U.S. EXPERIENCE WITH SPRINKLERS

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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 and the average property loss per fire are both 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.

In 1999, there were a number of useful changes to the coding of automatic suppression equipment performance in the NFIRS database, but these changes required most reported data to be converted from the old Version 4.1 to the new Version 5.0. Some of the conversions were problematic, and so this report does not combine1999 data with previous data and uses the period ending in 1998 for any multi-year analyses.

When measured by the average number of civilian deaths per thousand fires in 1989-1998 (and with the limitations cited above), 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 above), 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).

When sprinklers do not produce satisfactory results, the reasons usually involve one or more of the following: (1) partial, antiquated, poorly maintained, or inappropriate systems; (2) explosions or flash fires that overpower the system before it can react; or (3) fires very close to people or to sensitive, valuable property such that fatal injury or expensive damage, respectively, can occur before a system can react. "Poor maintenance" refers primarily to the problem of valves being shut off and inadvertently left shut off. "Inappropriate" systems are systems whose design is not adequate for the current level of hazard in the building.

Except for health care facilities, hotels and motels, department stores, and high-rise general office buildings, sprinkler usage is still rare in properties with large potential for life loss. While the public may hear more about the spectacular fires in office buildings or places of public assembly, the truth is that the most dangerous place to be, with respect to fire, is in the home.

Most of our statistics capture only sprinkler usage in properties that have fires reported to fire departments, so they will tend to understate sprinkler usage. For example, an industry-sponsored survey 11 years earlier, in 1988, showed sprinklers already in guest rooms of 45% of hotels and motels, while only 29.0% of hotel and motel fires showed sprinklers present. In 1999, only 49.1% of reported hotel and motel fires were shown as occurring in properties with automatic suppression equipment, which suggests that actual usage of sprinklers in hotels and motels, not limited to those that have fires, may be up to 60-70%.

The highest levels of sprinkler usage in other high-occupancy properties appear to be in health care facilities that care for the sick or aged (77.6% of 1999 fires reported as occurring in facilities with automatic suppression equipment). High levels of usage also probably exist in manufacturing properties (61.9%) and department stores (60.4%), based on the percentages of fires in sprinklered properties. However, sprinklers were cited in only 35.4% of reported fires in educational properties, 34.3% of fires in public assembly properties, 30.2% of fires in stores and offices, 28.5% of fires in correctional facilities, 12.9% of fires in apartments, and 3.4% of fires in dwellings and duplexes.

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.

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Introduction

Most of what we know about national trends and patterns, whether it be characteristics of fire, the method of extinguishment, or the usage and effectiveness of sprinklers, comes from the National Fire Incident Reporting System (NFIRS), the most detailed of the representative, national fire incident data bases. In terms of sprinklers, NFIRS Version 4.1 groups all automatic suppression equipment together and does not distinguish systems by type or extent of coverage. Therefore, it is important to keep in mind throughout this report that in most cases the statistics provided here are for all automatic suppression equipment combined - partial or complete; water-based, Halon, carbon dioxide, or dry chemical; operational or turned-off; adequate for hazard or not adequate; etc.

Changes in Sprinkler Performance Coding in NFIRS 5.0

NFIRS Version 4.1 had one data element for sprinkler performance, and it had five values: (1) sprinkler operated, (2) sprinkler did not operate but should have, (3) fire too small to activate sprinkler, (4) unclassified, and (5) unknown. In NFIRS Version 5.0, there are multiple data elements, including two that divide the information on presence and operation contained in the one data element in Version 4.1.

Sprinkler presence has two choices: Yes and No. There is no code for unknown, which should be treated as a proportional mix of sprinklers present vs. no sprinklers, similar to the mix found cases where sprinkler presence was reported as known. Instead, data reported in Version 4.1 as sprinklers status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as no-sprinkler really were no-sprinkler.

Sprinkler operation has six choices: (1) operated and effective, (2) operated and not effective, (3) fire too small to activate, (4) failed to operate, (5) other (i.e., unclassified), and (6) undetermined (i.e., unknown). Lacking a code for sprinkler operated with unknown effectiveness, the conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated (which was most of them).

Because of these special problems with converted data, statistics for 1999 have not been combined with pre-1999 statistics with caution. Change in estimates from 1998 to 1999 may be artifacts of coding and related analysis methods rather than real changes.

There is a new data element for type of system and equipment, differentiating wet-pipe, dry-pipe and other sprinkler systems from each other and from other types of automatic suppression equipment.

There is also a new single-digit data element with eight choices, plus other/unclassified and unknown, for a single reason for unsatisfactory automatic suppression equipment performance. Previous sprinkler performance approaches have also focused on the single reason for failure, using a short list of candidate reasons. NFPA's old sprinkler performance tables had a list of candidate reasons roughly twice as long as the eight codes in NFIRS Version 5.0.

Who Has Sprinklers?

Table 1 suggests a number of observations. First, with 78% of reported fires in care-of-aged and 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 also appear to be present in most manufacturing facilities and department stores. 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 - public assembly properties, schools, stores and offices, and dormitories and barracks. Residential sprinkler systems for one- and two-family dwellings are reported in only 3.4% of the fires in those properties. Clearly, there is great potential for expanded use of sprinklers.

Outside the limited data obtained through NFIRS, 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.

One exception is the lodging industry (see Figure 1). Fifteen years ago, nearly half of all hotels and motels surveyed had sprinkler systems. The survey may have been under-represented among poorer, poverty-area hotels, but its results still should be fairly representative of the lodging industry as a whole at that time.

Figure 1.
Sprinkler Usage in Hotels and Motels, 1988

Percentage of Hotels With These Areas Sprinklered

Areas of Hotel	Large-Chain Hotels	Independent Hotels	All Hotels
Guest rooms (all)	49	41	45
Corridors (some or all)	42	33	38
Public and service areas (some or all)	48	49	49

Source: "Fire Protection in the Lodging Industry," Washington, DC: American Hotel and Motel Association, June 30, 1988, pages 6 and 18-19. The "all hotel" figure is provided only for guest rooms but provides a basis for calculating the figures for the other two areas.

These results can be compared to the percentage of hotel and motel fires occurring in properties with sprinklers, as shown in Table 2. In 1988, that percentage was 29.0, or 10 to 20 percentage points below the percentages for all hotels and motels having sprinklered areas early in 1988. This provides a useful calibration for the figures in Table 2, which cover far more property classes. 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.

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%. Since it is known that the larger warehouses qualifying as highly protected risks tend to be sprinklered as a requirement of insurance coverage, it must be concluded that these warehouses represent only a fraction of all general warehouses, let alone all storage facilities. Table 2 also shows that high-rise apartments, hotels, and general office 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.

