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

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Abstract

In fires with sprinklers present, the chances of dying in a fire are reduced by one-half to three-fourths and the average property loss is cut by one-half to two thirds, compared to fires where sprinklers are not present. Sprinklers failed to operate in only 7% of structure fires large enough to activate them. System shut-offs and other human errors were responsible for nearly all the failures.

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

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

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

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Executive Summary

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. When sprinklers are present, the chances of dying in a fire are reduced by one-half to three-fourths and the average property loss per fire is cut by one-half to two-thirds, compared to fires where sprinklers are not present. What's more, this simple comparison understates the potential value of sprinklers because it lumps together all sprinklers, regardless of type, coverage, or operational status, and is limited to fires reported to fire departments. If unreported fires could be included and if complete, well maintained, and properly installed and designed systems could be isolated, sprinkler effectiveness would be seen as even more impressive.

As of 1998, the latest year for which good data on sprinkler presence are available, health care properties, high-rise hotels, high-rise office buildings, and selected mercantile and manufacturing properties had most of their reported fires in properties reported to have sprinklers. Sprinklers remain rare, however, in homes, where most fire fatalities occur, accounting for loss than 1% of reported 1998 one- and two-family dwelling structure fires and 8% of reported 1998 apartment structure fires. Sprinkler usage is growing in most properties, but most fires still occur in properties without sprinklers. There is considerable potential for expanded use of sprinklers to reduce the loss of life and property to fire. The 2006 editions of *NFPA 1, Uniform Fire Code*™, *NFPA 101®, Life Safety Code,* and *NFPA 5000®, Building Construction and Safety Code,* require sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs. This protection can be expected to increase in areas that adopt and follow these revised codes.

With the added detail provided in the National Fire Incident Reporting System (NFIRS) Version 5.0, it is now possible to develop much better estimates of sprinkler reliability. With pre-1999 data, past reports estimated that sprinklers failed to operate in 16% of structure fires large enough to activate sprinklers. The old data could not separate (a) fires in the sprinkler coverage area from fires outside the coverage area (e.g., in properties with partial systems), (b) sprinklers from other automatic extinguishing systems, and (c) human error from mechanical and other equipment problems.

The new estimates are that sprinklers failed to operate in 7% of structure fires (reported in NFIRS 5.0 in 1999-2002, after adjustment for errors in coding partial systems), and two-thirds of those failures were because the system had been shut off before the fire. Nearly all failures were entirely or primarily problems of human error.

A number of changes were made to the coding of automatic extinguishing equipment performance in NFIRS Version 5.0. Data originally reported in Version 4.1 are being converted to the new Version 5.0, and some of the conversions are problematic. This report uses the most current data where possible and retains 1989-1998 analyses when more current data cannot be analyzed with confidence.

When measured by the average number of civilian deaths per thousand fires in 1989-1998 (and with the limitations cited in the first paragraph), the reduction associated with automatic suppression equipment is 60% for manufacturing properties (from 2.0 to 0.8 deaths per thousand fires), 74% for stores and offices (from 1.0 to 0.3 deaths per thousand fires), 75% for health care

properties that care for the aged or the sick (from 4.9 to 1.2), and 91% for hotels and motels (from 9.1 to 0.8). Public assembly and educational properties show no deaths in reported fires in sprinklered properties in 1989-1998, but for educational properties, this was true of unsprinklered properties as well. The estimated impact of residential sprinkler systems in homes is a 74% reduction in death rate, which shows that the large impact of sprinklers on life safety also applies where most fire deaths occur.

When measured by the average number of dollars lost to direct property damage per fire in 1989-1998 (and again with the limitations cited earlier), reductions associated with automatic suppression equipment are illustrated by the following: 53% for stores and offices (from an average of $25,000 to an average of $11,700 per fire), 64% for manufacturing properties (from $52,500 to $18,700 per fire), 66% for health care properties that care for the aged or the sick (from $4,800 to $1,700 per fire), and 70% for public assembly properties (from $21,800 to $6,500 per fire).

Sprinklers are considered to be one of the most important parts of life safety, but they are far from the only part. Adherence to code provisions for factors such as number of occupants, control of heat sources, flammability of furnishings, and availability and capacity of exits are essential. The importance of building inspectors to public safety cannot be overstated. Working together, we can make the country safer from the threat of fire.

Table of Contents

List of Tables

Sprinkler Presence

Table 1 shows the percentage of reported structure fires in which sprinklers* were present and increased in most occupancies over the 1980-1998 time period. With 77% of 1998 reported fires in care-of-aged facilities and 71% of reported 1998 fires in care-of-sick facilities occurring in properties with sprinklers, it is probably safe to say that health care facilities without sprinklers are now a small minority of all such facilities, even if one includes those that are unlicensed and those that were built under older, less demanding codes.

Sprinklers appear to be present in most high-rise hotels and high-rise office buildings, and, to a lesser extent, in department stores and manufacturing facilities. However, sprinklers are still rare in storage facilities and appear to be the exception, not the rule, in most property classes where large numbers of people are at risk – e.g., public assembly properties, schools, general stores and offices, and dormitories and barracks. Residential sprinkler systems for one- and two-family dwellings are reported in only 0.7% of the fires in those properties. Clearly, there is great potential for expanded use of sprinklers.

One example of this is a statement from the National Residential Fire Sprinkler Initiative, of the U.S. Fire Administration, to the effect that currently no more than 2% of all new residences are being protected with residential sprinkler systems.** This very low proportion of sprinkler-protected new residences suggests that sprinklers continue to have only a token presence in dwellings. Also, most of this modest number of new installations are the result of local mandates, with few systems being installed voluntarily. The initiative hopes to increase interest in residential sprinkler systems among builders, developers, community officials, and especially homeowners.

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

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

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

*"Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

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

It may seem surprising that sprinkler usage is so low in general item storage properties (14.1% of 1998 fires were in properties with sprinklers). Even if the focus is narrowed to general warehouses, the percentage of 1998 fires in properties with sprinklers was only 26.1%. Table 1 also shows that high-rise buildings (those that are at least seven stories tall) are much more likely than their shorter counterparts to show sprinklers present when they have reported fires.

Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Sprinkler presence had two choices: Yes and No. Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. The 2004 NFIRS data is not yet available. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data.

Table 1.
Percentage of Structure Fires Estimated
to Have Occurred in Structures With Sprinklers*

Property Use	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Public assembly properties	12.2	12.3	13.5	14.3	14.6	15.6	15.9	17.9	18.5	19.2
(Eating and drinking establishment)	(14.3)	(14.6)	(16.4)	(17.4)	(17.7)	(19.0)	(18.7)	(21.8)	(22.1)	(22.7)
Educational properties	13.0	13.6	12.6	13.1	14.1	16.4	15.0	16.4	17.0	17.2
Health care and correctional facilities**	37.1	38.5	36.7	39.2	39.9	44.0	45.7	48.5	48.1	46.9
(Care of aged facilities)	(61.6)	(64.3)	(56.0)	(59.6)	(57.5)	(60.8)	(64.3)	(66.7)	(66.5)	(69.6)
(Care of sick facilities)	(43.5)	(43.6)	(48.3)	(46.3)	(47.4)	(56.2)	(59.3)	(60.7)	(58.5)	(59.2)
(Correctional facilities)	(8.6)	(9.2)	(8.4)	(11.4)	(15.8)	(19.6)	(17.0)	(19.2)	(15.6)	(16.2)

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998
Public assembly properties	20.1	19.8	20.9	21.2	22.6	24.2	24.5	25.6	30.7
(Eating and drinking establishment)	(23.8)	(23.2)	(24.9)	(24.9)	(26.3)	(28.9)	(28.7)	(30.6)	(31.5)
Educational properties	18.9	18.1	19.0	21.5	23.6	22.7	21.9	25.9	25.3
Health care and correctional facilities**	49.0	48.7	51.7	65.2	54.6	56.8	55.3	57.4	58.0
(Care of aged facilities)	(69.5)	(70.8)	(69.0)	(71.3)	(73.3)	(71.2)	(72.5)	(73.9)	(76.9)
(Care of sick facilities)	(62.5)	(60.7)	(66.7)	(68.8)	(65.6)	(69.1)	(69.5)	(71.7)	(70.7)
(Correctional facilities)	(15.8)	(14.8)	(22.3)	(23.2)	(16.3)	(21.8)	(17.2)	(20.1)	(22.4)

*"Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

**Includes only care of aged, care of sick, and correctional facilities.

Note: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Data reported in Version 4.1 as sprinkler status unknown were converted to no-sprinkler. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated
to Have Occurred in Structures With Sprinklers*

Property Use	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Residential properties	0.9	1.2	1.0	0.9	1.2	1.4	1.7	1.7	2.4	2.4
(One- and two-family dwellings)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.4)	(0.5)	(0.4)	(0.9)	(0.8)
(Apartments)	(3.2)	(4.4)	(3.8)	(3.3)	(4.1)	(4.2)	(4.5)	(4.5)	(6.0)	(5.9)
(Apartments at least 7 stories tall)	N/A	N/A	N/A	N/A	N/A	(11.8)	(21.5)	(23.2)	(23.9)	(23.1)
(Hotels and motels)	(11.5)	(14.8)	(16.7)	(15.2)	(17.6)	(19.0)	(23.4)	(24.9)	(29.0)	(30.1)
(Hotels at least 7 stories tall)	N/A	N/A	N/A	N/A	N/A	(51.4)	(60.7)	(59.0)	(63.2)	(63.0)
(Dormitories and barracks)	(16.5)	(19.5)	(12.1)	(15.6)	(15.2)	(22.8)	(17.2)	(22.0)	(21.3)	(21.7)

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998
Residential properties	2.6	2.5	2.7	2.6	2.5	2.2	2.6	3.0	3.1
(One- and two-family dwellings)	(0.8)	(0.8)	(0.7)	(0.7)	(0.7)	(0.4)	(0.6)	(0.7)	(0.7)
(Apartments)	(5.9)	(6.1)	(6.9)	(6.6)	(6.3)	(5.6)	(6.8)	(7.7)	(7.9)
(Apartments at least 7 stories tall)	(24.5)	(25.8)	(31.3)	(30.2)	(30.1)	(30.0)	(28.3)	(35.6)	(35.9)
(Hotels and motels)	(31.7)	(30.6)	(31.6)	(32.1)	(31.9)	(32.3)	(34.6)	(34.0)	(40.4)
(Hotels at least 7 stories tall)	(69.4)	(66.1)	(71.7)	(75.1)	(68.6)	(71.9)	(76.1)	(67.4)	(77.1)
(Dormitories and barracks)	(28.7)	(21.3)	(22.2)	(24.1)	(24.7)	(31.6)	(25.9)	(28.4)	(34.9)

N/A - Not available because building height was not well reported prior to 1985.

