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

**John R. Hall, Jr.**

**February 2010**

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

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**Abstract**

Automatic sprinklers are highly effective elements of total system designs for fire protection in buildings. They save lives and property, producing large reductions in the number of deaths per thousand fires, in average direct property damage per fire, and especially in the likelihood of a fire with large loss of life or large property loss. When sprinklers are present in the fire area, they operate in 93% of all reported structure fires large enough to activate sprinklers, excluding buildings under construction. When they operate, they are effective 97% of the time, resulting in a combined performance of operating effectively in 91% of reported fires where sprinklers were present in the fire area and fire was large enough to activate sprinklers. In homes (including apartments), wet-pipe sprinklers operated effectively 96% of the time. When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported structure fires is lower by 83% for home fires, where most structure fire deaths occur, and the rate of property damage per reported structure fire is lower by 40-70% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 74% lower average loss per fire. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 95% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present. When sprinklers fail to operate, the reason most often given (53% of failures) is shutoff of the system before fire began. (All statistics are based on 2003-2007 fires reported to U.S. fire departments, excluding buildings under construction.)

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

**Acknowledgements**

The National Fire Protection Association thanks all the fire departments and state fire authorities who participate in the National Fire Incident Reporting System (NFIRS) and the annual NFPA fire experience survey. These firefighters are the original sources of the detailed data that make this analysis possible. Their contributions allow us to estimate the size of the fire problem. We are also grateful to the U.S. Fire Administration for its work in developing, coordinating and maintaining NFIRS. For more information about the National Fire Protection Association, visit www.nfpa.org or call 617-770-3000. To learn more about the One-Stop Data Shop go to www.nfpa.org/osds or call 617-984-7443.

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# Executive Summary

Automatic sprinklers are highly effective and reliable elements of total system designs for fire protection in buildings. In 2003-2007, sprinklers operated in 93% of all reported structure fires large enough to activate sprinklers, excluding buildings under construction and buildings without sprinklers in the fire area. When sprinklers operate, they are effective 97% of the time, resulting in a combined performance of operating effectively in 91% of all reported fires where sprinklers were present in the fire area and fire was large enough to activate them. The combined performance for the more widely used wet pipe sprinklers is 92%, while for dry pipe sprinklers, the combined performance is only 79%. In homes (including apartments), wet-pipe sprinklers operated effectively 96% of the time. By comparison, combined performance is 60% for dry chemical systems, 79% for carbon dioxide systems, 81% for foam systems, and 88% for halogen systems. (Wet chemical systems may be included with dry chemical systems or with other special hazard systems.) These most current statistics are based on 2003-2007 fires reported to U.S. fire departments, excluding buildings under construction and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area and after some recoding between failure and ineffectiveness based on reasons given.

When wet-pipe sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, the fire death rate per 1,000 reported home structure fires is lower by 83% and the rate of property damage per reported structure fire is lower by 40-70% for most property uses. In homes (including apartments), wet-pipe sprinklers were associated with a 74% lower average loss per fire. Also, when sprinklers are present in structures that are not under construction and excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, 95% of reported structure fires have flame damage confined to the room of origin compared to 74% when no automatic extinguishing equipment is present.

Of reported 2003-2007 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (71%) and nursing homes (65%) and a much lower percentage for clinics and doctor's offices (28%). Sprinklers were also reported as present in half or more of all reported fires in laboratories (60%), manufacturing facilities (52%), theaters (50%), and prisons and jails (50%). In every other property use, more than half of all reported fires had no sprinklers.

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

When sprinklers fail to operate, the reason most often given (53% of failures) was shutoff of the system before fire began, as may occur in the course of routine inspection maintenance. Other leading reasons were inappropriate system for the type of fire (20%), lack of maintenance (15%), and manual intervention that defeated the system (9%). Only 2% of sprinkler failures were attributed to component damage.

When sprinklers operate but are ineffective, the reason usually had to do with an insufficiency of water applied to the fire, either because water did not reach the fire (43% of cases of ineffective performance) or because not enough water was released (31%). Other leading reasons were inappropriate system for the type of fire (12%), manual intervention that defeated the system (5%), and lack of maintenance (4%). Only 4% of cases of sprinkler ineffectiveness were attributed to component damage.

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

- 93% of fatal victims in home fires with wet-pipe sprinkler operation were located in the area of fire origin, where they could have suffered fatal injuries before sprinkler activation, compared to 53% of fatal home fire victims in general;
- 30% of fatal victims in home fires with wet-pipe sprinkler operation had their clothing on fire, compared to 7% of fatal home fire victims in general;
- 50% of fatal victims in home fires with wet-pipe sprinkler operation were age 65 or older, compared to 28% of fatal home fire victims in general; and
- 37% of fatal victims in home fires with wet-pipe sprinkler operation returned to the fire after escaping, compared to 19% of fatal home fire victims in general.

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# U.S. Experience with Sprinklers

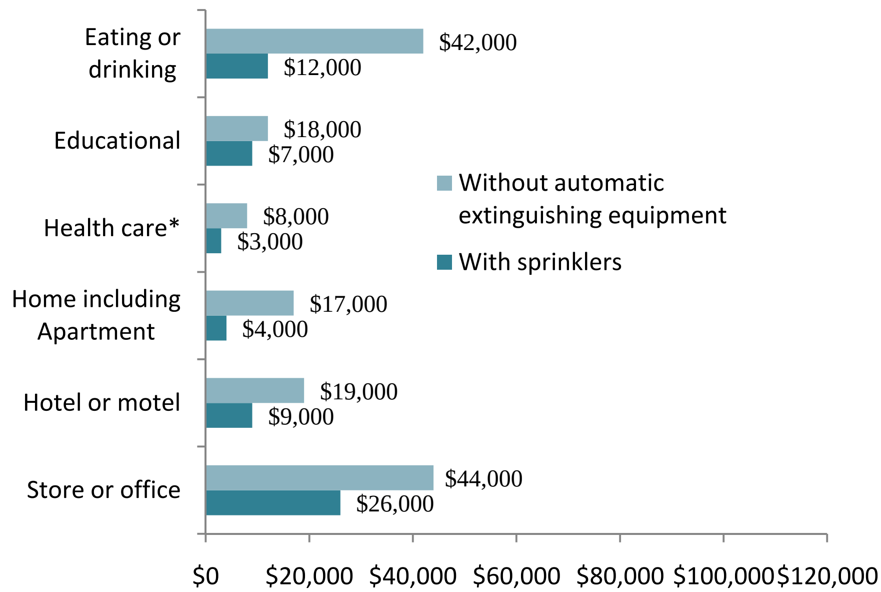
Sprinklers save lives and protect property from fires.

Compared to properties without automatic extinguishing equipment

- The death rate per fire in sprinklered homes is lower by 83%.
- For most property uses, damage per fire is lower by 40-70% in sprinklered properties.

Flame damage was confined to the room of origin in 95% of fires in sprinklered properties vs. 74% in fires with no automatic extinguishing equipment.

**Damage per Fire With and Without Sprinklers, 2003-2007**




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

Sprinklers are reliable and effective.

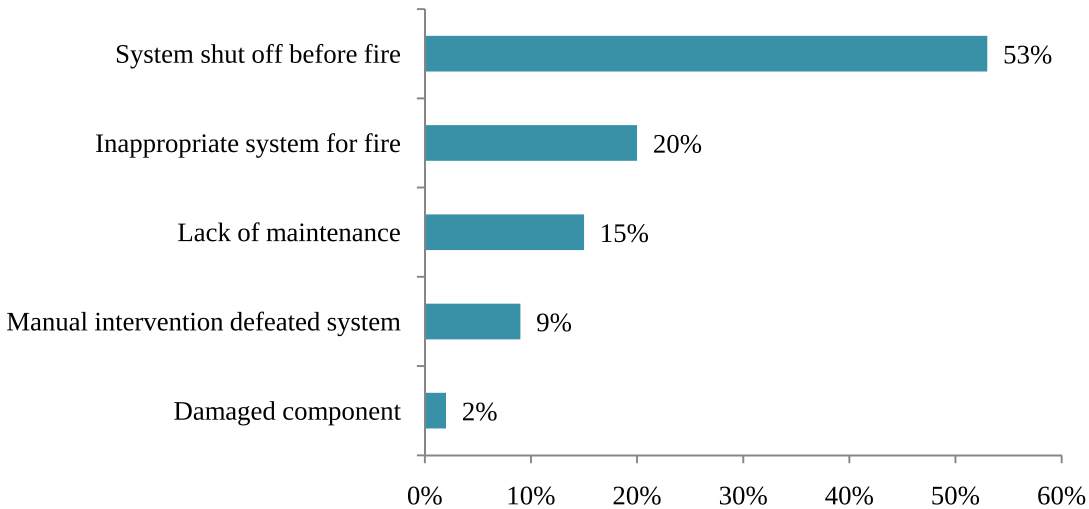
- In reported structure fires large enough to activate them, sprinklers operated in 93% of fires in sprinklered properties.
- Wet pipe sprinklers operated in 95% of these fires vs. 83% for dry pipe sprinklers.
- In reported structure fires large enough to activate them, sprinklers operated and were effective in 91% of fires in sprinklered properties.
- Wet pipe sprinklers operated and were effective in 92% of fires vs. 79% for dry pipe sprinklers.

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

Statistics are based on 2003-2007 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

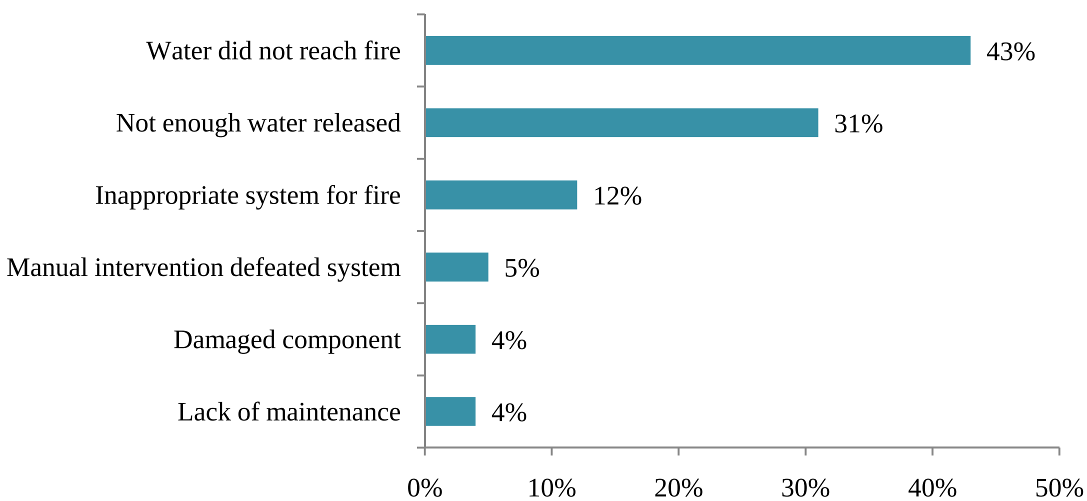
The graph below is based on the 7**%** of fires in sprinklered properties (roughly 1,000 fires per year) in which the sprinkler should have operated but did not.

**Reasons When Sprinklers Fail to Operate**
**2003-2007**




In fires where sprinklers operated, they were effective in 97% of the cases. The graph below is based on the other 3% (roughly 400 fires per year), in which the sprinkler was ineffective.

**Reasons When Sprinklers Are Ineffective**
**2003-2007**




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

- When wet pipe sprinklers operated, 89% of reported fires involved only 1 or 2 sprinklers.
- For dry pipe sprinklers, 74% involved only 1 or 2 sprinklers.

Statistics are based on 2003-2007 U.S. reported fires excluding buildings under construction. Sprinklered properties exclude properties with no sprinklers in fire area.

# Before You Read the Report:
# Some Introductory Notes on Incident Coding and Analysis

See Appendix A for general information on the statistical methodology and see Appendix B for a detailed overview of data elements related to automatic extinguishing equipment.

Here are some important points on incident coding and analysis that apply to this report:

**Fires excluded from analysis**

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

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

**Missing choices and misleading labels when coding presence or type of automatic extinguishing report**

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

- There is no code for wet chemical system, which was mandated as the type of non-water-based system to be used in eating and drinking establishments shortly after the coding rules were set for NFIRS Version 5.0, the current version of the U.S. Administration's National Fire Incident Reporting System.[1] Wet chemical systems may be coded as dry chemical systems, foam systems, or other special hazard systems and are probably more common than all of these other systems.

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

- There was no way to code automatic extinquishing equipment as unknown during 1999 to 2003, although there was the option of leaving the field blank. During that period, the U.S. Fire Administration advised that unknowns should be reported as no equipment present.[2] This arrangement had the potential to severely understate the presence of automatic extinguishing equipment. However, the estimates for 2002 and 2003 are not substantially lower than either the pre-1999 estimates or the three years of estimates from 2004 and later. Therefore, this potential problem seems to have had little effect in practice.

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[1] NFIRS compiles fire incident and casualty reports from participating U.S. local fire departments. NFPA's national estimates are based on NFIRS data and estimated totals from the annual NFPA fire experience survey of U.S. fire departments.
[2] U.S. Fire Administration, *NFIRS Coding Questions*, revised January 2, 2002, p.13.

**Recoding of sprinkler performance based on reasons for failure or ineffectiveness.**
The coding of reasons for failure or ineffectiveness has been used in this analysis to recode system performance entries. Unknown reasons have been proportionally allocated to avoid the dubious alternative assumption that the coded performance is correct if no reason is given for the performance.

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

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

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

## Presence of Sprinklers and Other Automatic Extinguishing Equipment

Of reported 2003-2007 structure fires in health care properties, an estimated 57% showed sprinklers present, with higher percentages for hospitals (71%) and nursing homes (65%) and a much lower percentage for clinics and doctor's offices (28%). Sprinklers were also reported as present in half or more of all reported fires in laboratories (60%), manufacturing facilities (52%), theaters (50%), and prisons and jails (50%). In every other property use, more than half of all reported fires had no sprinklers.

In 1994-1998, only 7% of reported structure fires had any type of automatic extinguishing equipment present. By 2003-2007, this percentage had risen by about half, to 10%. Before 1999, the type of automatic extinguishing equipment was not reported, and so it is not possible to show the trend in sprinkler presence. It is possible to show the trend in presence of automatic extinguishing equipment generally and to show how sprinkler presence compares to automatic extinguishing equipment presence in the most recent years. See Table 1 for percentage of reported structure fires, excluding buildings under construction, in which automatic extinguishing equipment was present for the year groups of 1994-1998 and 2003-2007.[3] Table 1 also shows percentage of fires with any type of sprinkler reported present for 2003 to 2007.