Table 1.
Percentage of Structure Fires Estimated
to Have Occurred in Structures With Sprinklers in 1999

Property Use	Fires With Sprinklers		Fires Without Sprinklers	
Public assembly	**4,200**	**(34.3%)**	**8,100**	**(65.7%)**
Eating and drinking	3,000	(37.7%)	4,900	(62.3%)
Educational	**1,800**	**(35.4%)**	**3,300**	**(64.6%)**
Health care and correctional	**4,000**	**(66.8%)**	**2,000**	**(33.2%)**
Care of sick and aged	3,500	(77.6%)	1,000	(22.4%)
Correctional	400	(28.5%)	900	(71.5%)
Residential	**18,400**	**(6.7%)**	**254,700**	**(93.3%)**
Homes	15,400	(5.8%)	248,300	(94.2%)
One- and two family dwellingss	6,600	(3.4%)	188,80	(96.6%
Apartments	8,800	(12.9%)	59,40	(87.1%
Boarding houses	300	(23.3%)	900	(76.7%)
Hotels and motels	1,600	(49.1%)	1,700	(50.9%)
Dormitories	600	(35.2%)	1,100	(64.8%)
Stores and offices	**5,000**	**(30.2%)**	**11,600**	**(69.8%)**
Food or beverage store	1,100	(36.0%)	1,900	(64.0%)
Department store	900	(60.4%)	600	(39.6%)
Offices	1,500	(39.4%)	2,300	(60.6%)
Industrial	**500**	**(18.7%)**	**2,200**	**(81.3%)**
Manufacturing	**5,900**	**(61.9%)**	**3,600**	**(38.1%)**
Storage facilities	**1,700**	**(5.9%)**	**26,800**	**(94.1%)**
Dwelling garages	1,500	(6.0%)	24,000	(95.0%)
Storage excluding dwelling garages	1,500	(6.0%)	24,000	(94.0%)
Special properties	**300**	**(7.1%)**	**4,200**	**(92.9%)**
Unclassified or unknown-type property	1,000	(16.0%)	5,200	(84.0%)
Total	**42,800**	**(11.6%)**	**325,500**	**(88.4%)**

Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as non-sprinkler really were no-sprinkler. The conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated.

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage.

Source: National estimates based on 1999 NFIRS and NFPA Survey.

Table 2.
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	1999
Public assembly properties	20.1	19.8	20.9	21.2	22.6	24.2	24.5	25.6	30.7	34.3
(Eating and drinking establishment)	(23.8)	(23.2)	(24.9)	(24.9)	(26.3)	(28.9)	(28.7)	(30.6)	(31.5)	(37.7)
Educational properties	18.9	18.1	19.0	21.5	23.6	22.7	21.9	25.9	25.3	35.4
Health care and correctional facilities*	49.0	48.7	51.7	65.2	54.6	56.8	55.3	57.4	58.0	66.8
(Care of aged facilities)	(69.5)	(70.8)	(69.0)	(71.3)	(73.3)	(71.2)	(72.5)	(73.9)	(76.9)	(77.6)**
(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)	(28.5)

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

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage.
Source: National estimates based on 1980-1998 NFIRS and NFPA Survey.

**Table 2. (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	1999
Residential properties	2.6	2.5	2.7	2.6	2.5	2.2	2.6	3.0	3.1	6.7
(One- and two-family dwellings)	(0.8)	(0.8)	(0.7)	(0.7)	(0.7)	(0.4)	(0.6)	(0.7)	(0.7)	(3.4)
(Apartments)	(5.9)	(6.1)	(6.9)	(6.6)	(6.3)	(5.6)	(6.8)	(7.7)	(7.9)	(12.9)
(Apartments at least 7 stories tall)	(24.5)	(25.8)	(31.3)	(30.2)	(30.1)	(30.0)	(28.3)	(35.6)	(35.9)	N/A
(Hotels and motels)	(31.7)	(30.6)	(31.6)	(32.1)	(31.9)	(32.3)	(34.6)	(34.0)	(40.4)	(49.1)
(Hotels at least 7 stories tall)	(69.4)	(66.1)	(71.7)	(75.1)	(68.6)	(71.9)	(76.1)	(67.4)	(77.1)	N/A
(Dormitories and barracks)	(28.7)	(21.3)	(22.2)	(24.1)	(24.7)	(31.6)	(25.9)	(28.4)	(34.9)	(35.2)

N/A-Not available.

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage. Statistics for 1980-1984 are not available for high-rise buildings, because height of building was too rarely coded prior to 1985. These are marked by N/A.

Source: National estimates based on 1980-1998 NFIRS and NFPA Survey.

Table 2. (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	1999
Stores and offices	19.6	19.2	20.3	20.6	20.9	20.1	21.1	22.2	22.7	30.2
(Food or beverage sales stores)	(23.1)	(23.6)	(24.8)	(21.8)	(25.9)	(25.1)	(26.8)	(27.9)	(28.0)	(36.0)
(Department stores)	(50.5)	(49.1)	(54.2)	(55.5)	(50.5)	(49.5)	(52.7)	(53.0)	(52.1)	(60.4)
(Offices)	(22.8)	(22.0)	(24.1)	(25.4)	(23.9)	(25.3)	(25.4)	(25.5)	(26.9)	(39.4)
(General office buildings)	(24.0)	(24.5)	(26.4)	(27.3)	(26.3)	(26.0)	(27.3)	(27.3)	(28.0)	N/A
(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)	N/A
										N/A
Industry, utility, or defense facilities	13.1	11.0	12.5	14.8	10.1	12.6	11.9	14.4	14.6	18.7

N/A-Not available

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage. Statistics for 1980-1984 are not available for high-rise buildings, because height of building was too rarely coded prior to 1985. These are marked by N/A. "General office building" is only one type of office building. The high-rise office building statistics include all types of office buildings.

Source: National estimates based on 1980-1998 NFIRS and NFPA Survey.

Table 2. (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)
(Other manufacturer)	(39.5)	(39.6)	(39.1)	(41.0)	(38.6)	(37.0)	(40.2)	(46.4)	(47.3)	(44.5)

Property Use	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Manufacturing facilities	49.3	48.9	48.6	50.1	48.5	50.1	50.7	51.2	51.5	61.9
(Food product manufacturer)	(32.8)	(35.4)	(32.0)	(40.4)	(35.1)	(41.9)	(37.7)	(41.6)	(38.1)	N/A
(Textile product manufacturer)	(67.5)	(70.1)	(72.0)	(75.5)	(71.3)	(72.4)	(78.1)	(74.7)	(74.9)	N/A
(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)	N/A
(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)	N/A
(Chemical, plastic, or petroleum product manufacturer)	(60.3)	(58.4)	(58.2)	(58.4)	(57.1)	(62.6)	(62.6)	(62.5)	(61.4)	N/A
(Metal product manufacturer)	(43.4)	(44.3)	(44.1)	(42.9)	(41.2)	(43.0)	(44.8)	(45.1)	(45.7)	N/A
(Vehicle assembly plant/manufacturer	(42.8)	(42.4)	(56.0)	(53.7)	(57.8)	(52.0)	(49.4)	(51.4)	(63.9)	N/A
(Other manufacturer)	(45.3)	(42.0)	(43.4)	(44.6)	(46.6)	(45.6)	(51.1)	(52.6)	(44.9)	N/A

N/A-Not available

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage.
Source: National estimates based on 1980-1998 NFIRS and NFPA Survey.

Table 2. (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
Storage facilities (excluding dwelling garages)	3.8	3.0	3.4	3.8	4.4	5.0	4.7	4.7	4.0	5.2
(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	1999
Storage facilities (excluding dwelling garages)	5.0	4.9	4.7	5.0	4.8	4.5	4.6	5.1	5.0	6.0
(General item storage)	(13.7)	(11.3)	(12.1)	(12.2)	(13.8)	(11.8)	(12.6)	(15.9)	(14.1)	N/A
All structures*	6.1	6.0	6.1	6.1	6.1	5.8	6.3	7.1	7.2	11.6

N/A-Not available

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

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. Coding for fires is for all automatic suppression equipment, not just fire sprinklers, and does not indicate type of system or partial vs. complete coverage.

