100%)
(Hotel or motel)	(100%)	(0%)	(0%)	(0%)	(0%)	(0%)	(100%)
Store or office	79%	0%	21%	0%	0%	0%	100%
Manufacturing	46%	15%	14%	12%	13%	0%	100%
Storage	0%	0%	100%	0%	0%	0%	100%
(Warehouse excluding cold storage)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)	(NA)
All structures**	51%	17%	18%	5%	5%	5%	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 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 9. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 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	0%	51%	0%	49%	0%	0%	100%
Store or office	NA	NA	NA	NA	NA	NA	NA
Manufacturing	0%	100%	0%	0%	0%	0%	100%
Storage	0%	100%	0%	0%	0%	0%	100%
All structures*	0%	86%	0%	14%	0%	0%	100%

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

* Includes some properties not listed separately above..

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 9. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 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	49%	26%	13%	9%	3%	0%	100%
(Eating or drinking establishment)	(49%)	(28%)	(14%)	(6%)	(3%)	(0%)	(100%)
Residential	0%	100%	0%	0%	0%	0%	100%
Store or office	10%	57%	22%	11%	0%	0%	100%
All structures*	37%	38%	13%	8%	4%	0%	100%

* Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 9. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate System and System Was Present in Area of Fire, by Property Use
2002-2004 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	0%	100%	0%	0%	0%	0%	100%
All structures*	57%	43%	0%	0%	0%	0%	100%

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

* Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 10.
Estimated Reduction in Civilian Deaths per Thousand Fires Due to Sprinklers by Property Use
2002-2004 Non-Confined Structure Fires

Property Use	Without AES	With sprinklers	Percent reduction
Public assembly	1.3*	0.0	100%
(Eating or drinking establishment)	(1.0)*	(0.0)	(100%)
Educational	0.0	0.0	NA
Health care**	21.6	2.7	88%
Residential	13.1	3.0	77%
(Apartment)	(11.0)	(4.7)	(57%)
(Hotel or motel)	(5.0)	(0.0)	(100%)
Store or office	1.3	0.0	100%
Manufacturing	1.8	1.3	28%

AES – Automatic extinguishing system

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 AES or for eating or drinking establishments without AES would be much higher.

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

Note: These are national estimates of 2002-2004 nonconfined 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 11.
Estimated Impact of Residential Sprinkler System in One- and Two-Family Dwellings

Impact of Sprinklers Base of Comparison	Residential sprinkler system and no smoke alarms	Residential sprinkler system with smoke alarms
A. Civilian Deaths		
1. Estimated reduction relative to death rate per thousand fires when no sprinklers or smoke alarms are present.	69%	82%
2. Estimated reduction relative to death rate per thousand fires when smoke alarms are present.	Not applicable	63%
B. Civilian Injuries		
1. Estimated reduction relative to injury rate per thousand fires when no sprinklers or smoke alarms are present.	46%	46%
2. Estimated reduction relative to injury rate per thousand fires when smoke alarms are present.	Not applicable	44%

Source: Rosalie T. Ruegg and Sieglinde K. Fuller, *A Benefit-Cost Model of Residential Fire Sprinkler Systems*, NBS Technical Note 1203, Gaithersburg, Maryland: U.S. Department of Commerce, National Bureau of Standards, November 1984, Table 6.

Table 12.
Estimated Reduction in Average Direct Property Damage per Fire Due to Sprinklers by Property Use
2002-2004 Non-Confined Structure Fires

Property Use	Without AES	With sprinkler	Percent reduction
Public assembly	$50,600	$42,700	15%
(Eating or drinking establishment)	($44,400)	($18,300)	(59%)
Educational	$38,600	$12,400	68%
Health care*	$23,000	$8,100	65%
Residential	$25,100	$14,700	42%
(Apartment)	($25,900)	($15,600)	(40%)
(Hotel or motel)	($35,500)	($9,600)	(73%)
Store or office	$49,500	$31,700	36%
Manufacturing	$102,600	$67,800	34%

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

Note: These are national estimates of 2002-2004 nonconfined 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 hundred 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.

Table 13.
Characteristics of Fatal Victims
When Sprinklers Operate vs. All Conditions
2002-2004 Non-Confined Structure Fires

	Percent of fire fatalities	
Victim Characteristic	**When sprinklers operate**	**All fires and all conditions**
Victim unable to act	17%	10%
Clothing on fire	11%	3%
Victim in area of fire origin	88%	55%
Victim age 65 or older	66%	27%

Note: Percentages are based on 2002-2004 non-confined 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.

