

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

John R. Hall, Jr.

September 2010



**National Fire Protection Association
Fire Analysis and Research Division**

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Abstract

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss. When sprinklers are present in the fire area, they operate in 91% of all reported non-confined structure fires large enough to activate sprinklers, excluding buildings under construction. When they operate, they are effective 96% of the time, resulting in a combined performance of operating effectively in 87% of reported non-confined fires where sprinklers were present in the fire area and fire was large enough to activate sprinklers. In homes (including apartments), wet-pipe sprinklers operated effectively 92% of the time. When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported structure fires is lower by 83% for home fires, where most structure fire deaths occur, and the rate of property damage per reported structure fire is lower by 34-77% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 71% lower average loss per fire. 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, 95% of reported structure fires have flame damage confined to the room of origin compared to 73% when no automatic extinguishing equipment is present. When sprinklers fail to operate, the reason most often given (64% of failures) is shutoff of the system before fire began.

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

Acknowledgements

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Executive Summary

Automatic sprinklers are highly effective and reliable elements of total system designs for fire protection in buildings. Sprinklers operated in 91% of all reported structure fires large enough to activate sprinklers, excluding buildings under construction and buildings without sprinklers in the fire area.* When sprinklers operate, they are effective 96% of the time, resulting in a combined performance of operating effectively in 87% of all reported fires where sprinklers were present in the fire area and fire was large enough to activate them.

The combined performance for the more widely used wet pipe sprinklers is 88%, while for dry pipe sprinklers, the combined performance is only 74%. By comparison, combined performance is 42% for dry chemical systems. (Wet chemical systems may be included with dry chemical systems or with other special hazard systems.) In homes (including apartments), wet-pipe sprinklers operated effectively 92% of the time.

These estimates are projections based on the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS 5.0) and the NFPA's annual fire department experience survey.

These most current statistics exclude buildings under construction and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area and after some recoding between failure and ineffectiveness based on reasons given.

When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported home structure fires is lower by 83% and the rate of property damage per reported structure fire is lower by 34-77% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 71% lower average loss per fire.

Also, when sprinklers of any type 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, 95% of reported structure fires have flame damage confined to the room of origin compared to 73% when no automatic extinguishing equipment is present.

Of reported 2004-2008 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (66%) and nursing homes (68%) and a much lower percentage for clinics and doctor's offices (29%). Sprinklers were also reported as present in half or more of all reported fires in laboratories (58%), manufacturing facilities (51%), and theaters (50%). In every other property use, more than half of all reported fires had no sprinklers.

The few surveys that have been done of sprinkler presence in general, not limited to fires, have found that in most property groups, the percentage of *buildings* with sprinklers is much higher than the percentage of *reported fires* with sprinklers present. Sprinklers apparently are still rare in many of the places where people are most exposed to fire, including educational properties, offices, most stores,

* Because nearly all fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment. See the first section of the report for additional details of statistical methodology, including the distinction between confined and non-confined fires.

and especially homes, where most fire deaths occur. There is considerable potential for expanded use of sprinklers to reduce the loss of life and property to fire.

When sprinklers fail to operate, the reason most often given (64% of failures) was shutoff of the system before fire began, as may occur in the course of routine inspection maintenance. Other leading reasons were manual intervention that defeated the system (17%), lack of maintenance (8%), and inappropriate system for the type of fire (6%). Only 5% of sprinkler failures were attributed to component damage.

When sprinklers operate but are ineffective, the reason usually had to do with an insufficiency of water applied to the fire, either because water did not reach the fire (44% of cases of ineffective performance) or because not enough water was released (27% of cases of ineffective performances). Other leading reasons were system component damage (8%), lack of maintenance (8%), manual intervention that defeated the system (7%), and inappropriate system for the type of fire (6%).

When people are fatally injured in spite of the operation of wet-pipe sprinklers, the victims often had special vulnerabilities that are less often found with fatal victims of home fires in general. For example,

- 90% of fatal victims in home fires with wet-pipe sprinkler operation were located in the area of fire origin, where they could have suffered fatal injuries before sprinkler activation, compared to 52% of fatal home fire victims when no automatic extinguishing equipment was present;
- 25% of fatal victims in home fires with wet-pipe sprinkler operation had their clothing on fire, compared to 8% of fatal home fire victims when no automatic extinguishing equipment was present;
- 65% of fatal victims in home fires with wet-pipe sprinkler operation were age 65 or older, compared to 28% of fatal home fire victims when no automatic extinguishing equipment was present; and
- 34% of fatal victims in home fires with wet-pipe sprinkler operation returned to the fire after escaping, were unable to act or acted irrationally, compared to 20% of fatal home fire victims when no automatic extinguishing equipment was present.

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.

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U.S. Experience with Sprinklers

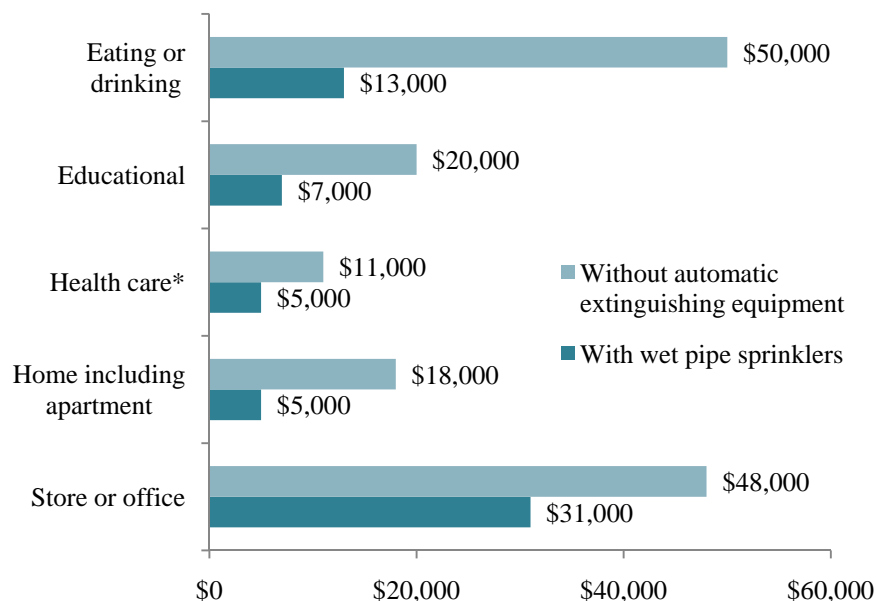
Sprinklers save lives and protect property from fires.

Compared to properties without automatic extinguishing equipment

- The death rate per fire in sprinklered homes is lower by 83%.
- For most property uses, damage per fire is lower by 34-77% in sprinklered properties.

Flame damage was confined to the room of origin in 95% of fires in sprinklered properties vs. 73% in fires with no automatic extinguishing equipment.

Damage per Fire With Wet Pipe Sprinklers versus Without Automatic Extinguishing Equipment, 2004-2008



*Health care refers to hospitals, nursing homes, clinics, doctor's offices, and mental retardation facilities.

Sprinklers are reliable and effective.

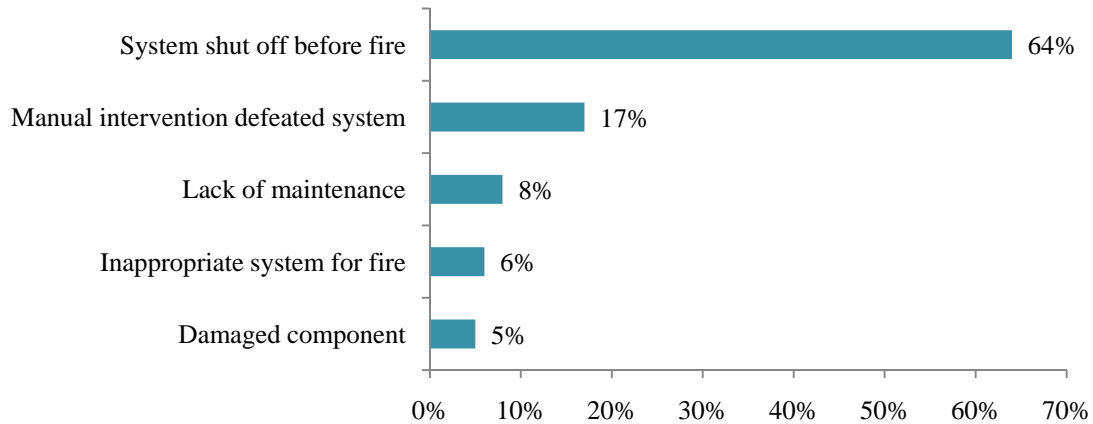
- In reported structure fires large enough to activate them, sprinklers operated in 91% of fires in sprinklered properties.
- Wet pipe sprinklers operated in 92% of these fires vs. 80% for dry pipe sprinklers.
- In reported structure fires large enough to activate them, sprinklers operated and were effective in 87% of fires in sprinklered properties.
- Wet pipe sprinklers operated and were effective in 88% of non-confined fires vs. 74% for dry pipe sprinklers.

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

Statistics are based on 2004-2008 U.S. reported fires excluding buildings under construction and properties with no sprinklers in fire area. Almost no reported confined fires are large enough to activate operating sprinklers, and so confined fires are excluded from analysis of reliability and effectiveness.

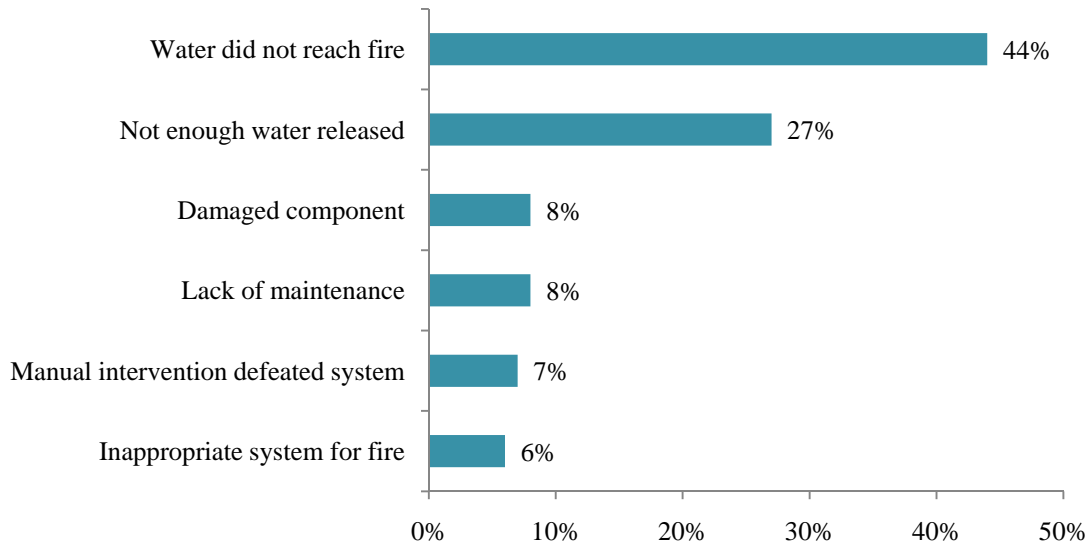
In 2004-2008 fires large enough to activate them, sprinklers operated in 91% of fires in sprinklered properties. The graph below is based on the other 9% in which sprinklers should have operated but did not.

Reasons When Sprinklers Fail to Operate, 2004-2008



In 2004-2008 fires where sprinklers operated, they were effective in 96% of the cases. The graph below is based on the other 4% in which the sprinkler was ineffective.

Reasons When Sprinklers Are Ineffective, 2004-2008



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

- When wet pipe sprinklers operated, 89% of reported fires involved only 1 or 2 sprinklers.
- For dry pipe sprinklers, 76% involved only 1 or 2 sprinklers.

Statistics are based on 2004-2008 U.S. reported fires excluding buildings under construction and properties with no sprinklers in fire area. Almost no reported confined fires are large enough to activate operating sprinklers, and so confined fires are excluded from analysis of reliability and effectiveness.

Section 1: Presence and Type of Automatic Extinguishing Equipment

Data Sources, Definitions and Conventions Used in This Report

The fire statistics in this analysis are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These estimates are projections based on the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS 5.0) and the NFPA's annual fire department experience survey.

NFIRS 5.0, first introduced in 1999, brought major changes to fire incident data, including changes in some definitions and coding rules. Because of these changes, caution should be used when comparing data before 1998 with data from 1999 on.

Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Most statistics are expressed as percentages, rounded to the nearest one percent. Fires are typically rounded to the nearest hundred, civilian deaths per thousand fires are expressed to the nearest tenth, and property damage per fire is rounded to the nearest thousand dollars.

Unless otherwise specified, property damage has not been adjusted for inflation. Additional details on the methodology used may be found in Appendix A. Our analysis methods are continually being refined, and previous estimates updated. See Appendix B for a detailed overview of data elements related to automatic extinguishing equipment.

Fires in buildings with reported structure status of under construction are excluded from analysis. No fire protection systems or features can be expected to perform as designed in a building that is under construction.

NFIRS incident type codes for structure fires include six types of confined fires - confined to chimney or flue, fuel burner or boiler, cooking vessel, incinerator, commercial compactor, or trash. Reporting of most details of optional for confined fires. Therefore, the standard NFPA analysis practice of proportional allocation of unknowns in all fields produces highly variable results for confined fires, which have much larger unknown shares. It is difficult to imagine a fire small enough to be coded as a confined fire but still large enough to activate operational automatic extinguishing equipment. Very few confined fires have equipment performance details coded and are not coded as fire too small to activate equipment. Because of the large share of reported fires that are confined and the large share of confined fires with no reported details, the few confined fires coded as operated, failed, or ineffective have a disproportionate effect on estimates of reliability and effectiveness. In all likelihood, most of these fires are miscoded non-confined fires or miscoded fires too small to activate equipment. Therefore confined fires are not included in estimates of reliability and ineffectiveness but are included in analyses of presence and type of equipment.