Source: National estimates based on 1980-1998 NFIRS and NFPA Survey.

Sprinkler Presence and Operationality

Table 3 shows the percent of fires that occur in properties where sprinklers operated. Table 3 suggests a number of observations. First, during 1989-1998 in fires large enough to activate the sprinklers, 74-91% of structure fires in properties with sprinklers occurred where sprinklers operated properly, 78-99% in 1999. These percentages are lower than sprinkler performance statistics typically cited in older studies, but the percentages may be misleadingly low, because the data do not separate cases where sprinklers could not be expected to operate, because the system was shut off or because coverage was incomplete.

Partial installations may be misleadingly coded, for example. Structure fires with sprinklers where the sprinklers did not operate may have been too small to activate. Second, while sprinklers tend to operate when they are present, the percentage of fires where sprinklers were present is so low in residential, manufacturing and storage properties that the net percentage of fires in properties with sprinklers that operate is quite low. Clearly, there is great potential for expanded use of sprinklers in these properties.

Percentages and rates for fires when automatic suppression systems were present were obtained by examining only those fires for which the status was known and classified.

Estimates of alarm performance in fires may be made using the National Fire Incident Reporting System (NFIRS), managed by the U.S. Fire Administration. Sprinkler performance in the fires in NFIRS is coded as follows:

- 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

This coding indicates whether sprinklers operated but not whether they were operational. If the "fire too small" code were used whenever it was appropriate, then one could estimate the percentage of sprinklers operational as the total of fires coded 1 divided by the total of fires coded 1, 2, 3, or 4. It is possible to check whether the "fire too small" code is being used whenever it is appropriate. If so, the estimated percentage of fires for which the sprinkler activated would be the same for small and large fires, because all characterizations of sprinklers having operated or not operated would be limited to fires deemed large enough to activate an operational sprinkler.

Table 3.
Sprinkler Presence and Operationality in Structure Fires, by Property Use,

Percentage of Operating Sprinklers Where Sprinklers Were Present*

Property Use	Percent of Fires During 1989-1998	Percent of Fires in 1999**
Public assembly properties	(73.9%)	(70.2%)
Educational properties	(79.6%)	(76.2%)
Health care or correctional facilities	(80.0%)	(80.5%)
All residential properties	(84.6%)	(86.3%)
One- and two-family dwellings	(80.0%)	(81.8%)
Apartments	(87.6%)	(89.2%)
Hotels and motels	(82.7%)	(90.4%)
Stores	(90.1%)	(88.3%)
Offices	(80.6%)	(81.1%)
Industrial facilities	(85.9%)	(88.3%)
Manufacturing facilities	(91.1%)	(90.7%)
Storage properties	(84.0%)	(84.5%)

*Excludes fires where sprinkler was present but fire was coded as too small to test operational status of sprinklers. Does not distinguish type of sprinklers or completeness of coverage.

** Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as non-sprinkler really were no-sprinkler. The conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated.

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.

Source: National estimates based on 1989-1998, 1999 NFIRS and NFPA Survey.

Number of Sprinklers Operating by Type of Sprinkler System

Table 4 shows, for wet and dry systems separately, the percentage of fires controlled by number of sprinklers operating. Ninety-six (96.3%) percent of all the fires were controlled by 10 or fewer sprinklers on wet pipe systems, 92.9 percent on dry pipe systems.

In certain occupancies, two or three sprinklers should be able to establish control if and when a fire occurs, while others may demand over 100. The sprinkler system and its water supply should be designed for the occupancy. When this purpose is defeated, the effect the fire has on the total loss is very apparent. The next section of this report goes into more detail on loss per fire with and without the presence of sprinklers.

In the average fire, more sprinklers open on dry-pipe systems than on wet-pipe systems, because of the time delay in tripping the dry-pipe valve and in passing water through the piping to the opened sprinklers. The delay permits heat to travel more widely and to open more sprinklers than is the case with the wet systems. Usually this fact does not prevent the establishment of control, although under certain marginal conditions it may.

In Version 5.0 of NFIRS, 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.

This data is based on sprinkler activations collected in NFIRS Version 5.0 only.

Table 4.
Number of Sprinklers Operating in
Structure Fires Where Sprinklers Were Present and Operated,
by Type of Sprinkler System, 1999

Number of Sprinklers Operating	Wet Pipe	Dry Pipe	Other or Unknown	All Types of Sprinklers
1 or fewer	62.3%	21.5%	42.7%	52.7%
2 or fewer	79.9%	42.9%	71.5%	72.2%
3 or fewer	86.3%	61.0%	78.6%	80.7%
4 or fewer	90.0%	78.7%	85.8%	87.9%
5 or fewer	90.9%	78.7%	85.8%	89.1%
6 or fewer	92.7%	82.3%	85.8%	91.0%
7 or fewer	93.6%	82.3%	85.8%	91.6%
9 or fewer	95.4%	82.3%	85.8%	92.8%
10 or fewer	96.3%	92.9%	85.8%	95.2%

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 presence or operation unknown or unreported. Wet-pipe systems outnumbered dry-pipe systems by more than 4-to-1; however roughly half (48%) the incidents had type of sprinkler system unreported.

Source: National estimates based on 1999 NFIRS Version 5.0 and NFPA Survey. Based on an estimated 474 fires where sprinklers were reported present and operating and there was reported information on number of sprinklers operating.

Extent of Flame Damage When Sprinklers are Present

Sprinkler effectiveness in reducing loss of life and property has been clearly documented in this report. Now the question is, how effective are sprinklers in containing a fire to an area near the point of fire origin? 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").

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.

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.

Table 5 examines selected occupancies and indicates the dollar loss per fire, with and without sprinklers and for different conditions of flame damage confinement.

Table 5 shows that every major property class except public assembly had greater success in confining fires to room of origin with sprinklers than without. Sometimes, the difference was quite substantial, as with department stores and offices buildings. The public assembly exception may reflect the unusual diversity of sizes of properties and types of activities among public assembly properties, combined with wide variations in sprinkler usage between different types of assembly properties. It may be too much to expect a distinct overall pattern to emerge from a category that combines, stadiums, nightclubs, restaurants, and bowling alleys. This is especially true with only one year of data, as Table 6 demonstrates.

Table 6 provides a similar breakdown but with results for more degrees of fire confinement and with loss-per-fire figures. The latter show smaller fires are typically less costly fires. Note, too, that sprinklers not only keep more fires small, in terms of the qualitative categories, but also typically keep fires smaller within those categories, as evidenced by typically lower loss-per-fire figures for fires of a given size in sprinklered properties, as compared to unspinklered properties.

Table 5.
Extent of Flame Damage by Major Property Use, 1999
Structure Fires Reported to U.S. Fire Departments

Property Use	With Sprinklers: Total Number of Fires	With Sprinklers: Confined to Room of Origin	Without Sprinklers: Total Number of Fires	Without Sprinklers: Confined to Room of Origin
Public assembly properties	4,200	(68.2%)	8,100	(77.1%)
Educational properties	1,810	(97.6%)	3,300	(88.4%)
Health care or correctional facilities	3,980	(98.1%)	2,000	(94.3%)
All residential properties	18,390	(86.8%)	254,700	(72.0%)
One- and two-family dwellings	6,620	(74.0%)	188,800	(69.0%)
Apartments	8,770	(93.7%)	59,400	(81.5%)
Hotels and motels	1,650	(96.4%)	1,700	(83.3%)
Department stores	930	(91.3%)	600	(71.5%)
Offices	1,520	(92.6%)	2,300	(76.4%)
Industrial facilities	500	(82.1%)	2,200	(44.9%)
Manufacturing facilities	5,910	(89.6%)	3,600	(75.0%)
Storage properties	1,690	(67.0%)	24,000	(38.1%)
Total	42,820	(88.6%)	325,500	(68.6%)

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. Fires in which the ext ent of flame damage was unknown or not reported have been allocated proportionately among fires with known extent of flame damage. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten. Sums may not equal total due to rounding errors.

