

LIGHTNING FIRES AND LIGHTNING STRIKES

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

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**National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471
www.nfpa.org**

Abstract

During the four-year-period of 2002-2005, NFPA estimates that U.S. fire departments responded to an estimated 31,400 fires started by lightning per year. These fires caused an estimated average of 12 civilian deaths, 57 civilian injuries and \$213 million in direct property damage per year. These estimates are based on data 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 fire department experience survey. Only 16% of reported lightning fires occurred in homes, but these fires caused a majority of the associated losses. Lightning is also a major factor in wildland fires. Most lightning fatalities do not result from fire. Most of these victims were outside when lightning struck.

Keywords: Fire statistics, lightning

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Copies of this analysis are available from:

National Fire Protection Association
One-Stop Data Shop
1 Batterymarch Park
Quincy, MA 02169-7471
www.nfpa.org
e-mail: osds@nfpa.org
phone: 617-984-7443

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Table of Contents

Table of Contents	i
List of Tables and Figures	ii
Fact Sheet	iii
Lightning Fires	1
Appendix A. How National Estimates Statistics Are Calculated	16
Appendix B. Fires Started by Lightning: Previously Published Incidents	21
Wildland Fires Started by Lightning	21
Home Fires Started by Lightning	24
Non-Residential Fires Started by Lightning	26
<i>Church Fires Started by Lightning</i>	29

List of Tables and Figures.

Figure 1.	Fires Started by Lightning Reported to Local Fire Departments by Incident Type	1
Figure 2.	Lightning Incidents by Month	2
Figure 3.	Lightning Fires by Alarm Time	3
Figure 4.	Home and Non-Home Lightning Structure Fires by Year	4
Figure 5.	Lightning Fatalities by Location	5
Table 1.	Lightning Fires Reported to Local Fire Departments by Type of Fire	7
Table 2.	Lightning Fires in Non-Home Structures, by Property Use	8
Table 3.	Non-Home Lightning Strikes without Fire Reported to Local Fire Departments in 2003, By Property Use	10
Table 4.	Lightning Fires Reported to Local Fire Departments by Year and Type of Fire	12
Table 5.	Lightning Deaths and Flashes by State	13



Lightning Fires and Lightning Strikes

During 2002-2005, U.S. fire departments responded to an estimated annual average of 31,400 fires started by lightning. These fires caused annual averages of

- 12 civilian deaths;
- 57 civilian injuries; and
- \$213 million in direct property damage.

The January 2006 West Virginia coal mine explosion that claimed 12 lives was the deadliest U.S. fire started by lightning in recent years.

Fires started by lightning peak in the summer months and in the late afternoon and early evening.

Outside and other fires accounted for 78% of the lightning fires reported to local fire departments.

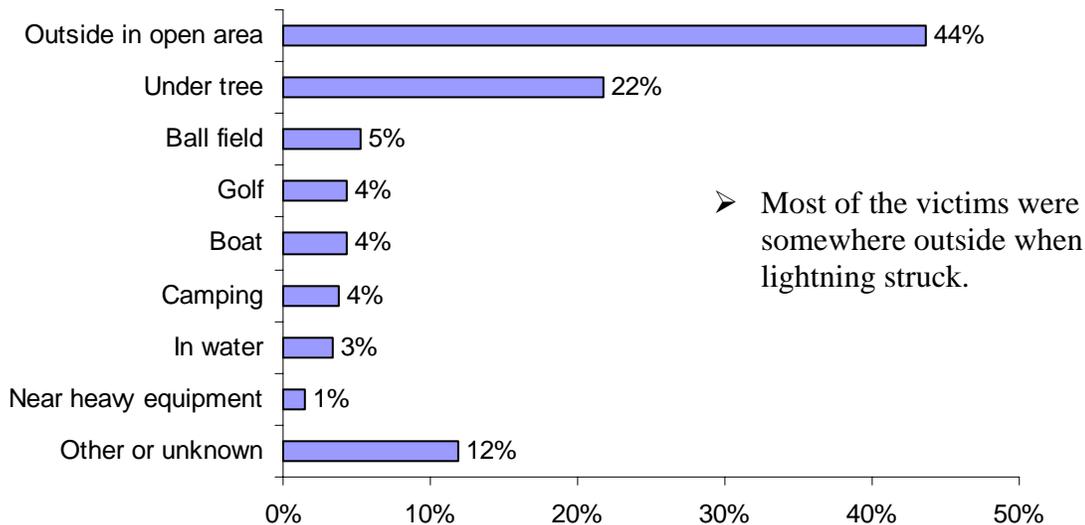
In 2002-2005, only 16% of reported lightning fires occurred in homes, but these accounted for

- nearly all the associated civilian deaths,
- 90% of the associated injuries, and
- 58% of the direct property damage.

National Interagency Fire Center statistics show that in 2002-2006, an average of 12,000 (16%) of the wildland fires were started by lightning per year. These fires burned an average of 5.2 million acres per year.

Lightning also causes non-fire deaths and injuries. According to the National Weather Service reports, in 2006, lightning caused 47 deaths and 242 injuries.

Lightning Fatalities by Location: 2002-2006

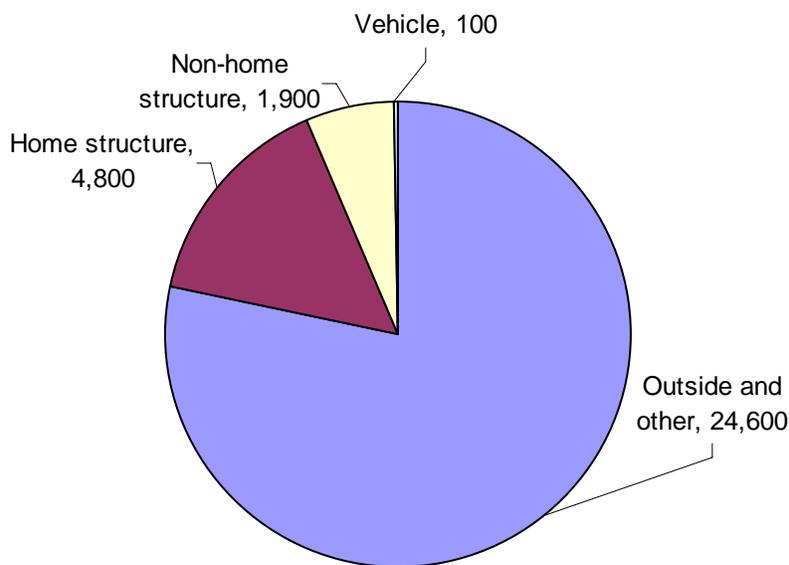


Lightning Fires and Lightning Strikes

31,400 lightning fires, on average, were reported to local fire departments per year. During 2002-2005, U.S. local fire departments responded to an estimated average of 31,400 fires per year that were started by lightning. These fires caused an average of 12 civilian deaths, 57 civilian injuries, and \$213 million in direct property damage. Figure 1 shows that 24,600 (78%) of these fires were outside and other non-structure, non-vehicle fires such as brush, grass, rubbish, etc. Table 1 shows that home structure fires accounted for only 4,800 (16%) of the lightning fires, but nearly all (98%) of the associated civilian fire deaths, 90% of the civilian fire injuries, and 58% of the direct property damage resulting from lightning fires reported to local departments annually.

Figure 1.

**Fires Started by Lightning
Reported to Local Fire Departments, by Incident Type
2002-2005**



Source: NFIRS 5.0 and NFPA survey.

2006 coal mine explosion was deadliest recent U.S. lightning incident.

In January 2006, a West Virginia fire in an underground coal mine claimed 12 lives. The incident occurred approximately two miles (3.2 kilometers) in from the mine entrance, Methane gas was ignited by a lightning strike that occurred a distance from the mine and followed a cable into the mine. The fire was reported at 6:26 a.m. The explosion killed one miner and a collapse forced the other 12 miners to retreat and await rescue behind a barricade curtain they built. Rescuers located one survivor and the bodies of the other 11 miners approximately 41 hours after the explosion.¹ A detailed report written by the U.S.

¹ Stephen G. Badger, 2007, "Catastrophic Multiple-Death Fires for 2006" NFPA, Fire Analysis and Research, Quincy, MA.

Department of Labor’s Mine Safety and Health Administration’s Coal Mine Safety and Health Division is available at <http://www.msha.gov/Fatals/2006/Sago/sagoreport.asp>.

Fifteen percent of non-home lightning structure fire property damage was in places of worship or funeral properties.