The following properties where large numbers of people routinely are present show less than one-third of reported fires in properties with sprinklers present in 2003-2007:

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

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

In 2003-2007, sprinklers were reported in only 5% of fires in homes (including apartments). Clearly, there is great potential for expanded installation.

The 2007 American Housing Survey included a question about sprinkler presence in homes.[4] The survey indicated 3.9% of occupied year-round housing units had sprinklers. A much smaller percentage of single family homes had sprinklers as compared to multi-unit housing. Sprinklers were present in:

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

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

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

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

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

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

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

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

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

As with detection/alarm systems and all other fire protection features, in property classes where sprinklers are not required, they will tend to go first into the properties that can afford them most, not the high-risk fire-prone properties that would benefit most from their presence.

**Table 1. Presence of Sprinklers and Other Automatic Extinguishing Equipment in Structure Fires, 1994-1998 vs. 2003-2007**

Number of Structure Fires With Equipment Present and Percentage of Total Structure Fires in Property Use

| Property Use | Any Automatic Extinguishing Equipment 1994-1998 | | Any Automatic Extinguishing Equipment 2003-2007 | | Any Sprinkler 2003-2007 | |
|---|---|---|---|---|---|---|
| All public assembly | 4,380 | (26%) | 7,650 | (49%) | 3,040 | (19%) |
| Fixed-use amusement place | 150 | (18%) | 170 | (29%) | 150 | (24%) |
| Variable-use amusement place | 140 | (16%) | 270 | (22%) | 260 | (22%) |
| Religious property | 90 | (5%) | 280 | (15%) | 270 | (14%) |
| Library or museum | 110 | (28%) | 190 | (28%) | 180 | (28%) |
| Eating or drinking establishment | 3,240 | (29%) | 4,730 | (58%) | 1,380 | (17%) |
| Passenger terminal | 60 | (35%) | 180 | (28%) | 110 | (16%) |
| Theater | 110 | (35%) | 140 | (51%) | 140 | (50%) |
| Educational property | 1,820 | (24%) | 2,250 | (34%) | 2,010 | (31%) |
| Health care property | 4,400 | (68%) | 4,010 | (61%) | 3,770 | (57%) |
| Nursing home | 2,060 | (76%) | 2,060 | (70%) | 1,910 | (65%) |
| Hospital | 1,650 | (74%) | 1,210 | (77%) | 1,110 | (71%) |
| Clinic or doctor's office | 70 | (29%) | 200 | (28%) | 200 | (28%) |
| Prison or jail | 430 | (19%) | 290 | (51%) | 290 | (50%) |
| All residential | 11,110 | (3%) | 26,980 | (8%) | 25,820 | (7%) |
| Home (including apartment) | 8,440 | (2%) | 21,110 | (5%) | 20,130 | (5%) |
| Hotel or motel | 1,690 | (35%) | 1,900 | (48%) | 1,790 | (45%) |
| Dormitory or barracks | 620 | (29%) | 1,670 | (46%) | 1,550 | (42%) |
| Rooming or boarding home | 230 | (17%) | 970 | (33%) | 950 | (32%) |
| Board and care home | NA | (NA) | 900 | (43%) | 790 | (38%) |
| Store or office | 5,230 | (21%) | 6,090 | (30%) | 4,660 | (23%) |
| Grocery or convenience store | 1,190 | (27%) | 2,030 | (44%) | 1,010 | (22%) |
| Laundry or dry cleaning or other professional service | 310 | (13%) | 350 | (19%) | 340 | (18%) |
| Service station or motor vehicle sales or service | 230 | (6%) | 230 | (10%) | 170 | (7%) |
| Department store | 1,100 | (52%) | 610 | (43%) | 560 | (39%) |
| Office | 1,470 | (25%) | 1,210 | (32%) | 1,170 | (31%) |
| Laboratory | 120 | (48%) | 110 | (65%) | 100 | (60%) |
| Manufacturing facility | 6,400 | (50%) | 4,070 | (57%) | 3,740 | (52%) |
| All storage | 1,090 | (3%) | 950 | (4%) | 920 | (4%) |
| Warehouse excluding cold storage** | 740 | (22%) | 510 | (38%) | 510 | (38%) |
| All structures | 37,100 | (7%) | 53,940 | (10%) | 44,310 | (9%) |

NA – Category not defined in fire incident data prior to 1999.
*Also includes development disability facilities. In 1994-98, this category also includes care of physically inconvenienced and excludes doctor's office and care of aged facilities without nursing staff.
**In 1994-1998, includes general warehouse, textile storage, processed food storage except cold storage and storage of wood, paper, plastics chemicals, and metals.

Notes: These are structure fires reported to U.S. municipal fire departments and so exclude fire reported only to Federal or state agencies or industrial fire brigades. Post-1998 estimates are based only on fires reported in Version 5.0 of NFIRS and include fires reported as confined fires. Estimates are not shown for 1999-2002 because of lower participation in NFIRS Version 5.0 in those years. After 1998, buildings under construction are excluded.
Source: NFIRS and NFPA survey.

## Automatic Extinguishing Equipment Type

**In reported fires, most automatic extinguishing equipment is recorded as sprinklers, and most sprinklers are wet pipe sprinklers.**
Table 2 shows the percentage of non-confined and confined fires, excluding buildings under construction, by type of automatic extinguishing equipment for each of the major property groups and some subgroups.[5] Percentage calculations are based only on fires where automatic extinguishing equipment presence and type were known and reported. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started.

Some type of sprinklers were present in 82% of 2003-2007 fires where automatic extinguishing equipment was present. Wet pipe sprinklers accounted for 73% of all systems and so out-numbered dry pipe sprinklers by roughly 10-to-1.

The major property class with the largest share for dry pipe sprinklers was storage, where dry pipe sprinklers accounted for 20% of the systems cited. Cold storage was the only property class for which dry pipe sprinklers constituted a majority (in this case, 53%) of systems cited.

For public assembly properties, there was a 40% to 60% split between sprinklers and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 40% of the systems present. Eating or drinking establishments (the dominant part of public assembly) had a 29% to 71% split between sprinkler systems and other types of automatic extinguishing equipment, respectively. Dry chemical systems accounted for 47% of total systems in eating or drinking establishments, compared to a 29% share for all sprinklers combined. Note that wet chemical systems have no clearly identified equipment type category but have been the mandated type of system for eating and drinking establishments for roughly a decade. It seems likely that most of the dry chemical systems reported are either wet chemical systems or dry chemical extinguishers, which should not be reported as any type of automatic equipment.

Public assembly properties, especially eating and drinking establishments, have the highest percentages for both dry chemical systems (40% and 47%, respectively) and other special hazard systems (11% and 12%, respectively), both of which probably are dominated by wet chemical systems, for which there is no labeled category. Roughly ten years ago, the applicable standards for eating and drinking establishments required that dry chemical systems be replaced by wet chemical systems. It seems likely that some wet chemical systems will be coded as other special hazard systems and some will be coded as dry chemical systems, the latter being the well-defined equipment type closest to a wet chemical system.

It would be useful to have a better sense of what kind of equipment is coded as “other special hazard systems.” There are some types of automatic extinguishing equipment that do not fit exactly into any of the defined categories, such as equipment using wet chemicals. It is also

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

possible that some fires will be coded as other special hazard system when they really involved automatic extinguishing equipment of one of the defined types.  The category also could be used for some devices that are not automatic and so should not be coded as automatic extinguishing equipment present, such as portable extinguishers.

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

**Table 2.**
**Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires Where Equipment Was Present and of Known Type, by Property Use**
**2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use | Fires per year with any automatic extinguishing equipment | All sprinklers | Wet pipe sprinklers | Dry pipe sprinklers | Other sprinklers* |
|---|---|---|---|---|---|
| All public assembly | 7,650 | 40% | 34% | 2% | 4% |
| Fixed-use amusement place | 170 | 85% | 82% | 3% | 1% |
| Variable-use amusement place | 270 | 97% | 84% | 13% | 0% |
| Religious property | 280 | 97% | 86% | 4% | 7% |
| Library or museum | 190 | 99% | 92% | 5% | 2% |
| Eating or drinking establishment | 4,730 | 29% | 23% | 2% | 4% |
| Passenger terminal | 180 | 58% | 35% | 22% | 1% |
| Theater | 140 | 99% | 95% | 3% | 1% |
| Educational property | 2,250 | 89% | 80% | 6% | 3% |
| Health care property** | 4,010 | 94% | 81% | 12% | 1% |
| Nursing home | 2,060 | 93% | 78% | 15% | 1% |
| Hospital | 1,210 | 92% | 85% | 6% | 1% |
| Clinic or doctor's office | 200 | 98% | 95% | 3% | 1% |
| Prison or jail | 290 | 98% | 87% | 10% | 2% |
| All residential | 26,980 | 96% | 87% | 7% | 2% |
| Home (including apartment) | 21,110 | 95% | 86% | 6% | 3% |
| Hotel or motel | 1,900 | 94% | 85% | 6% | 3% |
| Dormitory or barracks | 1,670 | 93% | 77% | 14% | 1% |
| Rooming or boarding house | 970 | 98% | 88% | 11% | 0% |
| Board and care home | 900 | 89% | 82% | 7% | 0% |
| Store or office | 6,090 | 77% | 67% | 7% | 3% |
| Grocery or convenience store | 2,030 | 50% | 44% | 3% | 3% |
| Laundry or dry cleaning or other professional service | 350 | 95% | 85% | 9% | 1% |
| Service station or motor vehicle sales or service | 230 | 76% | 70% | 5% | 1% |
| Department store | 610 | 91% | 78% | 12% | 1% |
| Office | 1,210 | 97% | 85% | 7% | 4% |
| Laboratory | 110 | 92% | 69% | 2% | 21% |
| Manufacturing facility | 4,070 | 92% | 79% | 10% | 3% |
| All storage | 950 | 97% | 75% | 20% | 2% |
| Warehouse excluding cold storage | 510 | 99% | 82% | 15% | 1% |
| All structures*** | 53,940 | 82% | 73% | 7% | 3% |

* Includes deluge and pre-action sprinkler systems and may include sprinklers of unknown or unreported type.
** Nursing home, hospital, clinic, doctor's office, or development disability facility
*** Includes some property uses that are not shown separately.

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

Source: NFIRS and NFPA survey.

**Table 2. (Continued)**
**Type of Automatic Extinguishing Equipment Reported as Percentage of All Fires Where Equipment Was Present and of Known Type, by Property Use**
**2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use | All systems other than sprinklers | Dry chemical system* | Carbon dioxide (CO2) system | Halogen type system* | Foam system | Other special hazard system* |
|---|---|---|---|---|---|---|
| All public assembly | 60% | 40% | 3% | 3% | 4% | 11% |
| Fixed-use amusement place | 15% | 14% | 0% | 0% | 0% | 1% |
| Variable-use amusement place | 3% | 2% | 0% | 0% | 0% | 1% |
| Religious property | 3% | 2% | 0% | 0% | 0% | 1% |
| Library or museum | 1% | 1% | 0% | 0% | 0% | 0% |
| Eating or drinking establishment | 71% | 47% | 3% | 3% | 5% | 12% |
| Passenger terminal | 42% | 41% | 0% | 0% | 0% | 1% |
| Theater | 1% | 1% | 0% | 0% | 0% | 0% |
| Educational property | 11% | 8% | 0% | 0% | 1% | 2% |
| Health care property** | 6% | 4% | 1% | 0% | 0% | 1% |
| Nursing home | 7% | 5% | 1% | 0% | 0% | 0% |
| Hospital | 8% | 5% | 0% | 0% | 0% | 3% |
| Clinic or doctor’s office | 2% | 0% | 0% | 0% | 0% | 1% |
| Prison or jail | 2% | 1% | 0% | 0% | 0% | 0% |
| All residential | 4% | 2% | 0% | 0% | 0% | 2% |
| Home (including apartment) | 5% | 2% | 0% | 0% | 0% | 2% |
| Hotel or motel | 6% | 2% | 0% | 0% | 0% | 4% |
| Dormitory or barracks | 7% | 5% | 0% | 0% | 1% | 1% |
| Rooming or boarding home | 2% | 1% | 0% | 0% | 0% | 0% |
| Board and care home | 11% | 4% | 0% | 0% | 4% | 3% |
| Store or office | 23% | 15% | 2% | 1% | 2% | 4% |
| Grocery or convenience store | 50% | 31% | 4% | 1% | 6% | 7% |
| Laundry or dry cleaning | 5% | 0% | 0% | 0% | 0% | 4% |
| Service station or motor vehicle sales or service | 24% | 20% | 0% | 1% | 0% | 2% |
| Department store | 9% | 8% | 0% | 0% | 0% | 0% |
| Office | 3% | 1% | 1% | 0% | 0% | 0% |
| Laboratory | 8% | 2% | 4% | 1% | 0% | 1% |
| Manufacturing facility | 8% | 2% | 4% | 0% | 0% | 1% |
| All storage | 3% | 1% | 0% | 0% | 0% | 2% |
| Warehouse excluding cold storage | 1% | 0% | 0% | 0% | 0% | 0% |
| Cold storage | 0% | 0% | 0% | 0% | 0% | 0% |
| All structures*** | 18% | 11% | 1% | 1% | 1% | 4% |

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

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

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

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

Source: NFIRS and NFPA survey.

## Automatic Extinguishing Equipment Reliability and Effectiveness

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

- All sprinklers
- Wet pipe sprinklers
- Dry pipe sprinklers
- Dry chemical systems (which probably includes and may be dominated by wet chemical systems and may include some miscoded portable extinguishers),
- Carbon dioxide systems (which may include some wet chemical systems and some miscoded portable extinguishers),
- Foam systems (which may include some wet chemical systems and some miscoded portable extinguishers), and
- Halogen systems (which may include some wet chemical systems and some miscoded portable extinguishers).

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

**For most property use groups and most types of automatic extinguishing equipment, the majority of reported fires were too small to activate operational equipment.**
When automatic extinguishing equipment was present, the percentages of fires too small to activate operating equipment, based on overall reported structure fires, were as follows:

- 65% for all sprinklers,
- 65% for wet pipe sprinklers,
- 70% for dry pipe sprinklers,
- 61% for dry (or possibly wet) chemical systems,
- 43% for carbon dioxide systems,
- 66% for foam systems, and
- 59% for halogen systems.