Source: National estimates based on 1999 NFIRS and NFPA Survey.

Table 6.
Loss per Fire in Public Assembly Properties, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	2,080	(69.3%)	$1.2	4,790	(47.7%)	$1.5
Confined to area of origin	610	(20.3%)	$5.1	2,200	(21.9%)	$5.5
Confined to room of origin	150	(5.0%)	$13.9	770	(7.7%)	$18.0
Confined to fire-rated compartment of origin	20	(0.7%)	$25.1	90	(0.9%)	$34.4
Confined to floor of origin	20	(0.7%)	$32.9	250	(2.5%)	$45.8
Confined to structure of origin	110	(3.7%)	$89.1	1,710	(17.0%)	$88.8
Extended beyond structure of origin	10	(0.3%)	$100.1	230	(2.3%)	$85.6
Total	3,000	(100.0%)	$6.5	10,040	(100.0%)	$21.8

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Educational Properties, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	840	(71.8%)	$1.4	2,560	(60.2%)	$1.1
Confined to area of origin	230	(19.7%)	$5.1	950	(22.4%)	$7.4
Confined to room of origin	70	(6.0%)	$11.2	350	(8.2%)	$17.3
Confined to fire-rated compartment of origin	10	(0.9%)	$30.9	20	(0.5%)	$61.2
Confined to floor of origin	10	(0.9%)	$61.9	60	(1.4%)	$77.7
Confined to structure of origin	20	(1.7%)	$61.5	260	(6.1%)	$121.0
Extended beyond structure of origin	0	(0.0%)	$5.6	50	(1.2%)	$58.5
Total	1,170	(100.0%)	$4.1	4,250	(100.0%)	$13.1

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Health Care Properties, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

Extent of Flame Damage	With Sprinklers: Fires		With Sprinklers: Loss per Fire (in Thousands)	Without Sprinklers: Fires		Without Sprinklers: Loss per Fire (in Thousands)
Confined to object of origin	3,410	(81.4%)	$0.9	2,780	(69.8%)	$2.3
Confined to area of origin	540	(12.9%)	$2.7	750	(18.8%)	$2.7
Confined to room of origin	170	(4.1%)	$6.1	250	(6.3%)	$10.3
Confined to fire-rated compartment of origin	20	(0.5%)	$4.7	20	(0.5%)	$31.3
Confined to floor of origin	20	(0.5%)	$16.6	50	(1.3%)	$30.3
Confined to structure of origin	30	(0.7%)	$66.4	120	(3.0%)	$48.7
Extended beyond structure of origin	0	(0.0%)	$100.6	10	(0.3%)	$37.5
Total	4,190	(100.0%)	$2.0	3,980	(100.0%)	$4.9

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Residential Properties, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

Extent of Flame Damage	With Sprinklers Fires		With Sprinklers Loss per Fire (in Thousands)	Without Sprinklers Fires		Without Sprinklers Loss per Fire (in Thousands)
Confined to object of origin	5,780	(66.1%)	$1.3	129,130	(39.5%)	$1.0
Confined to area of origin	1,780	(20.3%)	$4.5	74,490	(22.8%)	$3.2
Confined to room of origin	580	(6.6%)	$9.1	34,610	(10.6%)	$8.8
Confined to fire-rated compartment of origin	130	(1.5%)	$19.6	3,580	(1.1%)	$15.1
Confined to floor of origin	140	(1.6%)	$26.4	13,700	(4.2%)	$22.0
Confined to structure of origin	290	(3.3%)	$55.7	61,540	(18.8%)	$30.0
Extended beyond structure of origin	50	(0.6%)	$86.0	9,810	(3.0%)	$35.9
Total	8,750	(100.0%)	$5.5	326,860	(100.0%)	$9.9

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in One and Two-Family Dwellings, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	900	(53.3%)	$2.2	93,230	(37.5%)	$1.1
Confined to area of origin	370	(21.9%)	$4.4	55,450	(22.3%)	$3.4
Confined to room of origin	140	(8.3%)	$10.9	25,810	(10.4%)	$9.3
Confined to fire-rated compartment of origin	30	(1.8%)	$13.3	2,030	(0.8%)	$12.1
Confined to floor of origin	60	(3.6%)	$26.6	10,330	(4.2%)	$21.3
Confined to structure of origin	160	(9.5%)	$39.7	53,390	(21.5%)	$27.6
Extended beyond structure of origin	30	(1.8%)	$40.8	8,390	(3.4%)	$31.8
Total	1,690	(100.0%)	$8.6	248,630	(100.0%)	$10.1

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Apartments, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

Extent of Flame Damage	With Sprinklers: Fires		With Sprinklers: Loss per Fire (in Thousands)	Without Sprinklers: Fires		Without Sprinklers: Loss per Fire (in Thousands)
Confined to object of origin	3,450	(69.0%)	$0.9	32,830	(46.2%)	$0.6
Confined to area of origin	990	(19.8%)	$3.4	17,510	(24.6%)	$2.5
Confined to room of origin	310	(6.2%)	$8.3	7,970	(11.2%)	$7.2
Confined to fire-rated compartment of origin	80	(1.6%)	$24.4	1,480	(2.1%)	$18.7
Confined to floor of origin	60	(1.2%)	$28.6	3,150	(4.4%)	$22.7
Confined to structure of origin	100	(2.0%)	$59.0	6,950	(9.8%)	$46.6
Extended beyond structure of origin	20	(0.4%)	$118.8	1,150	(1.6%)	$64.9
Total	5,000	(100.0%)	$4.2	71,040	(100.0%)	$8.7

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Hotels and Motels, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	900	(69.8%)	$1.3	1,150	(43.6%)	$1.5
Confined to area of origin	260	(20.2%)	$6.8	640	(24.2%)	$3.7
Confined to room of origin	90	(7.0%)	$12.2	390	(14.8%)	$9.6
Confined to fire-rated compartment of origin	10	(0.8%)	$6.8	40	(1.5%)	$28.1
Confined to floor of origin	10	(0.8%)	$13.4	90	(3.4%)	$49.4
Confined to structure of origin	20	(1.6%)	$122.5	280	(10.6%)	$67.2
Extended beyond structure of origin	0	(0.0%)	$278.8	40	(1.5%)	$84.6
Total	1,290	(100.0%)	$6.0	2,640	(100.0%)	$13.5

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Stores, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	1,720	(59.9%)	$3.0	4,790	(40.6%)	$2.6
Confined to area of origin	780	(27.2%)	$12.7	2,580	(21.9%)	$6.9
Confined to room of origin	190	(6.6%)	$23.8	950	(8.1%)	$20.5
Confined to fire-rated compartment of origin	30	(1.0%)	$29.3	140	(1.2%)	$42.1
Confined to floor of origin	30	(1.0%)	$34.3	280	(2.4%)	$45.1
Confined to structure of origin	100	(3.5%)	$112.7	2,470	(20.9%)	$71.3
Extended beyond structure of origin	20	(0.7%)	$121.0	580	(4.9%)	$94.9
Total	2,870	(100.0%)	$12.1	11,790	(100.0%)	$25.4