Table 2 shows a breakdown of structure fires started by lightning in non-home properties. Half (51%) occurred in storage properties. Only five percent occurred in places of worship or funeral properties but these accounted for 15% of lightning non-home structure fire property damage. Only 1% occurred utility or distribution system properties, but these fires caused 15% of the property damage from non-home lightning structure fires.

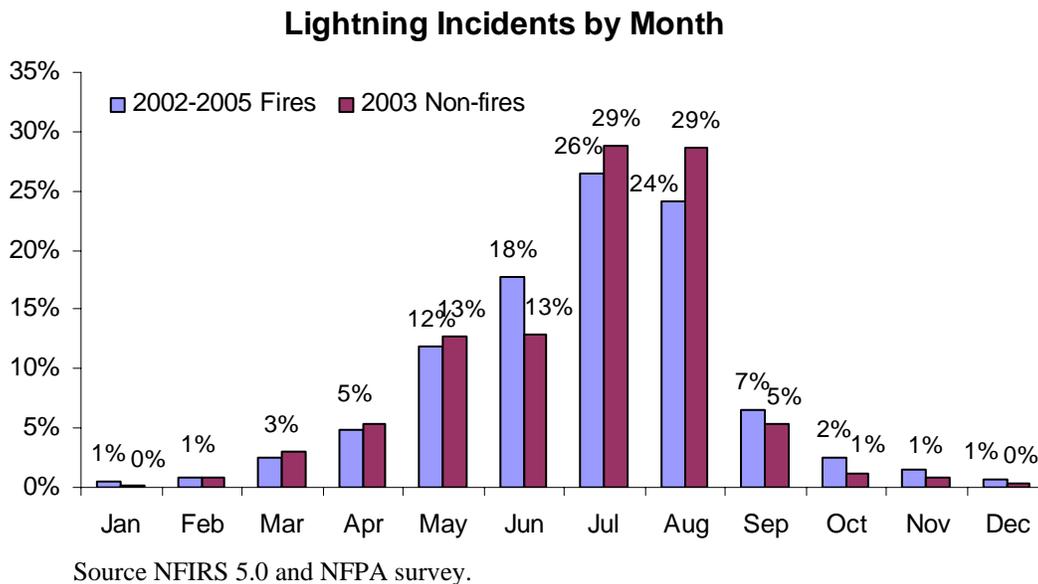
Lightning started 3% of outside and other fires reported to local fire departments.

During 2002-2005 lightning caused 1% of reported home structure fires, less than 1% of the home fire casualties, and 4% of the direct property damage from home fires. Lightning started 3% of outside and other non-structure, non-vehicle fires, 2% of non-home structure fires, and less than 1% of vehicle fires.

10,200 reported non-fire lightning strikes were reported in 2003.

In 2003, U.S. fire departments responded to an estimated 10,200 lightning strikes that did not result in fire. Sixty-two percent, or 6,300, of these incidents were at home properties. Table 3 shows that 17% of the non-home non-fire lightning strikes occurred on highways, streets or parking areas. NFIRS does not collect property damage or casualty data for non-fire incidents.

Figure 2.

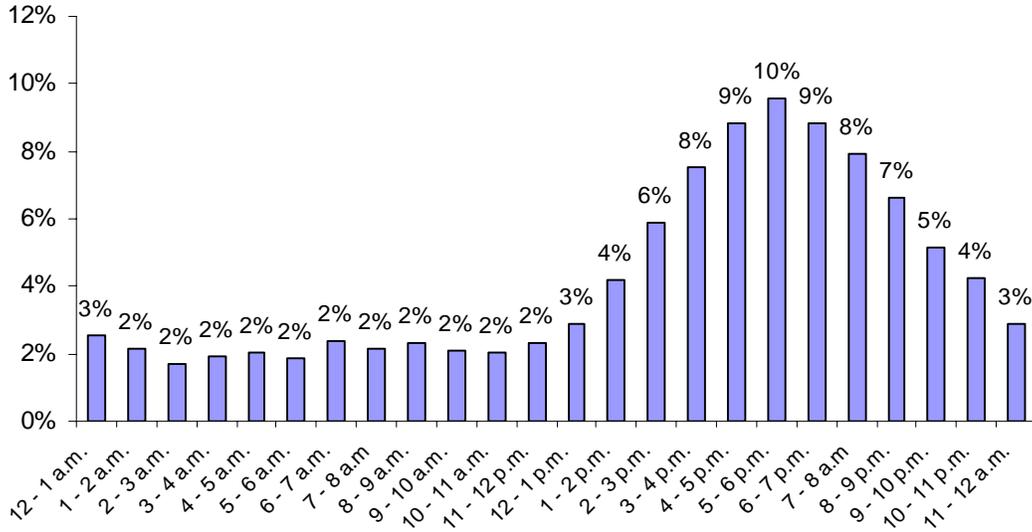


July was the peak month for lightning fires reported to local departments.

Not surprisingly, lightning fires and non-fire incidents are much more common in the summer months. Figure 2 shows that half of all lightning fires and almost three-fifths of the non-fire lightning strikes were reported in July and August. Ninety-one percent of these fires and 94% of the non-fire lightning strikes occurred in the six months of April through September.

Figure 3.

Lightning Fires by Alarm Time: 2002-2005

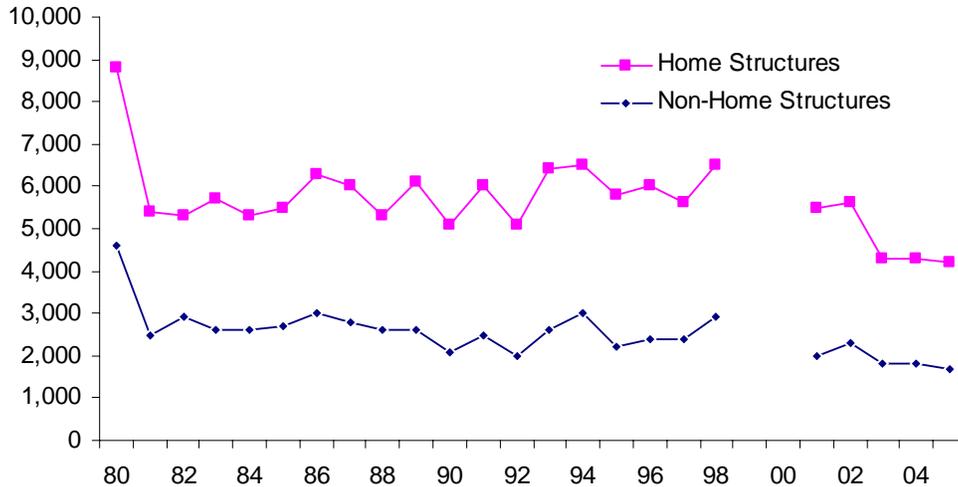


Source NFIRS 5.0 and NFPA survey.

Figure 3 shows that lightning fires peak in the late afternoon and early evening. Three-fifths (61%) of all fires started by lightning occurred between 2:00 and 10:00 p.m. The pattern was very similar for lightning strikes that did not result in fires.

Figure 4.

Home and Non-Home Lightning Structure Fires by Year: 1980-2005



Source NFIRS and NFPA survey.

Table 4 shows the estimates of lightning fires by year and type of fire. Figure 4 shows that both home and non-home structure fires were higher in 1980 and then fairly stable through the remainder of the 1980s and 1990s. Since 2002, the numbers have fallen. However, some changes may be due to changes introduced in NFIRS 5.0. Due to the small portion of fires collected in NFIRS 5.0 in 1999 and 2000, statistics for these years are omitted from Figure 4.

Outside and other fires started by lightning were on an upward trend through the 1980s and 1990s. The reason for this increase is unknown. Like structure fires, outside and other fires also fell in the most recent years.

Fire department statistics are derived from NFIRS and NFPA survey.

The estimates presented thus far (except for trend data) are projections derived from the detailed information reported in Version 5.0 of the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) combined with data from NFPA's annual fire department experience survey. NFIRS 5.0 was first introduced in some jurisdictions in 1999 and its use has steadily increased since then. Data collected in older versions were excluded from the analysis of current data. Due to complaints from the fire service about repeatedly documenting the same information for certain common fires, NFIRS 5.0 does not require causal information for 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 information is not required for these incidents, it is provided in some cases. These fires were also excluded from the analysis.

In NFIRS 5.0, fires started by lightning discharges were identified by heat source code 73. In 1980-1998, these fires were identified by form of heat of ignition code 73. Estimates include a proportional share of fires with unknown data. Annual averages were calculated from the four-year totals rather than the individual year's estimates. Wildland fires handled by state, federal, or tribal agencies are not included in these statistics.