**Sprinklers in the area of fire failed to operate in only 7% of reported structure fires large enough to activate sprinklers.**
Failure rates are equal to 100% minus the percentage of systems that operated, which is the percentage shown in Table 3A. The other estimated failure rates corresponding to percentage operating rates shown in Table 3A are:

- 5% for wet pipe sprinklers,

- 17% for dry pipe sprinklers,
- 26% for dry (or possibly wet) chemical systems,
- 17% for carbon dioxide systems,
- 3% for foam systems, and
- 4% for halogen systems.

For major property classes and sprinklers, the estimated failure rates range from a low of 4% for residential properties, public assembly properties and stores and offices to a high of 32% for educational properties and 29% for storage properties. The estimated failure rates for wet pipe sprinklers specifically were 25% for educational properties and 16% for storage properties.

**For sprinklers that operated, their performance was deemed effective in 97% of the cases. For all confined or non-confined fires large enough to activate sprinklers, excluding buildings under construction, sprinklers operated effectively 91% of the time.**
The percentages of effective operation for all structures were as follows for other types of automatic extinguishing equipment:

- 92% for wet pipe sprinklers,
- 79% for dry pipe sprinklers,
- 60% for dry (or possibly wet) chemical systems,
- 79% for carbon dioxide systems,
- 81% for foam systems, and
- 88% for halogen systems.

Wet pipe sprinklers are both much more reliable than dry pipe sprinklers (95% vs. 83%) and slightly more effective when they operate (98% vs. 95%), resulting in a much higher percentage of effective operation (92% vs. 79%). Operating effectiveness is much lower for dry (or possibly wet) chemical systems than for any other type of automatic extinguishing equipment (60% vs. 79-92%) and is especially low (51%) for eating or drinking establishments, which account for most of the fires reported with this type of equipment. Eating or drinking establishments also account for most fires reported with carbon dioxide, foam, or halogen systems. These installations may all include a high proportion of misclassified wet chemical systems or portable extinguishers, because carbon dioxide, foam, and halogen systems are rarely appropriate for eating or drinking establishments.

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

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

For all types of sprinklers combined:

- 53% of failures to operate were attributed to the equipment being shut off,
- 20% were because the equipment was inappropriate for the type of fire,
- 15% were because of lack of maintenance,
- 9% were because manual intervention defeated the equipment, and
- 2% were because a component was damaged.

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

*Only 2% were because of a failing of the equipment rather than a failing of the people who designed, selected, maintained, and operated the equipment.* If these human failings could be eliminated, the overall sprinkler failure rate would drop from the estimated 7% of reported fires to less than 0.2%. That is the kind of sprinkler failure rate reported by Marryatt[6] for Australia and New Zealand, where high standards of maintenance are reportedly commonplace.

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

**Most cases of sprinkler ineffectiveness were because water did not reach the fire (43%) or because not enough water was released (31%).**

Table 5 provides distributions of reasons for ineffectiveness, by property class and type of automatic extinguishing equipment. In Table 5, two of the reasons for ineffectiveness are (extinguishing) agent did not reach the fire and not enough (extinguishing) agent was released. For sprinklers, the agent is water. In addition to the two reasons cited, other reasons for sprinkler ineffectiveness for all structures were inappropriate equipment for the type of fire (12%), defeating due to manual intervention (5%), damage to a system component (4%), and lack of maintenance (4%).

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

Insufficient water can be released if there are problems with the system's water supply. This reason for ineffectiveness can also overlap with other reasons, such as inappropriate equipment (if, for example, the hazard has changed under the equipment and now requires a higher water flow density than is provided by the now inappropriate equipment) and defeating by manual intervention (if, for example, the sprinklers are turned off prematurely so that insufficient water reaches the fire). Insufficient water also could be one of the reasons that could be cited if a flash

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

fire or a fire with several points of origin overwhelms the system or if an explosion reduces the water flow but does not cause complete system failure.

Reasons for ineffectiveness are different for wet pipe sprinklers and dry pipe sprinklers, with dry pipe sprinklers having 60% of cases attributed to not enough water released compared to 25% for wet pipe sprinklers. Because the design of dry pipe sprinklers assures a delayed release of water, it is not surprising that when such systems are ineffective, an insufficiency of water is usually involved.

Even a well-maintained, complete, appropriate system requires the support of a well-considered integrated design for all the other elements of the building's fire protection. Unsatisfactory sprinkler performance can result from an inadequate water supply or 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.

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

**Table A. Non-Confined Fires With Areas of Origin That Could Be Room Larger Than the Sprinkler Design Area for the Space, as Percent of Total Non-Confined and Confined Structure Fires for Buildings Not Under Construction and With Sprinklers in Fire Area Percentage of 2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Property Use | Large Assembly Area (At Least 100 People) | Sales, Showroom or Performance Area | Storage Room, Area, Tank or Bin | Shipping, Receiving or Loading Area | Unclassified Storage Area | All Areas Combined |
|---|---|---|---|---|---|---|
| Eating or drinking establishment | 1.0% | 0.2% | 1.7% | 0.2% | 1.2% | 4.3% |
| Public assembly excluding eating or drinking establishment | 2.4% | 0.7% | 0.9% | 0.2% | 0.8% | 5.0% |
| Educational | 1.3% | 0.3% | 0.6% | 0.0% | 0.7% | 2.9% |
| Health care property* | 0.1% | 0.0% | 0.5% | 0.0% | 0.3% | 0.9% |
| Home (including apartment) | 0.0% | 0.0% | 0.2% | 0.0% | 0.2% | 0.4% |
| Hotel or motel | 1.6% | 0.0% | 0.3% | 0.0% | 0.5% | 1.4% |
| Store or office | 0.1% | 5.7% | 2.2% | 2.1% | 2.2% | 12.2% |
| Manufacturing facility | 0.1% | 0.0% | 2.5% | 2.1% | 1.7% | 6.4% |
| Warehouse excluding cold storage | 0.1% | 0.3% | 5.0% | 12.4% | 9.9% | 27.7% |

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

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

Source: NFIRS and NFPA survey.

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

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

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

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

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

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

Table 6 provides direct measurement of sprinkler effect involving the first scenario. For all structures combined, 74% have flame damage confined to room of origin when there is no automatic extinguishing equipment present. This rises to 95% of fires with flame damage confined to room of origin when any type of sprinkler is present.

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

**Dry pipe sprinklers tend to have more sprinklers operating than wet pipe sprinklers.**
Table 7A shows the number of sprinklers operating by type of sprinkler system. Five or fewer heads operated in 97% of the wet pipe system activations and 89% of the dry pipe system activations.

Dry-pipe systems are much more likely to open more than one sprinkler than wet pipe systems (39% vs. 23% of fires). The likely reason is the designed time delay in tripping the dry pipe valve and passing water through the piping to the opened sprinklers. The delay permits fire to spread, which can mean a larger fire, requiring and causing more sprinklers to activate.

**Table B. Combined Sprinkler Performance vs.
Sprinkler Success in Confining Fire to Room of Origin, by Property Use Group
2003-2007 Structure Fires Reported to U.S. Fire Departments Where Sprinklers Were Present in Fire Area, Fire Was Large Enough to Activate Sprinklers, and Building Was Not Under Construction**

| Property Use | Percentage of Fires Where Sprinklers Operated Effectively (from Table 3A) | Percentage of Fires with Flame Damage Confined to Room of Origin |
|---|---|---|
| Public assembly | 90% | 95% |
| Eating or drinking establishment | 90% | 93% |
| Educational | 68% | 98% |
| Health care property* | 87% | 99% |
| Residential | 95% | 96% |
| Home (including apartment) | 94% | 97% |
| Hotel or motel | 91% | 97% |
| Dormitory or barracks | 99% | 97% |
| Store or office | 94% | 93% |
| Grocery or convenience store | 94% | 96% |
| Laundry or dry cleaning or other professional supply or service | 92% | 92% |
| Service station or motor vehicle sales or service | 92% | 85% |
| Department store | 95% | 92% |
| Office building | 95% | 94% |
| Manufacturing facility | 86% | 87% |
| Storage | 77% | 80% |
| Warehouse excluding cold storage | 77% | 79% |
| All structures** | 91% | 95% |

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

** Includes some properties not separately listed above.

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

Table 7B shows the number of wet pipe sprinklers operating by property use group. In warehouses or manufacturing facilities respectively, 69-70% of the fires in properties where wet pipe sprinklers operated had two or fewer sprinklers operating, which means 30-31% of the fires in properties had at least three sprinklers operating. Similarly, 89-90% had five or fewer sprinklers operating, which means 10-11% had at least six sprinklers operating. By contrast, in public assembly properties and stores and offices where wet pipe sprinklers operated, 87-90% of fires in properties had two or fewer sprinklers operating, which means only 10-13% of fires in properties had at least three sprinklers operating. Similarly, 95-96% had five or fewer sprinklers operating, which means only 4-5% had at least six sprinklers operating.

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

**Effectiveness declines when more sprinklers operate.**
When more than 1-2 sprinklers have to operate, this may be taken as an indication of less than ideal performance. Table 8 shows that the percentage of fires where performance is deemed effective decreases as the number of wet pipe sprinklers operating decreases, falling from 97% of fires when one sprinkler opens to 79% when more than 10 sprinklers open. At the same time, the number of sprinklers operating should not be used as an independent indicator of effectiveness because sprinklers are deemed effective in most fires where sprinklers operate, no matter how many sprinklers operate. Furthermore, most sprinkler installations are designed for control, not extinguishment, and anticipate that multiple sprinklers will be needed for control in some fire scenarios.

**Table C. Reasons for Failure or Ineffectiveness as Percentages of All Cases of Failure or Ineffectiveness, for All Structures and All Sprinklers**

| Reason | Failure | | Ineffectiveness | | Combined | |
|---|---|---|---|---|---|---|
| System shut off | 521 | (38%) | 0 | (0%) | 521 | (38%) |
| Wrong type of (inappropriate) system for type of fire | 197 | (14%) | 47 | (3%) | 244 | (18%) |
| Water discharged but did not reach fire | 0 | (0%) | 169 | (12%) | 169 | (12%) |
| Lack of maintenance | 148 | (11%) | 16 | (1%) | 163 | (12%) |
| Not enough water discharged | 0 | (0%) | 121 | (9%) | 121 | (9%) |
| Manual interruption defeated system | 89 | (7%) | 20 | (1%) | 108 | (8%) |
| System component damaged | 20 | (1%) | 16 | (1%) | 35 | (3%) |
| Total | 974 | (72%) | 388 | (28%) | 1,362 | (100%) |

Source: Based on Tables 4A and 5A.

**Details on reasons for failure or ineffectiveness and how to address them.**
The following potential reasons for failure or ineffectiveness are defined in the statistical database:

- System shut off (a reason for failure but not for ineffectiveness),
- Wrong type of (inappropriate) system for the type of fire,
- Agent discharged but did not reach fire (a reason for ineffectiveness but not for failure),
- Lack of maintenance [including corrosion or heads painted],
- Not enough agent discharged (a reason for ineffectiveness but not for failure),
- Manual intervention [defeated the system] (8%)
- System component damaged,
- Fire not in area protected [by the system] (excluded from analysis of failure and ineffectiveness)

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

**System shut off**

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

**Inappropriate system**

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

"Inappropriate" system can refer to the wrong type of agent (e.g., water vs. chemical agent or carbon dioxide), the wrong type of system for the same agent (e.g., wet pipe vs. dry pipe), or the wrong design for the same system and agent (e.g., a design adequate only for Class I commodities vs. a design adequate for any class of commodities). The NFPA compilation identifies cases where the system was inadequate for the hazard or where the fire overwhelmed the system with no further details available.

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

**Agent did not reach fire**

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

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

**Lack of maintenance**

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

**Not enough agent discharged**

The NFPA incident compilation identifies several cases of fire overwhelming the sprinklers, but for most of these incidents, it was not reported whether the sprinkler system had problems affecting the flow or whether the system design was no longer adequate for the hazard being protected or whether some other problem was involved.

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

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

**Manual intervention**

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

**System component damaged**

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

### Fire not in area protected

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

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

**Table D. Leading Areas of Origin for Fires in One- or Two-Family Homes Excluding Buildings Under Construction 2003-2007 Structure Fires Reported to U.S. Fire Departments**

| Area of Origin | Percent of Fires Where Wet-Pipe Sprinklers Were Present But Not Present in Fire Area | Percent of All Fires |
|---|---|---|
| Kitchen | 32% | 32% |
| Wall assembly or concealed space | 9% | 3% |
| Attic or concealed space above top story | 8% | 3% |
| Crawl space or substructure space | 6% | 2% |
| Garage** | 6% | 3% |
| Exterior balcony or unenclosed porch | 5% | 2% |
| Courtyard, terrace or patio | 5% | 1% |
| Laundry room or area | 4% | 4% |
| Exterior wall surface | 4% | 3% |
| Other area of origin | 21% | 47% |
| Total | 100% | 100% |

* These are only fires where the absence of sprinklers in the fire area was identified because that absence was cited as a reason for failure or ineffectiveness.

** Excludes garages coded as separate building.

Source: NFIRS and NFPA survey.

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

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

One-third of fires with no sprinklers in the fire area were fires that began in the kitchen, an area that should be covered by sprinklers in any standard installation. However, concealed spaces and other structural areas, external areas, garages, and attics account for nearly half (43%) of the fires where sprinklers are present but not in the fire area. These same areas accounted for less than one-fifth (18%) of fires in dwellings in general.