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Offices, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	730	(68.2%)	$2.9	1,570	(46.9%)	$1.4
Confined to area of origin	230	(21.5%)	$10.6	760	(22.7%)	$6.1
Confined to room of origin	60	(5.6%)	$23.1	270	(8.1%)	$16.4
Confined to fire-rated compartment of origin	10	(0.9%)	$142.1	40	(1.2%)	$47.0
Confined to floor of origin	10	(0.9%)	$96.2	120	(3.6%)	$142.2
Confined to structure of origin	20	(1.9%)	$115.0	500	(14.9%)	$84.0
Extended beyond structure of origin	0	(0.0%)	$95.0	80	(2.4%)	$96.6
Total	1,070	(100.0%)	$10.7	3,350	(100.0%)	$23.6

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Industrial Facilities, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

	With Sprinklers			Without Sprinklers		
Extent of Flame Damage	**Fires**		**Loss per Fire (in Thousands)**	**Fires**		**Loss per Fire (in Thousands)**
Confined to object of origin	250	(61.0%)	$5.7	840	(29.8%)	$11.5
Confined to area of origin	90	(22.0%)	$31.2	370	(13.1%)	$8.7
Confined to room of origin	20	(4.9%)	$29.2	160	(5.7%)	$57.4
Confined to fire-rated compartment of origin	10	(2.4%)	$71.3	20	(0.7%)	$17.3
Confined to floor of origin	10	(2.4%)	$51.0	40	(1.4%)	$34.5
Confined to structure of origin	30	(7.3%)	$58.4	1,110	(39.4%)	$46.2
Extended beyond structure of origin	0	(0.0%)	$62.5	290	(10.3%)	$46.4
Total	410	(100.0%)	$19.1	2,820	(100.0%)	$31.3

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Manufacturing Facilities, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

Extent of Flame Damage	With Sprinklers Fires		With Sprinklers Loss per Fire (in Thousands)	Without Sprinklers Fires		Without Sprinklers Loss per Fire (in Thousands)
Confined to object of origin	3,040	(61.0%)	$4.9	2,280	(45.3%)	$4.8
Confined to area of origin	1,160	(23.3%)	$14.0	1,070	(21.3%)	$13.1
Confined to room of origin	330	(6.6%)	$28.2	380	(7.6%)	$29.1
Confined to fire-rated compartment of origin	50	(1.0%)	$21.2	60	(1.2%)	$88.3
Confined to floor of origin	70	(1.4%)	$71.5	90	(1.8%)	$96.7
Confined to structure of origin	290	(5.8%)	$124.6	950	(18.9%)	$182.8
Extended beyond structure of origin	40	(0.8%)	$254.9	190	(3.8%)	$204.8
Total	4,980	(100.0%)	$18.7	5,030	(100.0%)	$52.5

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

Table 6. (Continued)
Loss per Fire in Storage Facilities, by Extent of Flame Damage
Annual Average of 1989-1998 Structure Fires Reported to U.S. Fire Departments

Extent of Flame Damage	With Sprinklers Fires		With Sprinklers Loss per Fire (in Thousands)	Without Sprinklers Fires		Without Sprinklers Loss per Fire (in Thousands)
Confined to object of origin	450	(50.0%)	$4.6	5,840	(19.9%)	$3.1
Confined to area of origin	250	(27.8%)	$19.8	4,150	(14.1%)	$3.0
Confined to room of origin	60	(6.7%)	$31.5	1,450	(4.9%)	$7.4
Confined to fire-rated compartment of origin	10	(1.1%)	$59.1	180	(0.6%)	$13.5
Confined to floor of origin	20	(2.2%)	$46.7	320	(1.1%)	$15.0
Confined to structure of origin	90	(10.0%)	$310.7	13,200	(45.0%)	$18.6
Extended beyond structure of origin	20	(2.2%)	$1,716.2	4,190	(14.3%)	$22.6
Total	900	(100.0%)	$79.2	29,330	(100.0%)	$13.2

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. 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. Property damage figures have not been adjusted for inflation. Fires are rounded to the nearest ten and property damage is rounded to the nearest hundred dollars. Sums may not equal total due to rounding errors.

Source: National estimates based on NFIRS and NFPA Survey.

How Effective Are Sprinklers in Saving Lives?

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.

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 2 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 fire fighting 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.

Overall Impact on Life Safety

These considerations suggest there might be value in another approach to measuring sprinkler effectiveness, which is to compare the number of deaths per thousand fires in buildings with sprinklers (or other automatic suppression equipment) present with the death rate in buildings without sprinklers. Figures on death rates with and without sprinklers are shown in Tables 7 and 8 for several property classes where sprinkler usage is sufficiently common to permit meaningful calculations. Several points may be made from these figures.

First, the figures by property class in Table 7 indicate sprinklers typically reduce the rate of fire deaths per thousand fires by one-half to two-thirds. In fact, the impact for the most recent 10 years analyzed has been even better in most property classes.

Second, fatal fires are still a small fraction of all fires, so even in a ten-year average, one can see some unusual results by chance. A related point is that 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, with or without 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 (100% in 1999, 91% in 1989-1998) can translate into a substantial number of lives saved, even with comparatively few fires per year.

Third, if the basic risk is low, the results may be very sensitive to the effects of one major fire. For example, Tables 7 and 8 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 thetotal 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.

Fourth, these figures understate the *potential* value of a properly installed, well-maintained complete sprinkler system. As illustrated in the previous paragraph, the fires and fire deaths registered as occurring in properties with sprinklers in Tables 7 and 8 include 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.

Table 7.
Estimated Reduction in 1999 Civilian Deaths per Thousand Fires Due to Sprinklers, in Selected Property Classes

Property Use	Civilian Deaths per Thousand Fires			Estimated Number of Fires in 1999	
	Without Sprinklers	With Sprinklers	Percent Reduction*	Without Sprinklers	With Sprinklers
Public assembly	**1.1**	**0.0**	**100%**	**8,100**	**4,200**
Eating and drinking	1.1	0.0	100%	4,900	3,000
Educational	**0.0**	**0.0**	**N/A**	**3,300**	**1,800**
Health care and correctional	**0.6**	**0.4**	**31%**	**2,000**	**4,000**
Care of sick and aged	1.1	0.5	60%	1,000	3,500
Residential properties	**9.0**	**2.9**	**67%**	**254,700**	**18,400**
One- and two family dwellings	9.8	5.9	40%	188,800	6,600
Apartments	6.8	1.4	80%	59,400	8,800
Homes	9.1	3.3	64%	248,300	15,400
Hotels and motels	10.8	0.0	100%	1,700	1,600
Stores and offices	**1.2**	**0.0**	**100%**	**11,600**	**5,000**
Food or beverage store	0.0	0.0	N/A	1,900	1,100
Offices	2.1	0.0	100%	2,300	1,500
Total	**7.2**	**1.5**	**79%**	**325,500**	**42,800**

*Percent reductions calculated before death rates are rounded.

N/A- Not applicable because baseline was zero.

Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as non-sprinkler really were no-sprinkler. The conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated.

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. Fires are estimated to the nearest hundred. Sums may not equal total due to rounding errors. Total includes fires in properties without high occupancy, such as manufacturing and storage properties.