The 2003 national public data release file was the last to include all non-fire incidents reported to NFIRS. Consequently, non-fire incidents are shown for 2003 only. Lightning strikes that did not result in fire are identified by NFIRS 5.0 incident type 814. A detailed description of the national estimates methodology may be found in Appendix A.

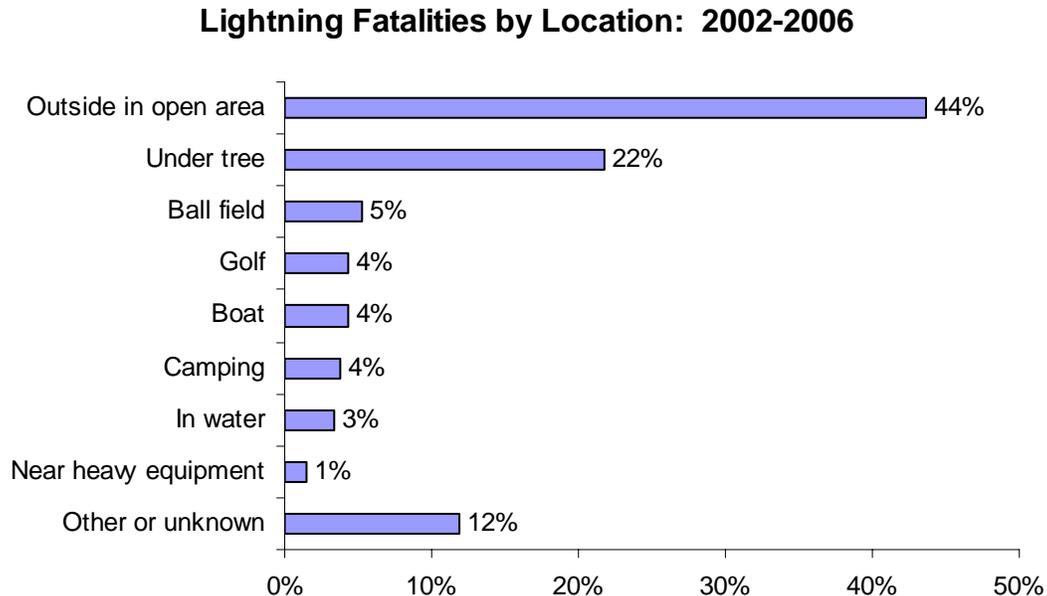
42 people, on average, were killed by lightning per year in 2002-2006.

Lightning also causes non-fire injuries and deaths. The National Weather Service reported that in 2006, lightning caused 47 confirmed deaths and 242 confirmed injuries.² According to data extracted from *Storm Data* and presented by the National Weather

² National Weather Service. "Lightning Safety," accessed online at <http://www.lightningsafety.noaa.gov> on December 20, 2007.

Service, during 2002-2006, an average of 42 people were killed by lightning per year.³ Figure 5 shows that most of the people killed by lightning were outside, with 44% in an outside open area.

Figure 5.



Source: These statistics are compiled by the Office of Services and the National Climatic Data Center from information contained in *Storm Data*. Online at <http://www.weather.gov/os/hazstats.shtml>.

Table 5 shows the average number of lightning deaths by state over the ten-year period of 1997-2006, as well as the death rate per million population for these deaths by state. This data was obtained from the National Oceanic and Atmospheric Administration’s website at <http://www.lightningsafety.noaa.gov>. State data is also shown for 1996-2005 average cloud-to-ground lightning flashes per year and average flashes per square mile. The top five in each category are in bold print. Florida led the country in number of deaths and average lightning flashes per square mile. Florida ranked second in average total cloud-to-ground flashes, and fifth in lightning deaths per million population. Wyoming ranked first in lightning deaths per million population but was more in the middle for the remainder of the measures.

The top five states for total lightning deaths were Florida, Colorado, Texas, Georgia, and North Carolina. The top five states for lightning deaths per million population were Wyoming, Colorado, Montana, Utah and Florida. The top five for total cloud-to-ground lightning flashes were Texas, Florida, Louisiana, Oklahoma, and Missouri, while the top five for lightning flashes per square mile were Florida, Louisiana, Mississippi, Alabama, and South Carolina.

³ Office of Climate, Water, and Weather Services and the National Climatic Data Center. *Lightning Fatalities* series for 2002-2006, accessed online at <http://www.weather.gov/os/hazstats.shtml> on December 19, 2007.

An average of 5.2 million acres burned in wildland fires started by lightning per year. On average, 12,000, or 16%, of the 73,000 wildland fires reported per year to the National Interagency Fire Center (NIFC) in 2002-2006 were started by lightning. Lightning fires burned an average of 5.2 million acres, or 68%, of the 7.5 million wildland fire acres burned per year. The remainder of the fires and acreage burned were attributed to human causes.⁴ (It is unclear how fires of unknown cause were handled.)

1994 Colorado wildland lightning fire claimed the lives of 14 firefighters.

In July 1994, lightning ignited a fire on a steep and rugged mountain ridge between two canyons. The blaze was allowed to burn for two days. As it grew, additional resources were deployed. Four days after ignition, as firefighters were establishing lines on a ridge, a cold front moved through the area, creating winds up to 45 miles per hour. A major blowup occurred, spreading flames at a rate of 18 miles per hour and as high as 200 to 300 feet. The rapid flame spread made escape extremely difficult. The combination of extremely dry fuels, high winds, steep topography and the fact that fire-behavior information wasn't provided to the fire crews, created a hazardous situation. Two of the 14 firefighters who died deployed their fire shelters but succumbed to smoke inhalation and heat. The other 12 had no time to open their shelters.⁵

Additional information on this incident may be found in "The Whole Canyon Blew Up..." by William Baden and Michael Isner, published in the March/April 1995 issue of *NFPA Journal*.

From 1997 through 2006, 27 U.S. firefighters were killed as a result of lightning-caused fires.

Three of the 27 firefighters were killed at structure fires and the other 24 were killed as the result of 18 wildland fires.⁶ At the structure fires, one of the firefighters collapsed and died of a heart attack during overhaul; one suffered a fatal heart attack while pulling hose from an engine; and one firefighter died as a result of smoke inhalation after falling through the fire-weakened floor into the basement of the structure.

Six firefighters died while responding to lightning-caused wildland fires: three in two helicopter crashes, two in separate road vehicle crashes, and one of a heart attack. Three firefighters were killed in two aircraft crashes during suppression activities. One firefighter died of a heart attack while at a wildland fire base camp. During suppression activities on the ground, three were killed when their vehicle went off the road, two were struck by lightning in one incident, two firefighters were struck and killed by a falling tree limbs, five suffered fatal burn injuries in four fires, one suffered a fatal heart attack, one came into contact with a downed power line and was electrocuted.

⁴ National Interagency Fire Center. *Fire Information – Wildland Fire Statistics*, accessed at http://www.nifc.gov/fire_info/lightning_human_fires.html on October 4, 2007.

⁵ Kenneth J. Tremblay, 1995, "Catastrophic Fires of 1994," *NFPA Journal*, September/October, p. 67.

⁶ National Fire Protection Association's Fire Incident Data Organization (firefighter fatality database), accessed January 18, 2007.

Previously published descriptions of lightning fires show what can happen.

Appendix B contains additional incident descriptions that were previously published in NFPA publications. Some from studies of large loss or catastrophic fires were originally published in a matrix format. These incidents have been extracted into a text format. The incidents shown here tend to be far more serious than average. They are included to show what *can* happen, not what is typical.

Protect yourself from lightning

Follow the guidelines below to protect yourself from lightning.

- Unplug appliances and other electrical items, such as computers, and turn off air conditioners. If you unable to unplug them, turn them off.
- Follow the 30-30 rule: When you see lightning, count the seconds until you hear thunder. If that time is 30 seconds or less, the thunderstorm is within six miles and is dangerous. Seek shelter immediately. The threat of lightning continues longer than most people think. Wait at least 30 minutes after the last thunder before leaving your shelter.
- If you can hear thunder, you are within striking distance of lightning. Seek shelter immediately.
- Stop outdoor activities at the first clap of thunder and get inside a house, large building, or a hard-topped vehicle.
- When inside, stay off corded phones, computers, and other electronic equipment that put you in direct contact with electricity or plumbing. Avoid washing your hands, showering, bathing, doing laundry, or washing dishes.
- If you are in open water, go to land and seek shelter immediately.
- If you feel your hair stand on end, indicating that lightning is about to strike, squat low to the ground on the balls of your feet. Place your hands over your ears and your head between your knees. Make yourself the smallest target possible and minimize your contact with the ground. Do *not* lie flat on the ground. This is a last resort when a building or hard-tipped vehicle is not available.
- If a person is struck by lightning, call 911 and get medical care immediately. Lightning strike victims carry no electrical charge; attend to them immediately. Check their breathing, heartbeat, and pulse.