* "Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

Note: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Data reported in Version 4.1 as sprinkler status unknown were converted to no-sprinkler. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated
to Have Occurred in Structures With Sprinklers*

Property Use	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Stores and offices	11.9	12.4	12.2	12.9	13.7	14.6	15.9	18.4	18.8	19.7
(Food or beverage sales stores)	(14.0)	(13.0)	(13.8)	(17.2)	(16.9)	(16.6)	(20.1)	(22.2)	(22.1)	(23.4)
(Department stores)	(47.2)	(48.2)	(44.1)	(41.4)	(39.2)	(42.8)	(46.7)	(49.8)	(54.0)	(52.5)
(Offices)	(9.9)	(11.3)	(12.8)	(12.7)	(14.3)	(16.2)	(15.9)	(19.3)	(20.1)	(21.1)
(General office buildings)	(10.2)	(11.9)	(12.7)	(13.1)	(15.4)	(15.6)	(17.3)	(21.0)	(22.1)	(21.9)
(Office buildings at least 7 stories tall)	N/A	N/A	N/A	N/A	N/A	(42.9)	(43.7)	(45.4)	(48.1)	(46.9)
Industry, utility, or defense facilities	5.4	4.9	5.0	6.5	5.8	6.8	7.2	8.5	8.1	11.6

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998
Stores and offices	19.6	19.2	20.3	20.6	20.9	20.1	21.1	22.2	22.7
(Food or beverage sales stores)	(23.1)	(23.6)	(24.8)	(21.8)	(25.9)	(25.1)	(26.8)	(27.9)	(28.0)
(Department stores)	(50.5)	(49.1)	(54.2)	(55.5)	(50.5)	(49.5)	(52.7)	(53.0)	(52.1)
(Offices)	(22.8)	(22.0)	(24.1)	(25.4)	(23.9)	(25.3)	(25.4)	(25.5)	(26.9)
(General office buildings)	(24.0)	(24.5)	(26.4)	(27.3)	(26.3)	(26.0)	(27.3)	(27.3)	(28.0)
(Office buildings at least 7 stories tall)	(55.7)	(53.7)	(54.8)	(58.2)	(63.0)	(59.3)	(59.8)	(62.3)	(65.9)
Industry, utility, or defense facilities	13.1	11.0	12.5	14.8	10.1	12.6	11.9	14.4	14.6

N/A - Not available because building height was not well reported prior to 1985.

* "Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

Note: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data. "General office building" is only one type of office building. The high-rise office building statistics include all types of office buildings.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred in Structures With Sprinklers*

Property Use	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Manufacturing facilities	44.9	44.2	42.1	44.6	44.8	46.5	47.7	49.1	48.5	49.0
(Food product manufacturer)	(29.0)	(26.2)	(22.5)	(23.5)	(26.9)	(28.6)	(31.7)	(29.7)	(29.6)	(30.0)
(Textile product manufacturer)	(69.1)	(65.1)	(53.4)	(64.5)	(66.0)	(71.3)	(74.2)	(66.9)	(61.6)	(67.3)
(Footwear, wearing apparel, leather or rubber product manufacturer)	(60.2)	(61.5)	(57.3)	(60.3)	(62.8)	(62.6)	(61.6)	(58.3)	(64.6)	(67.2)
(Wood, furniture, paper, or printing product manufacturer)	(56.1)	(56.3)	(53.4)	(55.0)	(53.2)	(55.7)	(53.6)	(55.6)	(57.3)	(54.6)
(Chemical, plastic, or petroleum product manufacturer)	(51.1)	(50.9)	(49.0)	(50.3)	(56.6)	(55.0)	(54.4)	(57.2)	(59.4)	(58.0)
(Metal product manufacturer)	(38.5)	(35.7)	(36.7)	(37.3)	(35.4)	(39.3)	(43.0)	(42.3)	(41.2)	(44.7)
(Vehicle assembly plant/manufacturer)	(50.8)	(44.2)	(38.6)	(48.7)	(45.0)	(39.9)	(36.7)	(51.0)	(43.5)	(42.6)

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacturing facilities	49.3	48.9	48.6	50.1	48.5	50.1	50.7	51.2	51.5
(Food product manufacturer)	(32.8)	(35.4)	(32.0)	(40.4)	(35.1)	(41.9)	(37.7)	(41.6)	(38.1)
(Textile product manufacturer)	(67.5)	(70.1)	(72.0)	(75.5)	(71.3)	(72.4)	(78.1)	(74.7)	(74.9)
(Footwear, wearing apparel, leather or rubber product manufacturer)	(65.6)	(68.5)	(65.3)	(68.0)	(63.9)	(61.5)	(61.5)	(70.8)	(76.0)
(Wood, furniture, paper, or printing product manufacturer)	(54.9)	(53.4)	(51.8)	(55.7)	(52.6)	(54.3)	(53.9)	(51.6)	(53.6)
(Chemical, plastic, or petroleum product manufacturer)	(60.3)	(58.4)	(58.2)	(58.4)	(57.1)	(62.6)	(62.6)	(62.5)	(61.4)
(Metal product manufacturer)	(43.4)	(44.3)	(44.1)	(42.9)	(41.2)	(43.0)	(44.8)	(45.1)	(45.7)
(Vehicle assembly plant/manufacturer	(42.8)	(42.4)	(56.0)	(53.7)	(57.8)	(52.0)	(49.4)	(51.4)	(63.9)

* "Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

Note: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data.

Source: NFIRS and NFPA survey.

Table 1. (Continued)
Percentage of Structure Fires Estimated to Have Occurred in Structures With Sprinklers*

Property Use	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Manufacturing facilities (continued)										
(Other manufacturer)	(39.5)	(39.6)	(39.1)	(41.0)	(38.6)	(37.0)	(40.2)	(46.4)	(47.3)	(44.5)
Storage facilities	3.8	3.0	3.4	3.8	4.4	5.0	4.7	4.7	4.0	5.2
(excluding dwelling garages)										
(General item storage)	(12.2)	(7.4)	(6.9)	(8.4)	(9.0)	(11.6)	(10.4)	(13.0)	(11.7)	(13.2)
All structures**	4.0	4.1	4.0	3.9	4.3	5.0	5.2	5.6	5.7	5.9

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998
Manufacturing facilities (continued)									
(Other manufacturer)	(45.3)	(42.0)	(43.4)	(44.6)	(46.6)	(45.6)	(51.1)	(52.6)	(44.9)
Storage facilities	5.0	4.9	4.7	5.0	4.8	4.5	4.6	5.1	5.0
(excluding dwelling garages)									
(General item storage)	(13.7)	(11.3)	(12.1)	(12.2)	(13.8)	(11.8)	(12.6)	(15.9)	(14.1)
All structures**	6.1	6.0	6.1	6.1	6.1	5.8	6.3	7.1	7.2

* "Sprinklers" refer to all automatic extinquishing systems in this section, because NFIRS Version 4.1 cannot make the distinction. Usage of sprinklers in public assembly properties, particularly eating and drinking establishments, may be significantly overstated for this reason.

**Includes dwelling garages, special structures, structures of unknown type and other structures not shown separately.

Note: These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 data is not provided because Version 5.0 of NFIRS had no code available to record unknown sprinkler presence until 2004. Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. Previously published 1999 estimates are withdrawn. These estimates will resume with 2004 data.

Source: NFIRS and NFPA survey.

Automatic Extinguishing System Type

Table 2 shows the percentage of fires by type of automatic extinguishing system for each of the major property groups and some subgroups. This data element is new to Version 5.0 of NFIRS, and the data shown is based on the 37% of 1999-2002 fires reported directly in the Version 5.0 format. Percentage calculations are based only on fires where automatic extinquishing system presence and type were known and reported.

Some type of sprinkler system was present in 88% of all structure fires and 96% of residential fires where an automatic extinguishing system was present. Wet pipe sprinkler systems accounted for 75% of all systems (85% of residential) and so out-numbered dry pipe systems by 7-to-1 and outnumbered all other types of sprinklers by nearly 30-to-1.

Dry pipe sprinklers were most common in storage properties, where they accounted for 29% of systems compared to 68% for wet pipe sprinklers.

For public assembly properties, there was a 55% to 45% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 34% of the systems present. Eating and drinking establishments (the dominant part of public assembly) had a 43% to 57% split between sprinkler systems and other systems, respectively. Dry chemical systems accounted for 43% of total systems in eating and drinking establishments, or the same share as all sprinklers combined.

In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system.

Table 2.

Type of Automatic Extinguishing System Reported in Structure Fires Where Systems Were Present, by Property Use 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

Automatic Suppression Systems	All Properties	Public Assembly	[Eating & Drinking Establishments]	Educational	Health Care & Correctional
Wet pipe sprinkler	75%	46%	36%	86%	83%
Dry pipe sprinkler	11%	6%	4%	7%	12%
Other sprinkler system*	3%	3%	3%	2%	2%
Dry chemical system	7%	34%	43%	4%	1%
Carbon dioxide (CO2) system	1%	2%	3%	0%	0%
Foam system	0%	2%	3%	0%	0%
Halogen type system**	0%	1%	2%	0%	0%
Other special hazard system	2%	5%	7%	1%	1%
Sprinkler systems	88%	55%	43%	95%	98%
Other systems	12%	45%	57%	5%	2%

*Includes deluge and pre-action sprinkler systems.

**Includes non-halogenated suppression systems that operate on the same principle.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Confined fires are excluded from this analysis. Percentages are based on fires in which type of system was known. "All properties" includes some properties not shown separately.

Eating and drinking establishments are part of public assembly.

Source: NFIRS and NFPA Survey.