Source: National estimates based on 1999 NFIRS and NFPA Survey.

Table 8.
Estimated Reduction in 1989-1998 Civilian Deaths per Thousand Fires Due to Sprinklers, in Selected Property Classes

Property Use	Civilian Deaths per Thousand Fires			Average Number of Fires per Year, 1989-1998	
	Without Sprinklers	With Sprinklers	Percent Reduction**	Without Sprinklers	With Sprinklers
Public assembly properties	**0.8**	**0.0***	**100%**	**10,000**	**3,000**
Eating and drinking facilities	0.8	0.0*	100%	6,200	2,300
Educational properties	**0.0***	**0.0***	**N/A%**	**4,200**	**1,200**
Health care facilities	**4.9**	**1.2**	**75%**	**1,400**	**3,200**
Care of aged facilities	7.1	1.7	76%	700	1,800
Care of sick facilities	2.7	0.7	74%	700	1,400
Residential properties	**9.4**	**2.1**	**78%**	**326,900**	**8,700**
One- and two-family dwellings	9.7	4.7	51%	248,600	1,700
Apartments	8.2	1.6	81%	71,000	5,000
Hotels and motels	9.1	0.8*	91%	2,600	1,300
Dormitories and barracks	1.5	0.0*	100%	1,300	500
Stores and offices	**1.0**	**0.3***	**74%**	**15,100**	**3,900**
Food or beverage store	1.2	0.0*	100%	2,600	900
Department store	1.2*	0.0*	100%	800	900
General office building	0.6*	0.0*	100%	3,300	1,100
Industrial facilities	**1.1**	**0.0***	**100%**	**2,800**	**400**
Manufacturing facilities	**2.0**	**0.8**	**60%**	**5,000**	**5,000**
Storage facilities	**1.0**	**0.0***	**100%**	**29,300**	**900**
Total	**7.6**	**1.1**	**86%**	**419,100**	**28,100**

*Based on fewer than two deaths per year in the entire ten-year period. Results may not be significant.
**Percent reductions calculated before death rates are rounded.

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

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

Sprinklers in Homes

The discussion above 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 8.2 in 1999) 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 Tables 1 and 2 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 half of all reported fires in sprinklered buildings now occur 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 9 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. Our latest estimate based on 1999 data is a 64% reduction in deaths per thousand fires, based on 51 deaths in 15,384 fires with sprinklers present and 2,257 deaths in 248,275 fires with no sprinklers. Both figures are 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 are 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, say, there were 5,400 home fire deaths, and their analysis would have predicted that sprinklers and smoke alarms could lower that figure to about 1,100. The 4,300 death reduction would have consisted of a combination of about 2,500 lives saved by completing the process of putting smoke alarms in all homes and 1,800 more lives saved by installing sprinklers. As of 1999, the home fire death toll had fallen by 3,100 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.

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.

*See Marty Ahrens, *U.S. Experience With Smoke Alarms*, Quincy, MA: NFPA Fire Analysis and Research Division, October 2003.

- 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.

Table 9.
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.

How Effective Are Sprinklers in Saving Property?

Table 10 and 11 show 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, manufacturing, and health care properties show the largest reductions in Table 11, where there are enough years of data for reasonable confidence in the results, while the reduction is notably lower, but still substantial, for residential and industrial properties.

The property use classes shown in Tables 10 and 11 are limited to those with significant numbers of fires in sprinklered properties, based on Table 2. (This is necessary to produce reasonably stable statistical estimates.) That is why industrial and storage properties are not shown. Clearly, many of the property classes not listed in these tables could benefit greatly from expanded sprinkler use.

The percentage reductions shown in both Tables 10 and 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. This makes the large percentage reductions that much more impressive. 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.

Ideally, one would like to compare loss per fire, with and without sprinklers, in comparable fires. Sometimes, a couple of large-loss fires can overwhelm the underlying evidence of the effectiveness of sprinklers. Conversely, other differences may cloud the measurement of effectiveness of sprinklers. Sprinklered properties 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). Most of these points were made earlier with respect to sprinkler effectiveness in saving lives.

Table 11 also shows high-rise buildings separately. As noted earlier in Table 2, 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 10.
Estimated Reductions in 1999 Average Direct Property Damage per Fire
Due to Sprinklers in Selected Property Classes

Property Use	Without Sprinklers	With Sprinklers	Percent Reduction
Public assembly properties	**$31,700**	**$9,200**	**71%**
Eating and drinking facilities	$25,300	$7,700	69%
Educational	**$16,500**	**$4,200**	**74%**
Health care and correctional facilities	**$6,100**	**$2,400**	**61%**
Facilities that care for sick or aged	$8,500	$2,300	73%
Correctional facilities	$3,600	$500	86%
Residential properties	**$13,500**	**$10,300**	**24%**
Homes (e.g., one- and two family dwellings and apartments)	$13,200	$11,000	17%
Apartments	$10,800	$6,000	45%
Boarding houses	$11,200	$1,900	83%
Hotels and motels	$34,600	$8,600	75%
Dormitories	$23,200	$2,600	89%
Stores and offices	**$47,800**	**$21,200**	**56%**
Food or beverage stores	$15,000	$8,600	43%
Department stores	$33,000	$17,300	48%
Manufacturing facilities	**$51,000**	**$26,200**	**49%**

Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as non-sprinkler really were no-sprinkler. The conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated.

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 1999 NFIRS and NFPA Survey.

Table 11.
Estimated Reductions in 1989-1998 Average Direct Property Damage per Fire Due to Sprinklers in Selected Property Classes

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%**
Care of sick and aged facilities	$4,000	$1,600	59%
Residential properties	**$9,400**	**$5,400**	**42%**
One- and two-family dwellings	$9,600	$7,800	19%
Apartments	$8,500	$4,400	49%
Apartments (at least 7 stories tall)	$3,200	$1,800	43%
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%
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.

What Causes Unsatisfactory Sprinkler Performance When It Occurs?

As previously noted, NFPA discontinued its sprinkler performance tracking data base after 1970 because it became clear that the data collection was biased toward cases of poor sprinkler performance. But a database that tends to miss success stories may still be useful for analyzing failures. In other words, that database still may give valid results on why unsatisfactory performance occurs when it occurs.

Table 12 summarizes the causes of unsatisfactory sprinkler performance, based on the 45 years of cases reported to NFPA from 1925 to 1969. Table 13 reorganizes these causes into major problem groups: (a) failure to maintain the system in operational status (primarily because of closed valves), which accounts for more than half the unsatisfactory-performance cases; (b) failure to assure that the system in place is complete and adequate for the current use of the property, which accounts for nearly one-fourth of the unsatisfactory-performance cases; (c) defects in other parts of the building's system of fire protection; (d) inadequate performance by components of the sprinkler system itself, which accounts for less than 6% of the unsatisfactory-performance cases; and (e) other factors.

With NFIRS Version 5.0, it is possible to recreate tables similar to the old NFPA sprinkler performance tables, but using representative national data rather than anecdotal data favoring larger fires, as the old tables were forced to do. (See Table 14.) There are two important differences. First, there is no measure directly based on fire control; it is necessary to use either “effectiveness” or fire confinement to room of origin as a substitute. Second, the list of possible reasons for system failure has weaknesses as a guide to action because it does not extinguish between problems in the sprinkler system and problems in the environment of the sprinkler system.