Lightning Safety Week is June 22-28, 2008

For safety tips and educational materials about lightning, visit the National Weather Service's Lightning Safety site at <http://www.lightningsafety.noaa.gov/>.

Table 1.
Lightning Fires Reported to Local Fire Departments by Type of Fire
2002-2005 Annual Averages

Type of Fire	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (In Millions)	
Home structure	4,800	(16%)	12	(98%)	51	(90%)	\$123	(58%)
Non-home structure	1,900	(6%)	0	(0%)	2	(3%)	\$77	(36%)
Vehicle	100	(0%)	0	(0%)	0	(0%)	\$2	(1%)
Outside and other	24,600	(78%)	0	(3%)	4	(7%)	\$12	(6%)
Total	31,400	(100%)	12	(100%)	57	(100%)	\$213	(100%)

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. National estimates are projections. Casualty and loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Fires are rounded to the nearest hundred, civilian deaths and injuries are rounded to the nearest one, and direct property damage is rounded to the nearest million dollars. Property damage has not been adjusted for inflation. These statistics include a proportional share of fires in which the heat source was undetermined or not reported. Lightning fires were identified by heat source code 73. Proportional shares of fires in which the heat source was unknown or not reported are included in this table. Sums may not equal due to rounding errors. Estimates of zero mean that the actual number rounded to zero – it may or may not actually be zero.

Source: NFIRS and NFPA survey.

Table 2.
Lightning Fires in Non-Home Structures, by Property Use
2002-2005 Annual Averages

Property Use	Fires		Direct Property Damage (in Millions)	
	Count	Percentage	Amount	Percentage
Storage	970	(51%)	\$20.1	(26%)
Unclassified or unknown-type storage property, including outbuildings, sheds, and outside material storage areas	700	(37%)	\$13.5	(18%)
Vehicle storage, garage or fire station	160	(9%)	\$3.6	(5%)
Grain or livestock storage	60	(3%)	\$2.2	(3%)
Warehouse, or residential or self-storage	40	(2%)	\$0.7	(1%)
Non-home residential	220	(12%)	\$8.0	(10%)
Unclassified or unknown-type residential	200	(10%)	\$7.8	(10%)
Hotel or motel	10	(1%)	\$0.1	(0%)
Mercantile and office	180	(9%)	\$11.8	(15%)
Office, bank or mail facility	30	(2%)	\$1.8	(2%)
Service station or vehicle sales, service or repair	30	(2%)	\$2.1	(3%)
Specialty shop	30	(1%)	\$0.8	(1%)
Unclassified or unknown-type mercantile or business	20	(1%)	\$0.6	(1%)
Department store or unclassified general retail	20	(1%)	\$1.1	(1%)
Grocery or convenience store	20	(1%)	\$0.4	(0%)
Laundry, dry cleaning or professional supplies or services	10	(1%)	\$0.1	(0%)
Public assembly	150	(8%)	\$15.4	(20%)
Place of worship or funeral property	90	(5%)	\$11.7	(15%)
Eating or drinking establishment	30	(1%)	\$1.2	(1%)
Special property	130	(7%)	\$3.0	(4%)
Bridge, tunnel or outbuilding	80	(4%)	\$1.3	(2%)
Open land, beach or campsite	10	(1%)	\$0.2	(0%)
Unclassified or unknown-type special property	10	(1%)	\$1.1	(1%)
Construction site, oil or gas field, pipeline or industrial plant yard	10	(1%)	\$0.1	(0%)
Highway, street or parking area	10	(1%)	\$0.2	(0%)

Table 2.
Lightning Fires in Non-Home Structures, by Property Use
2002-2005 Annual Averages
(Continued)

Property Use	Fires		Direct Property Damage (in Millions)	
Utility, defense, agriculture or mining	90	(5%)	\$8.0	(10%)
Agriculture	40	(2%)	\$1.7	(2%)
Utility or distribution system	20	(1%)	\$5.6	(7%)
Unclassified or unknown-type utility, defense, agriculture or mining	20	(1%)	\$0.5	(1%)
Manufacturing or processing	50	(3%)	\$5.4	(7%)
Institutional	30	(2%)	\$2.3	(3%)
Nursing home	10	(1%)	\$1.0	(1%)
Clinic or doctor's office	10	(1%)	\$0.6	(1%)
Educational	30	(1%)	\$1.9	(3%)
Preschool through grade 12	20	(1%)	\$1.4	(2%)
Adult education or college classroom	10	(0%)	\$0.3	(0%)
Completely unclassified, unreported or unknown-type property use	50	(3%)	\$0.9	(1%)
Total	1,890	(100%)	\$76.8	(100%)

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. National estimates are projections. Loss projections can be heavily influenced by the inclusion or exclusion of one unusually serious fire. Fires are rounded to the nearest ten and direct property damage is rounded to the nearest hundred thousand dollars. Property damage has not been adjusted for inflation. These statistics include a proportional share of fires in which the heat source was undetermined or not reported. Lightning fires were identified by heat source code 73. Sums may not equal due to rounding errors. Only properties with at least 1% of the incidents are shown.

Source: NFIRS and NFPA survey.

Table 3.
Non-Home Lightning Strikes without Fire
Reported to Local Fire Departments in 2003,
By Property Use

Property Use	Incidents	
Special property	1,130	(29%)
Highway, street or parking area	650	(17%)
Open land, beach or campsite	270	(7%)
Unclassified or unknown-type special property	100	(3%)
Construction site, oil or gas field, pipeline or industrial plant yard	90	(2%)
Non-home residential	380	(10%)
Unclassified or unknown-type residential	260	(7%)
Hotel or motel	70	(2%)
Dormitory, fraternity, sorority or barracks	30	(1%)
Residential board and care	20	(1%)
Mercantile and office	380	(10%)
Office, bank or mail facility	150	(4%)
Grocery or convenience store	50	(1%)
Unclassified or unknown-type mercantile or business	50	(1%)
Department store or unclassified general retail	40	(1%)
Service station or vehicle sales, service or repair	30	(1%)
Specialty shop	20	(1%)
Public assembly	260	(7%)
Place of worship or funeral property	110	(3%)
Eating or drinking establishment	70	(2%)
Utility, defense, agriculture or mining	200	(5%)
Utility or distribution system	120	(3%)
Educational	150	(4%)
Preschool through grade 12	100	(3%)
Day care	30	(1%)
Institutional	150	(4%)
Nursing home	70	(2%)
Clinic or doctor's office	30	(1%)
Hospital or hospice	20	(1%)
Storage	150	(4%)
Vehicle storage, garage or fire station	50	(1%)
Warehouse, residential or self-storage	40	(1%)
Unclassified or unknown-type storage property, including outbuildings, sheds, outside material storage areas	40	(1%)

**Table 3.
 Non-Home Lightning Strikes without Fire
 Reported to Local Fire Departments in 2003,
 By Property Use
 (Continued)**

Property Use	Incidents
Manufacturing or processing	60 (2%)
Completely unclassified, unreported or unknown-type property use	1,060 (27%)
Total	3,920 (100%)

Note: These are national estimates of incidents reported to U.S. municipal fire departments and so exclude incidents reported only to Federal or state agencies or industrial fire brigades. National estimates are projections. Incidents are rounded to the nearest ten. Non-fire lightning strikes were identified by incident type 814. Sums may not equal due to rounding errors. Only properties with at least 1% of the incidents are shown.

Source: NFIRS and NFPA survey.

Table 4.
Lightning Fires Reported to Local Fire Departments
by Year and Type of Fire: 1980-2005

Year	Home Structure	Non-Home Structure	Total Structure	Vehicle	Outside and Other	Total
1980	8,800	4,600	13,400	100	10,800	24,300
1981	5,400	2,500	7,900	100	11,900	19,900
1982	5,300	2,900	8,200	100	12,000	20,300
1983	5,700	2,600	8,300	100	14,400	22,800
1984	5,300	2,600	7,900	100	12,900	20,900
1985	5,500	2,700	8,200	100	14,800	23,100
1986	6,300	3,000	9,300	100	11,200	20,600
1987	6,000	2,800	8,900	200	18,000	27,100
1988	5,300	2,600	7,900	200	18,800	26,900
1989	6,100	2,600	8,700	200	14,000	22,900
1990	5,100	2,100	7,200	200	18,200	25,500
1991	6,000	2,500	8,500	200	20,500	29,200
1992	5,100	2,000	7,100	100	20,000	27,200
1993	6,400	2,600	9,000	200	18,300	27,400
1994	6,500	3,000	9,500	200	32,100	41,700
1995	5,800	2,200	8,000	100	20,900	29,000
1996	6,000	2,400	8,400	100	24,200	32,800
1997	5,600	2,400	8,000	200	22,700	30,800
1998	6,500	2,900	9,400	200	31,500	41,100
1999*	3,200	1,300	4,500	100	15,700	20,400
2000*	4,000	2,300	6,400	100	35,300	41,700
2001	5,500	2,000	7,500	100	31,200	38,900
2002	5,600	2,300	7,900	100	30,500	38,600
2003	4,300	1,800	6,100	100	24,500	30,700
2004	4,300	1,800	6,100	200	22,200	28,400
2005	4,200	1,700	5,900	100	21,900	27,900

* Version 5.0 of NFIRS was first introduced in 1999. Estimates from 1999 on are based on data originally collected in NFIRS 5.0. Due to the small portion of fires in 1999 and 2000 collected in NFIRS 5.0, estimates for these years should be viewed with extreme caution.

Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. National estimates are projections. Fires are rounded to the nearest hundred. These statistics include a proportional share of fires in which the heat source was undetermined or not reported. Sums may not equal due to rounding errors.

Source: NFIRS and NFPA survey.

**Table 5.
Lightning Deaths and Flashes by State**

State	1997-2006		1997-2006		1996-2005 Average		1996-2005	
	Total	Lightning Deaths	per Million	Population	Cloud-to-Ground	Flashes per Year	Average Flashes	per Square Mile
Alabama	16 (6a)	0.36 (9)	854,000 (8)	16.5 (4)				
Alaska	0 (46a)	0.00 (46a)	NA (50a)	NA (50a)				
Arizona	9 (17a)	0.18 (19)	673,000 (13)	5.9 (27)				
Arkansas	11 (12a)	0.41 (6)	719,000 (12)	13.5 (12a)				
California	7 (22a)	0.02 (45)	91,000 (36)	0.6 (47)				
Colorado	30 (2)	0.70 (2)	517,000 (18)	5.0 (31)				
Connecticut	2 (35a)	0.06 (39)	17,000 (46)	3.5 (36)				
Delaware	0 (46b)	0.00 (46b)	15,000 (47)	7.4 (24)				
Florida	71 (1)	0.44 (5)	1,507,000 (2)	26.3 (1)				
Georgia	21 (4)	0.26 (14)	835,000 (10)	14.2 (8)				
Hawaii	0 (46c)	0.00 (46c)	NA (50b)	NA (50b)				
Idaho	2 (35b)	0.15 (24a)	85,000 (38)	1.0 (46)				
Illinois	11 (12b)	0.09 (37)	760,000 (11)	13.5 (12b)				
Indiana	6 (26a)	0.10 (35a)	517,000 (19)	14.3 (7)				
Iowa	3 (31a)	0.10 (35b)	561,000 (15)	9.9 (19)				
Kansas	2 (35c)	0.07 (38)	852,000 (9)	10.4 (18)				
Kentucky	7 (22b)	0.17 (20)	547,000 (16)	13.6 (11)				
Louisiana	16 (6b)	0.36 (10)	975,000 (3)	21.1 (2)				
Maine	2 (35d)	0.16 (22a)	40,000 (41)	1.2 (45)				
Maryland	6 (26b)	0.11 (30a)	86,000 (37)	8.6 (21a)				
Massachusetts	2 (35e)	0.03 (43a)	23,000 (43)	2.8 (39)				
Michigan	10 (16)	0.10 (35c)	303,000 (29)	5.2 (29a)				
Minnesota	2 (35f)	0.04 (41a)	392,000 (23)	4.6 (33)				
Mississippi	11 (12c)	0.39 (8)	879,000 (7)	18.4 (3)				
Missouri	7 (22c)	0.13 (27a)	953,000 (5)	13.7 (10)				
Montana	5 (29)	0.55 (3)	363,000 (25)	2.5 (40a)				
Nebraska	4 (30)	0.23 (16a)	461,000 (20)	6.0 (26)				
Nevada	1 (43a)	0.05 (40)	172,000 (35)	1.6 (44)				
New Hampshire	0 (46d)	0.00 (46d)	20,000 (45)	2.2 (42)				
New Jersey	9 (17b)	0.11 (30b)	41,000 (40)	5.4 (28)				
New Mexico	3 (31b)	0.16 (22b)	919,000 (6)	7.6 (23)				
New York	7 (22d)	0.04 (41b)	218,000 (33)	4.5 (34)				
North Carolina	19 (5)	0.24 (15)	535,000 (17)	10.8 (16)				
North Dakota	1 (43b)	0.16 (22c)	290,000 (31)	4.1 (35)				
Ohio	13 (8a)	0.11 (30c)	453,000 (22)	11.0 (15)				
Oklahoma	8 (20a)	0.23 (16b)	966,000 (4)	13.8 (9)				
Oregon	1 (43c)	0.03 (43b)	52,000 (39)	0.5 (48)				
Pennsylvania	12 (10)	0.10 (35d)	307,000 (28)	6.8 (25)				

Table 5.
Lightning Deaths and Flashes by State
(Continued)

State	1997-2006		1997-2006		1996-2005 Average		1996-2005	
	Total	Lightning Deaths	per Million	Population	Cloud-to-Ground	Flashes per Year	Average Flashes	per Square Mile
Rhode Island	3 (31c)	0.29 (13)			2,000 (48)		2.1 (43)	
South Carolina	13 (8b)	0.32 (12)			459,000 (21)		14.8 (5)	
South Dakota	3 (31d)	0.40 (7)			372,000 (24)		4.8 (32)	
Tennessee	12 (11)	0.21 (18)			605,000 (14)		14.4 (6)	
Texas	25 (3)	0.12 (28)			2,875,000 (1)		10.8 (17)	
Utah	11 (12d)	0.49 (4)			260,000 (32)		3.1 (38)	
Vermont	2 (35g)	0.33 (11)			23,000 (42)		2.5 (40b)	
Virginia	9 (17c)	0.13 (27b)			347,000 (26)		8.6 (21b)	
Washington	0 (46f)	0.00 (46e)			20,000 (44)		0.3 (49)	
Washington D.C.	0 (46e)	0.00 (46f)			1,000 (49)		8.8 (20)	
West Virginia	2 (35h)	0.11 (30d)			214,000 (34)		11.4 (14)	
Wisconsin	8 (20b)	0.15 (24b)			293,000 (30)		5.2 (29b)	
Wyoming	6 (26c)	1.21 (1)			309,000 (27)		3.2 (37)	

Sources: "Lightning Deaths by State" data collected by National Oceanic and Atmospheric Administration, online at http://www.lightningsafety.noaa.gov/stats/1997-2006_Fatalities+Rates.pdf.

Vaisala's National Lightning Detection Network® (NLDN®) "Number of Cloud-To-Ground Flashes by State from 1996 to 2005" and "Rank of Cloud-To-Ground Flash Densities by State from 1996 to 2005."

Both are available online at <http://www.lightningsafety.noaa.gov/more.htm>. Cloud-to-ground flashes were not collected for Alaska and Hawaii. Average cloud-to-ground flashes per year were rounded to the nearest thousand by the author of this study.

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.

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/download/nfirpaperforms2007.pdf>.

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; and (3) information on the type of community protected (e.g., county versus township versus city) and the size of the population protected, which is used in the statistical formula for projecting national totals from sample results. The results of the survey are published in the annual report *Fire Loss in the United States*. To download a free copy of the report, visit <http://www.nfpa.org/assets/files/PDF/OS.fireloss.pdf>.

Projecting NFIRS to National Estimates

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

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

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

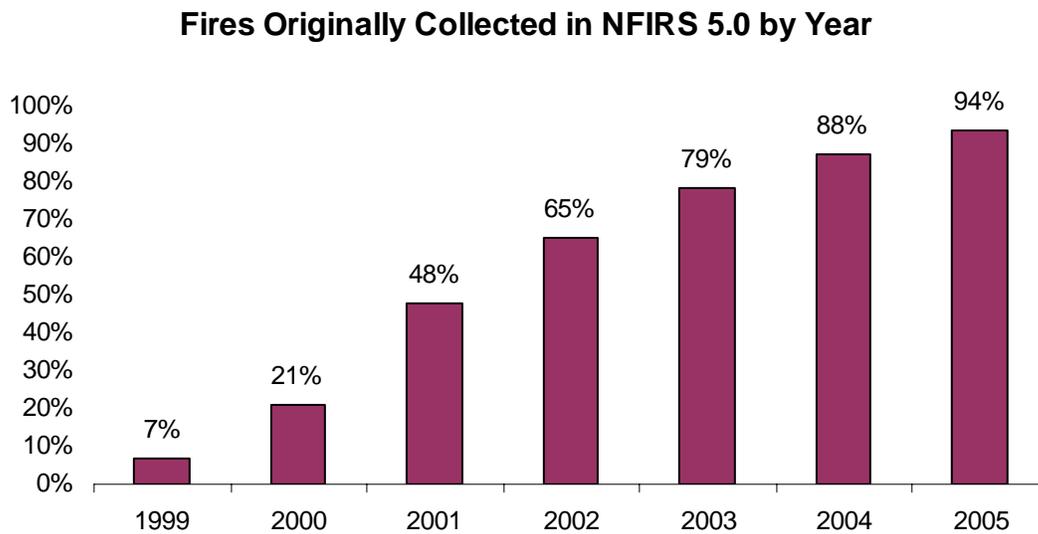
Version 5.0 of NFIRS, first introduced in 1999, used a different coding structure for many data elements, added some property use codes, and dropped others.