**Table 3.**
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**
**2003-2007 Structure Fires**

**A. All Sprinklers**

| Property Use | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area: Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
|---|---|---|---|---|---|---|
| All public assembly | 3,040 | 68% | 910 | 96% | 94% | 90% |
| Eating or drinking establishment | 1,380 | 54% | 580 | 97% | 93% | 90% |
| Educational property | 2,010 | 83% | 320 | 68% | 100% | 68% |
| Health care property* | 3,770 | 83% | 620 | 88% | 98% | 87% |
| Nursing home | 1,910 | 80% | 380 | 83% | 99% | 82% |
| Residential | 25,820 | 66% | 8,440 | 96% | 99% | 95% |
| Home (including apartment | 20,130 | 62% | 7,290 | 95% | 99% | 94% |
| Hotel or motel | 1,790 | 69% | 520 | 92% | 99% | 91% |
| Dormitory or barracks | 1,550 | 81% | 290 | 99% | 100% | 99% |
| Rooming or boarding house | 950 | 82% | 150 | 97% | 99% | 96% |
| Board and care home | 790 | 85% | 110 | 98% | 100% | 98% |
| Store or office | 4,660 | 64% | 1,580 | 96% | 99% | 94% |
| Grocery or convenience store | 1,010 | 64% | 340 | 97% | 97% | 94% |
| Laundry or dry cleaning | 340 | 59% | 130 | 96% | 96% | 92% |
| Service station or motor vehicle sales or service | 170 | 40% | 100 | 97% | 95% | 92% |
| Department store | 560 | 68% | 170 | 95% | 99% | 95% |
| Office | 1,170 | 75% | 280 | 95% | 100% | 95% |
| Manufacturing facility | 3,740 | 48% | 1,850 | 93% | 93% | 86% |
| All storage | 920 | 48% | 470 | 79% | 97% | 77% |
| Warehouse excluding cold storage | 510 | 43% | 280 | 80% | 97% | 77% |
| All structures** | 44,310 | 65% | 14,630 | 93% | 97% | 91% |

* Nursing home, hospital, clinic, doctor's office, or development disability facility.
** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**
**2003-2007 Structure Fires**

**B. Wet Pipe Sprinklers Only**

| | | | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area | | | |
|---|---|---|---|---|---|---|
| **Property Use** | **Number of fires per year where extinguishing equipment was present** | **Percent of fires too small to activate equipment** | **Number of fires per year** | **Percent where equipment operated (A)** | **Percent effective of those that operated (B)** | **Percent where equipment operated effectively (A x B)** |
| All public assembly | 2,570 | 70% | 730 | 97% | 97% | 94% |
| Eating or drinking establishment | 1,110 | 57% | 460 | 97% | 97% | 94% |
| Educational property | 1,800 | 85% | 250 | 75% | 100% | 75% |
| Health care property* | 3,270 | 83% | 520 | 90% | 99% | 89% |
| Nursing home | 1,600 | 81% | 300 | 85% | 99% | 84% |
| Residential | 23,370 | 64% | 7,920 | 96% | 100% | 96% |
| Home (including apartment | 18,220 | 61% | 6,840 | 96% | 99% | 96% |
| Hotel or motel | 1,620 | 70% | 470 | 88% | 99% | 87% |
| Dormitory or barracks | 1,290 | 77% | 290 | 99% | 100% | 99% |
| Rooming or boarding home | 850 | 79% | 150 | 97% | 99% | 96% |
| Store or office | 4,070 | 64% | 1,390 | 96% | 99% | 95% |
| Grocery or convenience store | 880 | 64% | 300 | 97% | 97% | 95% |
| Laundry or dry cleaning | 300 | 57% | 130 | 96% | 96% | 92% |
| Service station or motor vehicle sales or service | 160 | 40% | 90 | 97% | 95% | 92% |
| Department store | 480 | 69% | 140 | 95% | 99% | 94% |
| Office | 1,030 | 74% | 260 | 96% | 99% | 96% |
| Manufacturing facility | 3,210 | 49% | 1,540 | 96% | 92% | 89% |
| All storage | 710 | 48% | 360 | 84% | 98% | 82% |
| Warehouse excluding cold storage | 420 | 45% | 230 | 85% | 97% | 83% |
| All structures** | 39,110 | 65% | 13,000 | 95% | 98% | 92% |

* Nursing home, hospital, clinic, doctor's office, or development disability facility.
** Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**
**2003-2007 Structure Fires**

**C. Dry Pipe Sprinklers Only**

| | | | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area | | | |
|---|---|---|---|---|---|---|
| **Property Use** | **Number of fires per year where extinguishing equipment was present** | **Percent of fires too small to activate equipment** | **Number of fires per year** | **Percent where equipment operated (A)** | **Percent effective of those that operated (B)** | **Percent where equipment operated effectively (A x B)** |
| All public assembly | 190 | 60% | 70 | 94% | 76% | 71% |
| Eating or drinking establishment | 90 | 46% | 40 | 100% | 69% | 69% |
| Residential | 1,880 | 82% | 320 | 92% | 98% | 90% |
| Home (including apartment) | 1,350 | 81% | 250 | 89% | 98% | 88% |
| Store or office | 420 | 65% | 140 | 91% | 99% | 90% |
| Manufacturing facility | 410 | 45% | 210 | 90% | 95% | 86% |
| All storage | 190 | 49% | 90 | 57% | 97% | 55% |
| Warehouse excluding cold storage | 80 | 26% | 60 | 43% | 96% | 41% |
| All structures* | 3,810 | 70% | 1,100 | 83% | 95% | 79% |

* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**
**Automatic Extinguishing Equipment Reliability and Effectiveness, by Property Use**
**2003-2007 Structure Fires**

**D. Dry Chemical Systems Only**

| | | | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area | | | |
|---|---|---|---|---|---|---|
| **Property Use** | **Number of fires per year where extinguishing equipment was present** | **Percent of fires too small to activate equipment** | **Number of fires per year** | **Percent where equipment operated (A)** | **Percent effective of those that operated (B)** | **Percent where equipment operated effectively (A x B)** |
| All public assembly | 3,060 | 63% | 1,020 | 69% | 75% | 51% |
| Eating or drinking establishment | 2,230 | 63% | 730 | 68% | 75% | 51% |
| Residential | 570 | 50% | 300 | 94% | 95% | 89% |
| Store or office | 890 | 56% | 330 | 82% | 75% | 61% |
| Grocery or convenience store | 630 | 66% | 170 | 92% | 73% | 67% |
| All structures* | 5,930 | 61% | 2,060 | 74% | 81% | 60% |

* Includes some properties not listed above.

Note: "Dry chemical systems" may include some wet chemical systems, because there is no category designated for wet chemical systems. These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**
**Automatic Extinguishing Equipment Reliability, by Property Use**
**2003-2007 Structure Fires**

**E. Carbon Dioxide Systems Only**

| Property Use | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area: Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
|---|---|---|---|---|---|---|
| All public assembly | 220 | 50% | 100 | 37% | 93% | 34% |
| Eating or drinking establishment | 160 | 52% | 70 | 39% | 91% | 35% |
| Manufacturing facility | 180 | 3% | 160 | 99% | 93% | 93% |
| All structures* | 710 | 43% | 360 | 83% | 94% | 79% |

**F. Foam Systems Only**

| Property Use | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area: Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
|---|---|---|---|---|---|---|
| All public assembly | 320 | 66% | 70 | 96% | 69% | 66% |
| Eating or drinking establishment | 230 | 63% | 50 | 95% | 69% | 66% |
| All structures* | 670 | 66% | 160 | 97% | 84% | 81% |

* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 3. (Continued)**
**Automatic Extinguishing Equipment Reliability, by Property Use**
**2003-2007 Structure Fires**

**G. Halogen Systems Only**

| Property Use | Number of fires per year where extinguishing equipment was present | Percent of fires too small to activate equipment | When equipment is present, fire is large enough to activate equipment, and sprinklers were present in fire area: Number of fires per year | Percent where equipment operated (A) | Percent effective of those that operated (B) | Percent where equipment operated effectively (A x B) |
|---|---|---|---|---|---|---|
| All public assembly | 210 | 65% | 50 | 100% | 93% | 93% |
| Eating or drinking establishment | 150 | 65% | 40 | 100% | 91% | 91% |
| All structures* | 380 | 59% | 110 | 96% | 92% | 88% |

* Includes some properties not listed separately above.

Note: These are percentages of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Percentages are based on estimated total fires reported in NFIRS Version 5.0 with the indicated type of automatic extinguishing system and system performance not coded as fire too small to activate systems. Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to fail if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. Property use classes are shown only if they accounted for at least 100 projected fires per year with the specific type of automatic extinguishing equipment present.

Source: NFIRS and NFPA survey.

**Table 4.**
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**A. All Sprinklers**

| Property Use | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|---|---|---|---|---|---|---|
| All public assembly | 61% | 6% | 9% | 21% | 3% | 32 |
| Eating or drinking establishment | 60% | 0% | 17% | 23% | 0% | 17 |
| Residential | 35% | 43% | 3% | 16% | 2% | 377 |
| Home (including apartment) | 46% | 34% | 2% | 14% | 5% | 357 |
| Store or office | 64% | 7% | 17% | 10% | 1% | 70 |
| Manufacturing facility | 62% | 4% | 13% | 18% | 4% | 123 |
| Storage | 83% | 2% | 4% | 5% | 5% | 96 |
| All structures* | 53% | 20% | 15% | 9% | 2% | 974 |

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 4. (Continued)**
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**2003-2007 Non-Confined and Confined Structure Fires**

**B. Wet Pipe Sprinklers Only**

| Property Use | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|---|---|---|---|---|---|---|
| Public assembly | 67% | 4% | 8% | 20% | 0% | 23 |
| Eating or drinking establishment | 67% | 0% | 13% | 20% | 0% | 14 |
| Residential | 43% | 30% | 4% | 21% | 2% | 297 |
| Home (including apartment) | 57% | 18% | 3% | 19% | 5% | 264 |
| Store or office | 70% | 5% | 8% | 17% | 0% | 54 |
| Manufacturing facility | 57% | 7% | 11% | 19% | 6% | 60 |
| All structures* | 52% | 17% | 10% | 18% | 2% | 704 |

**C. Dry Pipe Sprinklers Only**

| Property Use | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|---|---|---|---|---|---|---|
| All structures | 65% | 19% | 5% | 6% | 5% | 185 |

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 4. (Continued)**
**Reasons for Failure to Operate When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**D. Dry Chemical Systems Only**

| Property Use | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|---|---|---|---|---|---|---|
| Public assembly | 13% | 2% | 80% | 3% | 1% | 320 |
| Eating or drinking establishment | 14% | 2% | 78% | 5% | 1% | 235 |
| Residential | 0% | 0% | 100% | 0% | 0% | 14 |
| Store or office | 5% | 5% | 79% | 4% | 7% | 59 |
| Grocery or convenience store | 9% | 20% | 22% | 18% | 32% | 13 |
| All structures* | 11% | 2% | 76% | 10% | 2% | 542 |

**E. Carbon Dioxide Systems Only**

| Property Use | System shut off | Inappropriate system for type of fire | Lack of maintenance | Manual intervention defeated system | System component damaged | Total fires per year |
|---|---|---|---|---|---|---|
| All structures | 4% | 0% | 90% | 0% | 6% | 60 |

* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 5.**
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**A. All Sprinklers**

| Property Use | Agent did not reach fire | Not enough agent released | Inappropriate system for type of fire | Manual intervention defeated system | System component damaged | Lack of maintenance | Fires per year |
|---|---|---|---|---|---|---|---|
| All public assembly | 45% | 48% | 4% | 3% | 0% | 0% | 55 |
| Eating or drinking establishment | 49% | 46% | 5% | 0% | 0% | 0% | 41 |
| Residential | 31% | 12% | 21% | 4% | 16% | 15% | 54 |
| Home (including apartment) | 35% | 8% | 14% | 2% | 23% | 16% | 50 |
| Store or office | 50% | 16% | 10% | 16% | 0% | 8% | 20 |
| Manufacturing facility | 46% | 35% | 4% | 9% | 1% | 5% | 127 |
| Storage | 38% | 13% | 0% | 25% | 24% | 0% | 12 |
| All structures* | 43% | 31% | 12% | 5% | 4% | 4% | 388 |

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 5. (Continued)**
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**B. Wet Pipe Sprinklers Only**

| Property Use | Agent did not reach fire | Not enough agent released | Inappropriate system for type of fire | Manual intervention defeated system | System component damaged | Lack of maintenance | Total fires per year |
|---|---|---|---|---|---|---|---|
| Public assembly | 60% | 20% | 11% | 9% | 0% | 0% | 18 |
| Eating or drinking establishment | 62% | 24% | 14% | 0% | 0% | 0% | 13 |
| Residential | 39% | 4% | 22% | 4% | 20% | 9% | 48 |
| Home (including apartment) | 39% | 3% | 14% | 3% | 26% | 15% | 43 |
| Store or office | 55% | 10% | 14% | 21% | 0% | 0% | 15 |
| Manufacturing facility | 49% | 33% | 5% | 9% | 0% | 4% | 114 |
| All structures* | 47% | 25% | 15% | 6% | 4% | 3% | 303 |

**C. Dry Pipe Sprinklers Only**

| Property Use | Agent did not reach fire | Not enough agent released | Inappropriate system for type of fire | Manual intervention defeated system | System component damaged | Lack of maintenance | Total fires per year |
|---|---|---|---|---|---|---|---|
| All structures | 16% | 60% | 3% | 3% | 3% | 14% | 45 |

* Includes some properties not listed above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 5. (Continued)**
**Reasons for Ineffectiveness When Fire Was Large Enough to Activate Equipment and Equipment Was Present in Area of Fire, by Property Use**
**Based on Indicated Estimated Number of 2003-2007 Structure Fires per Year**

**D. Dry Chemical Systems Only**

| Property Use | Agent did not reach fire | Not enough agent released | Inappropriate system for type of fire | Manual intervention defeated system | System component damaged | Lack of maintenance | Total fires per year |
|---|---|---|---|---|---|---|---|
| Public assembly | 72% | 19% | 2% | 2% | 0% | 5% | 178 |
| Eating or drinking establishment | 72% | 19% | 2% | 2% | 0% | 4% | 122 |
| Residential | 21% | 69% | 0% | 10% | 0% | 0% | 17 |
| Store or office | 44% | 45% | 6% | 0% | 2% | 3% | 68 |
| Grocery or convenience store | 81% | 10% | 10% | 0% | 0% | 0% | 43 |
| All structures* | 57% | 34% | 2% | 2% | 0% | 3% | 291 |

**E. Carbon Dioxide Systems Only**

| Property Use | Agent did not reach fire | Not enough agent released | Inappropriate system for type of fire | Manual intervention defeated system | System component damaged | Lack of maintenance | Total fires per year |
|---|---|---|---|---|---|---|---|
| All structures | 49% | 51% | 0% | 0% | 0% | 0% | 17 |

* Includes some properties not listed separately above.

Note: Percentages are based on structure fires reported in NFIRS Version 5.0 to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. Figures reflect recodings explained in Introduction: Fires are excluded if the reason for failure or ineffectiveness is system not present in area of fire, unclassified or unknown. Fires are recoded from operated but ineffective to failed if the reason for failure or ineffectiveness was system shut off. Fires are recoded from failed to operated but ineffective if the reason for failure or ineffectiveness was not enough agent or agent did not reach fire. In Version 5.0 of NFIRS, if multiple systems are present, the system coded is supposed to be the one system designed to protect the hazard where the fire started. This field is not required if the fire did not begin within the designed range of the system. Buildings under construction are excluded. Property use groups are shown only if there were at least 10 fires per year involving failure to operate and 10 fires per year involving operation not effective.