For example, “not enough agent discharged” 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). “Agent discharged but did not reach fire” could be coded because damaged sprinklers blocked or misdirected the water spray or because high-piled stock or some other arrangement shielded the fire. “Fire not in area protected” could be coded because the system was a partial system or had coverage not in compliance with the relevant standard or because the fire origin was in an area (e.g., exterior of building, concealed space) that was not part of the required coverage area for that property use.

Finally, 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.

Another perspective is provided by H.W. Marryatt's records on a century of automatic sprinkler protection in Australia and New Zealand. Marryatt estimates that his analysis was able to capture 99% of all fires involving sprinklers - much more completeness than any existing U.S. data base can achieve. This completeness and the superiority of performance (relative to sprinklers in the U.S.) shown by these records are credited by Marryatt to their high-density application of water, their universal use of alarm connections from sprinkler systems to fire departments, and their unusually high standard of installation, service, maintenance, and regular testing. The analysis is based on Marryatt's review of 49 incidents.*

While Maryatt's categories differ slightly from those used in NFPA's study, the principal problems identified are the same, but the shares are not. Water valves shut off, which led the U.S. list with 35.4%, are cited in only 4 of the 49 cases (8%), and half of those were cases of arsonists sabotaging a working system. The higher standard of maintenance and valve supervision is clear. Systems not adequate for the hazard, especially high-piled stock, rise from #2 on the U.S. list to #1, with 16 of 49 cases (33%), followed by fire origin in or early spread to unprotected areas (12 of 49 cases, or 24%), and explosions or flash fires (8 of 49 cases, or 16%).

Tables 12 and 13 demonstrate the three keys to obtaining full benefit from sprinklers and other automatic suppression systems. First and foremost, these systems need to be regularly maintained and tested. In particular, keeping the water turned on is a top priority. Use of a tag system to provide unambiguous visual reminders of the on/off status of the system is a good way to prevent inappropriate and dangerous water shutoff conditions. Valve supervision using a tamper switch connected to a central alarm monitoring station can also be helpful.

Second, 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. And no one should confuse a partial sprinkler system with complete sprinkler protection.

*H.W. Marryatt, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand, 1886-1986*, Second Edition, Victoria, Australia: Australian Fire Protection Association, 1988, pp. 385-410, 443, 445.

Third, 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 12.
Leading Reasons When Sprinkler Performance Is Unsatisfactory

Problem	Percentage of Cases
Water shut off	35.4
System not adequate for level of hazard in occupancy	13.5
Inadequate water supplies	9.9
Inadequate maintenance	8.4
Obstruction to water distribution	8.2
System designed for partial protection only	8.1
Faulty building construction	6.0
Antiquated system	2.1
Slow operation	1.8
Defective dry-pipe valve	1.7
Exposure fire	1.7
System frozen	1.4
Other or unknown	1.9
Total	100.0

Source: "Automatic Sprinkler Performance Tables, 1970 Edition," *Fire Journal,* July 1970, page 37. Based on 3,134 fires reported to NFPA during 1925 to 1969 for which sprinkler performance was deemed unsatisfactory. Of these, 75.0% were in industrial facilities, 12.0% were in storage facilities, 5.6% were in stores, and 7.4% were in all other properties.

Table 13.
Groups of Leading Reasons for Unsatisfactory Sprinkler Performance

Problem Group		% of Cases	Problem	% of Cases
A.	Failure to maintain operational status of system	53.4	A1. Water shut off	35.4
			A2. Inadequate maintenance	8.4
			A3. Obstruction to water distribution	8.2
			A4. System frozen	1.4
B.	Failure to assure adequacy of system for complete coverage of current hazard	21.6	B1. System not adequate for level of hazard in occupancy	13.5
			B2. System designed for partial protection only	8.1
C.	Defects affecting but not involving sprinkler system	15.9	C1. Inadequate water supply	9.9
			C2. Faulty building construction	6.0
D.	Inadequate performance by sprinkler system itself	5.6	D1. Antiquated system	2.1
			D2. Slow operation of sprinklers	1.8
			D3. Defective dry-pipe valve	1.7
E.	Other	3.6	E1. Exposure fire	1.7
			E2. Other or unknown	1.9
Total		100.0		100.0

Source: "Automatic Sprinkler Performance Tables, 1970 Edition," *Fire Journal*, July 1970, page 37. Based on 3,134 fires reported to NFPA during 1925 to 1969 for which sprinkler performance was deemed unsatisfactory. Of these, 75.0% were in industrial facilities, 12.0% were in storage facilities, 5.6% were in stores, and 7.4% were in all other properties.

Table 14.
Structure Fires Where Sprinklers Were Present, by Performance, 1999

Sprinkler Performance	Number of Fires	
System Operated or Fire Too Small	22,120	(51.7%)
Fire not in area protected by the system	440	(1.0%)
Reason system not effective, other	420	(1.0%)
Agent discharged, but did not reach the fire	330	(0.8%)
System shut off	80	(0.2%)
Not enough agent discharged to control the fire	60	(0.1%)
Lack of maintenance, including corrosion or heads	50	(0.1%)
Inappropriate system for the type of fire	40	(0.1%)
Manual intervention defeated the system	20	(0.0%)
Undetermined	19,260	(45.0%)
Total	42,820	(100.0%)

Data reported in Version 4.1 as sprinkler status unknown was converted to no-sprinkler. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as non-sprinkler really were no-sprinkler. The conversion of data reported in Version 4.1 converted all fires where sprinklers operated to other/unclassified. It was necessary to use pre-1999 data to estimate what fraction of the 1999 fires coded as other operation were really sprinkler-operated.

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

Source: National estimates based on 1999 NFIRS and NFPA Survey.

What Other Issues Exist Regarding Sprinklers?

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 the 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. Accidental 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.* Maryatt's study of sprinklers in Australia and New Zealand, cited earlier, found water damage from non-fire accidental discharges added only 25% to the fire losses suffered by sprinklered buildings.** Since the fire losses were so much lower as a result of sprinkler effectiveness, total fire and water damage was much lower, too. Prevention of non-fire water damage from sprinklers involves the same safety rules as one uses for the other elements of building fire protection, need to be approached cautiously and not decided on a cost basis alone.

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 that most people will find them well worth the cost. In

*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.

**Marryatt, *op. cit.*, p. 435.

many settings, this effectiveness can be incorporated into reduced insurance costs, allowing the systems to pay for themselves, in part or in whole, 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 one or two percent to total cost.

Other Methods of Extinguishment Used

Table 15 examines the mechanism by which the fire was completely extinguished for reported structure fires, by all major types of properties. This table gives an overall picture of the different methods of extinguishment and how often each one is used when a fire occurs.

The figures in Table 15 also show that in many high-occupancy property classes - public assembly, educational, health care and correctional, and hotels and motels - the fires were most often 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.

Early suppression by an appropriately designed and properly maintained automatic system (e.g., sprinklers) or by the use, with proper training and safeguards, of a portable extinguisher means smaller fires with less damage to property by fire and water and less risk of death. 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 is not provided because it is no longer being collected in Version 5.0 of NFIRS.

