U.S. EXPERIENCE WITH NON-WATER-BASED AUTOMATIC FIRE EXTINGUISHING EQUIPMENT

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National Fire Protection Association
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Abstract

Non-water-based automatic extinguishing systems were reported present in 2% of U.S. reported structure fires in 2005-2009. The percentage was higher in places where commercial cooking is common, including eating or drinking establishments (41%) and grocery or convenience stores (25%). Dry (or possibly wet) chemical systems were the specific type of system reported for most of these fires, and other special hazard systems were the systems cited for most of the rest.

Dry (or possibly wet) chemical systems in the area of fire failed to operate in 36% of reported structure fires large enough to activate operating equipment, and therefore operated in 64% (100% minus 36%) of these fires. For systems that operated, performance was deemed effective in 68% of the cases. For fires large enough to activate systems, systems operated effectively 44% of the time (64% times 68%).

Because the principal application of dry (and possibly wet) chemical systems is as area protection for commercial cooking operations, it may be more appropriate to limit the analysis to ranges and to include fires reported as confined fires in the analysis. If this is done, the likelihood of operating increases from 64% to 81%, the likelihood of effectiveness if equipment operates increases from 68% to 89%, and the likelihood of effective operation increases from 44% to 72%.

Keywords: wet chemical systems; dry chemical systems; fire statistics; automatic extinguishing systems; automatic suppression systems; halon

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.

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NFPA No. **USS91**

Executive Summary

Non-water-based automatic extinguishing systems were reported present in 2% of U.S. reported structure fires in 2005-2009.* The percentage was higher in places where commercial cooking is common, including eating or drinking establishments (41%) and grocery or convenience stores (25%). Dry (or possibly wet) chemical systems were the specific type of system specified for most of these fires, and other special hazard systems were the systems cited for most of the rest.

There are some odd patterns in the Table 1-1 statistics. Fires involving carbon dioxide systems, halogen-type systems, foam systems, and to a lesser extent, other special hazard systems, are not reported primarily in the industrial locations where the first three systems are appropriate but are instead reported primarily in the properties with commercial kitchens, where most dry (or possibly wet) chemical systems are reported, or in residential properties and specifically homes. This suggests that most of these fires involve either miscoded dry (or possibly wet) chemical systems or possibly portable fire extinguishers, which are not automatic and so should not be reported at all.

Dry (or possibly wet) chemical systems in the area of fire failed to operate in 36% of reported structure fires large enough to activate operating equipment, therefore operated in 64% (100% minus 36%) of these fires.** For systems that operated, performance was deemed effective in 68% of the cases. For fires large enough to activate systems, systems operated effectively 44% of the time (64% times 68%).

Because the principal application of dry (and possibly wet) chemical systems is as area protection for commercial cooking operations, it may be more appropriate to limit the analysis to ranges and to include fires reported as confined fires in the analysis. If this is done, the likelihood of operating increases from 64% to 81%, the likelihood of effectiveness if equipment operates increases from 68% to 89%, and the likelihood of effective operation increases from 44% to 72%.

Nearly half of dry (or possibly wet) chemical system failures (44%) were due to lack of maintenance. Other reasons cited for failure were as follows:

- 25% were because manual intervention defeated the equipment,
- 13% were because a component was damaged,
- 12% were because the system was shut off, and
- 6% were because the system was inappropriate for the type of fire.

* These estimates are projections based on the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS 5.0) and the NFPA's annual fire department experience survey. These statistics exclude buildings under construction and cases of failure or ineffectiveness because of a lack of automatic extinguishing equipment in the fire area and after some recoding between failure and ineffectiveness based on reasons given. 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. Because nearly all fires reported as confined fires are reported without automatic extinguishing equipment performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment. See Appendixes A and B for additional details of statistical methodology, including the distinction between confined and non-confined fires.

** Fire incident reports refers only to dry chemical systems, not wet chemical systems, but wet chemical systems are the only systems now listed for use in commercial kitchens, the most common application of chemical systems. Therefore, we refer to this equipment as dry (or possibly wet) chemical systems.