Table 2. (Continued)
Type of Automatic Extinguishing System Reported
in Structure Fires Where Systems Were Present, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments

Automatic Suppression Systems	All Residential	[One- and Two- Family Dwellings]	[Apartments]	[Hotels & Motels]	[Dormitories]
Wet pipe sprinkler	85%	68%	88%	85%	81%
Dry pipe sprinkler	8%	14%	5%	9%	9%
Other sprinkler system*	3%	6%	3%	3%	6%
Dry chemical system	2%	4%	2%	1%	0%
Carbon dioxide (CO2) system	0%	0%	0%	1%	1%
Foam system	0%	0%	0%	0%	0%
Halogen type system**	0%	0%	0%	0%	0%
Other special hazard system	2%	8%	2%	1%	2%
Sprinkler systems	96%	88%	96%	97%	96%
Other systems	4%	12%	4%	3%	4%

*Includes deluge and pre-action sprinkler systems.

**Includes non-halogenated suppression systems that operate on the same principle.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Confined fires are excluded from this analysis. Percentages are based on fires in which type of system was known. "All properties" includes some properties not shown separately.

One- and two-family dwellings, apartments, hotels and motels, and dormitories, all are part of residential.

Source: NFIRS and NFPA survey.

Table 2. (Continued)
Type of Automatic Extinguishing System Reported
in Structure Fires Where Systems Were Present, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments

Automatic Suppression Systems	Stores	Offices	Manufacturing	Storage
Wet pipe sprinkler	85%	86%	75%	68%
Dry pipe sprinkler	11%	9%	15%	29%
Other sprinkler system*	2%	3%	3%	1%
Dry chemical system	1%	0%	1%	1%
Carbon dioxide (CO2) system	0%	1%	3%	0%
Foam system	0%	0%	0%	0%
Halogen type system**	0%	0%	1%	0%
Other special hazard system	0%	0%	2%	1%
Sprinkler systems	98%	98%	93%	97%
Other systems	2%	2%	7%	3%

*Includes deluge and pre-action sprinkler systems.

**Includes non-halogenated suppression systems that operate on the same principle.

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Confined fires are excluded from this analysis. Percentages are based on fires in which type of system was known. "All properties" includes some properties not shown separately.

Source: NFIRS and NFPA survey.

Sprinkler Operationality

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

NFIRS Version 4.1

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

This data provided the only available basis for estimation of a statistic related to sprinkler operationality. NFPA estimated operationality as fires coded 1 (operated) divided by fires coded 1 or 2, thereby excluding fires deemed too small to activate an operational sprinkler. Table 3A shows the most recent such calculations, in which an average of 16% non-operational was estimated for all buildings combined.

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

Beginning in 1999, the new NFIRS Version 5.0 separated "equipment operated" into "equipment operated and was effective" and "equipment operated and was not effective." For fires coded in NFIRS Version 4.1 as equipment operated, there was no way to determine effectiveness, and so all such entries were converted to unknown. Therefore, only fires reported directly in NFIRS Version 5.0 could be used. Table 3B shows that this change in coding had little impact on the estimate. The overall average for all buildings was now 18% non-operational instead of the previous 16%, essentially no change.

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

The coding of reasons has been used in this analysis to recode sprinkler performance entries. Unknown reasons have been proportionally allocated to avoid the dubious alternative assumption that the coded performance is correct if no reason is given for the performance. Here are the rules used for recoding:

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

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

Tables 4A and 4B show, respectively, the revised operationality estimates by property, with Table 4A covering all extinguishing systems and Table 4B covering only sprinklers. As expected, the exclusions of systems other than sprinklers in Table 4B has its largest effect on public assembly statistics, which are dominated by fires in eating and drinking establishments. Dormitories are not listed because there has not yet been enough data for meaningful estimates, and in fact, many of the individual property classes have statistics based on a relatively small number of incidents.

With the corrected coding, it is also possible to develop more accurate tables on principal reasons for failure to operate. Tables 5A and 5B provide those results by property use. Later in the report, percentage of ineffective operation and principal reasons for ineffective operation are given.

Therefore, with the added detail provided by NFIRS Version 5.0, after corrections as noted above, we have new best estimates. Sprinklers in the fire area fail to operate in 7% of fires considered large enough to activate them, but two-thirds (65%) of those failures occur because the system was shut off. The likelihood of such failures can be greatly reduced through the use of programs that put highly noticeable tags on systems shut off for testing and maintenance. Valve supervision using a tamper switch connected to a central alarm monitoring station can also be helpful.

Training can also sharply reduce the likelihood of three other causes of failure – system defeats due to manual intervention (16%), lack of maintenance (11%), and installation of inappropriate systems for the types of fires (5%). Only 0.2% of fires large enough to activate sprinklers that are in the coverage area show failure due to damage to components (0.2% equals 7% that failed times 3% of failures due to component damage).

A sprinkler system needs to be designed to fit the current needs of a property. If the property use changes, it is essential to review the adequacy of the sprinkler system. Even if the property use has not changed, the passage of time alone can dictate a review of the system.

Table 3.

Depracated Table – Not for Use – Presented for Historic Perspective Only

Sprinkler Operationality in Structure Fires When Fire Was Large Enough to Activate Sprinkler, by Property Use

A. 1989-1998

Property Use	Percent Where Sprinklers Failed to Operate
Public assembly properties	26%
Educational properties	20%
Health care or correctional facilities	20%
Residential properties	15%
Stores and offices	19%
Manufacturing facilities	9%
Storage properties	16%
All properties*	16%

*Includes some properties not listed separately above.

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. They also exclude fires coded as fire too small to test operational status of sprinklers. They do not distinguish type of sprinklers or completeness of coverage.

Source: NFIRS and NFPA survey.

Table 3. (Continued)

Depracated Table – Not for Use – Presented for Historic Perspective Only

Sprinkler Operationality in Structure Fires When Fire Was Large Enough to Activate System, by Property Use

B. 1999-2002 Fires Reported in NFIRS Version 5.0

Property Use	Percent Where Sprinklers Failed to Operate
Public assembly properties	35%
Educational properties	26%
Health care or correctional facilities	20%
Residential properties	12%
Stores and offices	19%
Manufacturing facilities	12%
Storage properties	18%
All properties*	18%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, is still small and may not be representative. Figures exclude confined fires and fires coded as too small to test operationality.

Source: NFIRS and NFPA survey

Table 4.

Automatic Extinguishing System Operationality in Structure Fires When Fire Was Large Enough to Activate System After Recoding of Errors Based on Reasons for Ineffectiveness or Failure to Operate, by Property Use, 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

A. All Automatic Extinguishing Systems

Property Use	Percent Where Systems Failed to Operate
Public assembly	19%
Educational	11%
Health care or correctional	7%
Residential	3%
Stores or office	10%
Manufacturing	7%
Storage	15%
All properties*	9%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, is still small and may not be representative. Figures exclude confined fires and fires coded as too small to test operationality.

Source: NFIRS and NFPA survey

Table 4. (Continued)

Automatic Extinguishing System Operationality in Structure Fires When Fire Was Large Enough to Activate System After Recoding of Errors Based on Reasons for Ineffectiveness or Failure to Operate, by Property Use, 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments (Continued)

B. Sprinklers Only

Property Use	Percent Where Sprinklers Failed to Operate
Public assembly	10%
Educational	7%
Health care or correctional	5%
Residential	3%
One and two-family dwelling	6%
Apartment	2%
Hotel or motel	4%
Store or office	9%
Manufacturing	7%
Storage	14%
Cold-storage or other warehouse	11%
All properties*	7%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, is still small and may not be representative. Figures exclude confined fires and fires coded as too small to test operationality.

Source: NFIRS and NFPA survey

Table 5.
Reasons Why Automatic Extinguishing Systems Failed to Operate When Present in Area of Fire Origin and Fire Was Large Enough to Activate System, After Recoding of Errors, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments

A. All Automatic Extinguishing Systems

Property Use	System shut off	Manual intervention defeated system	Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Public assembly	17%	5%	49%	17%	12%	100%
Educational	41%	59%	0%	0%	0%	100%
Health care or correctional	50%	50%	0%	0%	0%	100%
Residential	61%	23%	8%	8%	0%	100%
Store or office	33%	25%	25%	13%	4%	100%
Manufacturing	71%	15%	12%	3%	0%	100%
Storage	88%	6%	6%	0%	0%	100%
All properties*	52%	16%	21%	7%	3%	100%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, is still small and may not be representative. Figures exclude confined fires and fires coded as too small to test operationality.

Source: NFIRS and NFPA survey

Table 5. (Continued)
Reasons Why Automatic Extinguishing Systems Failed to Operate When Present in Area of Fire Origin and Fire Was Large Enough to Activate System, After Recoding of Errors, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments

B. Sprinklers Only

Property Use	System shut off	Manual intervention defeated system	Lack of maintenance	Inappropriate system for type of fire	System component damaged	Total
Public assembly	23%	0%	39%	13%	25%	100%
Educational	68%	32%	0%	0%	0%	100%
Health care or correctional	35%	65%	0%	0%	0%	100%
Residential	80%	20%	0%	0%	0%	100%
One- or two-family dwelling	0%	100%	0%	0%	0%	100%
Apartment	81%	19%	0%	0%	0%	100%
Hotel or motel	100%	0%	0%	0%	0%	100%
Store or office	35%	30%	15%	16%	5%	100%
Manufacturing	76%	12%	12%	0%	0%	100%
Storage	79%	7%	7%	8%	0%	100%
Cold storage or other warehouse	89%	11%	0%	0%	0%	100%
All properties*	65%	16%	11%	5%	3%	100%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, is still small and may not be representative. Figures exclude confined fires and fires coded as too small to test operationality.

Source: NFIRS and NFPA survey

Number of Sprinklers Operating

Table 6A shows the number of sprinklers operating by type of sprinkler system. Ten or fewer heads operated in 97% of the wet pipe system activations and 86% of the dry pipe activations.

Dry-pipe systems are much more likely to open more than one sprinkler than wet-pipe systems (59% vs. 35% of fires). The likely reason is the 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.

When more than 1-2 sprinklers operate, this is often taken as an indication of less than ideal performance. Tables 6B and 6C address this point for wet-pipe sprinklers.

When sprinklers were effective, more than two sprinklers opened in only one of six fires (17%). When sprinklers were not effective, more than two sprinklers opened in one of three fires (34%). Table 6C shows that the percentage of fires where performance is deemed not effective increases as the number of sprinklers operating increases, rising from 5% of fires when one sprinkler opens to 19% when more than 10 sprinklers open.