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.

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

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

Figure 1.



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.

A second option is to omit year estimates for 1999-2001 from year tables.

NFIRS 5.0 has 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. In order for that limited detail to be used to characterize the confined fires, they must be analyzed separately from non-confined fires. Otherwise, the patterns in a factor for the more numerous non-confined fires with factor known will dominate the allocation of the unknown factor fires for both non-confined and confined fires. If the pattern is different for confined fires, which is often the case, that fact will be lost unless analysis is done separately.

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.

For Factor Contributing to Ignition, 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%. Groupings for this field show all category headings and specific factors if they account for a rounded value of at least 1%.

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, fusee,
68. Backfire from internal combustion engine. Excludes flames and sparks from an exhaust system, (11)
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, the 2006 data is not yet available and a large portion of the fires coded as no equipment involved (NNN) have heat sources in the operating equipment category. 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

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

Additional allocations may be used in specific analyses. For example, NFPA’s report about home heating fires treats Equipment Involved in Ignition Code 120, fireplace, chimney, other” as a partial unknown (like Heat Source 60) and allocates it over its related decade of 121-127, which includes codes for fireplaces (121-122) and chimneys (126-127) but also includes codes for fireplace insert or stove, heating stove, and chimney or vent connector. More general analyses of specific occupancies may not perform as many allocations of partial allocations. Notes at the end of each table describe what was allocated.

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. Values that appear identical may be associated with different percentages, and identical percentages may be associated with slightly different values.

Appendix B.

Fires Started by Lightning: Previously Published Incidents

The incident descriptions that follow were previously published in NFPA publications. Selections from studies of large loss or catastrophic fires were originally published in a matrix format. These incidents have been extracted into a text format. The incidents shown here tend to be far more serious than average. They are included to show what *can* happen, not what is typical. The property damages cited are what was published and have not been adjusted for inflation.

Wildland Fires Started by Lightning

Montana, 2000

A July 2000 wildland fire in Montana national forest caused an estimated \$16,258,725 in direct property damage. Lightning started the fire, which burned through 61,000 acres (24,685 hectares) of Ponderosa pine and conifers. The fuel moistures were low, the winds were strong, and the topography made the fire hard to reach. Multiple lightning strikes stretched resources thin. Timber loss was reported to be \$16,153,725, structural losses amounted to \$100,000, and there was \$5,000 in vehicle losses.

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

California, 1999

An October 1999 California wildland fire burned 140,000 acres (56 hectares) and caused \$121,365,000 in direct property damage. Lightning ignited four fires that burned into one, burning timber and recreation lands. One civilian camp worker died of a heart attack as a result of this fire and one firefighter was injured. Inaccessible areas, wilderness with limited access, and steep terrain made getting to the fire difficult. Resources were limited because of other fires burning in the state.

Stephen G. Badger and Thomas Johnson, 2000, "1999 Large-Loss Fires and Explosions," *NFPA Journal*, November/December, 94.

Colorado, 1994

In July 1994, lightning ignited a fire on a steep and rugged mountain ridge between two canyons. The fuel was initially pinyon-jumper, but the fire spread to gambel oak. The blaze was allowed to burn for two days. As it grew, additional resources were deployed. Four days after ignition, as firefighters were establishing lines on a ridge, a cold front moved through the area, creating winds up to 45 mph. A major blowup occurred, spreading flames at a rate of 18mph and as high as 200 to 300 feet. The rapid flame spread made escape extremely difficult.

The combination of extremely dry fuels, high winds, steep topography and the fact that fire-behavior information wasn't provided to the fire crews, created a hazardous situation. Several aspects of incident management were identified as casual factors, including lack of proper escape routes and safety zones, inability to adjust strategy and tactics, compromise of standard firefighting orders, and Watch Out situations, and improper briefings. Personal protective

equipment performed within design limitations, but those limits were exceeded by wind turbulence and the intensity and rapid advance of the fire. Two of the 14 firefighters who died deployed their fire shelters but succumbed to smoke inhalation and heat. The other 12 had no time to open their shelters.

Additional information on this incident may be found in “The Whole Canyon Blew Up...” by William Baden and Michael Isner, published in the March/April 1995 issue of *NFPA Journal*.

Kenneth J. Tremblay, 1995, “Catastrophic Fires of 1994,” *NFPA Journal*, September/October, 67.

Washington, 1994

In July 1994, a Washington state wildland/urban interface complex included at least six major fires. The fire was reported at 7:24 p.m. A total of 41,000 acres were burned, 19 homes and 18 outbuildings were destroyed, and 2 homes and 3 outbuildings were damaged. Losses were estimated at \$37,700,000.

A fire lookout spotted 18 lightning strikes during a dry thunderstorm that ignited downed timber, brush, and grass. One human-caused fire also contributed to this complex. The fire spread rapidly through heavy Ponderosa pine and Douglas fir. Up-canyon winds ventilated the blaze, and it overran the fire lines. One fire developed into a crown fire and destroyed several homes in the canyon. These fires burned for more than a month, although the main spread and most activity occurred in the first 3 weeks. Dry weather, low moisture, limited access, and steep terrain contributed to this complex.

Stephen G. Badger and Rita F. Fahy, 1995, “Billion Dollar Drop in Large-Loss Property Fires,” *NFPA Journal*, November/December, 98.

Washington, 1994

A July 1994 Washington wildland/urban interface fire was started by lightning during a thunderstorm in a nation forest. The fire was reported at 3:30 p.m. Fire spread to structures, private land, and state-protected-land. This lightning-caused fire occurred in an area full of logging debris, dead trees, and 20-foot reproduction from a fire more than 20 years before. Weather and fuel conditions contributed to the fire. Burning material fell down steep slopes, starting fires below. One firefighter suffered a fatal heart attack in the staging area. Approximately 140,000 acres burned. Direct property damage was estimated at \$39,500,000.

Stephen G. Badger and Rita F. Fahy, 1995, “Billion Dollar Drop in Large-Loss Property Fires,” *NFPA Journal*, November/December, 111.

Arizona, 1990

In June 1990, an Arizona wildland/urban interface fire was reported by a U.S. Forest Service reconnaissance aircraft at 12:30 p.m. A lightning strike ignited a decaying tree in a national forest with standing timber without logging operations. Flames spread to nearby dry brush and grass. The fire spread rapidly because of low humidity and dry conditions. It continued to burn for 5 days. High temperatures, low humidity, and dry

fuel conditions contributed to the rapid fire spread. Steep slopes and rough terrain hampered fire fighting efforts.

The fire destroyed 53 homes and more than 28,000 acres of valuable timber before it was brought under control. Six firefighters were killed and five were injured. Direct property damage was estimated at \$10,596,200.

Kenneth T. Taylor and Michael J. Sullivan, 1991, "Large-Loss Fires in the United States in 1990," *NFPA Journal*, November/December, 78.

Idaho, 1989

A July 1989 lightning storm moving through the area caused this major Idaho wildland fire in a forest with logging. The fire was reported at 3:00 p.m. Over 20,000 acres were destroyed before it was extinguished. Extreme drought conditions and low relative humidity contributed to the fire conditions. Direct property damage was estimated at \$21,700,000.

Kenneth T. Taylor and Kenneth J. Tremblay, 1990, "Large-Loss Fires of 1989," *Fire Journal*, November/December, 54.

Idaho, 1989

Also in July 1989, a lightning storm ignited three separate fires in an Idaho forest with logging. These combined to become a devastating wildland fire. There were extreme drought conditions and low relative humidity. On the third day of the fire, it overran a small town, destroying 26 structures and over 46,000 acres. Direct property damage was estimated at \$49,987,000. Suppression costs estimated at \$12 million were not included in the loss figure.