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

The coding of reasons for failure or ineffectiveness has been used in this analysis to recode system performance entries. First, fires with reason for failure or ineffectiveness coded as sprinklers not in fire area are excluded from analysis because reliability and effectiveness cannot be judged in these situations. Second, fires with reason for failure or ineffectiveness unclassified, unknown, or blank are proportionally allocated over the known reasons. Finally, the coding of performance as failure or ineffective is changed if that coding is inconsistent with the coded reason, as follows:

<u>If Performance</u>	=	<u>Not Effective</u>	
		<u>And Reason =</u>	<u>Then Change to:</u>
		System shut off	Performance = Failed to operate
<u>If Performance</u>	=	<u>Failed to Operate</u>	
		<u>And Reason =</u>	<u>Then Change to:</u>
		Not enough agent	Performance = Not effective
		Agent didn't reach fire	Performance = Not effective

The established generic name of “automatic extinguishing equipment” is misleading, because most such equipment is designed to control fires and not to fully extinguish them.

As defined in NFPA 13, section 3.4, a wet pipe sprinkler system has sprinklers attached to a piping system containing water so that water discharges immediately from sprinklers opened by heat from a fire, while a dry pipe sprinkler system has sprinklers attached to a piping system containing air or nitrogen under pressure so that sprinkler activation releases the air or nitrogen, allowing water pressure to open a valve and water to flow into the piping system and out the opened sprinklers.

There is no coding entry for wet chemical systems, which currently are the only systems that have been listed to UL300, *Standard for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*. NFPA 96, *Ventilation Control and Fire Protection of Commercial Cooking Operations*, Chapter 10, requires that commercial cooking operations that have grease removal devices, hood exhaust plenums, and exhaust duct systems be protected by fire extinguishing equipment that complies with UL300 or other equivalent standards. This means that wet chemical systems are the primary automatic extinguishing equipment in use in commercial kitchens but cannot be reported as such; they are likely to be reported as dry chemical systems and may account for more reported fires than the fires actually involving dry chemical systems. Wet chemical systems also may be coded as foam systems or other special hazard systems.

Fire extinguishers are not automatic equipment and should not be coded but sometimes are reported under any of several types of automatic extinguishing equipment.

There was no way to code automatic extinguishing equipment as unknown during 1999 to 2003, although there was the option of leaving the field blank. During that period, the U.S. Fire Administration advised that unknowns should be reported as no equipment present.¹ This arrangement had the potential to severely understate the presence of automatic extinguishing equipment. However, the estimates for 2002 and 2003 are not substantially lower than either the pre-1999 estimates or the estimates from 2004 and later. Therefore, this potential problem seems to have had little effect in practice. This reports uses no data from 1999-2003.

¹ U.S. Fire Administration, *NFIRS Coding Questions*, revised January 2, 2002, p.13.

Presence of Automatic Extinguishing Equipment

“Automatic extinguishing equipment” is an umbrella term for equipment designed to activate in response to specified fire conditions and to apply an extinguishing agent to extinguish or control fire. The most common type of automatic extinguishing equipment is the fire sprinkler, defined as equipment using water as the extinguishing agent.

Fire sprinklers are highly reliable and effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss. In 2004-2008, sprinklers were reported present in only 9% of reported structure fires and only 11% reported any type of automatic extinguishing equipment present, including but not limited to sprinklers. See Table 1 for percentage of reported structure fires, excluding buildings under construction, in which automatic extinguishing equipment was present for the year groups of 1994-1998 and 2004-2008, overall and for various property use groups.² Table 1 also shows percentage of fires with any type of sprinkler reported present for 2004 to 2008.

Of reported 2004-2008 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (66%) and nursing homes (68%) and a much lower percentage for clinics and doctor’s offices (29%). Sprinklers were also reported as present in half or more of reported fires in laboratories (58%), manufacturing facilities (51%), and theaters (50%). In every other property use, more than half of all reported fires had no sprinklers.

In 1994-1998, only 7% of reported structure fires had any type of automatic extinguishing equipment present. By 2004-2008, this percentage had risen by about half, to 11%. Before 1999, the type of automatic extinguishing equipment was not reported, and so it is not possible to show the trend in sprinkler presence specifically. It is possible to show the trend in presence of automatic extinguishing equipment generally and to show how sprinkler presence compares to automatic extinguishing equipment presence in the most recent years.

The following properties where large numbers of people routinely are present show at most one-third of reported fires in properties with sprinklers present in 2004-2008:

- Every type of public assembly property except theaters
- Educational properties
- Clinics and doctor’s offices
- Homes including apartments
- Rooming or boarding homes
- Every type of store or office except department stores

For most property use groups, the percentages of fires with sprinklers present and fires with any automatic extinguishing equipment present are similar. The exceptions are eating and drinking

² Some fires after 1999 are coded as confined fires, which are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reporting with most data fields not required and usually left blank. Confined fires combine with very low sprinkler usage to make estimates for one- and two-family homes too volatile and uncertain to list separately, and so estimates are provided only for all homes (including apartments) combined.

establishments (and the larger category of public assembly properties, whose fires are dominated by eating or drinking establishments) and grocery or convenience stores. In these properties, the most common type of automatic extinguishing equipment cited is dry (or possibly wet) chemical. However, only one type of equipment can be coded in any one fire incident, and it should be the type closest to the fire. It is possible that some or most of the fires reported with dry (or possibly wet) chemical equipment protecting a commercial cooking surface were in properties that also had sprinkler systems.

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

In 2004-2008, sprinklers were reported in only 6% of fires in homes (including apartments). Clearly, there is great potential for expanded installation.

The 2007 American Housing Survey included a question about sprinkler presence in homes.³ The survey indicated 3.9% of occupied year-round housing units had sprinklers. A much smaller percentage of single family homes had sprinklers as compared to multi-unit housing. Sprinklers were present in:

- 1.5% of single family detached homes,
- 1.9% of single family homes, whether detached or attached,
- 10.6% of all housing units in multi-unit buildings,
- 2.9% of housing units in buildings with 2-4 units,
- 5.8% of housing units in buildings with 5-9 units,
- 12.1% of housing units in buildings with 10-19 units,
- 16.3% of housing units in buildings with 20-49 units, and
- 27.3% of housing units in buildings with 50 or more units.

Sprinklers are installed in 13.0% of housing units in buildings that were constructed no more than four years ago. This is more than triple the percentage for all housing units. No statistics are provided on sprinkler installation specifically in recently constructed single family homes, but detached single-family homes are a larger share of recently built housing units than of total housing units (70% vs. 63%). This strongly suggests that single family homes are part of the recent jump in sprinkler installation.

Sprinkler presence percentages are higher in the West region than in other regions and lower in rural areas than in non-rural areas.

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

³ *American Housing Survey 2007*, U.S. Department of Commerce and U.S. Department of Housing and Urban Development, September 2008, Table 1C-4, 2-4, and 2-25.

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

Because sprinkler systems are so demonstrably effective, they can make a major contribution to fire protection in any property. NFPA 101®, *Life Safety Code*; NFPA 1, *Fire Code*; and NFPA 5000®, *Building Construction and Safety Code*, have required sprinklers in all new one- and two-family homes, all nursing homes, and many nightclubs since the 2006 editions. The 2009 edition of the *International Residential Code* also added requirements for sprinklers in one- and two-family homes, effective January 2011. This protection can be expected to increase in areas that adopt and follow these codes. NFPA is supporting adoption of these requirements through its Fire Sprinkler Initiative (see <http://www.firesprinklerinitiative.org>).

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

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. Note that the 2007 American Housing Survey showed sprinklers in 3.9% of all occupied year-round housing units but in 4.6% of occupied housing units where the occupant household was below the poverty line. This probably reflects the fact the sprinklers are much less common in single-family households (1.9% vs. 3.9% overall) as are poor households (8.5% of occupied housing units vs. 12.8% overall). If sprinkler usage could be analyzed separately for single-family homes and multi-family housing, it is likely that the general pattern of where sprinklers go first – to those who can most easily afford them rather than those who most need them – would be seen to apply.

Table 1. Presence of Sprinklers and Other Automatic Extinguishing Equipment in Structure Fires, 1994-1998 vs. 2004-2008

Property Use	Number of Structure Fires With Equipment Present and Percentage of Total Structure Fires in Property Use			
	<u>Any Automatic Extinguishing Equipment</u>		<u>Any Sprinkler</u>	
	1994-1998	2004-2008	2004-2008	
All public assembly	4,380 (26%)	7,830 (49%)	3,400 (21%)	
Fixed-use amusement place	150 (18%)	170 (27%)	140 (22%)	
Variable-use amusement place	140 (16%)	270 (22%)	260 (21%)	
Religious property	90 (5%)	270 (14%)	260 (14%)	
Library or museum	110 (28%)	210 (33%)	210 (32%)	
Eating or drinking establishment	3,240 (29%)	4,730 (58%)	1,550 (19%)	
Passenger terminal	60 (35%)	270 (40%)	230 (34%)	
Theater	110 (35%)	140 (51%)	140 (50%)	
Educational property	1,820 (24%)	2,400 (37%)	2,180 (33%)	
Health care property	4,400 (68%)	3,980 (61%)	3,750 (57%)	
Nursing home	2,060 (76%)	2,120 (72%)	1,990 (68%)	
Hospital	1,650 (74%)	1,130 (73%)	1,020 (66%)	
Clinic or doctor's office	70 (29%)	210 (30%)	210 (29%)	
Prison or jail	430 (19%)	290 (52%)	250 (44%)	
All residential	11,110 (3%)	26,720 (7%)	25,650 (6%)	
Home (including apartment)	8,440 (2%)	22,580 (6%)	21,580 (6%)	
Hotel or motel	1,690 (35%)	2,000 (50%)	1,870 (47%)	
Dormitory or barracks	620 (29%)	1,950 (51%)	1,850 (48%)	
Rooming or boarding home	230 (17%)	970 (32%)	950 (31%)	
Board and care home	NA (NA)	880 (42%)	840 (40%)	
Store or office	5,230 (21%)	6,040 (30%)	4,650 (23%)	
Grocery or convenience store	1,190 (27%)	1,980 (44%)	1,000 (22%)	
Laundry or dry cleaning or other professional service	310 (13%)	330 (18%)	300 (16%)	
Service station or motor vehicle sales or service	230 (6%)	230 (10%)	160 (7%)	
Department store	1,100 (52%)	610 (43%)	560 (40%)	
Office	1,470 (25%)	1,210 (32%)	1,170 (31%)	
Laboratory	120 (48%)	110 (63%)	100 (58%)	
Manufacturing facility	6,400 (50%)	3,740 (55%)	3,450 (51%)	
All storage	1,090 (3%)	900 (4%)	870 (4%)	
Warehouse excluding cold storage**	740 (22%)	490 (36%)	480 (36%)	
All structures	37,100 (7%)	55,310 (11%)	46,530 (9%)	

NA – Not available; category not defined in fire incident data prior to 1999.

*Also includes development disability facilities. In 1994-98, this category also includes care of physically inconvenienced and excludes doctor's office and care of aged facilities without nursing staff.

**In 1994-1998, includes general warehouse, textile storage, processed food storage except cold storage and storage of wood, paper, plastics chemicals, and metals.

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 fires reported in Version 5.0 of NFIRS and include fires reported as confined fires. After 1998, buildings under construction are excluded.

Source: NFIRS and NFPA survey.

Automatic Extinguishing Equipment Type

In reported fires, most automatic extinguishing equipment is recorded as sprinklers, and most sprinklers are wet pipe sprinklers.

Table 2 shows the percentage of fires, excluding buildings under construction, by type of automatic extinguishing equipment for each of the major property use groups and some subgroups.⁴ Percentage calculations are based only on fires where automatic extinguishing equipment presence and type were known and reported. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started.

Some type of sprinklers were present in 84% of 2004-2008 fires where automatic extinguishing equipment was present – wet pipe sprinklers in 74%, dry pipe sprinklers in 7%, and other sprinklers in 3%. Wet pipe sprinklers out-numbered dry pipe sprinklers by roughly 10-to-1.

The major property class with the largest share for dry pipe sprinklers was health care properties, where dry pipe sprinklers accounted for 13% of the systems cited, followed by prisons and jails, where 12% of cited systems were dry pipe. Manufacturing and storage both had 11% shares for dry pipe sprinklers.

For public assembly properties, there was a 43% to 57% split between sprinklers and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 36% of the systems present. Eating or drinking establishments (the dominant part of public assembly) had a 33% to 67% split between sprinkler systems and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 43% of systems in eating or drinking establishments, compared to a 33% share for all sprinklers combined. (Remember that only the equipment nearest the fire is recorded.) Note that wet chemical systems have no clearly identified equipment type category but probably have been the most common type of equipment in eating and drinking establishments for roughly a decade. It seems likely that most of the dry chemical systems reported are either wet chemical systems or dry chemical extinguishers, which should not be reported as any type of automatic equipment.

Public assembly properties, especially eating and drinking establishments, have the highest percentages for both dry chemical systems (36% and 43%, respectively) and other special hazard systems (11% and 12%, respectively), both of which probably are dominated by wet chemical systems, for which there is no labeled category.

Eating or drinking establishments also account for most fires reported with foam or halogen systems and the largest share of fires reported with carbon dioxide systems, as may be calculated from Table 2. These installations may all include a high proportion of misclassified wet chemical systems or portable extinguishers, because carbon dioxide, foam, and halogen systems are rarely appropriate for eating or drinking establishments.

⁴ Some fires after 1999 are coded as confined fires, which are fires confined to cooking vessel, chimney or flue, furnace or boiler, incinerator, commercial compactor, or trash receptacle. Confined fires permit limited reporting with most data fields not required and usually left blank. Confined fires combine with very low sprinkler usage to make estimates for one- and two-family dwellings too volatile and uncertain to list separately, and so estimates are provided only for all homes combined.

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

Some insight into what is being coded under “other special hazard systems” comes from a check of uncoded narratives for the three restaurant fires in recent years in Minnesota where such equipment was reported. (The narratives on these fires were part of a data set provided for a special analysis described on p. 49.) One fire involved a wet chemical system, and another involved an undefined hood system, which could have involved wet or dry chemical agents. The third fire involved use of portable extinguisher and should not have been coded as automatic extinguishing equipment present.