Table 6.

Number of Sprinklers Operating in Structure Fires Where Sprinklers Were Present and Operated 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

A. By Type of Sprinkler System

Number of Sprinklers Operating	Wet Pipe	Dry Pipe	Other Type Sprinkler
1	65%	41%	55%
2 or fewer	81%	56%	72%
3 or fewer	88%	65%	83%
4 or fewer	91%	73%	92%
5 or fewer	93%	77%	92%
6 or fewer	94%	80%	96%
7 or fewer	95%	80%	100%
8 or fewer	95%	82%	100%
9 or fewer	96%	83%	100%
10 or fewer	97%	86%	100%

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Wet-pipe systems outnumbered dry-pipe systems by 7-to-1. Wet-pipe systems outnumbered "other type sprinkler" systems by nearly 30-to-1. However, 38% of the incidents had type of sprinkler system unreported. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating.

Source: NFIRS and NFPA survey.

Table 6. (Continued)

Number of Sprinklers Operating in Structure Fires Where Sprinklers Were Present and Operated 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

B. Wet-Pipe Sprinklers by Reported Effectiveness

Number of Sprinklers Operating	Operated and Was Effective	Operated and Was Not Effective
1	67%	50%
2 or fewer	83%	66%
3 or fewer	89%	76%
4 or fewer	92%	83%
5 or fewer	94%	87%
6 or fewer	95%	88%
7 or fewer	96%	88%
8 or fewer	96%	89%
9 or fewer	97%	90%
10 or fewer	98%	92%

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Wet-pipe systems outnumbered dry-pipe systems by 7-to-1. Wet-pipe systems outnumbered "other type sprinkler" systems by nearly 30-to-1. However, 38% of the incidents had type of sprinkler system unreported. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating.

Source: NFIRS and NFPA survey.

Table 6. (Continued)

Number of Sprinklers Operating in Structure Fires Where Sprinklers Were Present and Operated, 1999-2002 Structure Fires (Excluding Confined Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

C. Effectiveness, by Number of Sprinklers Operating in Wet-Pipe Systems

Number of Sprinklers Operating	Percent of Fires Where Sprinklers Were Effective
1	95%
2	94%
3	91%
4 to 10	89%
More than 10	81%
Total	94%

Note: These are fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Wet-pipe systems outnumbered dry-pipe systems by 7-to-1. Wet-pipe systems outnumbered "other type sprinkler" systems by nearly 30-to-1. However, 38% of the incidents had type of sprinkler system unreported. Percentages are based on fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating.

Source: NFIRS and NFPA survey.

Sprinkler Effectiveness

Background

Up until about 1970, NFPA measured sprinkler effectiveness by looking at the percentage of fires in sprinklered properties showing satisfactory sprinkler performance. This statistic was then discontinued because of a recognition of a substantial and growing bias. Fewer and fewer small and even medium-sized fires could be captured. NFPA's data-collection procedures therefore were unavoidably biased toward cases of poor sprinkler performance because those cases produced larger fires that were more likely to require fire department intervention or insurance company attention and therefore were more likely to be reported to NFPA. The most dramatic sprinkler successes were so complete that no one but the managers of the facility might ever know of them. What really forced the discontinuation of NFPA's tracking was the realization that this bias was becoming worse each year and was causing some people to believe that sprinkler effectiveness was declining.

Another limitation in the old procedure was the ambiguous and subjective character of the term "satisfactory sprinkler performance." Such a measure is not nearly so straightforward as a measure of lives or property saved. Therefore, all subsequent attempts to measure sprinkler effectiveness have attempted to deal directly in impacts on measures of real fire loss.

These calculations have some limitations. First, it is not as clear as it is with loss measures what the benefit of sprinkler performance is, in terms of intrinsically meaningful outcomes. Money or lives saved cannot be safely inferred from a measure of fire confinement, as the size of the loss depends on much more than the size of the fire. Also, this is a less quantitative measure, being based on a qualitative outcome.

Second, by not including damage due to water, these calculations leave open the possibility that reduced fire damage is offset by increased water damage.

Third, the concept of “fire control” raises a number of definitional questions that are difficult to answer in a manner that is consistent from one observer to the next. If fire size is limited by the intervention of walls or other barriers, it may not be clear how much of a role the sprinkler system played in stopping fire growth. If an activated sprinkler system is always assumed to have had a significant role, then “fire control” may be indistinguishable in practice from “confined to room of fire origin.” If not, then some judgments must be made, and the measure itself can become highly subjective.

Effectiveness in NFIRS Version 5.0

Even more subjective is the approach used in NFIRS Version 5.0, which focuses on a judgment of “effective” performance. Here, you have all the potential ambiguities in “fire control” plus the much greater potential variations in definition of what constitutes “effective” performance. It is unlikely that every fire officer will define “effective” performance as fire control. Even so, this is a measure of sprinkler performance that we have not had for a long time.

Tables 7A to 7C provide an overview of system performance by property use. More detailed property use results are provided only for sprinkler-only estimates, and some property uses of interest (e.g., dormitories, high-rise office buildings) are omitted because of insufficient data.

The majority of reported fires are too small to activate an operational system. This is even more true for educational properties and for health care and correctional properties, which are more likely to be encouraged or required to report even the smallest fires, because of concerns over their unusually vulnerable populations.

Table 7C shows that system performance statistics are improved when systems other than sprinklers are excluded, particularly in public assembly properties. The lowest sprinkler effectiveness percentage is for storage properties, which also have by far the highest relative usage of dry-pipe over wet-pipe systems. As noted earlier, dry-pipe systems react later, which tends to mean more heads opening and less effectiveness.

Tables 8A and 8B provide an overview by property use of reasons for ineffective performance.

Roughly half the cases involved a failure of extinguishing agent to reach the fire. This can occur when fires are shielded (e.g., in racks when sprinklers are installed only at the ceiling), when sprinklers are blocked (e.g., by stock piled too high), or when sprinkler spray is unable to penetrate sufficiently far into the buoyant fire plume.

Roughly one-third of cases involved an insufficient release of agent. This could be coded because the sprinkler pipes were blocked or frozen (a system problem) or because the water supply was inadequate (a system environment problem).

A sprinkler system needs to be designed to fit the current needs of a property. If the property use changes, it is essential to review the adequacy of the sprinkler system. Even if the property use has not changed, the passage of time alone can dictate a review of the system.

NFIRS remains limited to reported incidents. Fires not reported to the fire department – including fires quickly controlled by sprinklers – are not included, which means the database will be missing a potentially large number of particularly notable successes.

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

Table 7.

Automatic Extinguishing System Performance, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments
After Recoding Based on Reasons for Failure or Ineffectiveness

A. All Automatic Extinguishing Systems

Fixed Property Use	Operated and Effective	Operated and Not Effective	Fire Too Small to Activate System	Failed to Operate
Public assembly	26%	11%	54%	9%
Educational	20%	1%	77%	3%
Health care or correctional	23%	1%	75%	2%
Residential	39%	3%	57%	1%
Stores and offices	33%	3%	61%	4%
Manufacturing	48%	5%	43%	4%
Storage	44%	8%	39%	9%
All properties*	36%	4%	56%	4%

*Includes some properties not separately listed above.

Note: These 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. Percentages are estimated from structure fires where sprinklers were present in area of fire origin and operation was known.

Source: NFIRS and NFPA survey.

Table 7. (Continued)

Automatic Extinguishing System Performance, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments
After Recoding Based on Reasons for Failure or Ineffectiveness

B. Sprinklers Only

Fixed Property Use	Operated and Effective	Operated and Not Effective	Fire Too Small to Activate System	Failed to Operate
Public assembly	34%	4%	58%	4%
Educational	22%	0%	76%	2%
Health care or correctional	24%	0%	74%	1%
Residential	40%	1%	58%	1%
One- or two-family dwelling	46%	0%	51%	3%
Apartment	47%	1%	51%	1%
Hotel or motel	31%	2%	66%	1%
Stores and offices	35%	1%	61%	3%
Manufacturing	48%	3%	45%	4%
Storage	47%	5%	38%	9%
Cold storage or other warehouse	56%	2%	34%	8%
All properties*	38%	2%	57%	3%

*Includes some properties not separately listed above.

Note: These 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. Percentages are estimated from structure fires where sprinklers were present in area of fire origin and operation was known.

Source: NFIRS and NFPA survey.

Table 7. (Continued)

Automatic Extinguishing System Performance, by Property Use
1999-2002 Structure Fires (Excluding Confined Fires)
Reported in NFIRS Version 5.0 to U.S. Fire Departments
After Recoding Based on Reasons for Failure or Ineffectiveness

C. Percentage Effective Among Fires Where Systems Operated

Fixed Property Use	All Automatic Extinguishing Systems	Sprinklers Only
Public assembly	72%	90%
Educational	96%	98%
Health care or correctional	98%	99%
Residential	93%	97%
One- or two-family dwelling	NC	100%
Apartment	NC	98%
Hotel or motel	NC	94%
Store or office	92%	97%
Manufacturing	90%	95%
Storage	85%	90%
Cold storage or other warehouse	NC	96%
All properties*	89%	96%

NC – Not calculated for all automatic extinguishing systems.

*Includes some properties not separately listed above.

Note: These are national estimates of fires reported to U.S. municipal fire departments and exclude fires reported only to Federal or state agencies or industrial fire brigades. Percentages are estimated from structure fires where sprinklers were present in area of fire origin and operation was known.

Table 8.

Reasons Why Automatic Extinguishing Systems Are Deemed Ineffective When Present in Area of Fire Origin and Fire Was Large enough to Activate System, After Recoding of Errors, by Property Use 1999-2002 Structure Fires (Excluding Confirmed Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

A. All Automatic Extinguishing Systems

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	System component damaged	Manual intervention defeated system	Total
Public assembly	46%	34%	11%	0%	9%	100%
Educational	0%	100%	0%	0%	0%	100%
Health care or correctional	100%	0%	0%	0%	0%	100%
Residential	78%	22%	0%	0%	0%	100%
Store or office	36%	51%	13%	0%	0%	100%
Manufacturing	55%	26%	9%	10%	0%	100%
Storage	21%	39%	41%	0%	0%	100%
All properties*	50%	32%	11%	4%	3%	100%

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, system is still small and may not be representative. Excludes confined fires and fires where system was present but fire coded as fire too small to test operationality.