Source: NFIRS and NFPA survey.

**Table 6.**
**Extent of Flame Damage,**
**for Sprinklers Present vs. Automatic Extinguishing Equipment Absent**
**2003-2007 Structure Fires**

| Property Use | Percentage of fires confined to room of origin excluding structures under construction and sprinklers not in fire area: With no automatic extinguishing equipment | With sprinklers of any type |
|---|---|---|
| Public assembly | 77% | 95% |
| Fixed-use amusement or recreation place | 74% | 96% |
| Variable-use amusement or recreation place | 84% | 97% |
| Religious property | 74% | 96% |
| Library or museum | 85% | 97% |
| Eating or drinking establishment | 76% | 93% |
| Educational | 90% | 98% |
| Health care property* | 92% | 99% |
| Residential | 76% | 96% |
| Home (including apartment) | 76% | 97% |
| Hotel or motel | 87% | 97% |
| Dormitory or barracks | 94% | 97% |
| Store or office | 71% | 93% |
| Grocery or convenience store | 77% | 96% |
| Laundry or dry cleaning or other professional supply or service | 81% | 92% |
| Service station or motor vehicle sales or service | 62% | 85% |
| Department store | 75% | 92% |
| Office building | 77% | 94% |
| Manufacturing facility | 69% | 87% |
| Storage | 32% | 80% |
| Warehouse excluding cold storage | 50% | 79% |
| All structures** | 74% | 95% |

* Nursing home, hospital, clinic, doctor's office, or development disability facility.
** Includes some properties not listed separately above.

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

Source: NFIRS and NFPA survey.

**Table 7.**
**Number of Sprinklers Operating**
**2003-2007 Structure Fires**

## A. By Type of Sprinkler

| Number of Sprinklers Operating | Percentage of structure fires where that many sprinklers operated: Wet pipe | Dry pipe | Other type sprinkler | All sprinklers |
|---|---|---|---|---|
| 1 | 77% | 61% | 39% | 75% |
| 2 or fewer | 89% | 74% | 53% | 87% |
| 3 or fewer | 92% | 79% | 65% | 91% |
| 4 or fewer | 95% | 86% | 88% | 94% |
| 5 or fewer | 97% | 89% | 90% | 96% |
| 6 or fewer | 98% | 90% | 95% | 97% |
| 7 or fewer | 98% | 90% | 96% | 97% |
| 8 or fewer | 98% | 90% | 96% | 98% |
| 9 or fewer | 98% | 90% | 96% | 98% |
| 10 or fewer | 99% | 92% | 98% | 98% |
| 20 or fewer | 99% | 96% | 99% | 99% |

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

Source: NFIRS and NFPA survey.

**Table 7. (Continued)**
**Number of Sprinklers Operating**
**2003-2007 Structure Fires**

**B. Wet Pipe Sprinklers, by Property Use Group**

| Number of Sprinklers Operating | Percentage of structure fires where that many wet pipe sprinklers operated | | | | | |
|---|---|---|---|---|---|---|
| | **Public assembly** | **Home** | **Hotel or motel** | **Store or office** | **Manufacturing facility** | **Warehouse excluding cold storage** |
| 1 | 72% | 90% | 87% | 67% | 49% | 47% |
| 2 or fewer | 90% | 97% | 94% | 87% | 69% | 70% |
| 3 or fewer | 92% | 98% | 96% | 91% | 79% | 76% |
| 4 or fewer | 95% | 99% | 99% | 94% | 86% | 78% |
| 5 or fewer | 96% | 99% | 100% | 95% | 89% | 90% |
| 6 or fewer | 97% | 99% | 100% | 97% | 92% | 93% |
| 7 or fewer | 97% | 99% | 100% | 97% | 93% | 94% |
| 8 or fewer | 99% | 100% | 100% | 97% | 94% | 94% |
| 9 or fewer | 99% | 100% | 100% | 98% | 94% | 95% |
| 10 or fewer | 99% | 100% | 100% | 98% | 96% | 95% |
| 20 or fewer | 100% | 100% | 100% | 98% | 98% | 97% |

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

Source: NFIRS and NFPA survey.

**Table 8.**
**Sprinkler Effectiveness Related to**
**Number of Sprinklers Operating**
**2003-2007 Structure Fires**

| | Percent of structure fires where sprinklers are effective | | | |
|---|---|---|---|---|
| | | Wet pipe sprinklers | | |
| **Number of Sprinklers Operating** | **All sprinklers All structures** | **All structures** | **Manufacturing facility** | **Warehouse excluding cold storage** |
| 1 | 97% | 98% | 93% | 95% |
| 2 | 94% | 96% | 93% | 100% |
| 3 to 5 | 91% | 93% | 92% | 99% |
| 6 to 10 | 87% | 86% | 85% | 88% |
| More than 10 | 79% | 74% | 75% | 90% |
| Total | 96% | 96% | 91% | 96% |

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

Source: NFIRS and NFPA survey.

## Automatic Extinguishing Equipment Impact

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

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

### Sprinkler Reduction in Loss of Life in Fire

**For 2003-2007 home fires, the death rate per 100 fires was 83% lower with wet pipe sprinklers than with no automatic extinguishing equipment.**
Table 9 shows fire death rate reductions for various property use groups. Only the statistics for homes (including apartments) are based on enough fatal fires, both with and without sprinklers, for reasonable confidence in the results. Even the home fire statistics are volatile because of the influence of confined fires, where details on sprinkler presence and performance are not required and rarely provided.

Manufacturing facilities show a small reduction in an already low death rate, while warehouses show no reduction. Warehouses illustrate the statistical problem of analyzing impact when there are very few fatal fires. Total fire deaths in sprinklered warehouses in 2003-2007 are estimated from projections based on only four fatal incidents. The most severe was an explosion in a fireworks warehouse that killed three people. When an initial explosion precedes the fire, sprinklers cannot save people even if the explosion does not knock out the sprinklers, as can easily happen. The second most severe was an intentional fire using flammable liquids as accelerants. That fire killed two people, and there were few details. In particular, we cannot tell from the coded records whether either or both of the victims might have been the arsonists, killed early in the fire before sprinklers could activate, or whether the area of origin – an unclassified storage area – might have been outside the range of the sprinklers, which if true should have excluded the incident as no sprinklers in initial fire area. The third fatal fire was in a building under major renovation. The analysis excludes buildings under construction, but buildings under major renovation can present the same challenge to fire protection, depending on the scale of the renovation and the location of the fire origin. The fourth fatal fire was a three-story facility, with a fourth level below grade, storing agricultural products, which suggests the possibility of a dust explosion. A total of 75 sprinklers opened but sprinklers were said to have failed to operate due to manual intervention; this indicates some confusion on incident details or how to code them.

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

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

2. Victims of fires that are beyond the design limits of the system, such as fires that were (a) so close that the victim is deemed “intimate with ignition” (a victim condition no longer shown in the data but most closely approximated by “victim in area of fire origin”; they constituted 93% of fatal victims when sprinklers operated vs. 53% of total victims, in Table 10); (b) very fast, such as explosions or flash fires; or (c) outside the sprinkler-protected area, such as fires originating on exterior areas of the building; and

3. Victims who are or may be unusually vulnerable to fire effects, such as (a) older adults, age 65 or older (who constituted 50% of fatal victims when sprinklers operated vs. 28% of total victims, in Table 10), or (b) people who are in poor health before fire begins.

**Absent these conditions, NFPA has no record of a fire killing 3 or more people in a completely sprinklered building where the system was properly operating.**
Appendix C lists fires after 1970 with three or more deaths in a completely sprinklered building where the system was properly operating and the fire began in the sprinkler-protected interior of the building. Each is marked by the condition that accounted for the large life loss, either explosion or flash fire, which is the most common condition, or firefighting.

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

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

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

**Sprinkler Reduction in Loss of Property in Fire**

**For most property uses, the property damage rate per reported structure fire is 40-70% lower than in properties with no automatic extinguishing equipment when wet pipe sprinklers are present in structures that are not under construction, after excluding cases of failure or ineffectiveness because of a lack of sprinklers in the fire area.**
Table 11 shows smaller reductions for manufacturing facilities (22%) and warehouses (7%).

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

The warehouse situation is a fairer indication of the limitations of sprinklers but also of the limitations of these statistical comparisons. Roughly half of the 2003-2007 estimate of total direct property damage in warehouses with wet pipe sprinklers, excluding buildings under construction and sprinklers not in fire area, comes from projections from six fires, each involving $5.2-$8.5 million in direct property damage. All six incidents are also included in NFPA's Fire Incident Data Organization (FIDO) database, which provides some additional details not included in NFIRS. Between the NFIRS coding and the FIDO data, we can say that in two of the six fires, sprinklers failed to operate because they had been shut off before fire began. Another two fires showed sprinklers operating effectively to contain and control fire, but high loss still resulting because of the inaccessible location of the fire, either inside rack storage where the racks blocked sprinklers or deep seated in palletized storage, where the stored goods blocked sprinklers. Of the other two fires, one was in a facility with no recent maintenance and an impaired sprinkler system. The other involved a large fire load and, according to news accounts, water problems that delayed firefighting operations for roughly an hour. This last incident also involved by far the largest warehouse of the six, with a footprint of 600,000 square feet in a 4-story building.

Focusing on the first two incidents, Table 3B showed that warehouses excluding cold storage have a lower operational percentage than nearly all other property uses – operation in 85% of fires where sprinklers were present in fire area and fire was large enough to activate equipment, compared to 95% for all structures combined. While not shown in Table 4B because there were too few incidents of ineffective operation to display, the reasons for sprinkler failure in warehouses excluding cold storage were dominated by system shut off, which accounted for 90% of failures.

With respect to the last four incidents, there is reason to believe that sprinklers are more common in warehouses that are larger and have higher values per square foot. It takes a substantial warehouse to permit a fire location too deep in storage to be reached by sprinklers that are operating effectively to contain fire, and the last incident involved a warehouse with 2.4 million square feet. This can mean that the average loss per fire in a sprinklered warehouse will not be a good estimate of the predicted average loss per fire if sprinklers were added to the unsprinklered warehouses, as our calculations implicitly assume. The use of average loss in unsprinklered warehouses as a proxy for average loss in sprinklered warehouses in the absence of sprinklers, as is done in this analysis, will produce a misleadingly low baseline for comparison and so a misleadingly low estimated reduction.

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

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

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

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

**Table 9.**
**Estimated Reduction in Civilian Deaths per Thousand Fires**
**Associated With Wet Pipe Sprinklers, by Property Use**
**2003-2007 Structure Fires**

| Property Use | Without automatic extinguishing equipment | With wet pipe sprinklers | Percent reduction |
|---|---|---|---|
| All public assembly | 0.6* | 0.0 | 100% |
| Eating or drinking establishment | 0.5* | 0.0 | 100% |
| Educational | 0.0 | 0.0 | NA |
| Health care property** | 4.6 | 1.3 | 72% |
| Residential | 7.7 | 1.5 | 80% |
| Home (including apartment) | 7.8 | 1.3 | 83% |
| Hotel or motel | 4.3 | 0.9 | 79% |
| Dormitory or barracks | 3.0 | 0.5 | 83% |
| Rooming or boarding house | 7.8 | 1.6 | 80% |
| Board and care home | 7.5 | 2.4 | 68% |
| Store or office | 0.9 | 0.2 | 75% |
| Manufacturing facility | 1.0 | 0.7 | 25% |
| Warehouse excluding cold storage | 1.2 | 9.8 | No reduction |

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

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

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

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

Source: NFIRS and NFPA survey.

**Table 10.**
**Characteristics of Fatal Victims**
**When Wet Pipe Sprinklers Operate vs. All Conditions**
**2003-2007 Structure Fires**

| | Percent of fire fatalities | |
|---|---|---|
| **Victim Characteristic** | **When wet pipe sprinklers operate, excluding sprinklers not in fire area** | **No automatic extinguishing equipment** |
| Victim in area of fire origin, whether or not involved in fire origin | 93% | 53% |
| Clothing on fire, whether or not while escaping | 30% | 7% |
| Victim age 65 or older | 50% | 28% |
| Victim returned to fire, unable to act, or acted irrationally | 37% | 19% |

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

Source: NFIRS and NFPA survey.

## Table 11.
## Estimated Reduction in Average Direct Property Damage per Fire Associated With Wet Pipe Sprinklers, by Property Use 2003-2007 Structure Fires

| Property Use | Without automatic extinguishing equipment | With wet pipe sprinklers | Percent reduction |
|---|---|---|---|
| All public assembly | $37,000 | $16,000 | 56% |
| Eating or drinking establishment | $42,000 | $12,000 | 71% |
| Educational | $18,000 | $7,000 | 63% |
| Health care property* | $8,000 | $3,000 | 63% |
| Residential | $16,000 | $5,000 | 68% |
| Home (including apartment) | $17,000 | $4,000 | 74% |
| Hotel or motel | $19,000 | $9,000 | 54% |
| Dormitory or barracks | $6,000 | $1,000 | 81% |
| Rooming or boarding house | $15,000 | $8,000 | 50% |
| Board and care home | $5,000 | $2,000 | 54% |
| Store or office | $44,000 | $26,000 | 40% |
| Manufacturing | $76,000 | $59,000 | 22% |
| Warehouse excluding cold storage | $101,000 | $95,000 | 7% |

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

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

Source: NFIRS and NFPA survey.

## Other Issues

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

### Water Damage from Sprinklers in the Absence of Fire

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

Sprinkler systems are carefully designed to activate early in a real fire but not to activate in a non-fire situation. Each sprinkler reacts only to the fire conditions in its area. Water release in a fire is generally much less than would occur if the fire department had to suppress the fire, because later action means more fire, which means more water is needed. According to a 15-year study done in Scottsdale, Arizona, on average, a fire sprinkler will use 25 gallons of water per minute to control a home fire as compared to the estimated 250 gallons used by firefighters.[7]

Unintentional release of water in a non-fire activation of a sprinkler appears to be less likely and much less damaging, according to the best available evidence, than is unintentional water release involving other parts of a building's plumbing and water supply, which tend to be both more frequent and more costly per incident.[8] Maryatt's study of sprinklers in Australia and New Zealand found water damage from non-fire accidental discharges added only 25% to the fire losses suffered by sprinklered buildings.[9] If sprinklers reduced average fire loss by only 20%, then combined fire and water damage in fire and non-fire incidents would be unchanged. (A 20% reduction means the sprinklered fire loss is 80% of the unsprinklered fire loss. Adding 25% for water damage adds 25% of 80%, which is 20%. 80%+20%=100%.) As previously noted, however, sprinklers reduce average fire loss by much more than 20%.