Table 2.
Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires
Where Equipment Was Present and of Known Type, by Property Use
2004-2008 Structure Fires Reported to U.S. Fire Departments

Property Use	Fires per year with any automatic extinguishing equipment	Type of Equipment			
		All sprinklers	Wet pipe sprinklers	Dry pipe sprinklers	Other sprinklers*
All public assembly	7,830	43%	37%	3%	4%
Fixed-use amusement place	170	81%	78%	2%	1%
Variable-use amusement place	270	97%	85%	13%	0%
Religious property	270	98%	84%	8%	6%
Library or museum	210	98%	82%	4%	13%
Eating or drinking establishment	4,730	33%	26%	2%	4%
Passenger terminal	270	86%	60%	25%	1%
Theater	140	99%	95%	3%	1%
Educational property	2,400	91%	82%	7%	2%
Health care property**	3,980	95%	80%	13%	1%
Nursing home	2,120	94%	76%	16%	2%
Hospital	1,130	91%	84%	6%	1%
Clinic or doctor's office	210	99%	95%	3%	1%
Prison or jail	290	95%	81%	12%	1%
All residential	26,720	96%	87%	7%	2%
Home (including apartment)	20,320	95%	85%	7%	3%
Hotel or motel	2,000	93%	83%	6%	4%
Dormitory or barracks	1,950	95%	82%	11%	1%
Rooming or boarding house	970	98%	89%	9%	0%
Board and care home	880	95%	88%	7%	0%
Store or office	6,040	77%	68%	7%	2%
Grocery or convenience store	1,980	50%	44%	4%	2%
Laundry or dry cleaning or other professional service	330	70%	62%	6%	2%
Service station or motor vehicle sales or service	230	95%	84%	10%	1%
Department store	610	92%	79%	11%	2%
Office	1,210	97%	84%	9%	4%
Laboratory	110	91%	73%	3%	16%
Manufacturing facility	3,740	92%	78%	11%	3%
All storage	900	92%	78%	11%	3%
Warehouse excluding cold storage	490	99%	84%	12%	2%
All structures***	55,310	84%	74%	7%	3%

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

** Nursing home, hospital, clinic, doctor's office, or development disability facility

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

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

Source: NFIRS and NFPA survey.

Table 2. (Continued)
Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires
Where Equipment Was Present and of Known Type, by Property Use
2004-2008 Structure Fires Reported to U.S. Fire Departments

Property Use	All systems other than sprinklers	Dry chemical system*	Carbon dioxide (CO2) system	Halogen type system*	Foam system	Other special hazard system*
All public assembly	57%	36%	3%	3%	4%	11%
Fixed-use amusement place	19%	11%	0%	0%	0%	8%
Variable-use amusement place	3%	1%	0%	0%	0%	1%
Religious property	2%	1%	0%	0%	0%	1%
Library or museum	2%	0%	0%	0%	0%	1%
Eating or drinking establishment	67%	43%	3%	3%	5%	12%
Passenger terminal	14%	13%	0%	0%	0%	1%
Theater	1%	0%	0%	0%	0%	0%
Educational property	9%	6%	0%	0%	1%	2%
Health care property**	5%	4%	0%	0%	0%	1%
Nursing home	6%	5%	0%	0%	0%	1%
Hospital	9%	7%	0%	0%	0%	2%
Clinic or doctor's office	1%	0%	0%	0%	0%	1%
Prison or jail	5%	4%	0%	0%	0%	0%
All residential	4%	2%	0%	0%	0%	2%
Home (including apartment)	5%	2%	0%	0%	0%	3%
Hotel or motel	7%	3%	0%	0%	0%	3%
Dormitory or barracks	5%	3%	0%	0%	1%	2%
Rooming or boarding home	2%	1%	0%	0%	0%	0%
Board and care home	5%	3%	0%	0%	1%	0%
Store or office	23%	15%	1%	1%	2%	4%
Grocery or convenience store	50%	33%	3%	1%	5%	8%
Laundry or dry cleaning	30%	19%	2%	1%	3%	5%
Service station or motor vehicle sales or service	5%	3%	0%	0%	1%	1%
Department store	8%	6%	0%	1%	0%	0%
Office	3%	1%	1%	0%	0%	0%
Laboratory	9%	2%	4%	1%	0%	1%
Manufacturing facility	8%	1%	4%	0%	0%	2%
All storage	8%	1%	4%	0%	0%	1%
Warehouse excluding cold storage	1%	1%	0%	0%	0%	0%
All structures***	16%	9%	1%	1%	1%	4%

* "Dry chemical system" may include wet chemical systems, because there is no category designated for wet chemical systems. "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.

** Nursing home, hospital, clinic, doctor's office, or development disability facility.

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

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

Source: NFIRS and NFPA survey.

Section 2. Sprinklers

Automatic Extinguishing Equipment Reliability and Effectiveness

In order to estimate reliability and effectiveness, the database must first be edited to remove fires, buildings, and systems where operation cannot be expected, such as small fires, buildings under construction, and partial installations. Table 3 shows the percentage of non-confined structure fires, excluding buildings under construction and incidents with partial systems not in area of fire, where fires were too small to activate operational sprinklers. Table 3 also shows, for fires large enough to activate sprinklers, the percentage of fires where sprinklers operated, the percentage of operating equipment cases where sprinklers were effective, and the percentage of fires where sprinklers operated effectively. This is shown for:

- All sprinklers,
- Wet pipe sprinklers, and
- Dry pipe sprinklers.

Property use classes are shown only if they accounted for at least 100 projected non-confined fires per year with the specific type of automatic extinguishing equipment present.*

For most property use groups and most types of sprinklers, roughly half of reported non-confined fires were too small to activate operational sprinklers.

When sprinklers were present, the percentages of fires too small to activate operational sprinklers, based on reported non-confined structure fires in any property use, were as follows:

- 49% for all sprinklers,
- 49% for wet pipe sprinklers, and
- 53% for dry pipe sprinklers.

Sprinklers in the area of fire failed to operate in 9% of reported non-confined structure fires large enough to activate sprinklers.

Failure rates are equal to 100% minus the percentage of systems that operated in fires large enough to activate equipment, which is the percentage shown in Table 3A. The other estimated failure rates corresponding to percentage operating rates shown in Table 3A are:

- 8% for wet pipe sprinklers, and
- 20% for dry pipe sprinklers.

For sprinklers that operated in non-confined fires, their performance was deemed effective in 96% of the cases. For non-confined fires large enough to activate sprinklers, excluding buildings under construction, sprinklers operated effectively 87% of the time (96% times 91%).

* Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, burner or boiler, commercial compactor, incinerator, or trash.

See Table 3A. Here is a summary of other effective operation percentages.

- 88% for wet pipe sprinklers, and
- 74% for dry pipe sprinklers.

Wet pipe sprinklers are both much more reliable than dry pipe sprinklers and more effective when they operate, resulting in a much higher percentage of effective operation.

A disadvantage of measuring automatic extinguishing equipment effectiveness by judgments made in incident reports is the ambiguity and subjectivity of the criterion of “effective,” which has never been precisely defined, let alone supported by an operational assessment protocol that could be executed consistently by different people.

Roughly two-thirds (64%) of sprinkler failures in non-confined fires occurred because the system was shut off.

Table 4 provides the percentages of reasons for failure, after recoding, by type of sprinkler and property use. Other or unclassified reason for failure is treated as an unknown and allocated.

For all types of sprinklers combined:

- 64% of failures to operate were attributed to the equipment being shut off,
- 17% were because manual intervention defeated the equipment,
- 8% were because of lack of maintenance,
- 6% were because the equipment was inappropriate for the type of fire, and
- 5% were because a component was damaged.

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

Only 5% 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 9% of reported fires to 0.4%. That is close to the sprinkler failure rate reported by Marryatt⁵ for Australia and New Zealand, where high standards of maintenance are reportedly commonplace.

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.

Most cases of sprinkler ineffectiveness in non-confined fires were because water did not reach the fire (44%) or because not enough water was released (27%).

Table 5 provides distributions of reasons for ineffectiveness, by property class and type of automatic extinguishing equipment. In Table 5, two of the reasons for ineffectiveness are

⁵ 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.

(extinguishing) agent did not reach the fire and not enough (extinguishing) agent was released. For sprinklers, the agent is water. In addition to the two reasons cited, other reasons for sprinkler ineffectiveness for all structures were damage to a system component (8%), lack of maintenance (8%), defeating due to manual intervention (7%), and inappropriate equipment for the type of fire (6%),

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 equipment (if, for example, the hazard has changed under the equipment and now requires a higher water flow density than is provided by the now inappropriate equipment) and defeating by manual intervention (if, for example, the sprinklers are turned off prematurely so that insufficient water reaches the fire). Insufficient water also could be 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.

There are a number of different ways in which water may not reach the fire. 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.

Even a well-maintained, complete, appropriate system 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 unique building construction features. 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.

Effectiveness should be measured relative to the design objectives for a particular system. For most rooms in most properties, sprinklers are designed to confine fire to the room of origin.

Some properties have some very large rooms in which the sprinkler installation is designed to confine fire to a design area that is much smaller than the entire room. These rooms could include large assembly areas; sales, showroom, or performance areas; and storage areas.

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

Table A. Non-Confined Fires With Areas of Origin That Could Be Room Larger Than the Sprinkler Design Area for the Space

**Percent of Structure Fires for Buildings Not Under Construction and With Sprinklers in Fire Area
2004-2008 Structure Fires Reported to U.S. Fire Departments**

Property Use	Large Assembly Area (At Least 100 People)	Sales, Showroom or Performance Area	Storage Room, Area, Tank or Bin	Shipping, Receiving or Loading Area	Unclassified Storage Area	All Areas Combined
Eating or drinking establishment	0.9%	0.1%	1.4%	0.2%	1.3%	4.0%
Public assembly excluding eating or drinking establishment	5.7%	0.8%	1.5%	0.1%	0.8%	8.8%
Educational	1.7%	0.2%	1.1%	0.0%	1.1%	4.1%
Health care property*	0.0%	0.0%	0.8%	0.0%	0.7%	1.7%
Home (including apartment)	0.0%	0.0%	0.2%	0.0%	0.1%	0.4%
Hotel or motel	0.9%	0.0%	0.8%	0.0%	0.5%	2.3%
Store or office	0.1%	6.0%	2.2%	3.9%	2.5%	14.8%
Manufacturing facility	0.1%	0.0%	3.0%	2.5%	2.3%	7.9%
Warehouse excluding cold storage	0.1%	0.3%	5.8%	20.3%	10.5%	36.9%

* Hospital, clinic, doctor's office, nursing home and development disability facility.

Note: Percentages are defined as non-confined fires with indicated area of origin divided by total non-confined and confined fires with any area of origin. Percentages sum left to right and may not equal totals in last column because of rounding. Fires reported as confined fires are excluded from the numerator because such fires could not be large enough to exceed the sprinkler design area. Statistics are based on structure fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Statistics exclude buildings under construction and fires with sprinklers not in fire area reported as reason for failure or ineffectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Sprinklers are designed to confine a fire to the room of origin or the design fire area, whichever is smaller.

Therefore, the benefits of sprinklers will tend to come in the following scenarios:

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

Table 6 provides direct measurement of sprinkler effect involving the first bulleted scenario on the previous page. For all structures combined, 73% have flame damage confined to room of origin

when there is no automatic extinguishing equipment present. This rises to 95% of fires with flame damage confined to room of origin when any type of sprinkler is present.

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

Table B. Sprinkler Effective Reliability vs. Sprinkler Success in Confining Fire to Room of Origin, by Property Use Group
2004-2008 Structure Fires Reported to U.S. Fire Departments Where Sprinklers Were Present in Fire Area, Fire Was Large Enough to Activate Sprinklers, and Building Was Not Under Construction

Property Use	Percentage of Fires Where Sprinklers Operated Effectively (from Table 3A)	Percentage of Fires with Flame Damage Confined to Room of Origin
Public assembly	89%	95%
Eating or drinking establishment	90%	94%
Educational	85%	98%
Health care property*	87%	99%
Residential	94%	97%
Home (including apartment)	94%	97%
Hotel or motel	91%	97%
Dormitory or barracks	91%	99%
Store or office	89%	93%
Grocery or convenience store	88%	96%
Laundry or dry cleaning or other professional supply or service	91%	92%
Service station or motor vehicle sales or service	93%	88%
Department store	88%	93%
Office building	89%	94%
Manufacturing facility	90%	86%
Storage	80%	80%
Warehouse excluding cold storage	85%	81%
All structures**	91%	95%

* Nursing home, hospital, clinic, doctor's office, or development disability facility.

** Includes some properties not separately listed above.

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

Table 7A shows the number of sprinklers operating by type of sprinkler system. Five or fewer heads operated in 97% of the wet pipe system activations and 90% of the dry pipe system activations.

Dry pipe systems are much more likely to open more than one sprinkler than wet pipe systems (38% vs. 22% 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.

Wet pipe sprinkler systems tend to have more sprinklers operating in fires in manufacturing facilities or warehouses than in other properties.

Table 7B shows the number of wet pipe sprinklers operating by property use group. In manufacturing facilities, 50% of the fires in properties where wet pipe sprinklers operated had two or fewer sprinklers operating, which means 50% of the fires in properties had at least three sprinklers operating. Similarly, 84% had five or fewer sprinklers operating, which means 16% had at least six sprinklers operating. By contrast, in public assembly properties and stores and offices where wet pipe sprinklers operated, 86-90% of fires in properties had two or fewer sprinklers operating, which means only 10-14% of fires in properties had at least three sprinklers operating. Similarly, 95-96% had five or fewer sprinklers operating, which means only 4-5% had at least six sprinklers operating.

In homes (including apartments), 97% of fires in properties had two or fewer sprinklers operating.

Effectiveness declines when more sprinklers operate.

When more than 1-2 sprinklers have to operate, this may be taken as an indication of less than ideal performance. Table 8 shows that the percentage of fires where performance is deemed effective decreases as the number of wet pipe sprinklers operating increases, falling from 97% of fires when one sprinkler opens to 85% when more than 10 sprinklers open. At the same time, the number of sprinklers operating should not be used as an independent indicator of effectiveness because sprinklers are deemed effective in most fires where sprinklers operate, no matter how many sprinklers operate. Furthermore, most sprinkler installations are designed for control, not extinguishment, and anticipate that multiple sprinklers will be needed for control in some fire scenarios.