Source: NFIRS and NFPA survey

Table 8. (Continued)

Reasons Why Automatic Extinguishing Systems Are Deemed Ineffective When Present in Area of Fire Origin and Fire Was Large enough to Activate system, After Recoding of Errors, by Property Use 1999-2002 Structure Fires (Excluding Confirmed Fires) Reported in NFIRS Version 5.0 to U.S. Fire Departments

B. Sprinklers Only

Property Use	Agent did not reach fire	Not enough agent released	Inappropriate system for type of fire	System component damaged	Manual intervention defeated system	Total
Public assembly	19%	65%	0%	0%	16%	100%
Educational	0%	100%	0%	0%	0%	100%
Health care or correctional	100%	0%	0%	0%	0%	100%
Residential	77%	23%	0%	0%	0%	100%
One- or two-family dwelling	NA	NA	NA	NA	NA	NA
Apartment	81%	19%	0%	0%	0%	100%
Hotel or motel	73%	27%	0%	0%	0%	100%
Store or office	63%	37%	0%	0%	0%	100%
Manufacturing	57%	21%	10%	12%	0%	100%
Storage	27%	50%	23%	0%	0%	100%
Cold storage or other warehouse	0%	100%	0%	0%	0%	100%
All properties*	55%	31%	7%	5%	2%	100%

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

*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. Percents are used without numbers because the fraction of data reported directly in Version 5.0, not converted from Version 4.1, system is still small and may not be representative. Excludes confined fires and fires where system was present but fire coded as fire too small to test operationality.

Source: NFIRS and NFPA survey

Sprinkler Effectiveness in Saving Lives

Table 9 shows that the civilian death rate per 1,000 fires, in 1989-1998, was 86% lower in fires with automatic extinguishing systems (primarily sprinklers) than in fires without them. Because of the problems with unknown presence in Version 5.0 codes, comparable data will not be available until the 2004 NFIRS data is released.

Table 9 indicate sprinklers typically reduce the rate of fire deaths per thousand fires by one-half to three-fourths, if the focus is on the few property classes with a sufficient number of deaths to support meaningful statistics.

The impact of sprinklers on the death rate depends to some degree on how low the basic fire risk is in the property before sprinklers are added. For example, in educational properties, there have been no reported deaths in properties with information on sprinklers for more than a decade. Conversely, in a property class with a comparatively high rate of deaths per 100 fires in the absence of sprinklers, such as hotels and motels, the impact of sprinklers on that death rate (91% in 1989-1998) can translate into a substantial number of lives saved, even with comparatively few fires per year.

If the basic risk is low, the results may be very sensitive to the effects of one major fire. For example, Table 9 seems to show sprinklers as totally effective in protecting life safety in public assembly properties. However, if the calculation had included 1980, statistical projection of the 26 deaths in the 1980 Stouffer's Inn fire in New York would have raised the total estimated number of deaths per year in sprinklered public assembly properties several times. Yet that property had sprinklers only in a stairway, a corridor length away from the origin of the fire, so the high death toll in that fire said little or nothing about the value of sprinklers. These results show that this crude statistical approach is only meaningful for properties with a substantial body of fatal fire experience. Similarly, the office fires shown in Table 9 do not include the Oklahoma City and first World Trade Center bombings.

These figures understate the *potential* value of a properly installed, well-maintained complete sprinkler system. The fires and fire deaths registered as occurring in properties with sprinklers in Table 9 includes cases of partial systems, antiquated systems, systems not designed for the current hazard, systems that had been turned off, and so on. Also, the fires shown are only those reported to fire departments. Sprinklers will control many fires before the fire department is notified, which can paradoxically appear to raise the death rate per thousand fires for the fires that remain to be handled by the fire department. On the other hand, sprinklered properties may tend to be better built and better maintained in terms of all other fire safety and fire protection features. This point alone will tend to mean that sprinklers will receive some credit for life savings that are actually produced by the whole integrated system of balanced fire protection in which sprinklers are an essential part but not the only part. Nevertheless, on balance, the figures in these tables probably reflect the positive impact that sprinklers will have, even with a normal dose of human error in their installation and maintenance and with a fair proportion of partial or outdated installations. The fact that these savings are as large as they are in spite of these considerations is even more evidence of sprinkler effectiveness.

The 2006 editions of *NFPA 1, Uniform Fire Code™, NFPA 101®, Life Safety Code,* and *NFPA 5000®, Building Construction and Safety Code,* require sprinklers in all new one- and two-family dwellings, all nursing homes, and many nightclubs. This protection can be expected to increase in areas that adopt and follow these revised codes.

Preventing Large Loss-of-Life Incidents

For the past decade at least, NFPA's principal statistic on sprinkler effectiveness has drawn attention to the ability of properly installed and maintained sprinklers to prevent deaths outside the area of fire origin in all but a few unusual situations:

> NFPA has no record of a fire killing more than two people in a completely sprinklered building where the system was properly operating, except in an explosion or flash fire or where industrial fire brigade members or employees were killed during fire suppression operations.

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

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

These two statements compress a number of points into a small number of words, so it is useful to review the key elements, see what these statements do and do not say, and use these results to point to the value of other measures of sprinkler effectiveness that might supplement the ones just given.

First, the statement's limitation to fires killing more than two people is linked to the fact that sprinkler systems (and all other fire protection systems and features) cannot be expected to prevent fatal fire injuries inflicted on someone very close to the starting point of a rapidly developing fire. Even fires involving cigarettes discarded onto mattresses, bedding, or clothing may cause fatal injury faster than a sprinkler can react. On the other hand, people worry most about the large fires starting in remote locations that grow large enough to threaten people throughout a large building, and these are precisely the fire risks that NFPA's statement addresses. At the same time, most fire deaths - even outside the home - occur in ones and twos. From another angle, then, this statement addresses only fatal fire scenarios (the fires that kill more than two persons) that are comparatively rare even in unsprinklered properties. Seen in this way, the statements do not say anything about the substantial impact of sprinklers on the risk of death in what would have been one- and two-death fires. That is a reason for developing new measures of sprinkler effectiveness that do address those benefits.

Second, the statement leaves open the possibility that no multiple-death fires have been recorded under these circumstances because few properties have complete sprinkler systems. In fact, because most properties do not have any sprinkler system, it is also true that most properties do not have complete sprinkler systems. That is a good reason for trying to develop sprinkler

effectiveness statistics that separate their impact on risk from their breadth of use, as is done later. At the same time, Table 1 showed that in some property classes, sprinklers are now more the rule than the exception. For these property classes, the absence of multiple-death incidents is a clear testament to the value of sprinklers.

Third, 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.

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

Who Dies When Sprinklers Are Present?

A second report from NIST provided a particularly concise description of the kinds of fire scenarios that account for the deaths that would still occur even if operational detector and sprinkler systems, designed to current codes, were in universal use in homes:

- Fires that begin so close to a victim that he or she could be described as being intimate with the ignition of the fire.
- Fires that begin in combustibles in a concealed space.
- Some fires with substantial smoldering periods in the same room with a victim who is immobile (e.g., bedridden or incapacitated by drugs or alcohol) and has no prospects for quick rescue.
- Some fast-flaming fires that begin in locations shielded from the sprinkler.

The majority of these deaths that would occur even with universal use of current smoke alarm and sprinkler technology probably would be of the first type - victims intimate with ignition.

Sprinklers in Homes

The discussion in the previous section suggested that the higher the fire death rate is in the absence of sprinklers, the greater the percentage reduction in fire death rate due to sprinklers is likely to be. That is another reason to be especially optimistic about the potential impact of the current residential sprinkler technology in homes, where the overall fire death rate per thousand fires where sprinklers were not present is still much higher (9.4 in 1989-1998 and still 8.1 in 2004) than in most of the other property classes already discussed. But that potential will be realized only if Americans can be convinced of their value. As Table 1 showed, sprinkler usage in homes that have fires is extremely rare. At the same time, home fires are so much more numerous than other structure fires that it is also true that nearly one-quarter of all reported 1998 fires in sprinklered buildings occurred in homes and dwelling garages.

Analysts at the National Institute of Standards and Technology (NIST) conducted an analysis of the estimated impact of sprinklers on home fires and associated losses, using laboratory test data, estimates from panels of fire researchers, and statistics on the relative frequency of various fire scenarios and of the proximity of victims to those fires. Table 10 summarizes those results for one- and two-family dwellings. The key result is a 63-69% reduction in the death rate per thousand fires if sprinklers are added to dwellings that do or do not already have smoke alarms, respectively.

Despite the extremely low proportion of fires in homes showing sprinklers present, the number of such fires is large enough to permit an estimate of their impact. In 1989-1998 there was a 74% reduction in deaths per thousand fires, based on 16 deaths in 6,700 fires with sprinklers present and 2,996 deaths in 319,700 fires with no sprinklers. This figure is close to the NIST estimates, but in our analysis, "homes" include apartments and townhouses, which the NIST analysis did not include.

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

The same NIST study estimated that, as a result of poor installation or maintenance, the sprinkler system would not operate effectively 8% of the time, while the smoke alarms would not operate effectively 15% of the time. Later studies by NFPA have indicated that home smoke alarms actually are non-operational in about 25% of the reported fires.*

This means good installation and maintenance practices are likely to need close attention for sprinklers as well. It suggests that the analysts at NIST may have been too optimistic about the

operational status of sprinklers, too, so their estimates of the impact of both systems may be overstated. Or, it could mean that a home sprinkler system, which is designed to need only minor maintenance, will have even more impact than estimated because the unexpectedly high rate of non-operational smoke alarms leaves more people needing to be saved by something else, like sprinklers.

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

*Marty Ahrens, *U.S. Experience With Smoke Alarms*, Quincy, MA: NFPA Fire Analysis and Research Division, November 2004.