Kenneth T. Taylor and Kenneth J. Tremblay, 1990, "Large-Loss Fires of 1989," *Fire Journal*, November/December, 54.

Washington, 1988

In August 1988, lightning started a fire in a remote area of forest in Washington state. There were high winds, and the humidity was low. The six separate locations covered four square miles. Firefighters had to hike one to two hours to reach the fire. Smoke jumpers fought six multiple fires for only a limited time due to high winds. Direct property damage was estimated at \$7 million, which does not include the \$10 million in suppression costs.

Kenneth T. Taylor and Kenneth J. Tremblay, 1989, "Large-Loss Fires in the United States," *Fire Journal*, November/December, 66.

Wildfire destroys \$1.8 million in timber, Florida

Wildfire destroyed more than 2,000 acres of timber and pulpwood when lightning ignited underbrush and the duff layer, the finely divided combustible organic material on the

forest floor. The fire smoldered for some time before erupting in flames the following day. Hot, dry conditions and a heavy fuel load contributed to the fire's spread.

At 1:01 p.m., personnel at a fire tower detected the fire and within 2 minutes notified the forestry division by radio. Firefighting efforts were delayed about 1 hour because of the fire's remote location. Swampy terrain and combustible muck complicated extinguishment by making control lines difficult to establish.

Officials believe that a lightning strike was the most likely ignition source and that the fire smoldered for a day before it was detected by the lookout. Once it was burning freely, the fire spread through available fuels, destroying 2,200 acres of timber.

Extinguished 11 days after operations began, the fire destroyed an estimated \$1.8 million of commercial timber. No injuries were reported.

Kenneth J. Tremblay, 1993, "Firewatch," *NFPA Journal*, May/June, 36.

Home Fires Started by Lightning

Lightning strike ignites siding, Connecticut

A building containing eight townhouses was struck by lightning, which damaged its cedar wall siding and started a fire in the concealed chimney space that soon spread to the building's wall and ceiling voids. The two-and-a-half story, wood-framed building, which was 120 feet long (36 meters) and 30 feet (9 meters) wide, had an asphalt shingle roof. It had no smoke detectors or sprinklers, although firewalls divided the attic space. All units were occupied at the time of the early-morning fire.

At 2:01 a.m., approximately 15 minutes after he saw a brilliant flash of light and heard a "horrific" clash of thunder, a resident discovered the fire and called 911. Responding firefighters found the exterior of the building in flames and, with the help of the police, evacuated the building's occupants. They then used a 1 3/4-inch hose line to extinguish the exterior fire and advanced a second hose line into the first floor of the end unit, where they opened the ceiling and walls to stop the fire spread. A third hose line was stretched to the second floor. The fire reached the attic before firefighters finally extinguished it. Damage to the building, valued at \$560,000, was estimated at \$20,000, while damage to the contents came to \$6,000. No one was injured.

Kenneth J. Tremblay, 2003, "Firewatch," *NFPA Journal*, May/June, 16.

Lightning strikes occupied dwelling, ignites fire, Massachusetts

A newly constructed, single-family dwelling located on a hill suffered severe fire damage when lightning struck its roof peak. The lightning was part of a squall line that passed through the area, causing numerous lightning strikes and simultaneous alarms for firefighters.

The two-and-a-half-story dwelling of unprotected, wood-frame construction contained a hardwired smoke detection system on every level, including the basement. It had no sprinklers.

A man and his two young children were at home when they heard a violent explosion. The father went outside with his son to investigate and noticed that the roof peak, clapboards, moldings, and an attic window had been damaged and that debris was strewn between 15 to 50 feet from the house. He then heard smoke detectors operating inside and re-entered the house. Smelling smoke, the father grabbed his other child, who was 9 months old, and the three of them escaped to a neighbor's home and called 911.

Firefighters responding to other calls in the area arrived within two minutes of the alarm and found heavy, black smoke issuing from the roof and fire showing from two rear, second-floor windows. Fire companies established a water supply and advanced two hose lines inside to try to reach the attic. They were able to control flames on the second floor, but intense fire conditions kept them from reaching the attic, which was fully engulfed.

Ladder crews ventilated windows in the attic and the second floor, but deteriorating conditions prevented them from opening up the roof. Seeing that an interior attack was impossible, the incident commander pulled firefighters from the dwelling and set up a defensive attack using ladder pipes and additional handlines to darken the fire. Once the fire had burned away the roof, crews entered the dwelling and extinguished the remaining fire on the second floor.

The temperature outside the house reached 88°F while firefighters were fighting the blaze. This oppressive heat, combined with an extremely high dew point and the fact that the dwelling was located high on a hill and engines had to be parked at a distance, quickly fatigued firefighters. Multiple alarms were struck to bring additional resources to the scene, including emergency medical technicians, paramedics, a doctor, and a nurse who formed a rehabilitation area. One firefighter suffered from heat exhaustion, and another sustained burns to the back of his neck.

Fire damage was limited to two second-floor bedrooms and the entire attic and roof. The first floor sustained heavy smoke and water damage. Damage to the home, valued at \$750,000, and its contents, valued at \$100,000, was estimated at \$300,000.

Kenneth J. Tremblay, 1996, "Firewatch," *NFPA Journal*, July/August, 21.

Non-Residential Fires Started by Lightning

Coal mine fire, West Virginia, 2006

A West Virginia, January 2006 fire in an underground coal mine approximately two miles (3.2 kilometers) in from the mine entrance claimed 12 lives. Methane gas was ignited by a lightning strike that occurred a distance from the mine and followed a cable into the mine. The fire was reported at 6:26 a.m. The explosion killed one miner and a collapse forced the other 12 miners to retreat and await rescue behind a barricade curtain

they built. Rescuers located one survivor and the bodies of the other 11 miners approximately 41 hours after the explosion.

Stephen G. Badger, 2007, "Catastrophic Multiple-Death Fires for 2006," *NFPA, Fire Analysis and Research*, Quincy, MA.

Refinery storage tank, Minnesota, 2004

In July 2004, lightning struck the top of a 120,000-gallon slurry oil storage tank in an operating Minnesota refinery. The top of the tank lifted off and oil ignited. The fire melted part of the side of the tank and some product escaped. The incident was reported at 5:50 a.m. Direct property damage was estimated at \$8,000,000.

Stephen G. Badger, 2005, "Large-Loss Fires in the United States-2004," *NFPA Journal*, November/December, 47.

Underground storage tank explodes, South Carolina

Lightning struck the vent pipe of a 10,000-gallon (37,853-liter) underground tank once used to store gasoline, igniting the residual gas vapors and triggering an explosion so powerful that it lifted a 15-by-30-foot (4.5-by-9-meter) section of concrete over the tank 10 feet (3 meters) in the air. An 18-by-18-inch (46-by-46-centimeter) steel plate covering a submersible pump and a leak detection monitor were also blown about 125 feet (38 meters) into the air, landing 70 feet (21 meters) from the concrete pad covering the tank.

The privately owned fueling station's pumps and electricity had been disconnected, and the contents of the single-wall fiberglass tank had been pumped out to within an inch (3 centimeters) of the bottom.

At about 7 p.m., witnesses reported that a squall line passed through the area, followed by a brilliant flash and a large explosion. Shortly after the explosion, they saw black smoke coming from the tank's fill port. One witness called the fire department at 7:04 p.m.

Responding firefighters taped off the area and confirmed that the dispenser's power had been disconnected and tagged correctly. Investigators interviewed the witnesses and confirmed that a single lightning strike caused the blast.

The fueling station's owners had complied with temporary closure requirements. However, a report produced by a private investigation company notes, "The fact that the UST [underground storage tank] was empty increased the likelihood that the tank environment would have been in the combustible range. Had the tank held fuel, it is very likely the tank atmosphere would have been above the upper explosive limit indicating the atmosphere was too rich for combustion." Experts believe that purging tanks with nitrogen or carbon dioxide would cause them to remain inert and eliminate the risk of a similar explosion. Property damage was estimated at \$13,000.

Kenneth J. Tremblay, 2005, "Firewatch," *NFPA Journal*, May/June, 32.

College offices and student center, Tennessee, 1999

In May 1999, lightning struck the roof eaves near the chimney of this Tennessee college campus four-story business office and student center. The resulting fire spread rapidly through the upper floors and attic. At the time of the fire, the offices were closed. The

structure was made of protected ordinary construction and covered a ground-floor area of 10,000 square feet (929.0 square meters). The building had no automatic detection or suppression systems. The structure was more than 100 years old. The wood was very dry and allowed rapid fire spread.