Details on reasons for failure or ineffectiveness and how to address them.

The following potential reasons for failure or ineffectiveness are defined in the statistical database:

- System shut off (a reason for failure but not for ineffectiveness),
- Wrong type of (inappropriate) system for the type of fire,
- Manual intervention [defeated the system]
- Not enough agent discharged (a reason for ineffectiveness but not for failure),
- Lack of maintenance [including corrosion or heads painted],
- Agent discharged but did not reach fire (a reason for ineffectiveness but not for failure),
- System component damaged,
- Fire not in area protected [by the system] (excluded from analysis of failure and ineffectiveness)

Table C shows how each reason contributes to failure and ineffectiveness.

Table C. Reasons for Failure or Ineffectiveness as Number of Fires per Year and Percentages of All Cases of Failure or Ineffectiveness, for All Structures and Wet Pipe Sprinklers

Reason	Failure		Ineffectiveness		Combined	
	Count	Percentage	Count	Percentage	Count	Percentage
System shut off	378	(43%)	0	(0%)	378	(43%)
Manual interruption defeated system	117	(13%)	23	(3%)	140	(16%)
Water discharged but did not reach fire	0	(0%)	107	(12%)	107	(12%)
Not enough water discharged	0	(0%)	73	(8%)	73	(8%)
Lack of maintenance	54	(6%)	15	(2%)	69	(8%)
Wrong type of (inappropriate) system for type of fire	40	(5%)	16	(2%)	56	(6%)
System component damaged	28	(3%)	21	(2%)	48	(6%)
Total	617	(71%)	254	(29%)	871	(100%)

Source: Calculated from percentages and numbers in Total lines of Tables 4B and 5B.

NFPA has compiled published incidents (see selected examples in Appendix C) that illustrate the different types of reasons for sprinkler failure or ineffectiveness, and NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, describes procedures to address most of these reasons that involve maintenance of an existing sprinkler system. An exception is systems designed to NFPA 13D (the home sprinkler standard), for which maintenance, inspection, and testing requirements are much fewer, reflecting the greater inherent reliability of the simpler design, and are included in the NFPA 13D standard. When the reasons involve a need to modify the sprinkler system, procedures to trigger those changes are found in NFPA 1, *Fire Code*, and NFPA 1620, *Standard for Pre-Incident Planning*.

System shut off

The NFPA incident compilation includes cases of systems shut off because of building status (e.g., vacant, being remodeled, still under construction) and cases of systems shut off because of system problems (e.g., leak in system, dirt in water supply for both building and system, damage from earlier forklift collision). NFPA 25 addresses all these circumstances under rules for dealing with impairments (Chapter 14). When the system is shut off or otherwise impaired, NFPA 25 requires use of a tag to provide a visible reminder that the system is out of service, close oversight of the schedule and steps required to correct the impairment, and appropriate practices to assure safety in the building while the impairment exists. NFPA 25 also addresses valve supervision using a tamper switch connected to a central alarm monitoring system.

Manual intervention

NFPA standards for specific occupancies or for fire service operations provide guidance for fire protection and firefighting in a sprinklered building. These rules address the best use of fire suppression equipment in combination with fire sprinklers and the need to confirm that fire conditions no longer pose a threat before shutting off sprinklers.

Agent did not reach fire

A number of conditions can result in this problem, but the most obvious one is a shielded fire. An incident identified in the NFPA compilation involved a convention center where a covering, operating like a temporary ceiling, blocked the sprinklers from reaching the fire. Shielding can also occur if fire grows under furniture (as in a residential property or an office) or under equipment (as in a manufacturing facility) or in the lower portions of an array of objects (as in a store or warehouse).

An engineered solution to the problem is to place sprinklers under the shielding, as with in-rack sprinklers. The other principal alternative is to avoid arrangements where shielding and blocking are likely to occur. The periodic inspections needed to identify shielding and blocking situations and to correct such problems if discovered can be conducted as part of fire code inspections (e.g., in support of NFPA 1) or pre-incident planning (e.g., in accord with NFPA 1620.)

Not enough agent discharged

The NFPA incident compilation identifies several cases of inadequate water flow; note that some are incidents where firefighters also found inadequate water flow for hydrants or hoses.

Inadequate water flow can also occur if the system design is no longer adequate for the hazard being protected. These incidents may also be reported as cases of inappropriate system.

NFPA 25 uses inspections and testing to address all sources of problems affecting water flow or delivered density, including standpipes, hose systems, fire service mains, fire pumps, and water storage tanks. If the problem is a system no longer appropriate for the hazard below it, NFPA 1 and NFPA 1620 are relevant, as discussed above under “inappropriate system”.

NFPA 25 also provides a procedure for periodic investigation of pipes for obstructions (Chapter 13). Such obstructions can reduce water flow and result in a problem of not enough agent discharged.

Lack of maintenance

The NFPA compilation identifies an incident where a sprinkler was coated with cotton dust in a textile manufacturing plant and an incident where sediment built up in the system. NFPA 13 and NFPA 25 include requirements for special protection in settings or during activities with a high vulnerability to accumulation of dust, paint, or other substances, and NFPA 25 uses inspections to detect such accumulations when they occur.

Inappropriate system

Statistically, this is the second leading reason for failure or ineffectiveness, after system shut off.

“Inappropriate” system can refer to the wrong type of agent (e.g., water vs. chemical agent or carbon dioxide), the wrong type of system for the same agent (e.g., wet pipe vs. dry pipe), or the wrong design for the same system and agent (e.g., a design adequate only for Class I commodities vs. a design adequate for any class of commodities). The NFPA compilation identifies cases where the system was inadequate for the hazard.

The NFPA 13, NFPA 13D and NFPA 13R standards for installation of automatic extinguishing equipment provide detailed requirements for selecting the right agent, the right system, and the right design, but this is all relative to conditions at the initial installation. The need for a change in system design can be identified during routine, periodic inspections in support of the local fire code or pre-incident planning. Section 13.3.3 of NFPA 1 requires the property owner or occupant to maintain the design level of performance and protection of the sprinkler system and to evaluate the adequacy of the installed system if there are any changes in occupancy, use, process, or materials. NFPA 1620 requires periodic review, testing, updating and refinement of the pre-incident plan. NFPA 1620 also states that a mismatch of sprinkler system with type or arrangement of protected commodities is a sprinkler system design deficiency that should be noted on the pre-incident plan.

System component damaged

In the NFPA compilation of incidents of failure or ineffectiveness, the incidents involving component damage consist entirely of fires where automatic extinguishing equipment was damaged by explosions or by ceiling, roof, or building collapse, nearly always as a consequence of fire. System component damage is the least frequently cited reason for sprinkler failure or ineffectiveness, which is consistent with the idea that the components are very reliable, absent a severe external cause like an explosion. Explosions are more severe than the design fires considered by NFPA 13, NFPA 13D, and NFPA 13R. NFPA 25 uses inspections and tests to detect less severe component damage.

Fire not in area protected

Under fire incident coding rules, automatic extinguishing equipment is deemed to be present in a building only if it is present in the area of fire. Therefore, fires are removed from the operability and effectiveness analysis in the report if equipment was deemed to have failed or been ineffective because of fire outside area protected.

However, some areas may be unprotected even in a system that is described as having complete coverage. NFPA 13 has provisions for sprinkler protection of concealed spaces and exterior locations, but coverage of these areas is required only in certain defined situations. The NFPA compilation includes several incidents involving partial coverage by any definition but also several incidents where coverage was described as complete but was not provided for areas of fire origin or of early fire growth in concealed or void spaces, on balconies or other outside locations, or above sprinklers in manufacturing or storage facilities.

This long-standing dilemma over how to describe a lack of coverage in concealed spaces and exterior locations has become more complicated with the emergence of specialized installation standards, such as NFPA 13D and NFPA 13R, that also exempt certain rooms from coverage.

Table D shows the leading areas of fire origin for one- and two-family home fires coded as sprinklers present but failed or ineffective because of no sprinkler in the fire area. In other words, sprinklers were present somewhere in the home but not in the area of origin. Percentage shares for all these areas of origin for one- and two-family home fires, regardless of sprinkler status, are also included for comparison.

Table D. Leading Areas of Origin for Non-Confined Fires in One- or Two-Family Homes Excluding Buildings Under Construction 2004-2008 Structure Fires Reported to U.S. Fire Departments

Area of Origin	Percent of Fires Where Wet-Pipe Sprinklers Were Present But Not Present in Fire Area*	Percent of All Fires
Attic or concealed space above top story	11%	5%
Wall assembly or concealed space	11%	4%
Kitchen	8%	19%
Garage*	7%	4%
Exterior balcony or unenclosed porch	7%	2%
Crawl space or substructure space	6%	3%
Living room, family room, or den	5%	6%
Courtyard, terrace or patio	5%	1%
Unclassified outside area	4%	2%
Exterior roof surface	3%	1%
Other area of origin	32%	52%
Total	100%	100%

* Excludes dwelling garages coded as separate buildings.

Note: These are only fires where the absence of sprinklers in the fire area was identified because that absence was cited as a reason for failure or ineffectiveness. Because nearly all fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

One in eight non-confined fires (13%) with no sprinklers in the fire area were fires that began in the kitchen or the living room, family room, or den, areas that should be covered by sprinklers in any standard installation. However, the eight listed concealed spaces and other structural areas, external areas, garages, and attics account for more than half (55%) of the non-confined fires where sprinklers are present but not in the fire area. These same areas accounted for only one-fourth (23%) of non-confined fires in one- or two-family homes in general.

Table 3.
Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use
2004-2008 Structure Fires (Excluding Fires Reported as Confined Fires)

A. All Sprinklers

Property Use	Number of fires per year where extinguishing equipment was present	Percent of fires too small to activate equipment	When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area			
			Number of fires per year	Percent where equipment operated (A)	Percent effective of those that operated (B)	Percent where equipment operated effectively (A x B)
All public assembly	1,350	50%	680	89%	92%	82%
Eating or drinking establishment	770	46%	410	90%	90%	81%
Educational property	810	71%	240	85%	96%	82%
Health care property*	1,320	69%	400	87%	97%	84%
Residential	6,760	44%	3,790	94%	97%	91%
Home (including apartment)	4,860	38%	3,000	94%	97%	92%
Hotel or motel	810	60%	330	91%	98%	89%
Dormitory or barracks	260	62%	100	91%	99%	90%
Rooming or boarding house	210	47%	110	93%	96%	90%
Board and care home	170	60%	70	91%	97%	89%
Store or office	2,590	54%	1,200	89%	97%	86%
Grocery or convenience store	510	60%	210	88%	95%	83%
Laundry or dry cleaning	240	47%	130	91%	95%	87%
Service station or motor vehicle sales or service	110	32%	80	93%	94%	87%
Department store	370	61%	150	88%	98%	86%
Office	520	62%	200	89%	97%	86%
Manufacturing facility	2,470	42%	1,420	90%	93%	84%
All storage	600	35%	390	80%	96%	76%
Warehouse excluding cold storage	340	34%	230	85%	97%	82%
All structures**	16,600	49%	8,430	91%	96%	87%

* Nursing home, hospital, clinic, doctor's office, or development disability facility.

** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail 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. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use
2004-2008 Structure Fires (Excluding Fires Reported as Confined fires)

B. Wet Pipe Sprinklers Only

Property Use	Number of fires per year where extinguishing equipment was present	Percent of fires too small to activate equipment	When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area			
			Number of fires per year	Percent where equipment operated (A)	Percent effective of those that operated (B)	Percent where equipment operated effectively (A x B)
All public assembly	1,150	51%	570	91%	94%	86%
Eating or drinking establishment	640	48%	340	92%	93%	86%
Educational property	740	71%	210	86%	96%	83%
Health care property*	1,140	68%	360	88%	97%	86%
Residential	6,210	43%	3,550	94%	97%	92%
Home (including apartment)	4,460	37%	2,810	95%	97%	92%
Hotel or motel	740	60%	300	90%	98%	89%
Dormitory or barracks	230	61%	90	93%	99%	92%
Rooming or boarding home	200	46%	110	94%	97%	91%
Board and care home	160	59%	60	93%	97%	90%
Store or office	2,330	54%	1,080	90%	97%	87%
Grocery or convenience store	460	59%	190	90%	96%	86%
Laundry or dry cleaning	220	46%	120	92%	95%	87%
Department store	340	62%	130	88%	97%	86%
Office	470	61%	180	89%	97%	87%
Manufacturing facility	2,080	43%	1,190	91%	94%	86%
All storage	440	35%	290	85%	97%	82%
Warehouse excluding cold storage	270	34%	180	87%	97%	84%
All structures**	14,640	49%	7,480	92%	96%	88%

* Nursing home, hospital, clinic, doctor's office, or development disability facility.

** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail 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. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 3. (Continued)
Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use
2004-2008 Structure Fires (Excluding Fires Reported as Confined Fires)

C. Dry Pipe Sprinklers Only

Property Use	Number of fires per year where extinguishing equipment was present	Percent of fires too small to activate equipment	When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area			
			Number of fires per year	Percent where equipment operated (A)	Percent effective of those that operated (B)	Percent where equipment operated effectively (A x B)
All public assembly	110	54%	50	81%	92%	75%
Residential	410	59%	170	91%	95%	86%
Home (including apartment)	260	57%	110	92%	94%	87%
Store or office	210	55%	100	78%	95%	74%
Manufacturing facility	310	42%	180	83%	88%	73%
All storage	130	33%	90	63%	94%	60%
All structures*	1,490	53%	700	80%	92%	74%

* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 4.
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment
and Equipment Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined 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 fires per year
All public assembly	61%	14%	12%	10%	2%	74
Eating or drinking establishment	64%	15%	21%	0%	0%	41
Residential	54%	20%	9%	9%	7%	234
Home (including apartment)	57%	15%	9%	11%	9%	167
Store or office	62%	20%	8%	6%	3%	131
Manufacturing facility	64%	17%	7%	4%	7%	141
Storage	84%	5%	5%	1%	4%	79
All structures*	64%	17%	8%	6%	5%	801

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 4. (Continued)
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment
and Equipment Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined 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 fires per year
Public assembly	73%	13%	7%	8%	0%	48
Eating or drinking establishment	79%	13%	7%	0%	0%	26
Residential	53%	22%	9%	10%	6%	207
Home (including apartment)	55%	16%	9%	12%	7%	148
Store or office	61%	21%	10%	5%	3%	105
Manufacturing facility	62%	17%	10%	4%	7%	102
All structures*	61%	19%	9%	6%	4%	617

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 fires per year
All structures	73%	4%	10%	4%	9%	136

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 5.
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment
and Equipment Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined Fires)

A. All Sprinklers

Property Use	Water did not reach fire	Not enough agent water released	System component damaged	Lack of maintenance	Manual intervention defeated system	Inappropriate system for type of fire	Fires per year
All public assembly	70%	21%	0%	0%	4%	5%	48
Eating or drinking establishment	75%	19%	0%	0%	0%	6%	39
Residential	27%	26%	18%	17%	3%	10%	103
Home (including apartment)	26%	21%	23%	13%	4%	13%	87
Store or office	34%	38%	0%	5%	16%	7%	37
Manufacturing facility	40%	33%	4%	9%	9%	5%	86
Storage	40%	20%	20%	0%	20%	0%	13
All structures*	44%	27%	8%	8%	7%	6%	327

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 5. (Continued)
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment
and Equipment Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined Fires)

B. Wet Pipe Sprinklers Only

Property Use	Water did not reach fire	Not enough water released	System component damaged	Lack of maintenance	Manual intervention defeated system	Inappropriate system for type of fire	Total fires per year
Public assembly	51%	34%	0%	0%	6%	8%	29
Eating or drinking establishment	53%	36%	0%	0%	0%	11%	21
Residential	32%	23%	21%	12%	4%	8%	92
Home (including apartment)	30%	19%	27%	10%	5%	10%	77
Store or office	37%	34%	0%	0%	20%	9%	31
Manufacturing facility	36%	39%	0%	10%	9%	6%	63
All structures*	42%	29%	8%	6%	9%	6%	254

C. Dry Pipe Sprinklers Only

Property Use	Water did not reach fire	Not enough water released	System component damaged	Lack of maintenance	Manual intervention defeated system	Inappropriate system for type of fire	Total fires per year
All structures	39%	28%	8%	17%	4%	4%	42

* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 6.
Extent of Flame Damage,
for Sprinklers Present vs. Automatic Extinguishing Equipment Absent
2004-2008 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 equipment	With sprinklers of any type	Difference (in percentage points)
Public assembly	76%	95%	19
Fixed-use amusement or recreation place	75%	96%	21
Variable-use amusement or recreation place	84%	97%	13
Religious property	72%	96%	24
Library or museum	83%	97%	14
Eating or drinking establishment	75%	94%	19
Educational	90%	98%	8
Health care property*	93%	99%	6
Residential	76%	97%	21
Home (including apartment)	76%	97%	21
Hotel or motel	86%	97%	11
Dormitory or barracks	96%	99%	3
Store or office	71%	93%	22
Grocery or convenience store	76%	96%	20
Laundry or dry cleaning or other professional supply or service	80%	92%	12
Service station or motor vehicle sales or service	61%	88%	27
Department store	73%	93%	20
Office building	76%	94%	18
Manufacturing facility	69%	86%	17
Storage	32%	80%	48
Warehouse excluding cold storage	53%	81%	28
All structures**	73%	95%	22

* Nursing home, hospital, clinic, doctor's office, or development disability facility.

** Includes some properties not listed separately above.

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

Source: NFIRS and NFPA survey.

**Table 7.
Number of Sprinklers Operating
2004-2008 Structure Fires**

A. By Type of Sprinkler

Number of Sprinklers Operating	Percentage of structure fires where that many sprinklers operated			
	Wet pipe	Dry pipe	Other type sprinkler	All sprinklers
1	78%	62%	43%	75%
2 or fewer	89%	76%	57%	88%
3 or fewer	93%	81%	66%	91%
4 or fewer	95%	88%	84%	95%
5 or fewer	97%	90%	91%	96%
6 or fewer	98%	91%	96%	97%
7 or fewer	98%	91%	96%	97%
8 or fewer	98%	92%	96%	98%
9 or fewer	98%	92%	97%	98%
10 or fewer	99%	93%	99%	98%
20 or fewer	100%	96%	100%	99%

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

Source: NFIRS and NFPA survey.

**Table 7. (Continued)
Number of Sprinklers Operating
2004-2008 Structure Fires**

B. Wet Pipe Sprinklers, by Property Use Group

Number of Sprinklers Operating	Percentage of structure fires where that many wet pipe sprinklers operated					
	Public assembly	Home	Hotel or motel	Store or office	Manufacturing facility	Warehouse excluding cold storage
1	72%	90%	86%	69%	35%	52%
2 or fewer	90%	97%	93%	86%	50%	71%
3 or fewer	93%	99%	95%	90%	68%	76%
4 or fewer	95%	99%	97%	93%	80%	79%
5 or fewer	96%	100%	100%	95%	84%	91%
6 or fewer	97%	100%	100%	97%	88%	93%
7 or fewer	97%	100%	100%	97%	89%	94%
8 or fewer	98%	100%	100%	98%	91%	94%
9 or fewer	98%	100%	100%	98%	92%	95%
10 or fewer	98%	100%	100%	98%	93%	96%
20 or fewer	100%	100%	100%	99%	99%	97%

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

Source: NFIRS and NFPA survey.

**Table 8.
Sprinkler Effectiveness Related to
Number of Sprinklers Operating
2004-2008 Structure Fires**

Number of Sprinklers Operating	<u>Percent of structure fires where sprinklers are effective</u>			
	All sprinklers All structures	<u>Wet pipe sprinklers</u>		
		All structures	Manufacturing facility	Warehouse excluding cold storage
1	97%	97%	95%	97%
2	95%	96%	96%	99%
3 to 5	92%	94%	95%	97%
6 to 10	85%	85%	84%	95%
More than 10	83%	85%	91%	87%
Total	96%	96%	94%	97%

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Impact of Sprinklers

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

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

Sprinkler Reduction in Loss of Life in Fire

For 2004-2008 home fires, the death rate per 100 fires was 83% lower with wet pipe sprinklers than with no automatic extinguishing equipment.

Table 9 shows fire death rate reductions for various property use groups. Only the statistics for all residential properties and for homes (including apartments) are based on enough fatal fires, both with and without sprinklers, for reasonable confidence in the results.

For properties other than homes, deaths tend to be extremely rare, with or without sprinklers. The associated rates of deaths per thousand fires will therefore be very sensitive to individual fires with large death tolls, fatal fires with unusual circumstances, the variability associated with analysis of confined fires, and fires with fatalities or other characteristics misreported.

Warehouses illustrate the statistical problem of analyzing impact when there are very few fatal fires. Total fire deaths in sprinklered warehouses in 2004-2008 are estimated from projections based on only two fatal incidents. The more severe was an intentional fire using flammable liquids as accelerants. That fire killed two people, and there were few details. In particular, we cannot tell from the coded records whether either or both of the victims might have been the arsonists, killed early in the fire before sprinklers could activate, or whether the area of origin – an unclassified storage area – might have been outside the range of the sprinklers, which if true should have excluded the incident as no sprinklers in initial fire area. The other fatal fire was a three-story facility, with a fourth level below grade, storing agricultural products, which suggests the possibility of a dust explosion. A total of 75 sprinklers opened but sprinklers were said to have failed to operate due to manual intervention; this indicates some confusion on incident details or how to code them.

The factors that make fatal injury possible even when sprinklers are present and operate would include the following, including those shown in Table 10:

1. Victims whose actions or lack of action add to their risk by prolonging their exposure to fire conditions, such as victims who (a) act irrationally; (b) return back into the building after safely escaping; (c) are unable to act to save themselves, such as people who are bedridden or under restraint; or (d) are engaged in firefighting or rescue;

2. Victims of fires that are beyond the design limits of the system, such as fires that were (a) so close that the victim is deemed “intimate with ignition” (a victim condition no longer shown in the data but most closely approximated by “victim in area of fire origin”; they constituted 90% of fatal victims when sprinklers operated vs. 52% of fatal victims when no automatic extinguishing equipment was present, in Table 10); (b) very fast, such as explosions or flash fires; or (c) outside the sprinkler-protected area, such as fires originating on exterior areas of the building; and
3. Victims who are or may be unusually vulnerable to fire effects, such as (a) older adults, age 65 or older (who constituted 65% of fatal victims when sprinklers operated vs. 28% of total victims, in Table 10), or (b) people who are in poor health before fire begins.

In group (2), although we can no longer identify victims who were intimate with ignition, we can identify victims who were both in the fire area and involved with ignition. Those victims constituted 84% of fatal victims when wet pipe sprinklers operated vs. 39% of fatal victims when no automatic extinguishing equipment was present. These victims are not primarily arsonists fatally injured while setting fires. As Table 10 also shows, intentional fires account for only a small share of fatal fire victims, and the share is much smaller when wet pipe sprinklers operate.

Absent these conditions listed above, NFPA has no record of a fire killing 3 or more people in a completely sprinklered 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.

The 2010 edition of NFPA 13 adds a clarifying sentence to the scope section of the standards: “This standard is written with the assumption that the sprinkler system shall be designed to protect against a single fire originating within the building.”

There are dangers in statements that rely on all-or-nothing statistics. Until 1981, NFPA had no record of a fatal fire involving *any* number of deaths in fully sprinklered hotels or motels. In fact, though, sprinklers cannot be expected to exclude all deaths under these circumstances.

Sprinkler Reduction in Loss of Property in Fire

For most property uses, the property damage rate per reported structure fire is 34-77% lower than in properties with no automatic extinguishing equipment when wet pipe sprinklers are present in structures that are not under construction, after excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area.

Table 11 shows no reductions for hotels and motels and for warehouses.

Estimates exclude a reported \$100 million loss in one 2006 California single family home fire, which appears to be a badly miscoded fire loss, based on other available details on the property.

As with death rates, loss rates can be very sensitive to individual fires with large losses, large loss fires with unusual circumstances, the variability associated with analysis of confined fires, and fire with losses or other characteristics misreported.

Warehouses and hotels and motels appear to illustrate these factors. Two incidents accounted for well over half (63%) of the 2004-2008 total estimated direct property damage in warehouse fires with wet pipe sprinklers present (excluding fires in buildings under construction and fires with sprinklers not in fire area as reported reason for ineffectiveness or failure). The two fires had reported losses of \$50 million and \$45 million, but neither fire was captured by NFPA's Fire Incident Data Organization (FIDO) data base, which is designed to capture any fire reported in news accounts or other sources as involving at least \$5 million in loss. The larger fire was reported to have 600 sprinklers operating, but sprinkler operation was not reported. It would not be surprising if these two fires had loss amounts inadvertently inflated, and the larger fire may have had number of sprinklers operating inflated as well.

Two fires also accounted for most (81%) of the 2004-2008 direct property damage in hotel and motel fires with wet pipe sprinklers present (and excluding buildings under construction and fires coded with sprinklers not in fire area as reason for failure or ineffectiveness). Both fires were captured by NFPA's FIDO. The larger fire was a \$100 million Nevada fire where fire began when hot work ignited exterior trim. The complete coverage sprinkler system was reported as effective, and the sprinklers that operated were credited with containing the fire on the 32nd (top) story. The smaller fire was a \$12 million Florida fire in a facility with unknown sprinkler system coverage but no sprinklers in the area of origin. Fire eventually spread to the sprinklered area, where sprinklers operated effectively. Possibly because that spread meant that it was no longer true that sprinklers were not in the fire area, there was no reason coded for sprinkler ineffectiveness. If the absence of sprinklers in the area of origin had been reported as sprinklers not in fire area, then this incident would have been removed from the calculations.

In both cases, the influence of a small number of cases or errors and the limitations of gross statistics in these circumstances produce a misleading picture of the input of sprinklers. It should also be noted that sprinklers are more common in warehouses that are larger and have higher values per square foot. This can mean that the average loss per fire in a sprinklered warehouse will not be a good estimate of the predicted average loss per fire if sprinklers were added to the unsprinklered warehouses, as our calculations implicitly assume. The use of average loss in unsprinklered warehouses as a proxy for average loss in sprinklered warehouses in the absence of sprinklers, as is done in this analysis, will produce a misleadingly low baseline for comparison and so a misleadingly low estimated reduction.

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

- Sprinkler design may not be appropriate to the hazard being protected. In the simplest form, the contents may be capable of supporting a larger, more intense fire than the sprinkler system can handle. The problem may be insufficient sprinkler density or insufficient water flow, which in turn may reflect the system's design, its age and maintenance, or its supporting water supply. Unlike explosions and flash fires, fire loads can be addressed by appropriate design, installation, maintenance, and operation. And although the effectiveness statement could be phrased to require a fully code-compliant installation, fire incident reports rarely have enough detail to confirm code compliance, and large property-loss fires are less likely than large life-loss fires to receive the detailed fire investigations that could confirm such details.
- The nature or configuration of contents may be sufficient to create a large loss even when sprinkler performance is deemed successful. Some bulk goods can shield a deep-seated fire from sprinklers. Rack storage may shield fires from ceiling sprinklers, although in-rack sprinklers should be sufficient to address such problems. High-piled stock may block sprinklers or even permit fire spread on the tops of contents above the sprinklers. And some areas – such as clean rooms – have contents so sensitive and valuable that even a small fire can produce a large financial loss.
- A fire with a sufficient number of different points of origin can overwhelm any sprinkler system. This could also be an exception to the life-saving effectiveness statement, although it has not been found to be the deciding factor in any multiple-death fire to date. It has been the deciding factor for at least one large-loss fire. Multiple points of origin can occur deliberately in an arson fire, but they can occur unintentionally or naturally, as when an outside fire spreads to numerous entry points in and on a building.