Another set of estimates based on recent U.S. experience can be developed from more recent data on water damage from sprinkler systems in the absence of fire. These estimates generally agree with the earlier estimates cited above.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Do People Want Sprinklers?**

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

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

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

A third myth has to do with the affordability of sprinklers. Sprinklers are not inexpensive, although their effectiveness, documented earlier, means most people will find them cost-effective. This often can be incorporated into reduced insurance costs and incentives applied by community planners in new developments.

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

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

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

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

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

A 1977 survey done for the U.S. Fire Administration, back when only 22% of U.S. homes had smoke alarms, found that 74% of households with smoke alarms were very concerned about fire compared to only 45% of households that had no smoke alarms and no intention of obtaining smoke alarms. For households without smoke alarms, whether or not they intended to obtain smoke alarms, the leading reason cited for not having obtained one was no perception of need (don't need one – 16%; no interest in one – 16%) and the second leading reason was cost (too expensive – 23%; not worth the money – 1%). These are the same reasons, in the same order, cited today by people not intending to obtain home fire sprinklers today.[11]

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

In fact, there is evidence that many homeowners are getting past these dated perceptions and moving on to more fact-based and positive views of home fire sprinklers. The Home Fire Sprinkler Coalition sponsored a December 2005 survey by Harris Interactive®.[12] Among the findings were that 45% of homeowners considered a sprinklered home more desirable than an unsprinklered home, that 69% believe a fire sprinkler system increases the value of a home, that 38% say they would be more likely to purchase a new home with sprinklers than one without, and that 43% would be more likely to have home fire sprinklers installed if the cost could be included in the mortgage. These read like the emerging perceptions of a nation that sees value for the cost of home fire sprinklers and sees ways to handle that cost within their home-buying budget.

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

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

## Concluding Points

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

Excluding fires too small to activate a sprinkler and cases of failure or ineffectiveness because of a lack of sprinklers in the fire area, sprinklers operated in 93% of reported structure fires and operated effectively in 91% of fires. More than half (53%) of the failures occurred because the system had been shut off.

There are certain fire situations where even a complete sprinkler system will have limited impact: (a) Explosions and flash fires that may overpower the system; (b) Fires that begin very close to a person (e.g., clothing ignition) or unusually sensitive and expensive property (e.g., an art gallery) where fatal injury or substantial property loss can occur before sprinklers can react; and (c) Fires that originate in unsprinklered areas (e.g., concealed wall spaces) or adjacent properties (e.g., exposure fires), which may grow to unmanageable size outside the range of the sprinkler system. These situations can arise when (a) sprinkler standards are based on design fires less severe than explosions or flash fires, as is the case for explosions in the NFPA 13, NFPA 13D, and NFPA 13R standards; (b) sprinkler objectives are defined in terms of a design fire area larger than the distance implied by a victim intimate with ignition; or (c) sprinkler standards exclude certain potential areas of fire origin from their definition of complete coverage, which is typically but not always the case.

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

On the other hand, human error is not a problem unique to sprinklers. In fact, all forms of active and passive fire protection tend to show more problems with human error than with intrinsic mechanical or electrical reliability.

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

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

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

# Appendix A.
# How National Estimates Statistics Are Calculated

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

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

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

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

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

The survey is stratified by size of population protected to reduce the uncertainty of the final estimate. Small rural communities have fewer people protected per department and are less likely to respond to the survey. A larger number must be surveyed to obtain an adequate sample of those departments. (NFPA also makes follow-up calls to a sample of the smaller fire departments that do not respond, to confirm that those that did respond are truly representative of fire departments their size.) On the other hand, large city departments are so few in number and protect such a large proportion of the total U.S. population that it makes sense to survey all of them. Most respond, resulting in excellent precision for their part of the final estimate.

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

**Projecting NFIRS to National Estimates**

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

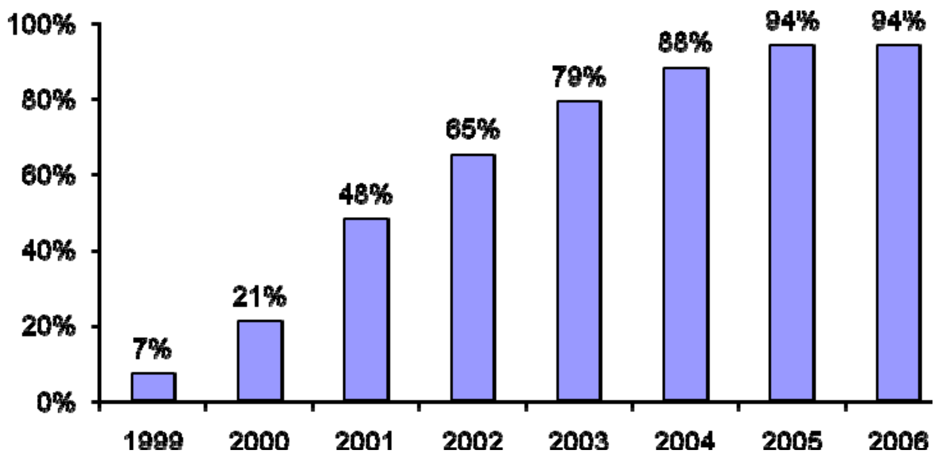
Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific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

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

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

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

**Figure 1. Fires Originally Collected in NFIRS 5.0 by Year**




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

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

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

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

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

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

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

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

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

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

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

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

31. Water-caused short circuit arc;
32. Short-circuit arc from mechanical damage;
33. Short-circuit arc from defective or worn insulation;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

| | | |
|---|---|---|
| | 143 | Oil-filled heater |
| Fireplace or chimney | 121 | Fireplace, masonry |
| | 122 | Fireplace, factory-built |
| | 125 | Chimney connector or vent connector |
| | 126 | Chimney – brick, stone or masonry |
| | 127 | Chimney-metal, including stovepipe or flue |
| Wiring, switch or outlet | 210 | Unclassified electrical wiring |
| | 211 | Electrical power or utility line |
| | 212 | Electrical service supply wires from utility |
| | 214 | Wiring from meter box to circuit breaker |
| | 216 | Electrical branch circuit |
| | 217 | Outlet, receptacle |
| | 218 | Wall switch |
| Power switch gear or overcurrent protection device | 215 | Panel board, switch board, circuit breaker board |
| | 219 | Ground fault interrupter |
| | 222 | Overcurrent, disconnect equipment |
| | 227 | Surge protector |
| Lamp, bulb or lighting | 230 | Unclassified lamp or lighting |
| | 231 | Lamp-tabletop, floor or desk |
| | 232 | Lantern or flashlight |
| | 233 | Incandescent lighting fixture |
| | 234 | Fluorescent light fixture or ballast |
| | 235 | Halogen light fixture or lamp |
| | 236 | Sodium or mercury vapor light fixture or lamp |
| | 237 | Work or trouble light |
| | 238 | Light bulb |
| | 241 | Nightlight |
| | 242 | Decorative lights – line voltage |
| | 243 | Decorative or landscape lighting – low voltage |
| | 244 | Sign |
| Cord or plug | 260 | Unclassified cord or plug |

| | | |
|---|---|---|
| | 261 | Power cord or plug, detachable from appliance |
| | 262 | Power cord or plug- permanently attached |
| | 263 | Extension cord |
| Torch, burner or soldering iron | 331 | Welding torch |
| | 332 | Cutting torch |
| | 333 | Burner, including Bunsen burners |
| | 334 | Soldering equipment |
| Portable cooking or warming equipment | 631 | Coffee maker or teapot |
| | 632 | Food warmer or hot plate |
| | 633 | Kettle |
| | 634 | Popcorn popper |
| | 635 | Pressure cooker or canner |
| | 636 | Slow cooker |
| | 637 | Toaster, toaster oven, counter-top broiler |
| | 638 | Waffle iron, griddle |
| | 639 | Wok, frying pan, skillet |
| | 641 | Breadmaking machine |

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

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

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

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

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

**M1. Presence of Automatic Extinguishment System**
This is to be coded based on whether a system was or was not present in the area of fire and is designed to extinguish the fire that developed. (The latter condition might exclude, for example, a range hood dry chemical extinguishing system from being considered if the fire began in a toaster.)

Codes:

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

**M2. Type of Automatic Extinguishment System**
If multiple systems are present, this is to be coded in terms of the (presumably) one system designed to protect the hazard where the fire started. This is a required field if the fire began within the designed range of the system. It is not clear whether questions might arise over a system that is not located in the area of fire origin but has the area of fire origin within its designed range; this has to do with the interpretation of the “area” of fire origin.

Codes:

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

**M3. Automatic Extinguishment System Operation**
This is designed to capture the “operation and effectiveness” of the system relative to area of fire origin. It is also said to provide information on the “reliability” of the system. The instructions say that “effective” does not necessarily mean complete extinguishment but does mean containment and control until the fire department can complete extinguishment.

Codes:

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

**M4. Number of Sprinklers Operating**

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

**M5. Automatic Extinguishment System Failure Reason**

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

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

Codes:

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

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

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

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

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

# Appendix D
# Selected Incidents

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

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

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

## NOT IN AREA PROTECTED

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| New Jersey<br>$7,100,000<br>September, 2005<br>1:41 p.m. | This four-story eight-unit condominium was of unprotected wood-frame construction and covered 4,225 square feet (392 square meters). The building was occupied. | There was completed coverage smoke detection equipment. The alarms sounded, but with a delay due to the fire's area of origin. There was a complete coverage wet-pipe sprinkler system present. There was no coverage in the area of ignition (outside). Upon arrival, the fire department pumped into the sprinkler system, but there was no effect on the fire spread. | This exposure fire began in the engine compartment of a car parked in a garage under the condominium structure. The garages were separated by wood latticework that allowed the fire to spread through the eight garages that contained vehicles, boats, and propane grills. The fire spread up cedar siding and through the truss floor assembly of the condominium units above. The fire spread to several other buildings in the condominium complex. At least 35 fire departments responded to fight the fire. | The day of the fire was very hot and humid, with a wind of 15 to 20 miles per hour (24 to 32 kilometers per mile). There had been no rain for three weeks, causing the siding to be very dry. One side of the structure was on a bay, forcing firefighters to hand lay fire hoses. The open-web truss construction of floors and roof allowed for rapid spread. Twenty-four firefighters and three civilians were treated for heat exhaustion and other injuries. The loss was $6,000,000 to structures and $1,100,000 to contents. |

Stephen G. Badger, 2006, "2005 Large-Loss Fires and Explosions in the United States", *NFPA Journal*, November/December, 72.

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Texas<br>$5,220,000<br>March, 2003<br>12:05 a.m. | This three-story, single-family dwelling of protected wood-frame construction covered 14,585 square feet (1,354 square meters) and was occupied when the fire broke out. | A partial coverage smoke detection system present operated and a partial coverage sprinkler system was present. The type and operation weren't reported, but the system wasn't in the area of origin. | The cause is undetermined. Arriving firefighters found a fire in the ceiling between the first and second story, which spread rapidly in voids throughout the house. Firefighters were forced to a defensive attack. | Loss to the house was $3,250,000 and loss to contents was $1,970,000. |

Stephen G. Badger November, 2004, *Large-Loss Fires in the United States 2003*, 25.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Virginia<br>$12,823,900<br>February, 2003<br>4:45 a.m. | This 4-story senior citizen apartment house of protected wood-frame construction contained 100 units and covered 23,536 square feet (2,186 square meters). Of the 100 units, 81 were occupied. | There was a complete coverage combination heat and smoke detection equipment. The system operated but it wasn't in the area of origin. An arriving police officer activated a manual pull station to sound the alarm. There was a complete coverage wet-pipe sprinkler system but one head operated. This system also was not in the area of origin (outside balcony). | The cause of this fire is undetermined and it originated on a third-story balcony. The fire spread up the exterior and entered the attic through roof soffits. The fire spread horizontally then down to the apartments on the fourth and third floors. | The balconies were of combustible materials, allowing for ignition. Two firefighters were injured. Loss to the building was $9,823,900 and loss to contents was $3,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 56.

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Ohio<br>$60,000,000<br>August, 2000<br>4:05 p.m. | Three-story steel manufacturing plant was of unprotected ordinary construction covering 355,320 square feet (33,010 square meters) and was in full operation at the time of the fire. | There was no automatic detection equipment present. A wet-pipe sprinkler system was present; the extent of the coverage was not reported. The system was not a factor as the fire was in the attic and roof area, above the system. An early collapse of the roof did damage the branch and trunk lines. | No information reported on the cause. Firefighters made an initial interior attack but were forced to withdraw due to roof and ceiling collapse. Operations were switched to a defensive attack. | Three firefighters were injured. Losses totaled $40,000,000 to the structure and $20,000,000 to the contents. |

Stephen G. Badger, November, 2002, *Large-Loss Fires in the United States 2001*, 11.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Hawaii<br>$10,000,000<br>April, 2000<br>8:13 a.m. | A 16-story office building of fire-resistive construction that covered 58,564 square feet (5,440 square meters). Although the building was closed for the weekend a few occupants were in the building. | Smoke detectors and manual pull stations of unknown type activated and alerted the occupants. The extent of the system's coverage wasn't reported. A partial-coverage wet-pipe sprinkler system wasn't in the area of the fire and didn't operate. | Undetermined. | Twelve firefighters were injured. Fire loss was listed as $8 million to the structure and $2 million to the contents. |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 63.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Pennsylvania<br>$25,000,000<br>May, 2000<br>8:00 a.m. | General product warehouse of unprotected noncombustible construction. The building was 40 feet (12 meters) high and covered 400,000 square feet (37,161 square meters). Its operating status wasn't reported. | The warehouse had no automatic detection system. Automatic suppression equipment had been installed, but only in two sections of the warehouse, and the fire originated elsewhere. By the time the system activated, the fire was too large for it to handle. | The fire's cause is still under investigation. No other details were reported. | One firefighter was injured. Fire loss was listed as $15 million to the structure and $10 million to the contents. |

Stephen G. Badger, 2001, "Large-Loss Fires of 2000", *NFPA Journal*, November/December, 62.

**Propane Gas Grill Fire Spreads from Apartment Balcony, Wisconsin**
A propane gas grill on a fourth-floor balcony leaked fuel, which ignited, and the resulting fire spread to the apartment building roof.