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NFPA's Fire Safety Resources

NFPA´s wealth of fire-related research includes investigations of technically significant fire incidents, fire data analysis, and the Charles S. Morgan Technical Library, one of the most comprehensive fire literature collections in the world. In addition, NFPA´s Fire Protection Research Foundation is a source of independent fire test data. Find out more at: www.nfpa.org/research

Properly installed and maintained smoke alarms are necessary to provide a warning of any fire to all occupants. You can find out more information about smoke alarms here: NFPA Smoke Alarm Information

Home fire sprinkler systems provide even greater protection. These systems respond quickly to reduce the heat, flames, and smoke from a fire until help arrives. More information about home fire sprinklers may be found at: www.firesprinklerinitiative.org

Research

Advocacy

Codes & Standards

Public Education

NFPA also develops, publishes, and disseminates more than 300 consensus codes and standards intended to minimize the possibility and effects of fire and other risks. Among these are:

NFPA12: Standard on Carbon Dioxide Extinguishing Systems

NFPA 17: Standard for Dry Chemical Extinguishing Systems

NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems

For consumers: NFPA has consumer safety information regarding causes, escape planning, fire & safety equipment, and many other topics.

For Kids: Sparky.org has important information for kids delivered via fun games, activities, and cartoons.

For public educators: Resources on fire safety education programs, educational messaging, grants & awards, and many other topics.

Section 1: Presence and Type of Automatic Extinguishing Equipment

Non-water-based automatic extinguishing systems were reported present in 2% of U.S. reported structure fires in 2005-2009. The percentage was higher in places where commercial cooking is common, including eating or drinking establishments (41%) and grocery or convenience stores (25%).

The fire incident coding in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS) identifies three types of sprinklers (wet pipe, dry pipe, and other) and five types of non-water-based automatic extinguishing equipment.[1] (Additional details on the methodology used may be found in Appendix A. See Appendix B for a detailed overview of data elements related to automatic extinguishing equipment.)

These are the five types of non-water-based automatic extinguishing equipment as they are identified in the coding for fire incident reports.

- Dry chemical system,
- Foam system,
- Halogen-type system (including non-halogenated suppression systems that operate on the same principle),
- Carbon dioxide system, and
- Other (unclassified) special hazard system.

The goal of any automatic extinguishing equipment is to control or extinguish fires of a certain size, type, and location, while also avoiding harm from the extinguishing agent to people, property, or the environment. Automatic extinguishing equipment can be designed for (1) coverage of a room or similar space (often called "total flooding when the agent is a gas), (2) local protection, (3) portable application, or (4) fire service application (an often larger variation of portable equipment).

These goals, design options, and extinguishing agent options have interacted to produce rapid change in available technologies and common practices. Although this list of five types of non-water-based automatic extinguishing equipment was developed in the late 1990s, it has already been overtaken by events in many respects. These changes in technology and practice are not easy to incorporate into a fixed set of reporting codes. This report necessarily incorporates some estimates and assumptions of where and how much the coded data departs from the more complex reality it tries to capture.

[1] The fire statistics in this analysis are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These estimates are projections based on the detailed information collected in NFIRS and the NFPA's annual fire department experience survey. Casualty and loss projections can be heavily influenced by the inclusion of one unusually serious fire. Unless otherwise specified, property damage has not been adjusted for inflation. Fires in buildings with reported structure status of under construction are excluded from analysis. No fire protection systems or features can be expected to perform as designed in a building that is under construction.

- Dry chemical systems were designed primarily for local protection of commercial cooking equipment. Most fires reported with this type of automatic extinguishing equipment are in properties where commercial kitchens would be expected, such as eating or drinking establishments and grocery stores.

  However, wet chemical systems are the only systems that have been listed to UL300, *Standard for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas*. NFPA 96, *Ventilation Control and Fire Protection of Commercial Cooking Operations*, Chapter 10, requires that commercial cooking operations that have grease removal devices, hood exhaust plenums, and exhaust duct systems be protected by fire extinguishing equipment that complies with UL300 or other equivalent standards. This means that wet chemical systems are the primary automatic extinguishing equipment in use in commercial kitchens but cannot be reported as such; they are likely to be reported as dry chemical systems and may account for more reported fires than the fires actually involving dry chemical systems. Therefore, in this report we use the phrase "dry (and possibly wet) chemical" to reflect our working assumption that most if not all of these reported fires involve the required wet chemical systems but are coded under dry chemical because wet chemical is very similar and does not have its own code.