Table 9.
Estimated Reduction in Civilian Deaths per Thousand Fires
Associated With Wet Pipe Sprinklers, by Property Use
2004-2008 Structure Fires

Property Use	Without automatic extinguishing equipment	With wet pipe sprinklers	Percent reduction
All public assembly	0.5*	0.0	100%
Educational	0.0	0.0	NA
Residential	7.5	1.3	83%
Home (including apartment)	7.6	1.3	83%
Hotel or motel	5.1	0.8	83%
Dormitory or barracks	3.2	0.4	88%
Rooming or boarding house	6.5	2.2	66%
Board and care home	7.9	2.1	73%
Store or office	1.1	0.2	80%
Manufacturing facility	1.1	0.2	78%
Warehouse excluding cold storage	1.2	2.7	No reduction
All structures	6.3	0.9	86%

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

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

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

Source: NFIRS and NFPA survey.

Table 10.
Characteristics of Fatal Victims
When Wet Pipe Sprinklers Operate vs. No Automatic Extinguishing Equipment
2004-2008 Structure Fires

Victim Characteristic	Percent of fire fatalities	
	When wet pipe sprinklers operate, excluding sprinklers not in fire area	No automatic extinguishing equipment
Victim in area of origin,	90%	52%
And involved in fire origin	84%	39%
Not involved in fire origin	6%	13%
Intentional fire	3%	13%
Clothing on fire, whether or not while escaping	25%	8%
Victim age 65 or older	65%	28%
Victim returned to fire, unable to act, or acted irrationally	34%	20%

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

Source: NFIRS and NFPA survey.

Table 11.
Estimated Reduction in Average Direct Property Damage per Fire
Associated With Wet Pipe Sprinklers, by Property Use
2004-2008 Structure Fires

Property Use	Without automatic extinguishing equipment	With wet pipe sprinklers	Percent reduction
All public assembly	\$44,000	\$12,000	74%
Eating or drinking establishment	\$50,000	\$13,000	73%
Educational	\$20,000	\$7,000	65%
Health care property*	\$11,000	\$5,000	52%
Residential	\$18,000	\$8,000	54%
Home (including apartment)	\$18,000	\$5,000	71%
Hotel or motel	\$23,000	\$49,000	No reduction
Dormitory or barracks	\$8,000	\$2,000	77%
Rooming or boarding house	\$14,000	\$6,000	54%
Board and care home	\$7,000	\$3,000	55%
Store or office	\$48,000	\$31,000	35%
Manufacturing facility	\$93,000	\$62,000	34%
Warehouse excluding cold storage	\$105,000	\$191,000	No reduction

*Nursing home, hospital, clinic, doctor's office, or development disability facility.

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

Source: NFIRS and NFPA survey.

Other Issues

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

Water Damage from Sprinklers in the Absence of Fire

Sprinkler systems can release water in the absence of fire, but the best available evidence indicates that this is a small source of loss compared to fire losses. For home sprinklers in particular, the threat from non-fire water damage is negligible.

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.⁶

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.⁷ 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.⁸ If sprinklers reduced average fire loss by only 20%, then combined fire and water damage in fire and non-fire incidents would be unchanged. (A 20% reduction means the sprinklered fire loss is 80% of the unsprinklered fire loss. Adding 25% for water damage adds 25% of 80%, which is 20%. $80\% + 20\% = 100\%$.) As previously noted, however, sprinklers reduce average fire loss by much more than 20%.

Another set of estimates based on recent U.S. experience can be developed from data on non-fire sprinkler system activations. These estimates generally agree with the earlier estimates cited above.

⁶ Home Fire Sprinkler Coalition, *Automatic Sprinklers, A 15-Year Study, Scottsdale, Arizona*, available at <http://www.homefiresprinkler.org/hfsc.html>.

⁷ 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.

⁸ H.W. Maryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986*, 2nd edition, Victoria, Australia: Australian Fire Protection Association, 1988, p. 435.

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

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

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

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

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

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

Source: Analysis of uncoded narratives from reported incidents in Austin (TX), Minnesota, and Massachusetts in 2007.

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

A sprinkler system can “activate” with no damaging release of water outside the sprinkler system. The most common example is a dry-pipe system that activates by flowing water into the pipes but does not release water outside the system. Such an activation would register as an activation in a centrally monitored system and could result in a fire department response.

To estimate the fraction of incidents where water is released, an exploratory data analysis was conducted on the uncoded narratives for 2007 non-fire sprinkler incidents from Austin, TX (thanks to Karyl Kinsey) and the states of Minnesota and Massachusetts (thanks to Nora Gierok and Derryl Dion). Table F shows the results, separating incidents confirmed as no water outside the system and, among incidents where water release was possible, those with water release outside the system confirmed.

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

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

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

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

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

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

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

- Proximity to very high levels of ambient heat, like that produced by certain manufacturing processes,
- Testing or maintenance not conducted according to standard, resulting in water surge or alarm activation.

Do People Want Sprinklers?

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

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

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

A third myth has to do with the affordability of sprinklers. 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 and incentives applied by community planners in new developments.

A 2008 study, conducted by Newport Partners under sponsorship of the Fire Protection Research Foundation, developed comprehensive and all-inclusive cost estimates for 30 diverse house plans in 10 communities.⁹ Cost per sprinklered square foot ranged from

⁹ Newport Partners, *Home Fire Sprinkler Cost Assessment – Final Report*, Fire Protection Research Foundation, Quincy, MA, September 2008, pp. iv and 6.

\$0.38 to \$3.66, with an average (mean) of \$1.61 and a median of \$1.42. Variables associated with higher cost systems included:

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

Many people are not aware how much the cost of sprinkler systems and the cost of installing them have been reduced in recent years as a result of continued innovation in the industry. When people say they are not interested in sprinklers for cost reasons, they may well be reacting to an inflated notion of those costs.

A 1977 survey done for the U.S. Fire Administration, back when only 22% of U.S. homes had smoke alarms, found that 74% of households with smoke alarms were very concerned about fire compared to only 45% of households that had no smoke alarms and no intention of obtaining smoke alarms. For households without smoke alarms, whether or not they intended to obtain smoke alarms, the leading reason cited for not having obtained one was no perception of need (don't need one – 16%; no interest in one – 16%) and the second leading reason was cost (too expensive – 23%; not worth the money – 1%). These are the same reasons, in the same order, cited today by people not intending to obtain home fire sprinklers today.¹⁰

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

In fact, there is evidence that many homeowners are getting past these dated perceptions and moving on to more fact-based and positive views of home fire sprinklers. The Home Fire Sprinkler Coalition sponsored a December 2005 survey by Harris Interactive®.¹¹ Among the findings were that 45% of homeowners considered a sprinklered home more desirable than an unsprinklered home, that 69% believe a fire sprinkler system increases the value of a home, that 38% say they would be more likely to purchase a new home with sprinklers than one without, and that 43% would be more likely to have home fire sprinklers installed if the cost could be included in the mortgage. These read like the emerging perceptions of a nation that sees value for the cost of home fire sprinklers and sees ways to handle that cost within their home-buying budget.

¹⁰ Based on 2007 slide presentation of results of NAHB National Survey, conducted August 14-15, 2006, by Public Opinion Strategies, #06811.

¹¹ See a summary of findings in a press release at <http://www.homefiresprinkler.org/release/HarrisPoll.html>.

Concluding Points

Fire sprinklers are highly reliable and effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss.

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 88-93% of reported structure fires and operated effectively in 84-91% of fires. Nearly half (47%) of the failures occurred because the system had been shut off.

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 the case for explosions in the NFPA 13, NFPA 13D, and NFPA 13R standards; (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.

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, human error is not a problem unique to sprinklers. 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.

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*.

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

Section 3: Other Automatic Extinguishing Equipment

After the database is edited to remove fires, buildings, and systems where operation cannot be expected, such as small fires, buildings under construction, and partial installations, dry (or possibly wet) chemical systems are the only type of equipment other than sprinklers with enough data to support estimates of reliability and effectiveness.*

Property use classes are shown only if they accounted for at least 100 projected non-confined fires per year with the specific type of automatic extinguishing equipment.**

When dry (or possibly wet) chemical systems were present, 42% of reported total non-confined structure fires were reported as too small to activate operating equipment.

Dry (or possibly wet) chemical systems in the area of fire failed to operate in 36% of reported non-confined structure fires large enough to activate operating equipment. Therefore, they operated in 64% (100% minus 36%) of these fires. For systems that operated in non-confined fires, their performance was deemed effective in 66% of the cases. For non-confined fires large enough to activate systems, excluding buildings under construction, systems operated effectively 42% of the time (64% times 66%). (See Table 12.)

A disadvantage of measuring automatic extinguishing equipment effectiveness by judgments made in incident reports is the ambiguity and subjectivity of the criterion of “effective,” which has never been precisely defined, let alone supported by an operational assessment protocol that could be executed consistently by different people.

Nearly half of dry (or possibly wet) chemical system failures (44%) in non-confined fires were due to lack of maintenance. (See Table 13.) Other reasons cited for failure were as follows:

* There is no coding entry for wet chemical system, which currently are the only systems that have been listed to UL300, *Standard for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*. NFPA 96, *Ventilation Control and Fire Protection of Commercial Cooking Operations*, Chapter 10, requires that commercial operations that have grease removal devices, hood exhaust plenums, and exhaust duct systems be protected by fire extinguishing equipment that complies with UL300 or other equivalent standards. This means that wet chemical systems are the primary automatic extinguishing equipment in use in commercial kitchens but cannot be reported as such; they are likely to be reported as dry chemical systems and may account for more reported fires than the fires actually involving dry chemical system.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fire reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

- 17% were because manual intervention defeated the equipment,
- 15% were because the system was shut off,
- 13% were because a component was damaged, and
- 11% were because the system was inappropriate for the type of fire.

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 extinguishing equipment operates, one would expect that to constitute ineffective performance, not failure to operate. What is left is manual intervention after fire begins but before extinguishing equipment operates, but we do not know whether that is the only condition associated with this coding.

Most cases of dry (or possibly wet) chemical system ineffectiveness in non-confined fires were because not enough agent was released (51%) or agent did not reach fire (40%). (See Table 14.)

Table 12.
Dry (or Possibly Wet) Chemical System Reliability and Effectiveness, by Property Use
2004-2008 Structure Fires (Excluding Fires Reported as Confined Fires)

Property Use	When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area					
	Number of fires per year where extinguishing equipment was present	Percent of fires too small to activate equipment	Number of fires per year	Percent where equipment operated (A)	Percent effective of those that operated (B)	Percent where equipment operated effectively (A x B)
All public assembly	590	46%	320	56%	58%	33%
Eating or drinking establishment	560	45%	310	56%	58%	32%
Residential	120	24%	90	91%	81%	74%
Store or office	170	41%	100	57%	65%	37%
Grocery or convenience store	120	43%	70	54%	64%	35%
All structures*	1,020	42%	600	64%	66%	42%

* Includes some properties not listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail 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. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 13.
Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment
and Dry (or Possibly Wet) Chemical System Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined Fires)

Property Use	Lack of maintenance	Manual intervention defeated system	System shut off	System component damaged	Inappropriate system for type of fire	Total fires per year
Public assembly	49%	19%	11%	12%	10%	140
Eating or drinking establishment	49%	19%	11%	12%	10%	136
Store or office	19%	13%	21%	24%	22%	43
All structures*	44%	17%	15%	13%	11%	215

* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 14.
Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment
and Dry (or Possibly Wet) Chemical System Was Present in Area of Fire, by Property Use
Based on Indicated Estimated Number of 2004-2008 Structure Fires per Year
(Excluding Fires Reported as Confined Fires)

	Not enough agent released	Agent did not reach fire	Lack of maintenance	Manual intervention defeated system	Inappropriate system for type of fire	System component damaged	Total fires per year
Public assembly	48%	44%	6%	2%	0%	0%	74
Eating or drinking establishment	49%	42%	6%	2%	0%	0%	72
Store or office	23%	57%	0%	0%	12%	9%	20
All structures*	51%	40%	4%	3%	2%	1%	130

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Section 4. Summary by Property Use

This chapter summarizes key facts for each of several property use groups.

Homes* (Including Apartments)

- In 2004-2008, 6% of reported home structure fires** indicated some type of automatic extinguishing equipment present. 95% of that equipment was sprinklers (85% wet pipe, 7% dry pipe, 3% other). 6% of home fires had sprinklers present.
- The 2007 American Housing Survey reported that 4% of occupied year-round housing units had sprinklers. The percentage was higher for housing units in multi-unit buildings (11%) than for single family homes (2%).
- Wet pipe sprinklers operated in 95% of fires and operated effectively in 92% of fires.*** When failure occurred, leading reasons were system shutoff (55%) and manual intervention defeated system (16%). When operating equipment was ineffective, leading reasons were water did not reach fire (30%) and system component damaged (27%).
- Only one or two sprinklers operated in 97% of reported fires where wet pipe sprinklers operated.
- In homes, deaths per thousand reported fires were 83% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.
- In homes, direct property damage per reported fire was 71% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Home includes single family homes, duplexes, rowhouses, apartments, flats, and manufactured homes.

** Excluding buildings under construction.

*** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Public Assembly Properties

- In 2004-2008, 49% of reported public assembly structure fires* indicated some type of automatic extinguishing equipment present. 43% of that equipment was sprinklers (37% wet pipe, 3% dry pipe, 4% other), and 36% of that equipment was dry (or possibly wet) chemical systems.** 21% of public assembly fires had sprinklers present. In properties with more than one type of automatic extinguishing equipment present, only the type closest to the fire is reported.
- Wet pipe sprinklers operated in 91% of fires and operated effectively in 86% of fires.*** When failure occurred, leading reasons were system shutoff (73%) and manual intervention defeated system (13%). When operating equipment was ineffective, leading reasons were water did not reach fire (51%) and not enough water released (34%).
- Only one or two sprinklers operated in 90% of reported fires where wet pipe sprinklers operated.
- Dry (or possibly wet) chemical systems operated in 56% of fires and operated effectively in 33% of fires.*** When failure occurred, leading reasons were lack of maintenance (49%) and manual intervention defeated system (19%). When reporting equipment was ineffective, leading reasons were not enough agent released (48%) and agent did not reach fire (44%).
- In public assembly properties, deaths per thousand reported fires were 100% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing systems present.
- In public assembly properties, direct property damage per reported fire was 74% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** There is no coding entry for wet chemical systems, which currently are the only systems that have been listed to UL300, *Standard for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*. NFPA 96, *Ventilation Control and Fire Protection of Commercial Cooking Operations*, Chapter 10, requires that commercial operations that have grease removal devices, hood exhaust plenums, and exhaust duct systems be protected by fire extinguishing equipment that complies with UL300 or other equivalent standards. This means that wet chemical systems are the primary automatic extinguishing equipment in use in commercial kitchens but cannot be reported as such; they are likely to be reported as dry chemical systems and may account for more reported fires than the fires actually involving dry chemical systems.

*** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Eating or Drinking Establishments

- In 2004-2008, 58% of reported eating or drinking establishment structure fires* indicated some type of automatic extinguishing equipment present. 33% of that equipment was sprinklers (26% wet pipe, 2% dry pipe, 4% other), and 43% of that equipment was dry (or possibly wet) chemical systems.** 19% of eating or drinking establishment fires had sprinklers present. In properties with more than one type of automatic extinguishing equipment present, only the type closest to the fire is reported.
- Wet pipe sprinklers operated in 92% of fires and operated effectively in 86% of fires.*** When failure occurred, leading reasons were system shutoff (79%) and manual intervention defeated system (13%). When operating equipment was ineffective, leading reasons were water did not reach fire (53%) and not enough water released (36%).
- Dry (or possibly wet) chemical systems operated in 56% of fires and operated effectively in 32% of fires.*** When failure occurred, leading reasons were lack of maintenance (49%) and manual intervention defeated system (19%). When operating equipment was ineffective, leading reasons were not enough agent released (49%) and agent did not reach fire (42%).
- In eating or drinking establishments, deaths per thousand reported fires were 100% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.
- In eating or drinking establishments, direct property damage per reported fire was 73% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** There is no coding entry for wet chemical systems, which currently are the only systems that have been listed to UL300, *Standard for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*. NFPA 96, *Ventilation Control and Fire Protection of Commercial Cooking Operations*, Chapter 10, requires that commercial operations that have grease removal devices, hood exhaust plenums, and exhaust duct systems be protected by fire extinguishing equipment that complies with UL300 or other equivalent standards. This means that wet chemical systems are the primary automatic extinguishing equipment in use in commercial kitchens but cannot be reported as such; they are likely to be reported as dry chemical systems and may account for more reported fires than the fires actually involving dry chemical systems.

*** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Educational Property

- In 2004-2008, 37% of reported educational property structure fires* indicated some type of automatic extinguishing equipment present. 91% of that equipment was sprinklers (82% wet pipe, 7% dry pipe, 2% other). 33% of educational property fires had sprinklers present.
- Wet pipe sprinklers operated in 86% of fires and operated effectively in 83% of fires.
- In educational properties, direct property damage per reported fire was 65% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Health Care Properties

- In 2004-2008, 61% of reported health care property structure fires* indicated some type of automatic extinguishing equipment present. 95% of that equipment was sprinklers (80% wet pipe, 13% dry pipe, 1% other). 57% of health care property fires had sprinklers present.
- Sprinklers were present in 68% of nursing home structure fires, and 66% of hospital structure fires but only 29% of clinic or doctor's office structure fires.
- Wet pipe sprinklers operated in 88% of fires and operated effectively in 86% of fires.
- In health care properties, direct property damage per reported fire was 52% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Stores and Offices

- In 2004-2008, 30% of reported store and office structure fires* indicated some type of automatic extinguishing equipment present. 77% of that equipment was sprinklers (68% wet pipe, 7% dry pipe, 2% other). 23% of store and office fires had sprinklers present.
- Wet pipe sprinklers operated in 90% of fires and operated effectively in 87% of fires.** When failure occurred, leading reasons were system shutoff (61%) and manual intervention defeated system (21%). When operating equipment was ineffective, leading reasons were water did not reach fire (37%) and not enough water released (34%).
- Only one or two sprinklers operated in 86% of reported fires where wet pipe sprinklers operated.
- In stores and offices, deaths per thousand reported fires were 80% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.
- In stores and offices, direct property damage per reported fire was 35% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Manufacturing Facilities

- In 2004-2008, 55% of reported manufacturing facility structure fires* indicated some type of automatic extinguishing equipment present. 92% of that equipment was sprinklers (78% wet pipe, 11% dry pipe, 3% other). 51% of manufacturing facility fires had sprinklers present.
- Wet pipe sprinklers operated in 91% of the fires and operated effectively in 86% of the fires.** When failure occurred, leading reasons were system shutoff (62%) and manual intervention defeated system (17%). When operating equipment was ineffective, leading reasons were not enough water released (39%) and water did not reach fire (36%).
- Only one or two sprinklers operated in 50% of reported fires where wet pipe sprinklers operated. In 84% of reported fires, five or fewer sprinklers operated, and in 93% of reported fires, ten or fewer sprinklers operated.
- In manufacturing facilities, deaths per thousand reported fires were 78% lower when wet pipe sprinklers were present, compared to fires with automatic extinguishing equipment present.
- In manufacturing facilities, direct property damage per reported fire was 34% lower when wet pipe sprinklers were present, compared to fires with no automatic extinguishing equipment present.

* Excluding buildings under construction.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Warehouses Excluding Cold Storage

- In 2004-2008, 36% of structure fires in warehouses (excluding cold storage) reported some type of automatic extinguishing equipment present. 99% of that equipment was sprinklers (84% wet pipe, 12% dry pipe, 2% other). 36% of warehouse fires had sprinklers present.
- Wet pipe sprinklers operated in 87% of fires and operated effectively in 84% of fires.**
- Only one or two sprinklers operated in 71% of reported fires where wet pipe sprinklers operated and no more than five sprinklers operated in 91% of these fires.

* Excluding buildings under construction.

** Estimates of reliability and effectiveness are based only on fires and installations where the fire should have activated and been controlled by an operational system, therefore excluding buildings under construction, fires with sprinklers not in fire area reported as reason for failure or ineffectiveness, fires reported as too small to activate equipment, and fires reported as confined to cooking vessel, chimney or flue, fuel burner or boiler, commercial compactor, incinerator, or trash.

Source: 2004-2008 NFIRS and NFPA survey except where noted.

Appendix A. How National Estimates Statistics Are Calculated

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

NFIRS provides the most detailed incident information of any national database not limited to large fires. NFIRS is the only database capable of addressing national patterns for fires of all sizes by specific property use and specific fire cause. NFIRS also captures information on the extent of flame spread, and automatic detection and suppression equipment. For more information about NFIRS visit <http://www.nfirs.fema.gov/>. Copies of the paper forms may be downloaded from [http://www.nfirs.fema.gov/documentation/design/NFIRS Paper Forms 2008.pdf](http://www.nfirs.fema.gov/documentation/design/NFIRS_Paper_Forms_2008.pdf).

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

Methodology may change slightly from year to year.

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

NFPA's fire department experience survey provides estimates of the big picture.

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

The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities have fewer people protected per department and are less likely to respond to the survey. A larger number must be surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did respond are truly representative of fire departments their size.) On the other hand, large city

departments are so few in number and protect such a large proportion of the total U.S. population that it makes sense to survey all of them. Most respond, resulting in excellent precision for their part of the final estimate.

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

Projecting NFIRS to National Estimates

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

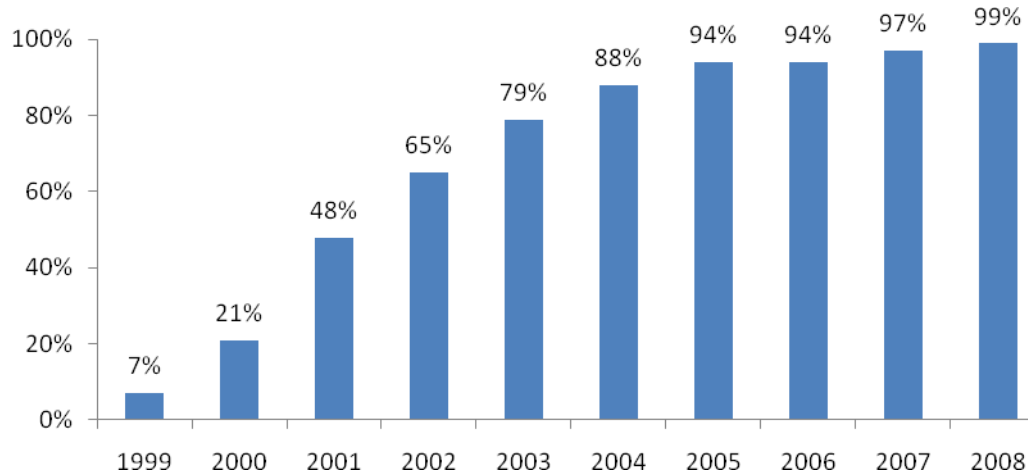
Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific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

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

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

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

Figure 1. Fires Originally Collected in NFIRS 5.0 by Year



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

$$\frac{\text{NFPA survey projections}}{\text{NFIRS totals (Version 5.0)}}$$

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

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

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

Although causal and other detailed information is typically not required for these incidents, it is provided in some cases (typically 10-20%). Some analyses, particularly those that examine cooking equipment, heating equipment, fires caused by smoking materials, and fires started by playing with fire, may examine the confined fires in greater detail. Because the confined fire incident types describe certain scenarios, the

distribution of unknown data differs from that of all fires. Consequently, allocation of unknowns must be done separately.

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

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

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

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

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

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

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

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

(All fires – TMI Not required)
(All fires – TMI Not Required – Undetermined – Blank)

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

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

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

All fires in range 60-69
All fires in range 61-69

The downside of this approach is that heat sources that are truly a different type of open flame or smoking material are erroneously assigned to other categories. The grouping “smoking materials” includes codes 61-63 (cigarettes, pipes or cigars, and heat from undetermined smoking material, with a proportional share of the code 60s and true unknown data.

Equipment Involved in Ignition (EII). NFIRS 5.0 originally defined EII as the piece of equipment that provided the principal heat source to cause ignition if the equipment malfunctioned or was used improperly. In 2006, the definition was modified to “the piece of equipment that provided the principal heat source to cause ignition.” However, much of the data predates the change. Individuals who have already been trained with

the older definition may not change their practices. To compensate, NFPA treats fires in which EII = NNN and heat source is not in the range of 40-99 as an additional unknown.

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

All fires

(All fires – blank – undetermined – [fires in which EII =NNN and heat source <>40-99])

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

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

Code Grouping	EII Code	NFIRS definitions
Central heat	132	Furnace or central heating unit
	133	Boiler (power, process or heating)
Fixed or portable space heater	131	Furnace, local heating unit, built-in
	123	Fireplace with insert or stove
	124	Heating stove
	141	Heater, excluding catalytic and oil-filled
	142	Catalytic heater
	143	Oil-filled heater
Fireplace or chimney	121	Fireplace, masonry
	122	Fireplace, factory-built
	125	Chimney connector or vent connector
	126	Chimney – brick, stone or masonry
	127	Chimney-metal, including stovepipe or flue
Wiring, switch or outlet	210	Unclassified electrical wiring
	211	Electrical power or utility line
	212	Electrical service supply wires from utility

	214	Wiring from meter box to circuit breaker
	216	Electrical branch circuit
	217	Outlet, receptacle
	218	Wall switch
Power switch gear or overcurrent protection device	215	Panel board, switch board, circuit breaker board
	219	Ground fault interrupter
	222	Overcurrent, disconnect equipment
	227	Surge protector
Lamp, bulb or lighting	230	Unclassified lamp or lighting
	231	Lamp-tabletop, floor or desk
	232	Lantern or flashlight
	233	Incandescent lighting fixture
	234	Fluorescent light fixture or ballast
	235	Halogen light fixture or lamp
	236	Sodium or mercury vapor light fixture or lamp
	237	Work or trouble light
	238	Light bulb
	241	Nightlight
	242	Decorative lights – line voltage
	243	Decorative or landscape lighting – low voltage
	244	Sign
Cord or plug	260	Unclassified cord or plug
	261	Power cord or plug, detachable from appliance
	262	Power cord or plug- permanently attached
	263	Extension cord
Torch, burner or soldering iron	331	Welding torch
	332	Cutting torch
	333	Burner, including Bunsen burners
	334	Soldering equipment
Portable cooking or warming equipment	631	Coffee maker or teapot
	632	Food warmer or hot plate
	633	Kettle
	634	Popcorn popper
	635	Pressure cooker or canner

636	Slow cooker
637	Toaster, toaster oven, counter-top broiler
638	Waffle iron, griddle
639	Wok, frying pan, skillet
641	Breadmaking machine

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

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

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

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

Appendix B

Data Elements in NFIRS 5.0 Related to Automatic Extinguishing Systems

M1. Presence of Automatic Extinguishment System

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

Codes:

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

M2. Type of Automatic Extinguishment System

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

Codes:

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

M3. Automatic Extinguishment System Operation

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

Codes:

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

M4. Number of Sprinklers Operating

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

M5. Automatic Extinguishment System Failure Reason

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

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

Codes:

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

Appendix C

Selected Incidents

The following published incidents are detailed examples reinforcing the need for proper inspection and testing maintenance programs and reflect the analysis discussed in the reliability and effectiveness section of the report. The collection may not be representative of all fires in terms of relative frequency or specific circumstances.

Included are short articles from the “Firewatch” column in *NFPA Journal* and incidents from the large-loss and catastrophic fires report. It is important to remember that this is anecdotal information. Anecdotes show what can happen; they are not a source to learn about what typically occurs.

NFPA’s Fire Incident Data Organization (FIDO) identifies significant fires through a clipping service, the Internet and other sources. Additional information is obtained from the fire service and federal and state agencies. FIDO is the source for articles published in the “Firewatch” column of the *NFPA Journal*.

LARGE FIRES WHERE SPRINKLERS WERE NOT IN AREA PROTECTED

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Georgia \$6,000,000 July, 2003 5:50 p.m.	This 7-story university library of protected noncombustible construction covered 200,000 square feet (18,580 square meters). There was an older (the original) building attached and the building was open and operating at the time of the fire.	A partial coverage smoke detection system was present and it activated, notifying the fire department. There was partial coverage wet-pipe system, but not in the area of origin.	This incendiary fire was set in a second-story storage area. The fire was contained to the floor of origin. An arson arrest has been made in the case.	Loss to the building was \$1,000,000 and loss to the contents was \$5,000,000.