The four-story building, constructed of wood framing with a brick veneer, housed several apartments on the second, third, and fourth floors. Retail businesses were located on the first floor, and there was a parking garage in the basement. Smoke alarms were installed throughout, and there were heat detectors in the attic and mechanical rooms. Manual pull stations were located on every floor. A residential wet-pipe sprinkler system installed in compliance with NFPA 13R, *Installation of Sprinkler Systems in Residential Occupancies Up To and Including Four Stories in Height*, was operational at the time of the fire.

The fire began when the occupant of the fourth-floor unit started a propane grill on her balcony in preparation for cooking. She had only had the grill for about a month and had difficulty lighting the grill due to a faulty igniter switch. To start the grill, she resorted to either matches or lighted pieces of paper.

As she waited for the grill to warm up, the woman got a phone call and after five minutes shut off the grill. When she returned 45 minutes later, she restarted the grill again using a match when the igniter didn't work. Once the fire was going, however, she noticed flames near the neck of the propane cylinder. Although she immediately turned the burners off, the fire still burned at the cylinder. The woman called 911 to report the fire, then returned to the balcony to find that the fire had spread to the floor.

The woman tried to control the fire, but the flames continued to spread, so she left the apartment with her 4-year-old son. On the way out, she told occupants of the building she met in the stairwell about the fire but failed to activate a pull station that would have alerted the entire building.

Attempts by two occupants to control the fire with a portable extinguisher knocked down about 70 percent of the blaze, but failed to extinguish the flames that soon reached the ceiling of the balcony.

Responding to the 7:13 p.m. call, firefighters found fire on the top floor. Shortly after their arrival, they saw fire rolling across the fourth-floor ceiling. They later discovered fire in the eaves, but didn't realize fire was in the attic above them. Then firefighters discovered there was no standpipe connection available, they lowered ropes from a fourth-floor window and pulled a hose line up.

A second alarm was sounded as firefighters fought for more than two hours to control the fire.

Investigators determined that the fire began when a propane gas leak was ignited by the grill's burners. The fire then spread to combustible wood framing and roof supports, through the vinyl and aluminum covered soffits.

The residential sprinkler system in the apartment operated, but the fire spread in the attic. Eventually, the ceiling collapsed. Fire spread from the deck into the fourth floor was reduced by the sprinkler system, which didn't extend to the attic and roof.

The building suffered a $2 million loss. There were no injuries during the fire.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, July/August, 18.

**Neon Signs Ignite Wood Siding in Strip Mall, Arkansas**

Flames traveled along a strip mall's open exterior façade before firefighters extinguished it. Although sprinklers and a fire wall kept the flames from entering the main building, damage was estimated at nearly $1 million.

The 15 retail stores in a single-story shopping center were of wood-frame construction. Each store had an individual fire detection system, and a wet-pipe sprinkler system had been installed throughout the building. The stores were closed for the night when the fire broke out.

A passerby discovered the blaze and called 911 on his mobile phone at 1:50 a.m. When firefighters arrived, they found the façade engulfed in flames and used a deck gun to extinguish the blaze. The wood-frame façade was sheathed in wood siding and affixed with a neon sign for each occupancy. Unfortunately, it was open from one end to the other with no separation.

The fire heavily damaged the facade, although three sprinklers and a fire wall kept flames from entering the stores. Investigators determined that one of the neon signs, which had recently been replaced, short circuited and ignited the siding.

The building, which had an estimated value of $750,000, suffered $650,000 in damage. Damage to the contents, valued at $300,000, came to $250,000.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, September/October, 23.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Illinois<br>$15,000,000<br>August, 1999<br>5:47 a.m. | This one-story warehouse for palletized cardboard cartons was of unprotected ordinary construction with a ground floor area of 140,000 square feet (13,006 square meters). When the fire broke out, the plant was closed. | The plant didn't have any automatic detection equipment. It did have a complete coverage wet-pipe sprinkler system, which activated and sounded an alarm. The sprinklers were ineffective, however, because the fire spread above the sprinkler heads. | The fire originated at ceiling level above the sprinklers system and spread through the wood truss roof. The cause was undetermined. Firefighters initiated an offensive attack. While venting the roof, firefighters found it to be spongy and evacuated the entire building. Soon after the roof collapsed. No injuries were reported. | The collapsing roof broke cross feeds to the sprinkler system. The open truss area contributed to the fire spread. |

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Wisconsin<br>$5,000,000<br>September, 1999<br>6:11 p.m. | This one-story wood product manufacturing plant was of protected, ordinary construction and covered a ground-floor area of 100,000 square feet (9,290 square meters). The plant was in operation at the time of the fire. | The plant had no automatic detection equipment but did have a complete coverage wet-pipe sprinkler system. Although the sprinklers operated and sounded an alarm, they were ineffective because the fire started above them. | Workers performing roofing operations ignited a small fire in the roofing materials. The workers thought they completely extinguished the fire and left the area two hours later. A fire broke out approximately one hour later in the Styrofoam insulation between the upper and lower plywood roof decks. Firefighters initiated an interior attack on the fire until conditions deteriorated and they withdrew to a defensive attack. One firefighter was injured. | Fire department notification of the initial fire was delayed almost three hours. The water supply in the area was limited. Firefighters had trouble getting to the fire building. Railroad tracks on one side of the building and a lake on two other sides limited firefighters accessibility to only one side. |

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

## SHUT OFF

**Two Intentional Fires in Foreclosed Home, Arizona**
An intentionally set fire substantially damaged the second floor of a large, single-family house. Although the house, which was under foreclosure, had a fire sprinkler system, it failed to operated because the water had been shut off due to nonpayment.

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

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

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

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

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

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

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

**Large-Loss Fire Involving Former Mill Building, Massachusetts**
Dollar Loss: $26,000,000
Month: July 2007
Time: 4:14 am

Property Characteristics and Operating Status:
This three-story, irregularly-shaped former mill building was used by 56 mercantile businesses and covered 350,000 square feet (32,500 square meters). It was of unprotected ordinary construction. The building was closed at the time of the fire.

Fire Protection Systems:
There was no smoke detection equipment present. There was a full-coverage combination wet- and dry-pipe sprinkler system. A sprinkler valve in the area of ignition was padlocked shut, allowing the fire to quickly overwhelm the rest of the system. The fire department was not notified that the system was shut down.

Fire Development:
Investigators believe the fire started after welding was done in the basement the day before, without a permit from the fire department.

Contributing Factors and Other Details:
Several code noncompliance issues, such as the welding and shutting down the sprinkler system, contributed to the fire. Four hundred firefighters from 78 fire departments in two states responded to this fire. Nine firefighters were injured. The loss was estimated at $16,000,000 to the structure and $10,000,000 to the contents.

Stephen G. Badger, 2008, *" Large-Loss Fires in the United States in 2007", NFPA* Fire Analysis and Research, Quincy, MA

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Illinois<br>$20,000,000<br>April, 2005<br>6:00 p.m. | This one-story paper products manufacturing plant was of protected noncombustible construction and covered 243,000 square feet. The plant was at full operation when the fire broke out. | There was a partial coverage combination smoke and heat detection system present. The system was not located in the area of origin and it was not reported if the system activated. There was a complete coverage wet-pipe sprinkler system present. The flow from this system was not sufficient. The main switch to the fire pump was found shut off. How or when it was shut off was not reported. | An incendiary fire was set in the rolled paper storage area. This fire is still under investigation. | None Reported. |

Stephen G. Badger, 2003, "Large-Loss Fires for 2002", *NFPA Journal*, November/December, 77.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Texas<br>$11,000,000<br>August, 2004<br>5:56 p.m. | This four-story 100-unit apartment building was of unprotected wood-frame construction covering 32,000 square feet. The building was under construction at the time. Some workers were at the site when the fire broke out. | There was no detection equipment yet installed. There was a complete coverage wet-pipe sprinkler present but it was shut down before the fire due to a leak in the system. | A fire of unknown cause broke out on the second level of the building. Wind helped spread the fire throughout the units I the section of the building that was still in the framing phase. The fire spread to a parking garage then ignited a structure on the opposite side of the street. | Despite openings not yet protected by fire-rated doors, fire walls were effective in limiting the spread of fire. Two firefighters were injured. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 44.

**School Fire Spreads Due to Sprinkler Shut-Off, California**

Fire heavily damaged an unoccupied school, because the water supply to the sprinkler system was shut off, allowing the fire to spread to the attic.

The single-story, wood-framed elementary school, which was 60 feet (18 meters) by 60 feet (18 meters), contained five classrooms, two work rooms, two bathrooms, and two mechanical rooms. The building had a peaked roof with a skylight in the middle. Although the property had sprinklers, the building's well, which supplied its water, was shut-down due to dirt in the system. There was also no fire detection system.

When neighbors saw smoke from the school at 7:07 p.m., they called 911 and activated the fire alarm on the building. Nine minutes later, arriving firefighters found smoke and flames coming from the roof and fire at one end of the interior hallway. They stretched hoselines to the building, entered, and began extinguishment.

Several fire companies coordinated a fire attack and ventilation strategy to extinguish the blaze, which had spread to the attic and roof before it even damaged the classrooms below.
One of the building's heating units was found within inches of the wall of origin. No other potential heat sources were found in the area.

Because there was no detection system or operating sprinkler system, the fire burned undetected into concealed spaces.

The structure, valued at $1 million, sustained an estimated $400,000 in direct property damage. Contents were valued at $150,000 and sustained $60,000 in damage.

Kenneth J. Tremblay, 2000, "Firewatch," *NFPA Journal*, July/August, 20.

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Massachusetts<br>$10,000,000<br>June, 1999<br>3:37 p.m. | The warehouse in which the main losses occurred was in an old mill complex and stored new commercial dryers. The ground-floor area wasn't reported. The building in which the fire originated was a vacant one-story structure of unprotected, wood-frame construction. | No information was reported on automatic detection equipment. The warehouse's sprinkler system had been shut down before the fire. | Investigators believe that smoking materials caused the fire, which started in grass outside. The fire spread to a wood-frame dye house then to the warehouse. More than 250 firefighters responded from 24 cities and towns. Crews managed to contain the fire to approximately half the complex. | If the sprinkler system hadn't been shut down, it could have extinguished the fire in its incipient stage. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 88, 90.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Oregon<br>$13,522,500<br>August, 1999<br>4:13 a.m. | This five-story apartment building with businesses on the lower level was under construction at the time of the fire. It was of protected, wood-frame construction and covered a ground-floor area of more than 50,000 square feet 4,645.0 square meters). There was no one at the site when the fire broke out. | No information was reported on automatic detection equipment. The building had a wet-pipe sprinkler that had been shut down during construction. | The only information reported was that this was an incendiary fire. No injuries were reported. | None reported. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 95.

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

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

**Large-Loss Fire Warehouse Fire, Alabama**
Dollar Loss: $5,000,000
Date: October 1997
Time: Not reported.

Property Characteristics and Operating Status:
This one-story general item warehouse was of unprotected, wood-frame construction with a ground-floor area of 297,000 square feet (28,000 square meters). It was in operation when the fire broke out.

Fire Protection Systems:
The building had no automatic detection system. It did have a complete-coverage dry-pipe sprinkler system, but the system didn't operated because it was out of service undergoing repair.

Fire Development:
The crew members of a passing fire department EMS transport unit discovered the fire when they noticed a large smoke plume in the air. The fire, which spread rapidly through

paper and wood and involved some pesticides, was allowed to burn to reduce the toxicity of involved areas. Its cause and origin are undetermined.

Contributing Factors:
None were reported.

Stephen G. Badger and Thomas Johnson, 1998, 1997 Large-Loss Fires and Explosions, *NFPA Journal*, November/December, 88.

**Large-Loss Warehouse Fire, Texas**
Dollar Loss: $45,000,000
Time: 10:31 a.m.
Month: November 1993

The Building:
The warehouse was used to store baled and rolled paper, and plastics. The single-story structure was of unprotected noncombustible construction with a ground-floor area of 500,000 square feet. It was operating at the time.

Detection and Suppression Systems:
The warehouse was not equipped with automatic detectors, but it did contain a complete wet-pipe sprinkler system.

The Fire:
Fire investigators believe that loose scrap paper became lodged in a forklift that was being used to move bales of paper. The paper caused the forklift to overheat and ignite the baled paper. Workers discovered the fire and notified the fire department using 911. Fire fighters attempted an interior fire attack, but they were forced out of the warehouse after the roof started to show signs of collapse. The entire warehouse and its contents were destroyed.

Contributing Factors and Other Details:
The water supply to the sprinkler system had been turned off due to a leak in the supply pipe for the system.

Large undivided areas, tons of combustible paper storage, and open overhead doors contributed to the rapid spread of fire throughout the warehouse.

Michael J. Sullivan, 1994, "Property Loss Rises in Large-Loss Fires" *NFPA Journal*, November/December, 95.

## INOPERATIVE

### Delayed Alarm Leads to $2 Million Loss, Texas

A plastic manufacturing plant was completely destroyed when a cutting torch ignited cardboard, plastics, and other trash, and the fire spread rapidly to storage. A delay in fire department notification and a disabled sprinkler contributed to the huge loss.

The two-story plant had a steel frame, with a metal deck roof and masonry walls. It was 200 feet (61 meters) long and 400 feet (122 meters) wide. A wet-pipe system was inoperable, and its owners had been issued a notice to repair by fire officials. There were no smoke alarms, and the building was operating at the time of the fire.

Employees were using a cutting torch to remove a metal gate and overhead door assembly on a loading dock when the torch came into contact with the combustible trash. The resulting fire spread quickly while the employees tried to control it with hand-held extinguishers before calling the fire department.

The department received a 911 call from the plant manager at 10:35 A.M. Arriving 2 ½ -minutes later, the first company saw “a wall of fire” at one corner of the building.

Two firefighters and two civilians were injured during the incident. The structure, valued at $1 million, and contents, valued at $1 million, were a total loss.

Kenneth J. Tremblay, 2000, “Firewatch,” *NFPA Journal*, May/June, 38.