- Carbon dioxide was the extinguishing gas of choice for many decades, because gaseous agents are able to penetrate deep into large pieces of equipment or large burnable items to attack deep-seated fires. However, concentrations of carbon dioxide that are effective against fire can be harmful, even fatal, to people.

  One or two fatal incidents involving non-fire discharges of carbon dioxide accelerated the search for an alternative less harmful to people, and some of the halogenated agents appeared to fill the bill. However, these agents were later found to cause unacceptable harm to the environment, and the search for an acceptable alternative resumed.

  A number of other gases have drawn attention, as has water mist, which achieves the deep penetration of a gas while using water as an agent. However, no one agent has yet proven so dominant and so popular as to justify inclusion in the short list of NFIRS and alternatives. These other gases (excluding water mist) could be coded under halogen type system in light of the annotation of "halogenated-type system" to indicate that that code should also be used for non-halogenated agents in a system using similar design principles.

Table 1-1 indicates, for various property uses, how many reported structure fires, constituting what percentage of total reported fires for that property use, involved each of the five types of non-water-based automatic extinguishing equipment. Dry (or possibly wet) chemical systems account for most of these fires, and other special hazard systems account for most of the rest.

There are some odd patterns in the Table 1-1 statistics. Fires involving carbon dioxide systems, halogen-type systems, foam systems, and to a lesser extent, other special hazard systems, are not reported primarily in the industrial locations where the first three systems are appropriate but are instead reported primarily in the properties with commercial kitchens, where most dry (or possibly wet) chemical systems are reported, or in residential properties and specifically homes (not shown in Table 1-1). This suggests that most of these fires involve either miscoded dry (or possibly wet) chemical systems or possibly portable fire extinguishers, which are not automatic and so should not be reported at all.

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 of non-fire releases of water from sprinkler systems.) 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 a portable extinguisher and should not have been coded as automatic extinguishing equipment present.

Table 1-1. Presence of Non-Water-Based Automatic Extinguishing Equipment in Structure Fires, Annual Average of 2005-2009 Structure Fire Reported to U.S. Fire Departments

	Number of Structure Fires With Equipment Present and Percentage of Total Structure Fires in Property Use					
Property Use	**Any Non-Water-Based Equipment**	**Dry (or Possibly Wet) Chemical***	**Carbon Dioxide (CO2) System**	**Halogen Type System***	**Foam System**	**Other Special Hazard System***
All public assembly	4,480 (29%)	2,800 (18%)	200 (1%)	240 (2%)	360 (2%)	880 (6%)
Eating or drinking establishment	3,270 (41%)	2,060 (26%)	150 (2%)	170 (2%)	270 (3%)	620 (8%)
Educational property	220 (4%)	140 (2%)	0 (0%)	0 (0%)	20 (0%)	60 (1%)
Health care property**	260 (4%)	160 (3%)	10 (0%)	10 (0%)	0 (0%)	70 (1%)
All residential	1,310 (0%)	570 (0%)	20 (0%)	0 (0%)	20 (0%)	690 (0%)
Store or office	1,490 (8%)	950 (5%)	70 (0%)	90 (0%)	80 (0%)	300 (2%)
Grocery or convenience store	1,440 (25%)	690 (16%)	50 (1%)	60 (1%)	70 (2%)	190 (5%)
Manufacturing facility	290 (5%)	80 (1%)	130 (2%)	10 (0%)	10 (0%)	60 (1%)
All structures***	8,990 (2%)	5,190 (1%)	520 (0%)	400 (0%)	570 (0%)	2,310 (0%)

* "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. Buildings under construction are excluded.

Source: NFIRS and NFPA survey.

For 40 years, NFPA has been collecting reports on major fires of technical interest, principally focusing on large-loss and multiple-death fires. While those records are not representative of fires of all sizes, they are of interest. In these records, there are eight references to CO2 extinguishers for every reference to CO2 systems and nearly ten references to dry chemical extinguishers for every reference to dry chemical systems. However, in eating and drinking establishments, there are nearly three citations of dry chemical systems for every citation of dry chemical extinguishers. All of this supports the idea that many of the non-water based systems are actually extinguishers, but that citations of dry (or possibly) wet chemical systems in eating or drinking establishments are much more likely to be valid.

There are few fires reported with carbon dioxide systems, halogen-type systems, or foam systems. There are serious doubts whether most of these fires and most of the fires reported with other special hazard systems are properly coded as to being automatic equipment and as to type of agent. For all these reasons, the rest of the report will address only the dry and possibly wet chemical systems.