Stephen G. Badger, November, 2004, *Large-Loss Fires in the United States 2003*, 29.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Illinois \$15,000,000 August, 1999 5:47 a.m.	This one-story warehouse for palletized cardboard cartons was of unprotected ordinary construction with a ground floor area of 140,000 square feet (13,006 square meters). When the fire broke out, the plant was closed.	The plant didn't have any automatic detection equipment. It did have a complete coverage wet-pipe sprinkler system, which activated and sounded an alarm. The sprinklers were ineffective, however, because the fire spread above the sprinkler heads.	The fire originated at ceiling level above the sprinklers system and spread through the wood truss roof. The cause was undetermined.	The collapsing roof broke cross feeds to the sprinkler system. The open truss area contributed to the fire spread.

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Colorado \$28,000,000 November, 2000 8:47 p.m.	Seven-story hotel of protected noncombustible construction that covered 96,000 square feet (8,918.7 square meters). The hotel was operating at the time of the fire.	Although the hotel's complete-coverage smoke and heat detection system wasn't in the area of ignition, it operated. The hotel also had a complete-coverage wet-pipe sprinkler system. The fire began in a void and burned through the unprotected area. When the system activated, 31 sprinklers opened, causing a drop in pressure and overwhelming the system. Firefighters pumped water into the standpipes that fed both the sprinkler system and the standpipe hose connections, but pressure was inadequate.	The fire began in a second-floor fireplace and ignited a build-up of creosote, causing the vent pipe in the soffit near the fifth floor to separate. The unsupported chimney fell into the chase, allowing fire to spread throughout the void. Firefighters, who were already at the hotel on a medical call, heard the smoke alarms and discovered fire in the chase. Upon investigation, they found flames spreading rapidly through the concealed space above the top floor.	The concealed space above the top-floor ceiling was undivided, allowing the fire to burn the length of the building. Combustible exterior siding contributed to the fire's spread outside the building. It's believed that the fire burned undetected for up to three hours. Two firefighters were injured. Structural loss came to \$19 million, and contents loss is estimated at \$9 million.

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 64.

LARGE FIRES WHERE SPRINKLERS WERE SHUT OFF

Two Intentional Fires in Foreclosed Home, Arizona

An intentionally set fire substantially damaged the second floor of a large, single-family house. Although the house, which was under foreclosure, had a fire sprinkler system, it failed to operate because the water had been shut off due to nonpayment.

The two-story wood-frame home, which covered approximately 5,900 square feet (548 square meters), was vacant at the time of the fire. All it contained was some trash and an upholstered couch. Hardwired smoke detectors were located in the common areas and bedrooms, but they had been disabled by lack of electricity.

A neighbor noticed the fire and called 911 at 11:58 p.m. Firefighters arrived minutes later to find heavy smoke and flames coming from the second floor, and extinguished the blaze using a tower ladder and several monitor nozzles.

Investigators found evidence that a door had been forced open before the firefighters arrived. They also determined that an accelerant poured on the second floor and in the first floor hallway had been ignited by an unknown ignition source. The fire consumed some of the remaining contents before it spread through structural floor and ceiling voids to the attic.

The home, valued at \$1 million, incurred \$200,000 in damage.

Two nights later, the house was destroyed by a second fire. By the time firefighters were summoned to the property at 8:05 p.m., flames were visible on both floors of the structure, and they had to use more than 160,000 gallons (606,000 liters) of water to extinguish the blaze.

Investigators found that the lock on the natural gas supply valve had been broken and that valves on the gas line in the laundry room had been opened before an accelerant poured in a first-floor hallway was ignited. The fire spread up the open stairs and vented through the roof, which had been opened during the previous fire.

Ken Tremblay, 2009, "Firewatch", *NFPA Journal*, September/October, 24.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Maryland \$11,000,000 May, 2005 7:00 p.m.	This storage complex consisted of a one-story vacant warehouse of unprotected ordinary construction and a second warehouse of unprotected noncombustible construction and covered 100,000 square feet (9,290 square meters). The site was closed.	There was no detection equipment present. There was a complete coverage dry-pipe sprinkler system present. The system was not operational, as it had been shut down when building became vacant.	This was an incendiary fire. The fire caused a complete collapse of the older brick building and fire damage to the steel storage building.	Four firefighters were injured. The loss was \$10,000,000 to the structure and \$1,000,000 to the contents.

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 68.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Colorado \$15,000,000 April, 1999 2:58 p.m.	This two-story single-family home had a ground-floor area of more than 5,000 square feet (464 square meters). The type of construction wasn't reported. No one was home when the fire broke out.	The house had an automatic detection system of unknown type and coverage, which operated. It also had a residential set-pipe sprinkler system, but it had been shut down during remodeling.	A light fixture in a closet ignited structural members. No details on the fire's subsequent growth and spread were reported. No injuries were reported.	None reported.

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 93.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Washington \$7,000,000 December, 1999 3:23 a.m.	This 12-foot (3.7 meter) retail tool store was of unprotected, ordinary construction with a ground-floor area of 102,000 square feet (9,475.8 square meters). The store of origin, which was one of six businesses in the strip mall, covered a ground-floor area of 32,400 square feet (3,010 square meters). The store was closed.	No information was reported on automatic detection equipment. The entire strip mall had a shared wet-pipe sprinkler system, which had been disabled in the store of origin by a prior forklift incident. The sprinkler in the adjoining business helped control fire spread. There was also a dry-pipe system in a dry storage area.	Cardboard boxes containing plastic tarps failed and fell from rack storage, landing within a foot (.03 meters) of a heater. The propane heater was set up to help dry out the stock made wet by the sprinkler incident earlier in the day. The heater ignited the boxes and the blower pushed the burning embers into other storage. No injuries were reported.	With the sprinkler system disabled, there was no water flow alarm to notify the fire department, allowing the fire to burn a long time before the neighboring business' sprinkler activated.

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 91.

LARGE FIRES IN WHICH WRONG TYPE OF SYSTEM WAS USED

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development:	Contributing Factors and Other Details
Arizona \$100,000,000 August, 2000 4:58 p.m.	The fire broke out in a warehouse containing a home and garden supply company and a pharmaceuticals distribution company. The construction and height of the structure weren't reported. Employees were working in one of the companies when the fire broke out.	No information was available on automatic detection equipment. A sprinkler system, whose type and extent of coverage weren't known, wasn't adequate for the stored merchandise.	Due to litigation, officials are releasing no information on the fire's development.	None reported.

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 61.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development:	Contributing Factors and Other Details
Pennsylvania \$6,000,000 August, 1999 5:57 p.m.	This approximately 50-foot (15.2 meters) steel manufacturing building was of unprotected, noncombustible construction with a ground-floor area of 20,000 square feet (1,858 square meters). Although the plant was closed for the night, maintenance workers were inside.	The plant didn't have any automatic detection equipment, but it did have a partial coverage wet-pipe sprinkler system. The sprinklers were ineffective because of missing heads and the fact that the system wasn't designed for this hazard. The system outside the area did help stop the fire spread.	Investigators haven't determined the cause of this fire, but they believe it started in a dip-tank area. Six firefighters were injured fighting the blaze.	The poorly maintained sprinkler system wasn't designed for the hazard involved, and heads were missing.

Stephen G. Badger and Thomas Johnson., 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 85-86.

LARGE FIRES IN WHICH SPRINKLERS HAD COMPONENT DAMAGE

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Indiana \$10,000,000 September, 2005 11:59 p.m.	This outdoor furniture and cushion manufacturing plant was of unprotected ordinary construction and had a ground floor area of 279,000 square feet (25,919 square meters). The height was not reported. The plant was in full operation.	There was no detection equipment present. There was a complete coverage combination wet- and dry-pipe sprinkler system. The system operated but risers were heavily damaged by a roof collapse.	The fire broke out in a woodworking area. The ignition sequence is still under investigation.	Over the years, the building had many additions and multiple roofs that firefighters had to work through to reach to the fire.

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 70.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Missouri \$5,000,000 October, 2005 2:42 p.m.	This two-story food preparation plant was under construction. It was of protected noncombustible construction. The ground floor area was not reported. Workmen were on location with ongoing construction.	There was unreported coverage smoke detection equipment present. The system had been shut off due to construction work. There was an unreported coverage wet-pipe sprinkler system present. The system was damaged during the explosion and it did not operate.	An explosion and fire occurred when a natural gas valve was installed in the kitchen area and left in the open position and uncapped. The source of ignition is still under investigation.	One person died and 15 were injured in the explosion.

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 69-70.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Minnesota \$10,000,000 March, 2001 5:08 a.m.	Two-story wood products manufacturing plant of unprotected wood frame construction was in full operation at the time the fire broke out. The ground floor area was not reported.	There was no automatic detection equipment present. A dry-pipe sprinkler system was present. The extent of coverage was not reported. A ceiling collapse preceding the fire damaged the system, rendering it ineffective.	A roof collapse caused by a heavy snow load is believed to have caused wires to spark and ignite dust that had accumulated above the ceiling. The fire then spread to pallets of wood product.	None reported.

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 13-14.

LARGE FIRES WHERE SPRINKLERS HAD LACK OF MAINTENANCE

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
South Carolina \$8,000,000 March, 2005 6:53 a.m.	Four-story textile manufacturing plant of heavy timber construction covering 67,500 square feet (6,271 square meters) was in full operation at the time this fire broke out.	There was a complete coverage detection system of an unreported type. This system was out of service for an unreported reason at the time of the fire. A complete coverage wet-pipe sprinkler system was present. The system operated but was ineffective due to lack of maintenance. The sprinkler heads were coated with cotton dust. There were pressurized water and ABC extinguishers present, which the employees used to extinguish the fire in a baler.	A fire originating in a baler was believed extinguished by the employees. The cause was not reported. When firefighters arrived and investigated they found the fire had extended to the second floor. Firefighters attempted an interior attack, but conditions deteriorated rapidly and walls started to collapse, so all firefighters were withdrawn to a defensive attack.	Three firefighters were injured. Holes in the floor on the second story allowed the fire to extend to the second story. Losses totaled \$5,000,000 to the structure and \$3,000,000 to the contents.

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 14.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
California \$6,000,000 July, 1999 7:25 p.m.	This four-story furniture showroom of protected, non-combustible construction covered a ground-floor area of approximately 44,000 square feet (4,087.5 square meters). The showroom was closed but construction workers were in the building.	The building had no automatic detection system but did have a partial-coverage sprinkler system. Sprinklers helped control fire spread on the second and third floors but weren't effective on the fourth floor because of sediment in the system. Firefighters found sediment blocking several heads. The building also had portable extinguishers and a stand pipe system. Investigators believe that workers used the extinguishers.	Molten slag came in contact with furniture during welding operations and ignited a fire. The fire spread out the second-floor windows and into the third floor. Flames then breached a ceiling and entered the fourth floor where there was a flashover. No injuries were reported.	Sediment blocked sprinklers on the fourth floor.

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 92.

LARGE FIRES WHERE SPRINKLERS HAD OBSTRUCTED WATER FLOW

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
<p>Arizona \$8,000,000 December, 2004 7:33 p.m.</p>	<p>This two-story convention center was of protected non-combustible construction. The ground floor area was not reported. The center was fully operating at the time of the fire.</p>	<p>There was a smoke detection system present that operated and alerted the occupants. The coverage was not reported. There was a wet-pipe sprinkler system present. The system did activate with over 30 heads flowing water.</p>	<p>Heat from a halogen light ignited walnut dust used in filming a collapse scene in a mine for a movie. The fire ignited polyurethane beams and walls of a cave and extended to the cave roof. A covering over the movie set prevented water from the sprinkler from reaching the seat of the fire but the sprinkler flow did prevent the fire's spread beyond the set.</p>	<p>Original reports were that one worker was missing. A primary search was initiated but the worker was located unharmed. Visibility was zero as firefighters attempted an initial fire attack. Firefighters were warned initially of loose rattlesnakes at the movie set. The snakes were corralled by an animal handler and posed no threat to the firefighters and harmed no one.</p>

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 49.

LARGE FIRES WHERE SPRINKLERS HAD WATER FLOW ISSUES

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
<p>Iowa \$250,000,000 February, 2000 7:02 a.m.</p>	<p>One-story machinery storage warehouse of unprotected non-combustible construction covering 990,000 square feet (91,974 square meters) was in full operation at the time the fire broke out.</p>	<p>There was no automatic detection equipment. A system was in the process of being installed. A wet-pipe sprinkler system was present. The extent of the coverage was not reported. This system activated but was not effective because of a water flow problem. The cause of the problem is still being investigated.</p>	<p>A fire of unknown cause broke out in the shipping/receiving area of this warehouse. Responding firefighters reported a large column of smoke from a distance away. With the sprinkler system activated, firefighters made an interior attack. Walls without openings within the warehouse hindered firefighters in reaching the fire. When large areas of the roof began to collapse and high rack storage failed, firefighters withdrew to a defensive attack.</p>	<p>Five firefighters were injured. The water supply was far below the fire flow requirements. A tanker shuttle was set up to assist until late in the day when the water problems were corrected.</p>

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 17.

Location, Dollar Loss, Date, Time	Property Characteristics and Operating Status	Fire Protection Systems	Fire Development	Contributing Factors and Other Details
Oregon \$8,501,000 March, 2004 8:21 a.m.	This one-story petroleum recycling plant was of heavy-timber, construction and covered 186,900 square feet. The plant was in full operation at the time.	No information was reported on any detection equipment. There was a complete coverage dry-pipe sprinkler system present. The system operated, but its rate of application was insufficient to control the fire.	A spark from an oxy/acetylene cutting torch fell into an open sludge-oil pit and ignited the contents instantaneously. The fire grew out of control quickly despite the activation of the sprinkler system. The fire spread through several businesses inside the building.	Firefighters reported insufficient water pressure in hydrants originally. Two firefighters were injured. Damage to the structure was estimated at \$3,000,000 and \$5,501,000 to the contents.

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 47.