## WRONG TYPE OF SYSTEM

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development: | Contributing Factors and Other Details |
|---|---|---|---|---|
| Georgia<br>$7,300,000<br>March, 1999<br>1:23 p.m. | This two-story general storage warehouse of protected noncombustible construction covered a ground-floor area of 75,000 square feet (6,967.5 square meters). The warehouse was operating at the time of the fire. | The warehouse didn't have an automatic detection system. It did have a wet-pipe sprinkler system, but its coverage wasn't known. The system operated but wasn't effective because it hadn't been maintained well and because it wasn't designed for the commodities stored. | Because investigators believe that toxic materials were present, they suspended investigation of this fire before determining a cause. The fire broke out in an unoccupied area. With a rapid fire spread due to 700 to 1,000 tons (635 to 907.2 metric tons) of group A plastics and a delay in notifying the fire department, an interior fire attack wasn't possible. By the time the fire department arrived, flames had consumed 100 feet (30.5 meters) of the building. No injuries were reported. | The sprinkler system was poorly maintained and not appropriate for the commodities stored. It took awhile for someone to discover the fire because it stared in a remote, unoccupied area. The person who discovered the fire called others in the building before notifying the fire department. |

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

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

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

## SYSTEM COMPONENT DAMAGE

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

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

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Indiana<br>$5,000,000<br>Apri, 2004<br>7:45 a.m. | This two-story foam products vinyl coating plant was of protected non-combustible construction and covered 20,000 square feet. The plant was in full operation at the time of the fire. | There was no automatic detection equipment present. There was a complete coverage wet-pipe sprinkler system. The system did not operate due to damage to its supply line during an explosion. | A small explosion occurred in or around an automatic spray booth where vinyl was sprayed onto foam. The cause is still under investigation. A second and larger explosion occurred, blowing out walls and collapsing the roof. A fire broke out in two of the paint booths. The fire was contained to this area by the fire department. | Five civilians suffered various injuries related to the explosion and fire. Damage to the structure was estimated at $1,500,000 and $3,500,000 to the contents. |

Stephen G. Badger, November, 2005, "Large-Loss Fires in the United States 2004", 22.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| North Carolina<br>$9,000,000<br>December, 2003<br>12:24 p.m. | This one-story plastics item manufacturing plant of heavy timber construction covered 18,000 square feet (1,672 square meters) and was in full operation at the time of the fire. | No automatic detection equipment was present. A complete coverage wet-pipe sprinkler system was present and operated but it was ineffective due to damage from a collapse that caused a large loss of water to other sections of the system. | Welding on a piece of machinery ignited a pile of polyester waste on the floor. Employees attempted to extinguish the blaze with hand-held extinguishers but were unsuccessful against a large spreading fire. | Three firefighters were injured and loss to building was $5,000,000 and loss to contents was $4,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 52.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Wisconsin<br>$17,000,000<br>July, 2002<br>9:23 p.m. | This 110-foot-high magazine printing plant with automated rack storage retrieval was of unprotected noncombustible construction and covered 61,600 square feet. The plant was in full operation when the fire broke out. | There was a complete coverage smoke detection system present but its installation was not yet complete. There was a complete coverage wet-pipe sprinkler system present. A building collapse prior to the fire damaged and rendered useless the sprinkler system and risers. | A building collapse caused stored magazine paper to come in contact with a broken 400-watt metal halide light bulb. Fire then spread rapidly throughout the collapsed structure. The reason for the collapse was not reported. | The paper contents and windy conditions contributed to rapid fire spread. The suppression system was damaged in the collapse and did not operate. The collapse also blocked alleyways, hampering firefighting operations. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Mississippi<br>$16,070,001<br>May, 2002<br>6:00 p.m. | This one-story rubber reclaiming plant was of unprotected noncombustible construction and covered 60,000 square feet. The plant was in full operation at the time of the fire and explosion. | There was a complete coverage heat detection system present. This system did not operate because an explosion destroyed a large portion of it. There was a local suppression system in the drying system, which operated but was not effective. There was a complete coverage wet-pipe sprinkler system present. The system was damaged by the explosion and was not effective in the area of origin but did control the fire in the area unaffected by the blast. | A fire in a rubber dust particle drying system was not fully extinguished by the dryer's suppression system, allowing the fire to extend through a vent pipe located above the roof. Embers ignited accumulated rubber dust on the roof. The fire then spread to the bagging station where a rubber dust explosion occurred throughout the plant, igniting more rubber dust and combustibles. | Five civilians were killed and seven injured in this fire. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Kansas<br>$15,000,000<br>September, 2002<br>2:26 p.m. | This 70-foot-high alcohol distillery was of unprotected noncombustible construction. The area covered was not reported. The plant was in full operation at the time of the explosion and fire. | There was no automatic detection system present. There was a partial coverage wet sprinkler system present. It was not effective due to damage caused by the explosion. | A manhole cover door left open in a lower vapor chamber of a still allowed vapors to escape into the still house. An unknown ignition source caused an explosion that ruptured additional pipes, allowing a large amount of grain alcohol to flow and continue to burn. | Four civilians were injured in this fire. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires ", *NFPA Journal*, November/December, 78.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Virginia<br>$40,000,000<br>September, 2001<br>9:40 a.m. | Five-story office building of protected noncombustible construction was in full operation at the time. The building covered a ground floor area of approximately 1.3 million square feet (approximately 123,500 square meters). | There was a complete coverage smoke detection system present. There was a partial coverage wet-pipe sprinkler system. These systems were overwhelmed by the massive explosion, fire and structural collapse. | A hijacked commercial airliner crashed into the side of the office building and exploded on impact. Burning jet fuel ignited standard office furniture and materials. | One hundred and eighty-nine civilians were killed and 99 building occupants and 12 firefighters were injured. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 29.

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

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

| State, Date, Time of Alarm, Dollar Loss | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Michigan.<br>March, 2001<br>8:11 a.m.<br>$5,500,000 | One-story plastic products manufacturing plant of protected ordinary construction covering 44,160 square feet (4,103 square meters) was in full operation at the time of the explosion and fire. | There was a partial coverage smoke detector system that was not in the area of the explosion and it did not activate. There was a complete coverage wet-pipe sprinkler system present. This system was damaged by the explosion and roof collapse. Water flowing from the severed branch main did extinguish the fire. | A fire on a forklift vehicle in this plant impinged on the propane cylinder on the vehicle. The cylinder exploded. The explosion collapsed the wall and roof of the plant and caused a small fire. | Losses totaled $4,000,000 to the structure and $1,500,000 to the contents. |

Stephen G. Badger, November, 2002, "Large-Loss Fires in the United States 2001", 16.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Michigan<br>$650,000,000<br>February, 1999<br>1:00 p.m. | This six-story power plant at an automobile manufacturing complex was of protected, noncombustible construction and covered a ground-floor area of 80,874 square feet (7,513.2 square meters). The plant was in full operation at the time of the explosion and ensuing fire. | The power plant didn't have automatic detection equipment. There was a partial area coverage wet-pipe sprinkler system. The areas covered weren't reported. This system did activate but wasn't able to contain or extinguish the fire due to the extreme circumstances and damage to the system by the explosion and fire. | A build-up of natural gas in a boiler was ignited by an undetermined source. The explosion heavily damaged the building. Six civilians died in the blast and another 38 were injured. | According to investigators, several safety devices were removed or inoperative. |

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions", *NFPA Journal*, November/December, 95-96.

| Location, Date, Time of Alarm, Number of Deaths | Occupancy Type and Use, Construction Type, Number of Stories, and Operating Status | Detection Systems | Suppression Systems | Fire Origin and Path | Contributing Factors and Other Details |
|---|---|---|---|---|---|
| Michigan<br>November, 1999<br>9:00 p.m.<br>Five | Convalescent home; protected ordinary construction; one story; full operation. | The building had smoke alarms and heat detectors throughout. | The wet-pipe sprinkler system in the basement was destroyed in the explosion. | The fire started in the boiler room. A small initial explosion was followed by another. Other details of the ignition remain undetermined. | The occupants had no time to react to the explosion. |

Robert S. McCarthy, 2000, "1999 Catastrophic Multiple-Death Fires", *NFPA Journal*, September/October, 59.

## LACK OF MAINTENANCE

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

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

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

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

## OBSTRUCTED WATER FLOW

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

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

## WATER FLOW ISSUES

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

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

## OTHER

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Texas<br>$18,000,000<br>December, 2005<br>2:06 p.m. | This was a cotton storage facility of unprotected noncombustible construction was operating. The height and area were not reported. | No information on detection equipment was reported. There was a sprinkler system in the building. The coverage and type was not reported. The system operated but was overwhelmed by the spreading fire. | This was an exposure fire. A welder working in a livestock auction facility unintentionally ignited hay in a pen. The fire spread to grass and then across a road to cotton bales, and into the storage building. | High winds spread the fire very rapidly. Embers blowing from the fire ignited several smaller fires in town. Ten fire departments were called to assist. |

Stephen G. Badger, 2006, "Large-Loss Fires for 2005", *NFPA Journal*, November/December, 72.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Louisiana<br>$11,000,000<br>September, 2005<br>12:57 p.m. | This L-shaped, one-story mall of unprotected ordinary construction had a floor area of 100,000 square feet (929 square meters) and contained 110 stores and eateries. The operating status was not reported. | There was smoke detection equipment present. The coverage and operation was not report. There was a wet-pipe sprinkler system of unreported coverage. The system did operate as designed until pressure was lost to the system. By the time the fire department re-established water flow and pressure to the systems the fire had overwhelmed the system and 100 sprinklers operated. | This incendiary fire was set in a show room of a mall store in wearing apparel. The fire spread to and destroyed 15 stores in one wing of the building, and caused smoke and water damage to the rest of the mall. | The loss was $8,000,000 to the structure and $3,000,000 to the contents. |

Stephen G. Badger, November, 2006, "Large-Loss Fires In The United States 2005," 25.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Oregon<br>$23,013,625<br>July, 2005<br>12:42 p.m. | This one-story sawmill was of heavy-timber construction and covered a ground floor area of more than 100,000 square feet (9,290 square meters). The mill was at full operation at the time of the fire. | There was no detection equipment present. There was an unreported coverage wet-pipe sprinkler system present. The system operated but was overpowered by the spreading fire. | The fire originated in the area of an electric motor above a dryer. The exact heat source and first materials ignited were still under investigation. The fire burned in hidden areas until it spread to the heavy timber bowstring truss roof construction. Several interior attacks were attempted but the fire was very deep-seated and firefighters were withdrawn for an exterior attack. Shortly after this, there was a structural collapse. | There was a long delay in notifying the fire department while workers attempted to extinguish the fire. Firefighters were told upon arrival the fire was out, but on investigation, firefighters found a deep-seated fire. Three firefighters were injured. The loss was $5,013,000 to the structure and $18,000,625 to contents. |

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Georgia<br>$50,000,000<br>May, 2004<br>4:25 a.m. | This one-story chemical manufacturing plant was of protected ordinary construction and covered 400,000 square feet. The plant was in operation at the time. | There was no automatic detection equipment present. There was a complete coverage wet-pipe sprinkler system present. The system activated but was overpowered by the spreading fire. The reason for this was not reported. | A fire broke out when a chemical reaction occurred in the warehouse area of the plant. The chemicals involved were not identified. | Very heavy smoke covered the area, causing local officials to evacuate many downwind of the fire. Damage to the structure was estimated at $20,000,000 and $30,000,000 to the contents. |

Stephen G. Badger, 2005, "Large-Loss Fires for 2004", *NFPA Journal*, November/December, 46.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Illinois<br>$6,800,000<br>October, 2003<br>4:03 a.m. | This three-story warehouse containing tires was of heavy timber construction and covered 150,000 square feet (13,935 square meters). The warehouse was closed for the weekend. | No automatic detection equipment was present. A complete coverage wet-pipe sprinkler system was present and operated, but was ineffective due to the large fire load. | The cause is undetermined. | Fire growth was extremely fast due to the fire load. Firefighters were forced to withdraw to a defensive attack. Two firefighters were injured. Loss to the building was $800,000 and loss to contents was $6,000,000. |

Stephen G. Badger, 2004, "Large-Loss Fires for 2003", *NFPA Journal*, November/December, 57.

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

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

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Colorado<br>$30,000,000<br>December, 2002<br>8:47a.m. | This 24-foot-high, one-story general products warehouse was of protected ordinary construction and covered a ground floor area of 120,415 square feet. The warehouse was closed at the time of the fire. | There was no automatic detection system present. There was a complete coverage wet-pipe system present. The system did activate but was ineffective when it was overwhelmed by the fire's growth. | Several incendiary fires were set in this warehouse to cover up a burglary. | One firefighter and four civilians were injured. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 78.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Indiana<br>$27,000,000<br>October, 2002<br>3:00 a.m. | This one-story steel manufacturing plant was of unprotected ordinary construction. The ground floor area was not reported. The plant was in full operation at the time of the fire. | There was no automatic detection system present. There was a complete coverage sprinkler system of unreported type present. The system operated but was overwhelmed by the spreading fire. | The fire originated in a hanging natural gas furnace and swept through the plant. | None Reported. |

Stephen G. Badger, 2003, "2002 Large-Loss Fires", *NFPA Journal*, November/December, 77.

| Location, Dollar Loss, Date, Time | Property Characteristics and Operating Status | Fire Protection Systems | Fire Development | Contributing Factors and Other Details |
|---|---|---|---|---|
| Montana<br>$7,000,000<br>January, 2002<br>9:40 p.m. | This two-story lumber warehouse was of unprotected noncombustible construction and covered a ground floor area of 9,000 square feet. The warehouse was closed for the night. | There were no automatic detection or suppression systems present. An exposure building did have a dry-pipe sprinkler system, but this was overcome and ineffective when the fire attacked that structure from the exterior. | This incendiary fire was set in available combustible materials. The building was fully engulfed in fire when the fire department arrived, forcing them to go to an exterior attack. The fire spread to several warehouses in the area. | Because of the remote location, the fire burned undetected for some time. Faulty hydrants and dead-end mains impeded water supply. Three firefighters were injured. |

Stephen G. Badger, November, 2003, "Large-Loss Fires in the United States 2002", 17.

| Location, Date, Time of Alarm, Number of Deaths | Occupancy Type and Use, Construction Type, Number of Stories, and Operating Status | Detection Systems | Suppression Systems | Fire Origin and Path | Contributing Factors and Other Details |
|---|---|---|---|---|---|
| Michigan<br>February, 1999<br>1:00 p.m.<br>Six | Industrial power plant; unprotected non-combustible construction; six stories; full operation. | None. | The power plant had a partial wet-pipe sprinkler system. | An undetermined source ignited an accumulation of natural gas in a boiler. | According to the state OSHA report, several safety devices at the plant had been defeated or removed, and there were no written procedures posted for shutting down the boiler. Sprinklers were unable to control the fire caused by the explosion. Thirty-eight workers were injured in the blast. |

Robert S. McCarthy, 2000, "1999 Catastrophic Multiple-Death Fires", *NFPA Journal*, September/October, 59.