Section 2. Reliability and Effectiveness of Dry (and Possibly Wet) Chemical Systems

Dry (or possibly wet) chemical systems in the area of fire failed to operate in 36% of reported structure fires large enough to activate operating equipment and therefore operated in 64% (100% minus 36%) of these fires.[2] For systems that operated in non-confined fires, their performance was deemed effective in 68% of the cases. For fires large enough to activate systems, systems operated effectively 44% of the time (64% times 68%). (See Table 2-1.)

Editing the Database to Estimate Reliability and Effectiveness

In order to estimate reliability and effectiveness, the database must first be edited to remove fires, buildings, and systems where operation cannot be expected, such as buildings under construction. Statistics on reliability and effectiveness exclude partial systems, whether identified by coding under sprinkler presence or identified by reason for failure and ineffectiveness as equipment not in area of fire. Not all partial systems will be so identified and the codes and standards for many types of sprinklers do not require coverage in all areas. For example, concealed spaces and exterior locations may not be required to have coverage.

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

If Performance =	Not Effective	
	And Reason =	Then Change to:
	System shut off	Performance = Failed to operate

If Performance =	Failed to Operate	
	And Reason =	Then Change to:
	Not enough agent	Performance = Not effective
	Agent didn't reach fire	Performance = Not effective

Fires reported as confined fires are normally not included in analysis of reliability and effectiveness of automatic extinguishing equipment because they are collectively presumed to be too small to activate operating equipment. However, dry (or possibly wet) chemical systems are local coverage

[2] These estimates are projections based on the detailed information collected in Version 5.0 of the U.S. Fire Administration's National Fire Incident Reporting System (NFIRS 5.0) and the NFPA's annual fire department experience survey. These statistics exclude buildings under construction and cases of failure or ineffectiveness because of a lack of automatic extinguishing equipment in the fire area and after some recoding between failure and ineffectiveness based on reasons given. 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. Because nearly all fires reported as confined fires are reported without automatic extinguishing equipment performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment. See Appendixes A and B for additional details of statistical methodology, including the distinction between confined and non-confined fires.

systems designed to control cooking fires while they are still in a cooking vessel. Table 2-1A shows how reliability and effectiveness estimates change if confined fires are included. Percentages of operation increase slightly when confined fires are included, and percentages of effectiveness when operating and of effective operation increase more. Either way, these systems are estimated to operate effectively in roughly half of the fires large enough to activate an operational system in the fire area.

It is possible to restrict the analysis further to range fires only, which should further improve the match between fires used to assess reliability and effectiveness and fires for which the system is defined. If this is done for fires, including confined fires in all properties, the percentage where equipment operated increases from 64% to 81%, the percentage effective when operating increases from 68% to 89%, and the combined percentage of effective operation increases from 44% to 72%.

The largest group of fires removed from the calculation when focusing on ranges only is fires involving deep fryers. In fact, there are more deep fryer fires than range fires with dry (or possibly wet) chemical systems present. If the calculation is limited to deep fryer fires and confined fires are included, for all properties, the percentage where equipment operated declines from 64% to 56%, the percentage effective when operating increases from 68% to 73%, and the combined percentage of effective operation declines from 44% to 41%.

Nearly half of dry (or possibly wet) chemical system failures (44%) in non-confined fires were due to lack of maintenance. (See Table 2-2.) Other reasons cited for failure were as follows:

- 25% were because manual intervention defeated the equipment,
- 13% were because a component was damaged,
- 12% were because the system was shut off, and
- 6% were because the system was inappropriate for the type of fire.

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

Most cases of dry (or possibly wet) chemical system ineffectiveness in non-confined fires were because not enough agent was released (46%) or agent did not reach fire (44%). (See Table 2-3.)

NFPA's Fire Incident Data Organization contains records on the past 40 years of major fires of technical interest. Table 2-A provides relevant excerpts from the published accounts of 11 of these fires that involved dry chemical systems, commercial kitchens, and some problems with the performance of the system. These incidents are provided as more detailed examples of what can go wrong when systems fail or are ineffective. The incidents should not be considered representative. Also, note that all but the most recent one of these incidents involve dry, not wet, chemical systems, with one as recent as 2005.