Source: NFIRS and NFPA survey.

Table 14.
Extent of Flame Damage,
for Sprinklers Present vs. Automatic Extinguishing System Absent
2002-2004 Non-Confined Structure Fires

Property Use	Percentage of fires confined to room of origin excluding structures under construction and sprinklers not in fire area: With no automatic extinguishing system	With sprinklers of any type
Public assembly	66%	87%
(Eating or drinking establishment)	(67%)	(85%)
Educational	84%	95%
Health care*	82%	97%
Residential	60%	91%
(One- or two-family dwelling)	(57%)	(67%)
(Apartment)	(74%)	(92%)
(Hotel or motel)	(80%)	(95%)
(Dormitory or barracks)	(81%)	(97%)
Store or office	63%	88%
(Food or beverage sales)	(69%)	(89%)
(Department store)	(66%)	(88%)
(Office building)	(66%)	(91%)
Manufacturing	65%	85%
Storage	30%	74%
(Warehouse excluding cold storage)	(44%)	(76%)
All structures**	57%	89%

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

** Includes some properties not listed separately above.

Note: Percentages are based on 2002-2004 non-confined 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.

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.

The truth is that 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 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.

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.

*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.

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 in the industry. Particularly for new construction, a complete sprinkler system may add only 1-2% to total cost.

A little historical perspective may be useful to put current public attitudes toward sprinklers in context. 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.

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

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Concluding Points

1. Fire sprinklers are highly effective elements of total system designs for fire protection in buildings. For most property uses, when 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 fire occurs are reduced by at least 57%, and the average property loss per fire is cut by one-third to two-thirds (34-68%), compared to fires where sprinklers are not 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 93% of reported structure fires and operated effectively in 90% of fires. Two-thirds (66%) 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. 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.

The strength of NFIRS is that it 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/.

NFPA conducts an annual stratified random sample survey of fire departments which enables us to capture a summary of fire department experience on a larger scale. The NFPA survey is based on a stratified random sample of roughly 3,000 U.S. fire departments (or just over one of every ten fire departments in the country). 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 by the NFPA 901 Standard; (2) the number of on-duty firefighter injuries, by type of duty and nature of illness; and (3) 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.

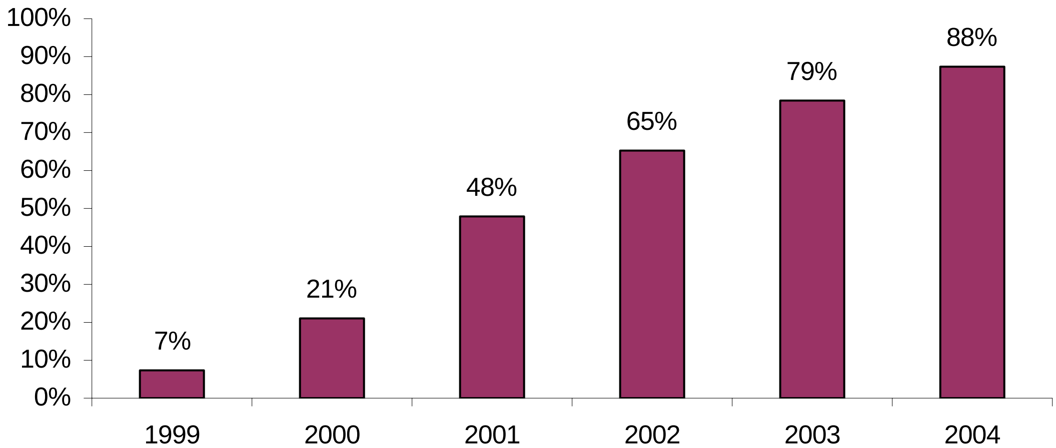
The NFPA survey begins with the NFPA Fire Service Inventory, a computerized file of about 30,000 U.S. fire departments. The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities protect fewer people per department and are less likely to respond to the survey, so a large 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 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.

Analysts at the NFPA, the USFA and the Consumer Product Safety Commission have developed the specific 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

Fires Originally Collected in NFIRS 5.0 by Year



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. It also introduced incident type codes for certain confined structure fires, including confined cooking fires, confined chimney fires, confined fuel burner fires, confined incinerator and

compactor fires, and contained or confined trash fires. Very limited causal information is required for these incidents.

Note that percentages are calculated from unrounded values, and so it is quite possible to have a percentage entry of up to 100%, even if the rounded number entry is zero.

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	

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.