Table 9.
Estimated Reduction in Civilian Deaths per Thousand Fires Due to Sprinklers by Property Use, 1989-1998 Structure Fires Reported to U.S. Fire Departments

Property Use	Without Sprinklers	With Sprinklers	Percent Reduction
Public assembly properties	**0.8**	**0.0***	**100%**
Eating and drinking facilities	0.8	0.0*	100%
Educational properties	**0.0***	**0.0***	**N/A**
Health care facilities	**4.9**	**1.2**	**75%**
Care of aged facilities	7.1	1.7	76%
Care of sick facilities	2.7	0.7	74%
Residential properties	**9.4**	**2.1**	**78%**
One- and two-family dwellings	9.7	4.7	51%
Apartments	8.2	1.6	81%
Hotels and motels	9.1	0.8*	91%
Dormitories and barracks	1.5	0.0*	100%
Stores and offices	**1.0**	**0.3***	**74%**
Food or beverage store	1.2	0.0*	100%
Department store	1.2*	0.0*	100%
General office building	0.6*	0.0*	100%
Industrial facilities	**1.1**	**0.0***	**100%**
Manufacturing facilities	**2.0**	**0.8**	**60%**
Storage facilities	**1.0**	**0.0***	**100%**
Total	**7.6**	**1.1**	**86%**

*Based on fewer than two deaths per year in the ten-year period. Results may not be significant.

Note: These 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. Fire statistics do not include proportional shares of fires with sprinkler status unknown or unreported.

Source: NFIRS and NFPA survey.

Table 10.
Estimated Impact of Residential Sprinkler System in One- and Two-Family Dwellings

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

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

Sprinkler Effectiveness in Protecting Property

Table 11 shows that sprinklers typically cut the average loss by one half to two-thirds, although the estimated impact for particular property classes was as low as 19% and as high as 88%. Public assembly, educational, most manufacturing, and health care and correctional properties show the largest reductions in Table 11, while the reduction is notably lower, but still substantial, for residential (except hotel and motel) and office properties.

The property use classes shown in Table 11 are limited to those with significant numbers of fires in sprinklered properties, based on Table 1. This is necessary to produce reasonably stable statistical estimates. Even so, the disproportional influence of some large-loss fires can misleadingly inflate or shrink the measure of sprinkler impact on loss. Also, sprinklers will control or extinguish many fires so quickly that fire departments will not need to be notified, which may increase the loss per fire in sprinklered-property fires seen by fire departments.

The percentage reductions shown in Table 11 almost certainly understate the actual impact of a properly designed and maintained complete sprinkler system. The "with sprinklers" column includes an unknown number of properties with partial, antiquated, or poorly maintained sprinkler systems.

Ideally, one would like to compare loss per fire, with and without sprinklers, in comparable fires. Sprinklered properties may tend to be larger and may contain more valuable contents (which means a higher potential loss per fire).

Sprinklered properties also may tend to be handled with greater attention to all other aspects of fire safety than is seen in unsprinklered properties (which means some of the reduced loss per fire is due to the larger fire protection system of which sprinklers are part). These points also apply to sprinkler effectiveness in saving lives.

Table 11 also shows three types of high-rise buildings separately. As noted earlier in Table 1, high-rise apartment buildings, hotels, and general office buildings are much more likely than their shorter counterparts to report sprinklers present when they report fires. However, Table 11 shows that the estimated impact of sprinklers is not substantially higher or lower in high-rise apartment buildings or general office buildings than it is in those properties generally.

Table 11.

Estimated Reduction in Average Direct Property Damage per Fire Due to Sprinklers by Property Use, 1989-1998 Structure Fires Reported to U.S. Fire Departments

Property Use	Without Sprinklers	With Sprinklers	Percent Reduction
Public assembly properties	**$21,600**	**$6,500**	**70%**
Eating and drinking establishments	$17,200	$5,900	66%
Educational properties	**$13,900**	**$4,400**	**68%**
Health care and correctional facilities	**$4,700**	**$1,700**	**64%**
Health care facilities*	$4,000	$1,600	59%
Residential properties	**$9,400**	**$5,400**	**42%**
One- and two-family dwellings	$9,600	$7,800	19%
All apartments	$8,500	$4,400	49%
Apartments at least 7 stories tall	$3,200	$1,800	43%
All hotels and motels	$13,400	$5,900	56%
Hotels and motels at least 7 stories tall	$13,400	$4,500	67%
Dormitories and barracks	$7,400	$4,700	36%
Stores and offices	**$24,400**	**$12,200**	**50%**
Food or beverage stores	$21,000	$6,500	69%
Department stores	$36,900	$14,900	60%
Offices	$22,700	$10,100	55%
All general office buildings	$23,100	$10,800	53%
General office buildings at least 7 stories tall	$27,700	$13,000	53%
Manufacturing properties	**$50,200**	**$16,700**	**67%**
Food product manufacturers	$66,100	$23,300	65%
Textile product manufacturers	$23,100	$12,000	48%
Footwear or wearing apparel manufacturers	$137,500	$16,500	88%
Wood product manufacturers	$47,700	$14,100	70%
Chemical product manufacturers	$60,700	$24,900	59%
Metal product manufacturers	$45,800	$15,000	67%
Vehicle assembly manufacturers	$45,400	$21,600	52%
Other manufacturers	$39,900	$15,400	61%

*Refers to care of aged and care of sick facilities only.

These are fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Fire statistics do not include proportional shares of fires with sprinkler status unknown or unreported. Direct property damage is estimated to the nearest hundred dollars.

Source: National estimates based on 1989-1998 NFIRS and NFPA Survey.

Sprinkler Effectiveness in Containing Fires

Fire confinement measures are intended to more clearly define "success" and "failure" in engineering terms than loss-based measures do. Moreover, the fire confinement measures focus on the type of confinement sprinklers are designed to achieve, thereby more closely aligning the measure of sprinkler performance (confinement to a defined space) with a criterion of achievement of design goals (typically called "fire control").

Table 12 shows the extent of flame damage in sprinklered structure fires in 1989-1998. Because of the problems with unknown presence in Version 5.0 codes, comparable data will not be available until the 2004 NFIRS data is released.

Table 12.

Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

A. Public Assembly Properties

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	2,080	(69%)	4,790	(48%)
Confined to area of origin	610	(20%)	2,200	(22%)
Confined to room of origin	150	(5%)	770	(8%)
Confined to fire-rated compartment of origin	20	(1%)	90	(1%)
Confined to floor of origin	20	(1%)	250	(2%)
Confined to structure of origin	110	(4%)	1,710	(17%)
Extended beyond structure of origin	10	(0%)	230	(2%)
Total	3,000	(100%)	10,040	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

B. Educational Properties

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	840	(72%)	2,560	(60%)
Confined to area of origin	230	(20%)	950	(22%)
Confined to room of origin	70	(6%)	350	(8%)
Confined to fire-rated compartment of origin	10	(1%)	20	(0%)
Confined to floor of origin	10	(1%)	60	(1%)
Confined to structure of origin	20	(2%)	260	(6%)
Extended beyond structure of origin	0	(0%)	50	(1%)
Total	1,170	(100%)	4,250	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

C. Health Care or Correctional Properties

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	3,410	(81%)	2,780	(70%)
Confined to area of origin	540	(13%)	750	(19%)
Confined to room of origin	170	(4%)	250	(6%)
Confined to fire-rated compartment of origin	20	(0%)	20	(1%)
Confined to floor of origin	20	(0%)	50	(1%)
Confined to structure of origin	30	(1%)	120	(3%)
Extended beyond structure of origin	0	(0%)	10	(0%)
Total	4,190	(100%)	3,980	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

D. Residential Properties

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	5,780	(66%)	129,130	(40%)
Confined to area of origin	1,780	(20%)	74,490	(23%)
Confined to room of origin	580	(7%)	34,610	(11%)
Confined to fire-rated compartment of origin	130	(1%)	3,580	(1%)
Confined to floor of origin	140	(2%)	13,700	(4%)
Confined to structure of origin	290	(3%)	61,540	(19%)
Extended beyond structure of origin	50	(1%)	9,810	(3%)
Total	8,750	(100%)	326,860	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

E. One- or Two-Family Dwellings

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	900	(53%)	93,230	(37%)
Confined to area of origin	370	(22%)	55,450	(22%)
Confined to room of origin	140	(8%)	25,810	(10%)
Confined to fire-rated compartment of origin	30	(2%)	2,030	(1%)
Confined to floor of origin	60	(4%)	10,330	(4%)
Confined to structure of origin	160	(9%)	53,390	(21%)
Extended beyond structure of origin	30	(2%)	8,390	(3%)
Total	1,690	(100%)	248,630	(100%)

These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table. One- and two-family dwellings are a subset of residential properties.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

F. Apartments

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	3,450	(69%)	32,830	(46%)
Confined to area of origin	990	(20%)	17,510	(25%)
Confined to room of origin	310	(6%)	7,970	(11%)
Confined to fire-rated compartment of origin	80	(2%)	1,480	(2%)
Confined to floor of origin	60	(1%)	3,150	(4%)
Confined to structure of origin	100	(2%)	6,950	(10%)
Extended beyond structure of origin	20	(0%)	1,150	(2%)
Total	5,000	(100%)	71,040	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table. Apartments are a subset of residential properties.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

G. Hotels and Motels

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	900	(70%)	1,150	(44%)
Confined to area of origin	260	(20%)	640	(24%)
Confined to room of origin	90	(7%)	390	(15%)
Confined to fire-rated compartment of origin	10	(1%)	40	(2%)
Confined to floor of origin	10	(1%)	90	(3%)
Confined to structure of origin	20	(2%)	280	(11%)
Extended beyond structure of origin	0	(0%)	40	(2%)
Total	1,290	(100%)	2,640	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table. Hotels and motels are a subset of residential properties.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

H. Stores

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	1,720	(60%)	4,790	(41%)
Confined to area of origin	780	(27%)	2,580	(22%)
Confined to room of origin	190	(7%)	950	(8%)
Confined to fire-rated compartment of origin	30	(1%)	140	(1%)
Confined to floor of origin	30	(1%)	280	(2%)
Confined to structure of origin	100	(3%)	2,470	(21%)
Extended beyond structure of origin	20	(1%)	580	(5%)
Total	2,870	(100%)	11,790	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

I. Offices

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	730	(68%)	1,570	(47%)
Confined to area of origin	230	(21%)	760	(23%)
Confined to room of origin	60	(6%)	270	(8%)
Confined to fire-rated compartment of origin	10	(1%)	40	(1%)
Confined to floor of origin	10	(1%)	120	(4%)
Confined to structure of origin	20	(2%)	500	(15%)
Extended beyond structure of origin	0	(0%)	80	(2%)
Total	1,070	(100%)	3,350	(100%)

Note: These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

J. Manufacturing Facilities

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	3,040	(61%)	2,280	(45%)
Confined to area of origin	1,160	(23%)	1,070	(21%)
Confined to room of origin	330	(7%)	380	(8%)
Confined to fire-rated compartment of origin	50	(1%)	60	(1%)
Confined to floor of origin	70	(1%)	90	(2%)
Confined to structure of origin	290	(6%)	950	(19%)
Extended beyond structure of origin	40	(1%)	190	(4%)
Total	4,980	(100%)	5,030	(100%)

These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Table 12. (Continued)
Extent of Flame Damage, by Sprinkler Presence
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

K. Storage Facilities

Extent of Flame Damage	With Sprinklers		Without Sprinklers	
Confined to object of origin	450	(50%)	5,840	(20%)
Confined to area of origin	250	(28%)	4,150	(14%)
Confined to room of origin	60	(7%)	1,450	(5%)
Confined to fire-rated compartment of origin	10	(1%)	180	(1%)
Confined to floor of origin	20	(2%)	320	(1%)
Confined to structure of origin	90	(10%)	13,200	(45%)
Extended beyond structure of origin	20	(2%)	4,190	(14%)
Total	900	(100%)	29,330	(100%)

These 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. Fires in which the extent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors. Fires in which sprinkler performance was unclassified, unknown or not reported are not included in this table.