At least half of the incidents involved fire spread into ducts and the ventilation system beyond system coverage before the system could operate or contain the fire. Some incidents cite problems with the hood filters that promoted fire spread or delayed fire detection and system activation. Some mention a failure to interlock so that system activation would automatically shut off the cooking equipment. Some mention that not all cylinders contained agent or were discharged. Two mention specific provisions of NFPA standards that were not followed.

Not included are several incidents where fire spread to the coverage area from other areas and some incidents involving dry chemical system applications other than commercial cooking.

Table 2-A.
Selected Published Fire Incidents Involving Wet or Dry Chemical Systems and Commercial Cooking with Problems in System Performance

"Sprinkler system saves restaurant after hood system fails – Colorado"

A restaurant's sprinkler system controlled a fire that started when cooking oil heating on a gas stove ignited until firefighters arrived to extinguish it.

The restaurant, located in a large, single-story strip mall 250 feet (76 meters) long and 60 feet (18 meters) deep, covered 1,800 square feet (167 square meters) and included a dining room, a service counter, and a kitchen in the rear. The steel-framed mall had concrete block walls covered with a brick veneer and steel roof trusses covered with a metal deck. A monitored wet-pipe sprinkler system provided coverage throughout the mall, and a wet-chemical hood extinguishing system provided coverage in the restaurant's kitchen.

Crews found that the fire in the stove area had spread into the kitchen hood exhaust system and was being held in check by the sprinkler.

Investigators learned that the fire began when a cook heating 2.5 gallons (9.5 liters) of cooking oil went out of the room to prepare another ingredient. Upon his return, he saw that the oil was smoking heavily and watched as it burst into flames. When the fire alarm sounded, he left the kitchen.

Investigators examining the kitchen hood fire extinguishing system found that, although the system tripped, it did not control or extinguish the fire because the cylinders containing the agent has been disconnected from the distribution piping to the nozzles. The system was heavily damaged by the heat, which melted the exterior aluminum siding of the fan assembly, burned the fan blades off, and damaged the motor.

NFPA Journal, May/June 2011, pp. 45-46.

"Aerosol can falls into deep fat fryer, starts fire – Washington"

Investigators searching for the cause of a fire that damaged a restaurant in a bed and breakfast facility believe an aerosol can of bug repellent fell into an operating deep-fat fryer and exploded, spewing hot oil around the first-floor kitchen. The resulting fire spread into wall voids.

The two-story, wood-frame building, which had an asphalt-shingled roof, was protected by a monitored fire alarm system that alerted the occupants. The deep fat fryer was protected by a dry-chemical hood suppression system, but it failed to operate because its cylinder had no pressure. There were no sprinklers. The restaurant's lunch crowd had dispersed 20 minutes before the fire started.

NFPA Journal, May/June 2006, p.30.

Table 2-A.
Selected Published Fire Incidents Involving Wet or Dry Chemical Systems and Commercial Cooking with Problems in System Performance (Continued)

"No filters delay activation – New Jersey"

A hospital cafeteria worker discovered a fire in a deep fat fryer in the cafeteria about 45 minutes after the fryer was turned on. Fortunately, a sprinkler activated, preventing the blaze from spreading.

The hospital was fully sprinklered, and a central station alarm company monitored the system's waterflow alarm. In addition, a dry-chemical extinguishing system protected the cafeteria's cooking area.

The worker who discovered the fire used the manual pull station to activate the dry-chemical system, and the sprinkler activated shortly afterward. By the time firefighters arrived, the hospital's security staff had extinguished the blaze with portable fire extinguishers.

Investigators determined that the filters in the hood over the fryer were missing, preventing heat from building up and activating the dry-chemical extinguishing system.

NFPA Journal, March/April, 2003, p.22.

"Grill fire damages restaurant – Indiana"

A grill fire damaged a restaurant when flames spread to duct work and concealed attic spaces, despite the activation of a dry chemical hood suppression system.

The single-story building, which measured 80 by 40 feet, was of unprotected, wood-frame construction. Its only suppression equipment – a localized dry-chemical system – was located in the hood over the grill. The building had no detection system.

The restaurant was open when a cook accidentally dropped a plastic container filled with an oil-based marinade on the hot grill. The plastic melted and the escaping oil caused flames to flare up toward the hood and duct work. Grease in the duct work ignited, and flames vented through the roof before the suppression system could activate. The fire spread to concealed attic spaces and combustible wood framing.