The fire was reported at 6:19 p.m. Firefighters were able to stop the downward spread and protect the first two floors. No injuries were reported. Direct property damage was estimated at \$6,050,000.

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

Indiana store, 1999

In April 1999, lightning hit a one-story Indiana store of unprotected wood-frame construction, starting a fire that spread rapidly in the unprotected open attic space. Open construction in the attic allowed for rapid fire spread. The store, located in a mini strip mall with four to five other businesses, covered a ground-floor area of 19,500 square feet (1,812 square meters). It was closed for the night when the 3:57 a.m. incident was reported. Direct property damage was estimated at \$6,000,000.

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

Indiana warehouse, 1997

In March 1997, an Indiana fire began when lightning struck a metal structure on the roof of the warehouse. No information was available on fire spread, but it's estimated to have burned for two hours before an automatic detection system in an adjacent building activated. The fire was reported at 5:31 a.m. The warehouse itself, made of unprotected, ordinary construction with a ground-floor area of 300,000 square feet (28,000 square meters), had no automatic detection or suppression systems. The building, which was 20 feet (6 meters) high, was closed when the fire broke out. Direct property damage was estimated at \$7,000,000. No injuries were reported.

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

Lightning sparks fire in historic mansion, causes \$1.5 million loss, Pennsylvania

A mansion that was an historical landmark was severely damaged during an electrical storm when lightning struck its roof.

The city-owned mansion contained priceless 18th century antiques and was used for exhibitions and tours. The three-story building measured 45 feet by 60 feet and was of stone and stucco construction with wood structural members. It had a raised-seam tin roof. The building contained heat and smoke detectors and a burglar alarm system, which were supervised by a central station alarm company. It did not contain any sprinklers.

The mansion was closed and unoccupied around 8:00 p.m. when the caretaker, who lived in a nearby cottage, saw a large flash of light. He looked outside toward the mansion, but

detected nothing unusual. A short time later, however, the property's alarm activated. The caretaker walked around the mansion before he called the security company. Someone there advised him to check inside the mansion because most of their security officers were investigating numerous other alarm activations that had been caused by the storm. The caretaker did not have access to the mansion, so he waited for the alarm to reset. While waiting, he saw smoke coming from the chimney and cornice and called 911 at 9:03 p.m.

Fire investigators determined that lightning had struck the mansion and ignited a fire in the cockloft. The fire spread from the attic and roof to two rooms and a second-floor stairway. Unobstructed horizontal openings in the cockloft allowed the blaze to spread rapidly in the early stages.

Damage to the property was conservatively estimated at \$1.5 million.

Kenneth J. Tremblay, 1994, "Firewatch," *NFPA Journal*, July/August, 31.

Multi-use university building, Kansas, June 1991

In June 1991, lightning struck and ignited the roof of the auditorium in a multi-use building at a Kansas university. The fire then spread into the concealed ceiling space of the building. The steel truss roof framing failed and collapsed, spreading burning debris to floors below, and forcing the firefighters out of the building.

The single-story building, measuring 150 feet by 150 feet, had a 160-foot ceiling. The walls were brick, the floor was masonry, and the roof framing was wood with steel trusses. The structure contained an auditorium, lecture hall, offices and storage. There was no automatic detection, suppression equipment or lightning protection present. The building was closed at the time of the fire. A passerby discovered the fire and reported it to 911 by emergency telephone at 3:20 p.m. Because of this incident and another unrelated fire that occurred simultaneously, the fire department recalled off-duty personnel and requested mutual aid. Forty minutes elapsed before firefighting personnel had enough additional support to fight the fire effectively.

Direct property damage was estimated at \$12,870,000.

John R. Hall, Kenneth T. Taylor and Michael J. Sullivan, 1992, "Large-Loss Fires in the United States in 1991," *NFPA Journal*, November/December, 78.

Church Fires Started by Lightning

Lightning ignites church, Texas

A motorist driving by a church during an intense thunderstorm noticed flames coming from the roof above the sanctuary and called the fire department at 12:46 a.m. Despite firefighters' efforts, the blaze quickly engulfed the church, whose roof collapsed.

The one-story, wood-framed building, which measured 100 feet (30 meters) by 40 feet (12 meters), had brick-veneer exterior walls. It had no fire detection or suppression system.

Firefighters arrived seven minutes after the 911 call to find flames coming from the roof above the sanctuary. They entered the burning building to fight the fire from inside, but the incident commander ordered them out in just five minutes just before the roof collapsed.

Investigators determined that the fire started in the attic and quickly spread to other areas of the church. After eliminating other sources of ignition, they determined lightning was responsible for the blaze.

Building losses were estimated at \$600,000.

Kenneth J. Tremblay, 2004, "Firewatch," *NFPA Journal*, May/June, 22.

Lightning strikes start church fire, Florida

A church sustained \$1.3 million in structural damage after lightning struck the building in two places, igniting it and causing a power surge through the electrical wiring. These events led to numerous points of ignition in the attic and a second ignition at a corner of the second-floor day school area.

The 51-year-old, two-story church had concrete-and-block walls, wood roof trusses, and a slate roof. It was 122 feet (37 meters) long and 80 feet (24 meters) wide, and contained a workshop and a day care center. Only the day care center had a fire detection system, which operated after firefighters began suppression activities. There were no sprinklers.

Nearby lightning strikes caused a massive power surge in the building's electrical system and first-floor main power room, causing all the wiring and fuses in one of three main circuit breaker boxes to melt. The surge continued through the building's internal wiring and arced at several points in the electrical distribution system. A second, more direct, lightning bolt struck a second-floor corner of the building, causing the roof overhang to smolder. The current also spread through and out of the conduit, igniting several areas of wood truss in the attic.

A passerby called 911 at 1:12 a.m. The building, valued at \$3 million, sustained an estimated \$1.3 million in damage. Contents, valued at \$500,000, sustained an estimated \$250,000 in losses. A National Weather Service Doppler radar map showed 500 lightning strikes within one-half mile (0.8 kilometers) of the church during the storm.

Kenneth J. Tremblay, 2002, "Firewatch," *NFPA Journal*, May/June, 34.

Lightning damages historic church, Iowa

A fire destroyed a historic church when lightning struck its steeple and ignited wood shingles and structural framing. Winds of more than 40 miles (65 kilometers) per hour helped fan the flames.

The single-story, wood-frame structure measured 40 by 30 feet (12 by 9 meters) and had no sprinklers or automatic detection systems. Located in a restored historic district along with a school and a barn, the church was a popular tourist attraction.

Storms had been passing through the area for about an hour, dumping more than an inch of rain, when a farmer noticed a light coming from the historic district. He drove toward

the light until he saw flames coming from the church steeple. He then drove to a neighbor's house and called the county sheriff's office at 7:07 a.m. The sheriff's office notified the fire department, and firefighters arrived within five minutes to find that the fire had already engulfed the steeple and spread to the roof and attic. The ceiling was collapsing, and the wind was blowing sparks around, threatening exposures.

The first-arriving engine company attacked the fire and summoned additional units for water because there weren't any hydrants in the area. A second pumper arrived and began to wet down the wood-shake shingles of a nearby barn and provide a water curtain to keep sparks from igniting exposures.

Additional units set up dump tanks and began to shuttle water to the site.

Firefighters maintained a defensive attack as flames engulfed the church. Despite the high winds that intensified the fire, firefighters were able to protect the exposures. The church, valued at \$45,000, and its contents, valued at \$20,000, were destroyed. More important, however, the local fire chief said, "we have lost...a piece of our history."

Kenneth J. Tremblay, 1999, "Firewatch," *NFPA Journal*, May/June, 43-44.

Virginia church, 1994

In July, 1994, lightning struck the steeple of a two-story church made of heavy timber construction. It traveled along the ridge of the metal roof, igniting combustible rafters. Within minutes, smoke was billowing from the roof and steeple. The fire department was notified by a 911 call at 6:04 p.m. The church had a ground-floor area of 20,000 square feet and a steeple 200 feet high. The church wasn't occupied at the time of the fire.

The structure had no automatic fire detection system. There were no sprinklers in the church itself, but there was a partial system of an unreported type in a classroom. Fusible-link fire doors did activate.

When firefighters arrived, they found heavy smoke and fire pouring from the roof. Crews made an aggressive attack, but were driven back when the roof collapsed. The presence of large, open areas contributed to fire spread. The fire involved hard-to-reach areas in the church. The sanctuary was destroyed, but the classrooms were saved. Direct property damage was estimated at \$7,700,000. Three firefighters were injured.

Stephen G. Badger and Rita F. Fahy, 1995, "Billion Dollar Drop in Large-Loss Property Fires," *NFPA Journal*, November/December, 98.