Reliability of Automatic Sprinkler Systems

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Whether one is preparing a performance design or working with a prescriptive code, the reliability of fire protection systems and features must be considered. Budnick[1] explains that reliability includes both operational reliability and performance reliability. The operational reliability is a measure of the probability that a system or component will operate as intended when needed. The performance reliability is a measure of the adequacy of the system once it has operated. While critical for all fire protection features and systems, this paper will focus on the reliability of automatic sprinkler systems, in particular the operational reliability.

Past Studies

Table 1 provides a list of previous studies in which the reliability of automatic sprinkler systems has been documented. The scope, breadth, and reporting periods of the various studies vary significantly. One must also carefully review the scope of each study.

Table 1

Reference	Reliability of Success	Comments
Marryat[2]	99.5	Inspection, testing, and maintenance exceeded normal expectations and higher pressures
Maybee[3]	99.4	Inspection, testing, and maintenance exceeded normal expectations.
Powers[4]	98.8	Office buildings only in New York City
Powers[5]	98.4	Other than office buildings in New York City
Finucane et al.[6]	96.9 – 97.9	
Milne[7]	96.6/97.6/89.2	

[1] Budnick, Edward K. , P.E., "Automatic Sprinkler System Reliability," *Fire Protection Engineering*, Society of Fire Protection Engineers, Winter 2001

[2] Marryat, H. W., *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand 1886 – 1986*, Australia Fire Protection Association, Melbourne, Australia.

[3] Maybee, W. W. "Summary of Fire Protection Programs in the U.S. Department of Energy—Calendar Year 1987," U.S. Department of Energy, Frederick, MD, August 1988.

[4] Powers, R. W. "Sprinkler Experience in High-Rise Buildings (1969-1979)," *SFPE Technology Report 79-1*, Society of Fire Protection Engineers, Boston, MA, 1979.

[5] Powers, R. W., ibid

[6] Finucane, M, and Pickney, D. "Reliability of Fire Protection and Detection Systems," United Kingdom Atomic Energy Authority, University of Edinburgh, Scotland.

NFPA[8]	88.2 – 98.2	Data provided for individual occupancies – total for all occupancies was 96.2%.
Linder[9]	96	
Richardson[10]	96	
Miller[11]	95.8	
Powers[12]	95.8	Low rise buildings in New York City
US Navy[13]	95.7	1964 – 1977
Smith[14]	95	UK data
Miller[15]	94.8	
Budnick[16]	92.2/94.6/97.1	Values are lower in commercial uses (excludes institutional and residential)
Kook[17]	87.6	Limited data base
Ramachandran[18]	87	Increases to 94 percent if estimate number of fires not reported is included and based upon 33% of fires not reported to fire brigade.
Factory Mutual[19]	86.1	1970 – 1977
Miller[20]	86	Commercial uses (excludes institutional and residential)
Oregon State Fire Marshal[21]	85.8	1970 – 1978
Taylor[22]	81.3	Limited data base

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[7] Milne, W. D., "Automatic Sprinkler Protection Record, "*Factors in Special Fire Risk Analysis*, Chapter 9, pp. 73-89.
[8] NFPA. "Automatic Sprinkler Performance Tables, 1970 Edition," *Fire Journal*, July 1970, pp. 35-39.
[9] Linder, K. W. "Field Probability of Fire Detection Systems," Balanced Design Concepts Workshop, NISTIR 5264, R.W. Bukowski (ed.), Building and Fire Research Laboratory, National Institute of Standards and Technology, September 1993.
[10] Richardson, J. K. "The Reliability of Automatic Sprinkler Systems," *Canadian Building Digest*, Vol. 238, July 1985.
[11] Miller, M. J. "Reliability of Fire Protection Systems," *Loss Prevention ACEP Technical Manual 8*, 1974.
[12] Power, R. W., ibid.
[13] Kelly, Kevin J. "Trade Ups", *Sprinkler Quarterly*, Summer 2003
[14] Smith, Frank. "How Successful are Sprinklers," *SFPE Bulletin*, Vol. 83-2, April 1983, pp 23-25.
[15] Miller, M. J., ibid.
[16] Budnick, Edward J., ibid.
[17] Kook, K. W. "Exterior Fire Propagation in a High-Rise Building," Master's Thesis, Worcester Polytechnic Institute, Worcester, MA, November 1990.
[18] Ramachandran, Ganapathy. "The Economics of Fire Protection," New York: E & FN Spon, 1998.
[19] Kelly, Kevin J., ibid.
[20] Miller, M. J., ibid.
[21] Kelly, Kevin J., ibid.
[22] Taylor, K. T. "Office Building Fires…A Case for Automatic Fire Protection," *Fire Journal*, 84(1), January/February 1990, pp. 52-54.