Table 15.
Structure Fires in Specified Properties, by Method of Extinguishment
Annual Average of 1989-1998 Fires with Method of Extinguishment Unknown 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%)

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

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

Table 15. (Continued)
Structure Fires in Specified Properties, by Method of Extinguishment
Annual Average of 1989-1998 Fires with Method of Extinguishment Unknown 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%)

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

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

Table 15. (Continued)
Structure Fires in Specified Properties, by Method of Extinguishment
Annual Average of 1989-1998 Fires with Method of Extinguishment Unknown 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 fires reported to U.S. municipal fire departments and so exclude fire 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: National estimates based on 1989-1998 NFIRS and NFPA Survey.
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Other Research, Ongoing Studies and Resources

Research:

Free Scottsdale Report Available Online

In 1996 the Rural/Metro Fire Department developed The Scottsdale Report, which examined local fire records for the last 10 years. During that time there were 598 home fires, 44 were in homes with sprinklers. There were no deaths in the homes with sprinklers. Unfortunately there were 10 deaths in the homes without sprinklers. Fifteen-year data now available. This report is now available for free on the Home Fire Sprinkler Coalition (HFSC) website.

http://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

Online Resources:

www.homefiresprinkler.org

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.sprinklernet.org

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.nfsa.org

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.

NFPA Documents:

- 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 13E: *Recommended Practice for Fire Department Operations in Properties Protected by Sprinkler and Standpipe Systems*
- NFPA 13R: *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height*
- NFPA 16: *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*
- NFPA 25: *Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems*
- NFPA 101: *Life Safety Code®*

Discussion and Recommendations

1. Automatic sprinklers are highly effective elements of total systems designs for fire protection in buildings. When sprinklers are present, the chances of dying in a fire and the average property loss per fire are both 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. When sprinklers do not perform satisfactorily, which is rare, the reason is almost always some type of human error - 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 Tables 12-13 show 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 the human errors that dominate Tables 12-13 as intrinsic to sprinkler performance. In fact, all the elements of 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 suppression 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. NFPA 101, the *Life Safety Code®*, identifies some properties where the use of sprinklers is essential to produce minimal fire protection for life safety. These properties should receive top priority in any national program to expand the use of sprinklers. But no one in the fire community, least of all the NFPA, endorses an approach of settling for minimum standards of fire safety.

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.

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 fire fighter 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 1998 civilian deaths in residential structures is equal to the total number of 1998 civilian deaths in residential structure fires reported to fire departments, according to the NFPA survey (3,250), divided by the total number of 1998 civilian deaths in residential structure fires reported to NFIRS (1,224). Therefore, the scaling ratio is 3,250/1,224 = 2.66.

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 Sprinkler 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.

Codes:

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

Appendix C: Adjustments Made to the Data Converted from Earlier Versions of NFIRS

Version 5.0 of NFIRS was initially introduced in 1999. About 7% of the fires and 10% of the fire fatalities reported in 1999 were originally reported in Version 5.0 format.

Data that had been reported in an earlier version of NFIRS (the majority of the database, and referred to here as 4.1) was converted to Version 5.0 before the national database was released. The conversions relevant to this report are shown below.[1]

Figure 2.
How Sprinkler Data from Earlier Versions of NFIRS Convert to Version 5.0

Version 4.1 and earlier sprinkler status	Version 5.0 sprinkler present	Version 5.0 sprinkler operation
1. Equipment operated	Yes	U. Undetermined
2. Equipment should have operated but did not	Yes	4. System did not operate
3. Equipment present but fire too small to operate	Yes	3. Fire too small to activate the system
8. None present	No	Not present
9. Unclassified	Yes	U. Undetermined
0. Undetermined	No	Not present

In the past, sprinkler status codes 1-3 indicated that sprinklers were present. The Version 5.0 field asks if sprinklers were present. The conversion process dropped sprinkler presence unknown. The presence of these devices in Version 4.1 could not be determined, so they were considered "not present" in the conversion process. Incidents in which the sprinklers status was undetermined also converted to "not present." Blanks remained blank. The unadjusted data show a smaller percentage of fires with sprinklers, and a larger percentage with operating devices.

To compensate for these artificial changes introduced by the conversion process, NFPA developed a procedure that made adjustments to the data originally collected in the older format based on percentages seen in 1989-1998 data. For purposes of convenience, the 1999 data collected in earlier versions of NFIRS will all be called 4.1 data.

The adjusted total of sprinklers present in 4.1 data was calculated by the following formula:

Adjusted 4.1 data with sprinklers present =
(Present $_{1999,\ 4.1}$) x [(Codes 1, 2 and 3 $_{1989\text{-}1998}$) /(codes 1, 2, 3 and 9 $_{1989\text{-}1998}$)]

To obtain the percent of fires with sprinklers present, it is necessary to know the number of fires in which these devices were not present. The following adjustments were made to the 4.1 and 5.0 1999 data:

Adjusted 4.1 data with sprinklers NOT present =

[1] Extracted from the 7/30/2002 version of Table 3-55 "Sprinkler Performance Conversion," of the *NFIRS 4.1 to 5.0 Conversion Tables,* available from http://www.nfirs.fema.gov/design.htm.

(Not Present $_{1999,\ 4.1}$) x [(Code 8 $_{1989\text{-}1998}$) /(codes 8 and 0 $_{1989\text{-}1998}$)]

The percent Adjusted 4.1 present is based on the Adjusted 4.1 present divided by the sum of the Adjusted 4.1 present and Adjusted 4.1 not present.

Adjusted 5.0 data with sprinklers NOT present =
(Not Present $_{1999,\ 5.0}$) x [(Code 8$_{1989\text{-}1998}$) /(codes 8 and 0 $_{1989\text{-}1998}$)]

The percent Adjusted 5.0 present is based on the Adjusted 5.0 present divided by the sum of the Adjusted 5.0 present and Adjusted 5.0 not present.

Total present =
(4.1 adjusted present + 5.0 adjusted present)/(4.1 adjusted not present + 5.0 adjusted not present)

The 1999 total was derived by adding the Adjusted 4.1 present and Adjusted 4.1 not present to the corresponding data originally collected in Version 5.0 and repeating the division.

Adjustments were also needed to calculate the percentage of sprinklers that operated. The old code 2 – equipment should have operated but did not - converted to "Present" in the first field, and "Failed to operate" in the operationality field. The old code 1 and 9 – present and unclassified,– converted to "Undetermined" and the operationality field was left blank. To track operationality in a manner consistent with previous years, the following calculations were done to determine the number of fires with non-operational sprinklers originally collected in Version 4.1.

Adjusted 4.1 data with sprinklers operating =
(Undetermined $_{1999,\ 4.1}$) x [(Code 1 $_{1989\text{-}1998}$)/(Codes 1 and 9 $_{1989\text{-}1998}$)]

The percent Adjusted 4.1 operating is based on the 4.1 operating divided by the sum of the 4.1 operating and Adjusted 4.1 Failed to operate.

The 1999 total was derived by adding the 4.1 operated and Adjusted 4.1 not operating to the corresponding data originally collected in Version 5.0 and repeating the division.

1999-Percentage of operating sprinklers where sprinklers were present =
(Codes 1 & 2 $_{1999,\ 5.0}$ + Adjusted 4.1 Operated $_{1999}$)/ (Codes 1 & 2 $_{1999,\ 5.0}$ + Code 4 $_{1999,\ 5.0}$ + Adjusted 4.1 Operated $_{1999}$ + Code 4 $_{1999,\ 4.1}$)

The percent Adjusted 4.1 operating is based on the 4.1 operating divided by the sum of the 4.1 operating and Adjusted 4.1 Failed to operate.

The 1999 total was derived by adding the 4.1 operated and Adjusted 4.1 not operating to the corresponding data originally collected in Version 5.0 and repeating the division.