NFPA Journal, September/October 1996. P.25.

"Dry chemical system controls grease fire in restaurant – Florida"

Grease and food cooking on a restaurant's grill ignited, spreading flames beyond the grill's hood to the exhaust system, the ceiling, and the underside of the roof before a local dry chemical system activated.

The single-story restaurant, which was constructed of concrete block walls and unprotected wood roof framing, measured 60 feet by 50 feet. Its built-in fire protection was limited to a dry chemical system located over the grill and in the exhaust duct work.

A chef was cooking chicken on a grill when grease ignited. Flames quickly spread to the hood. An employee, probably the chef, first tried to extinguish the fire before calling the fire department at 6:39 p.m. By then, flames had spread to the ceiling tiles, to the combustible roof framing above the ceiling, past the hood filters, and into the exhaust duct work.

Investigators determined that there had been an unexplained delay in the automatic activation of the dry chemical system. This allowed the fire to spread beyond the hood system. The system did not activate until fusible links located in the duct work released. Investigators also found that improper filters had been installed in the hood.

NFPA Journal, March/April 1996. P.31.

Table 2-A.
Selected Published Fire Incidents Involving Wet or Dry Chemical Systems and Commercial Cooking with Problems in System Performance (Continued)

"New Year's Eve fire claims landmark – Massachusetts"

A fire that started in the deep-fat fryer of this famous restaurant sent 250 patrons and staff into the winter night and destroyed the building.

In the kitchen, a fixed dry chemical extinguishing system protected the gas-fired deep-fat fryer.

The deep-fat fryer, which operated at 700ºF, had been in use all evening, and the cooks left it on after they had finished with it. At approximately 11:30 pm, the hot oil in the fryer flashed over and ignited. The fixed system over the fryer snuffed out the flames, however, and restaurant employees did not notify the fire department of the situation. About half an hour later, an employee looking out a window saw a bright glow reflected above the building and went outside to find the restaurant's roof on fire. He tried to extinguish the flames with a garden hose, but to no avail. Eventually, a passerby pulled the fire alarm box outside the building, and firefighters spent the next 11 hours futilely battling the blaze.

Investigators determined that the fire from the deep-fat fryer had extended into the exhaust duct of the range hood. Neither the range hood's fixed system nor sprinklers protected this duct, so the fire was allowed to spread unchecked. It eventually burned through the duct and began consuming the roof.

NFPA Journal, January 1986, p.11.

"Grease spilled on broiler; building destroyed – California"

A fire in this one-story restaurant of ordinary construction originated in the kitchen when an employee who was cleaning accidentally spilled a can of cooking grease onto an open-pit broiler. The fire spread into the exhaust ventilation system through the grease filters before the dry chemical extinguishing system that protected the hood and duct system could control it.

The automatic extinguishing system was apparently overpowered and did not discharge the entire contents of one of the dry chemical storage containers.

NFPA Journal, October 1983, p.19.

"Fire in deep fat fryer; extinguishing system fails – District of Columbia"

A fire in a restaurant's deep fat fryer, coupled with failure of the dry chemical extinguishing system, resulted in damage to several fryers and the hood.

The fire occurred when one of the restaurant's engineers was lighting off the gas burners for the deep fat fryers. The first two were lit off, with the fryers full of cooking oil. When a third refused to ignite, the engineer thought the pilot line was clogged and went to the stockroom to get a spare.

After he left the kitchen, a fire broke out at the second fryer. Kitchen employees responded with hand extinguishers and notified the fire department. Nine extinguishers had been used and an asbestos blanket was thrown over the fryer before smoke forced restaurant personnel to evacuate. Dry chemical was discharged from the restaurant's automatic extinguishing system; however it was later found that only one cylinder had discharged.

Fire fighters arrived shortly thereafter and completely extinguished the fire using a small hose line. The fryers and the hood were severely damaged. Food in the kitchen was smoke-contaminated and had to be discarded.

Fire officials determined that the fire was caused by overheating of the cooking oil, most likely caused by a stuck gas valve.

The main 30-pound dry chemical cylinder failed to activate due to misalignment between the spring-loaded firing trigger and the release handle. This was caused by people or objects hitting the cylinder and loosening the mounting bracket. The cylinders were mounted on a wall along a kitchen aisleway.