Source: NFIRS and NFPA Survey.

Other Issues

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

The truth is that sprinkler systems are carefully designed to activate early in a real fire but not to activate in a non-fire situation. Each sprinkler reacts only to the fire conditions in its area. Water release in a fire is generally much less than would occur if the fire department had to suppress the fire, because later action means more fire, which means more water is needed. According to a 15-year study done in Scottsdale, Arizona, on average, a fire sprinkler will use 25 gallons of water per minute to control a home fire opposed to the estimated 250 gallons that is used by firefighters which equals 8 ½-15 times more water used than a sprinkler system.*

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 accidental water release involving other parts of a building's plumbing and water supply, which tend to be both more frequent and more costly per incident.** Maryatt's study of sprinklers in Australia and New Zealand found water damage from non-fire accidental discharges added only 25% to the fire losses suffered by sprinklered buildings.*** Because fire losses average one-half to two-thirds lower in sprinklered properties, as noted, total fire and water damage is much lower in sprinklered properties. Prevention of non-fire water damage from sprinklers involves the same safety rules as one uses for the other elements of building fire protection.

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

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

Many people are not aware how much the cost of sprinkler systems and the cost of installing them have been reduced in recent years as a result of continued innovation in the industry. Particularly for new construction, a complete sprinkler system may add only 1-2% to total cost.

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

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

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

Automatic Extinguishing Systems versus Other Methods of Extinguishment

Table 13 examines the mechanism by which the fire was extinguished, by property use. Automatic systems rank fairly low, but this table addresses only the means used to fully extinguish the fire. Automatic systems may have contained or controlled a fire later extinguished by fire department hose lines.

Table 13 shows that many fires are put out with a portable extinguisher. However, the data cannot distinguish whether the portable extinguisher was used by the occupant or the fire department. Homes, industrial properties (including mines and some other structures that are not buildings), and storage properties had the smallest shares of fires extinguished by portable extinguishers. This is probably because proportionally fewer of these properties are equipped with portable extinguishers and proportionally fewer of these occupants are trained to operate an extinguisher effectively.

Every property class showed less than 10% of fires extinguished by sprinklers, and only manufacturing properties showed more than 5%. However, sprinklers are normally expected to control fires, not to extinguish them, so these low percentages do not mean either low sprinkler usage or poor sprinkler performance.

Data for 1999 and later are not provided because method of extinguishment is no longer being collected in Version 5.0 of NFIRS.

Table 13.
Method of Extinguishment
Annual Average of 1989-1998 Fires Reported to U.S. Fire Departments
Unknowns Proportionally Allocated

Method of Extinguishment	All Properties	Public Assembly	Educational	Health Care or Correctional
Pre-connected hose line with water from apparatus tanks	188,300	4,300	1,200	1,000
Pre-connected hose line with water from hydrant, draft or standpipe	98,200	2,200	500	400
Make-shift aids (e.g., garden hoses, sand, baking soda)	89,000	1,500	1,300	1,900
Fire self-extinguished	87,500	2,500	1,800	2,900
Portable extinguisher	76,100	5,000	2,300	3,600
Hand-laid hose line with water from standpipe, hydrant or draft	27,800	600	100	100
Automatic suppression system	***5,300***	***800***	***100***	***500***
Master stream device used	4,200	200	0	0
Method not classified	15,500	400	200	400
Total	591,800	17,700	7,700	10,800
Percent of fires extinguished by automatic suppression system	(0.9%)	(4.5%)	(1.3%)	(4.6%)

Note: These 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. Fires are estimated to the nearest hundred. Sums may not equal total due to rounding errors.

Source: NFIRS and NFPA survey.

Table 13. (Continued)
Method of Extinguishment
Annual Average of 1989-1998 Fires Reported to U.S. Fire Departments
Unknowns Proportionally Allocated

Method of Extinguishment	All Residential	One- and Two-Family Dwellings	Apartments	Hotels and Motels	Stores
Pre-connected hose line with water from apparatus tanks	134,800	105,300	19,300	1,300	5,900
Pre-connected hose line with water from hydrant, draft or standpipe	70,900	52,300	13,900	600	3,400
Make-shift aids (e.g., garden hoses, sand, baking soda)	79,800	51,200	23,900	800	1,400
Fire self-extinguished	73,100	48,300	20,000	900	2,800
Portable extinguisher	55,300	35,100	15,700	1,400	3,900
Hand-laid hose line with water from standpipe, hydrant or draft	18,500	12,400	4,900	200	1,100
Automatic suppression system	***1,700***	***300***	***1,000***	***200***	***600***
Master stream device used	2,000	1,100	700	0	400
Method not classified	12,900	8,800	3,200	200	500
Total	449,000	333,700	102,700	5,600	19,900
Percent of fires extinguished by automatic suppression system	(0.4%)	(0.1%)	(1.0%)	(3.6%)	(3.0%)

Note: These 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. Fires are estimated to the nearest hundred. Sums may not equal total due to rounding errors.

Source: NFIRS and NFPA survey.

Table 13. (Continued)
Method of Extinguishment
Annual Average of 1989-1998 Fires Reported to U.S. Fire Departments
Unknowns Proportionally Allocated

Method of Extinguishment	Offices	Industrial	Manufacturing	Storage
Pre-connected hose line with water from apparatus tanks	1,300	2,300	3,500	14,100
Pre-connected hose line with water from hydrant, draft or standpipe	900	500	2,600	4,000
Make-shift aids (e.g., garden hoses, sand, baking soda)	600	200	700	800
Fire self-extinguished	1,700	400	1,000	1,100
Portable extinguisher	1,300	400	2,900	900
Hand-laid hose line with water from standpipe, hydrant or draft	200	300	900	1,700
Automatic suppression system	***200***	***100***	***1,300***	***300***
Master stream device used	100	100	200	200
Method not classified	200	100	300	400
Total	6,500	4,400	13,400	23,400
Percent of fires extinguished by automatic suppression system	(3.1%)	(2.3%)	(9.7%)	(0.9%)

These 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. Fires are estimated to the nearest hundred. Sums may not equal total due to rounding errors.

Source: NFIRS and NFPA survey.
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Other Resources

Research

NASFM Sprinkler Activation Project

The Residential Sprinkler Activation Project is a cooperative undertaking between the US Fire Administration, the National Institute of Standards and Technology (NIST), and the National Association of State Fire Marshals (NASFM). The purpose is to gather current and relevant data regarding residential sprinkler activations. It is anticipated that this data will demonstrate the effectiveness of sprinklers, be useful in offsetting objections to sprinklers, and provide valuable reference material for the fire code process.

http://www.firemarshals.org/

Prince George's County Sprinkler Research Project

NFPA has been working with Prince George's County since March, 2004, on data collection as part of a project funded by National Fire Sprinkler Association, intended to provide a sounder statistical basis for characterizing sprinkler performance. The first phase of this project (2002-2003) was to determine what data existed in fire department records and with sprinkler industry sources in Prince George's County and to make recommendations for how that information might be improved. Phase 2 (2004-2005) was designed to test the quality, sufficiency, and completeness of data on sprinkler performance that can be collected in the field using the instruments and procedures developed in Phase 1. A final report on the findings will be available in the Fall of 2005.

Free Scottsdale Report Available Online

In Scottsdale, AZ, the community has recognized the importance of sprinklers and has implemented a highly successful residential sprinkler program, with over 40,000 homes with sprinklers. After 15-years of requiring all new homes built in Scottsdale, Ariz. to have a residential fire sprinkler system, data collected by the local fire department indicates that 13 lives were saved and more than $20 million in property loss was prevented. This report is now available for free on the Home Fire Sprinkler Coalition (HFSC) website.

http://www.homefiresprinkler.org/hfsc.html

Initiatives

The Home Fire Sprinkler Coalition

The Home Fire Sprinkler Coalition (HFSC) provides independent information about the life and property saving benefits of home fire sprinklers. For more information, call 1-888-635-7222. www.homefiresprinkler.org

USFA National Residential Fire Sprinkler Initiative

The United States Fire Administration (USFA) released a report that outlines an agreement between the administration and national fire protection professionals advocating the use of fire suppression and sprinkler systems. The report, titled *National Residential Fire Sprinkler Initiative*, outlines specific national strategies that might reduce the number of deaths due to home fires each year. In particular, the report draws attention to the aspect of localized fire suppression in high-risk areas of the home and residential sprinklers in buildings supported by the federal government. http://www.usfa.fema.gov/inside-usfa/media/2003releases/03-071503.shtm

Fire Sprinkler Incentive Act

This proposed legislation was introduced in 2005 to the U.S. House and Senate in parallel. The bill would provide a substantial tax benefit to building owners who install or retrofit their properties with fire sprinkler systems. The bill would amend the 1986 Internal Revenue Code to classify automatic fire sprinkler systems as "five year property" for the purpose of depreciation.