Fire Journal, May 1981, p.27.

Table 2-A.
Selected Published Fire Incidents Involving Wet or Dry Chemical Systems and Commercial Cooking with Problems in System Performance (Continued)

"Fire in kitchen exhaust hood – Louisiana"

There was an exhaust duct over a broiler in the kitchen, plus an automatic dry chemical extinguishing system in the hood leading to the duct. The duct, made of 10-gauge steel, is 16-inches-by-42-inches in cross section. The duct crosses the kitchen ceiling, goes up a stairwell tower to the penthouse, across the ceiling of the penthouse, and out through a fan with louvers. The duct is completely enclosed with hollow tile up to the penthouse but is exposed in the penthouse.

An employee was cooking on the broiler when he was distracted for a moment. He looked back to find that grease on the broiler had ignited a fire up in the exhaust hood. He discharged a carbon dioxide fire extinguisher into the hood and extinguished the visible fire. He did not activate the dry chemical system manually, and it did not go off automatically. The fire burned above the protected area.

Fire Journal, March 1975, p.65.

"Extinguishing system not interlocked with electric deep fat fryer – New York"

A 50,000-square foot two-story golf club of ordinary construction was destroyed by a fire that originated in the kitchen. The nonsprinklered building was protected with a rate-of-rise fire detection system connected to the Fire Department through an automatic telephone-dialing system. An automatic dry chemical extinguishing system installed to protect a deep fat fryer under a range hood in the kitchen was not arranged to shut off the electric fryer when the system was activated (the system would shut off gas-fired cooking equipment).

At 9:07 am a fire occurred in the deep fat fryer and the system activated, controlling the fire; but the fire apparently reignited, spreading beyond the point of origin to the ceiling above.

NFPA Standard No. 96, *Removal of Smoke and Grease-Laden Vapors from Commercial Cooking Equipment* (1971 edition), requires that operation of any extinguishing system shall automatically shut off all sources of fuel and heat to all equipment protected or located under the ventilating equipment. This requirement at present exempts electrically heated equipment other than deep fat fryers. Investigators indicated that in this fire the extinguishing system was not arranged to shut off the electric deep fat fryer.

Fire Journal, May 1972, p.62.

"Overheated deep fat fryer – North Carolina"

Oil in a deep fat fryer apparently overheated, ignited, and flamed up through ductwork. An automatic dry chemical extinguishing system installed to protect the deep fat fryer and the filter system activated but did not control the fire, which communicated from the duct to combustible construction. The fire extended through the second floor and the common attic, destroying the restaurant and three other store occupancies in the wood-frame building. The loss was estimated at $326,700.

Investigation by fire officials indicated that the restaurant had been unoccupied at the time of the fire. It was concluded that the deep fat fryer had been left on and the equipment overheated, leading to ignition. It was not established exactly why the automatic extinguishing system failed to extinguish the fire. However, the extinguishing system was not interlocked to shut down the cooking equipment, as is required by current standards, and the hood, filter, and duct system was not installed in accordance with current standards. Among other deficiencies, the duct joints were not welded and ductwork was too close to combustible construction.

NFPA No. 96, *Vapor Removal from Cooking Equipment* (1971), contains standards for the ventilation of restaurant-type cooking equipment.

Fire Journal, March 1971, p.49.

Table 2-1.
Dry (or Possibly Wet) Chemical System Reliability and Effectiveness, by Property Use
2005-2009 Structure Fires When Fire Was Coded as Not Confined and Large Enough to Activate Equipment and Equipment Was Present in Area of Fire

Property Use	Number of fires per year where extinguishing equipment was present	Non-confined fires too small to activate equipment	Fires coded as confined fires	Number of qualifying 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	2,800	290	2,150	350	57%	63%	35%
Eating or drinking establishment	2,060	280	1,450	330	57%	62%	35%
Store or office	950	70	760	110	57%	66%	38%
Grocery or convenience store	690	60	550	80	51%	70%	35%
All structures	5,190	460	4,080	650	64%	68%	44%

* 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. Because fires reported as confined fires are reported without sprinkler performance details or as fires too small to activate operating equipment, confined fires are not included in any analysis involving reliability or effectiveness of automatic extinguishing equipment.

Source: NFIRS and NFPA survey.

Table 2-1A.
Dry (or Possibly Wet) Chemical System Reliability and Effectiveness,
With and Without Confined Fires, by Property Use
2005-2009 Structure Fires When Fire Was Coded as Large Enough to Activate Equipment and Equipment was Present in Area of Fire

	Excluding Confined Fires			**Including Confined Fires**		
	Percent where equipment operated	**Percent effective of those that operated**	**Percent where equipment operated effectively**	**Percent where equipment operated**	**Percent effective of those that operated**	**Percent where equipment operated effectively**
All public assembly	57%	63%	35%	60%	78%	47%
Eating or drinking establishment	57%	62%	35%	60%	76%	46%
Store or office	57%	66%	38%	65%	86%	57%
Grocery or convenience store	51%	70%	35%	62%	90%	56%
All structures*	64%	68%	44%	64%	83%	53%

* 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.

Source: NFIRS and NFPA survey.

Table 2-2.
Reasons for Failure to Operate When Fire Was Coded as Not Confined and Large Enough to Activate Equipment and Dry (or Possibly Wet) Chemical System Was Present in Area of Fire, by Property Use
Based on Estimated Number of 2005-2009 Structure Fires per Year

Property Use	Lack of maintenance	Manual intervention defeated system	System component damaged	System shut off	Inappropriate system for type of fire	Total fires per year
Public assembly	46%	29%	14%	8%	4%	152
Eating or drinking establishment	47%	28%	13%	8%	4%	143
Store or office	36%	19%	10%	18%	18%	47
Grocery or convenience store	28%	29%	15%	14%	15%	39
All structures*	44%	25%	13%	12%	6%	232

* Includes some properties not listed above.

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

Source: NFIRS and NFPA survey.

Table 2-3.
Reasons for Ineffectiveness When Fire Was Coded as Not Confined and Large Enough to Activate equipment And Dry (or Possibly Wet) Chemical System Was Present in Area of Fire, by Property Use Based on Indicated Estimated Number of 2005-2009 Structure Fire Per Year

	Not enough agent released	Agent did not reach fire	Lack of maintenance	Manual intervention defeated system	Inappropriate system for type of fire	System component damaged	Total fires per year
Public assembly	51%	39%	5%	2%	2%	0%	74
Eating or drinking establishment	50%	40%	5%	2%	2%	0%	71
Store or office	0%	80%	0%	0%	10%	10%	22
Grocery or convenience store	0%	100%	0%	0%	0%	0%	12
All structures*	46%	44%	3%	3%	3%	1%	133

* Includes some properties not listed above.

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

Source: NFIRS and NFPA survey.

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.

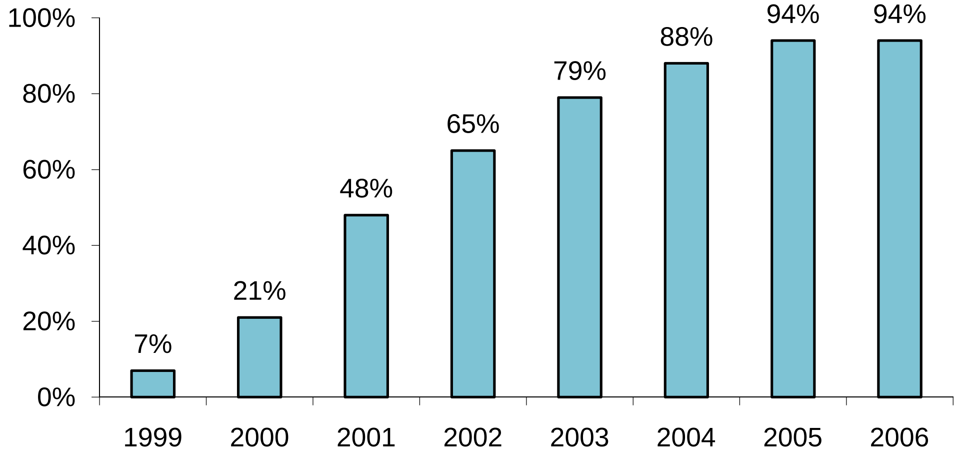
Scaling ratios are obtained by comparing NFPA's projected totals of residential structure fires, non-residential structure fires, vehicle fires, and outside and other fires, and associated civilian deaths, civilian injuries, and direct property damage with comparable totals in NFIRS. Estimates of specific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

<u>NFPA survey projections</u>
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.*

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