NFPA supports this legislation. Details on this legislation may be found at http://www.sprinklernet.org/committees/legiscom/bills/FSIA.html

Online Resources

The National Fire Sprinkler Association

The National Fire Sprinkler Association (NFSA) is an organization dedicated to creating a market for the widespread acceptance of competently installed automatic fire sprinkler systems in both new and existing construction, from homes to high rise. www.nfsa.org

The American Fire Sprinkler Association

The American Fire Sprinkler Association (AFSA) is a non-profit, international association representing open shop fire sprinkler contractors, dedicated to the educational advancement of its members and promotion of the use of automatic fire sprinkler systems. www.sprinklernet.org

Concluding Points

1. Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. When sprinklers are present, the chances of dying in a fire are reduced by one-half to three-fourths, and the average property loss per fire is cut by one-half to two-thirds, compared to fires where sprinklers are not present. What's more, this simple comparison understates the potential value of sprinklers because it lumps together all sprinklers, regardless of type, coverage, or operational status, and is limited to fires reported to fire departments. If unreported fires could be included and if complete, well maintained, and properly installed and designed systems could be isolated, sprinkler effectiveness would be seen as even more impressive.

2. Excluding fires too small to activate a sprinkler and fires not located in an area covered by sprinklers, sprinklers failed to operate in 7% of reported structure fires. Two-thirds of these failures occurred because the system had been shut off, and most of the other failures also involved some type of human error, e.g., failure to maintain the system, failure to keep the system appropriate to the hazard, or failure to provide for other aspects of building fire protection.

3. There are certain fire situations where even a complete sprinkler system will have limited impact: (a) Explosions and flash fires that may overpower the system; (b) Fires that begin very close to a person (e.g., clothing ignition) or unusually sensitive and expensive property (e.g., an art gallery) where fatal injury or substantial property loss can occur before sprinklers can react; and (c) Fires that originate in unsprinklered areas (e.g., concealed wall spaces) or adjacent properties (e.g., exposure fires), which may grow to unmanageable size outside the range of the sprinkler system.

There is reason to believe that the importance of sprinklers in concealed ceiling spaces with combustibles is not universally recognized, even though it has been a code requirement for many years. Judging by fire reports available to NFPA, some "complete" systems omit these areas.

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

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

It is important for all concerned parties to (a) distinguish between human and mechanical problems because they require different strategies; (b) include both as concerns to be

addressed when deciding when and how to install, maintain, and rely on sprinklers and other automatic extinguishing systems; (c) strive to use performance analysis in assessing any other element of fire protection; and (d) remember that the different elements of fire protection support and reinforce one another and so must always be designed and considered as a system.

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

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

Appendix A: How National Estimates Statistics Are Calculated

Estimates are made using the National Fire Incident Reporting System (NFIRS) of the Federal Emergency Management Agency's (FEMA's) United States Fire Administration (USFA), supplemented by the annual stratified random-sample survey of fire experience conducted by the National Fire Protection Association (NFPA), which is used for calibration.

Data Bases Used

NFIRS provides annual computerized data bases of fire incidents, with data classified according to a standard format based on the NFPA 901 Standard. Roughly three-fourths of all states have NFIRS coordinators, who receive fire incident data from participating fire departments and combine the data into a state data base. These data are then transmitted to FEMA/USFA. Participation by the states, and by local fire departments within participating states, is voluntary. NFIRS captures roughly one-third to one-half of all U.S. fires each year. More than one-third of all U.S. fire departments are listed as participants in NFIRS, although not all of these departments provide data every year. Additional information about NFIRS can be found at http://www.nfirs.fema.gov.

The strength of NFIRS is that it provides the most detailed incident information of any national data base not limited to large fires. NFIRS is the only data base capable of addressing national patterns for fires of all sizes by specific property use and specific fire cause. (The NFPA survey separates fewer than 20 of the hundreds of property use categories defined by NFPA 901 and solicits no cause-related information except for incendiary and suspicious fires.) NFIRS also captures information on the avenues and extent of flame spread and smoke spread and on the performance of detectors and sprinklers.

The NFPA survey is based on a stratified random sample of roughly 3,000 U.S. fire departments (or just over one of every ten fire departments in the country). The survey includes the following information: (1) the total number of fire incidents, civilian deaths, and civilian injuries, and the total estimated property damage (in dollars), for each of the major property use classes defined by the NFPA 901 Standard; (2) the number of on-duty firefighter injuries, by type of duty and nature of illness; and (3) information on the type of community protected (e.g., county versus township versus city) and the size of the population protected, which is used in the statistical formula for projecting national totals from sample results.

The NFPA survey begins with the NFPA Fire Service Inventory, a computerized file of about 30,000 U.S. fire departments, which is the most complete and thoroughly validated such listing in existence. The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities protect fewer people per department and are less likely to respond to the survey, so a large number must be surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did

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

Projecting NFIRS to National Estimates

To project NFIRS results to national estimates, one needs at least an estimate of the NFIRS fires as a fraction of the total so that the fraction can be inverted and used as a multiplier or scaling ratio to generate national estimates from NFIRS data. But NFIRS is a sample from a universe whose size cannot be inferred from NFIRS alone. Also, participation rates in NFIRS are not necessarily uniform across regions and sizes of community, both of which are 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 data base - 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.

There are separate projection formulas for four major property classes (residential structures, non-residential structures, vehicles, and other) and for each measure of fire severity (fire incidents, civilian deaths, and civilian injuries, and direct property damage).

For example, the scaling ratio for 2002 civilian deaths in residential structures is equal to the total number of 2002 civilian deaths in residential structure fires reported to fire departments, according to the NFPA survey (2,695), divided by the total number of 2002 civilian deaths in residential structure fires reported to NFIRS (1,029). Therefore, the scaling ratio is 2,695/1,029 = 2.62.

The scaling ratios for civilian deaths and injuries and direct property damage are often significantly different from those for fire incidents. Except for fire service injuries, average severity per fire is generally higher for NFIRS than for the NFPA survey. Use of different scaling ratios for each measure of severity is equivalent to assuming that these differences are due either to NFIRS under-reporting of small fires, resulting in a higher-than-actual loss-per-fire ratio, or possible biases in the NFIRS sample representation by region or size of community, resulting in severity-per-fire ratios characteristic only of the oversampled regions or community sizes.

Note that this approach also means that the NFPA survey results for detailed property-use classes (e.g., fires in storage structures) may not match the national estimates of the same value.

Calculating National Estimates of Particular Types of Fires

Most analyses of interest involve the calculation of the estimated number of fires not only within a particular occupancy but also of a particular type. The types that are mostly frequently of interest are those defined by some ignition-cause characteristic. The six cause-related characteristics most commonly used to describe fires are: form of the heat that caused the ignition, equipment involved in ignition, form or type of material first ignited, the ignition factor that brought heat source and ignited material together, and area of origin. Other characteristics of interest are victim characteristics, such as ages of persons killed or injured in fire.

For any characteristic of interest in NFIRS, some reported fires have that characteristic unknown or not reported. If the unknowns are not taken into account, then the propensity to report or not report a characteristic may influence the results far more than the actual patterns on that characteristic. For example, suppose the number of fires remained the same for several consecutive years, but the percentage of fires with cause unreported steadily declined over those years. If the unknown-cause fires were ignored, it would appear as if fires due to every specific cause increased over time while total fires remained unchanged. This, of course, does not make sense.

Consequently, most national estimates analyses allocate unknowns. This is done by using scaling ratios defined by NFPA survey estimates of totals divided by only those NFIRS fires for which the dimension in question was known and reported. This approach is equivalent to assuming that the fires with unreported characteristics, if known, would show the same proportions as the fires with known characteristics. For example, it assumes that the fires with unknown ignition factor contain the same relative shares of child-playing fires, incendiary-cause fires, short circuit fires, and so forth, as are found in the fires where ignition factor was reported.

Rounding Errors

The possibility of rounding errors exists in all our calculations. One of the notes on each table indicates the extent of rounding for that table, e.g., deaths rounded to the nearest one, fires rounded to the nearest hundred, property damage rounded to the nearest hundred thousand dollars. In rounding to the nearest one, functional values of 0.5 or more are rounded up and functional values less than 0.5 are rounded down. For example, 2.5 would round to 3, and 3.4 would round to 3. In rounding to the nearest one, a stated estimate of 1 could be any number from 0.5 to 1.49, a roughly threefold range.

The impact of rounding is greatest when the stated number is small relative to the degree of rounding. As noted, rounding to the nearest one means that stated values of 1 may vary by a factor of three. Similarly, the cumulative impact of rounding error - the potential gap between the estimated total and the sum of the estimated values as rounded - is greatest when there are a large number of values and the total is small relative to the extent of rounding.

Suppose a table presented 5-year averages of estimated deaths by item first ignited, all rounded to the nearest one. Suppose there were a total of 30 deaths in the 5 years, so the total average would be 30/5 = 6.

In case 1, suppose 10 of the possible items first ignited each accounted for 3 deaths in 5 years. Then there would be 10 entries of 3/5 = 0.6, rounded to 1, and the sum would be 10, compared to the true total of 6.

In case 2, suppose 15 of the possible items first ignited each accounted for 2 deaths in 5 years. Then there would be 15 entries of 215 = 0.4, rounded to 0, and the sum would be 0, compared to the true total of 6.

Here is another example: Suppose there were an estimate of 7 deaths total in 1992 through 1996. The 5-year average would be 1.4, which would round to 1, the number we would show as the total. Each death would represent a 5-year average of 0.2.

If those 7 deaths split as 4 deaths in one category (e.g., smoking) and 3 deaths in a second category (e.g., heating), then we would show 4 x 0.2 = 0.8 deaths per year for smoking and 3 x 0.2 = 0.6 deaths per year for heating. Both would round to 1, there would be two entries of 1, and the sum would be 2, higher than the actual rounded total.

If those 7 deaths split as 1 death in each of 7 categories (quite possible since there are 12 major cause categories), then we would show 0.2 in each category, always rounding to 0, and the sum would be 0, lower than the actual rounded total. The more categories there are, the farther apart the sum and total can -- and often do -- get.

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

Appendix B: Sprinkler-Related Data Elements in NFIRS 5.0

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 origin 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

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