Operational Reliability

Table 1 includes both domestic and international estimates regarding the reliability of sprinklers. Many of the studies include limited data bases and are based upon experience over 15 years ago. A review of more recent fire experience in the United States indicates that the reliability of automatic sprinkler systems, while still good, may not be as high as reported by several of the studies in Table 1. In an NFPA report[23], Rohr provides considerable data regarding the fire experience in the United States in buildings protected with automatic sprinklers.

The NFPA data over a ten year reporting period regarding the operational reliability of automatic sprinkler systems can be summarized as indicated in Table 2.

Table 2

Property Use	Estimated Number of Fires with Sprinklers Present (1989-1998)	% of Fires With Sprinklers Where Sprinklers Operated
Public Assembly	30,000	73.9%
Educational	11,700	79.6%
Health Care and Correctional Facilities	41,900	80.0%
All Residential	87,500	84.6%
One- and two- family dwellings	16,900	80.0%
Apartments	50,000	87.6%
Hotels and Motels	12,900	82.7%
Department Stores	28,700	84.9%
Offices	10,700	80.6%
Industrial Facilities	4,100	85.9%
Manufacturing Facilities	49,800	91.1%
Storage Properties	9,000	84.0%
Total All Uses	273,400	83.6%

As with any data collection system, there are some limitations regarding the accuracy of the data. While identified as a limitation in some of the studies reported in Table 1, it should be noted that the Estimated Number of Fires with Sprinklers Present in Table 2 does not include fires which were too small to operate a sprinkler. For example, if the incident report indicated that the fire was too small to operate a sprinkler, that data point is not included in Table 2.

[23] Rohr, Kimberly, "U.S. Experience With Sprinklers," National Fire Protection Association, September 2001

The data in Table 2 does not include fires that are not reported to fire departments. The data does not discern whether the systems have been properly designed, installed, and maintained which would obviously increase the operational reliability of automatic sprinkler systems. Also not included is the type of sprinkler system provided and as such, it is not clear that sprinklers were present in the area of origin for all the reported fires. For example, it is possible that sprinklers were present in the building and the incident report may indicate the presence of sprinklers. However, the area of origin may not be in an area where sprinklers were present and there is no way to discern this from the data. While not the same data base, a separate NFPA report[7] indicated that partial sprinklers where the fire originated in an area that was not sprinklered constitute 7.8% of the sprinkler system failures.

Performance Reliability

Performance reliability is not as easily determined using NFPA fire data. Some of the studies cited in Table 1 use number of sprinklers operating as a means of evaluating performance reliability. In a performance-based design, the ultimate evaluation may be whether the outcome is consistent with the expected performance as documented during the design process.

It is understood that most automatic sprinkler systems are designed to control a fire but not necessarily completely extinguish the fire. The NFPA fire data supports the concept that sprinkler systems control fires but do not necessarily result in complete extinguishment. Table 3 indicates the percentage of fires where sprinklers are present that are reported as being extinguished by an automatic suppression system. Note that the data includes the fires reported to be extinguished by all types of automatic suppression systems and not only those extinguished by automatic sprinkler systems. However, since automatic extinguishing systems other than sprinkler systems constitute only a tiny fraction of protected areas, it is reasonable to assume that the overall automatic extinguishing system data can be interpreted as a relatively accurate indication of sprinkler system data.

Table 3

Property Use	Estimated Number of Fires with Sprinklers Present (1989-1998)	Estimated Number of Fires reported to be Extinguished by an Automatic Suppression System (1989-1998)	Percent of Fires Extinguished by System
Public Assembly	30,000	8,000	26.7%
Educational	11,700	1,000	8.5%
Health Care and Correctional Facilities	41,900	5,000	11.9%
All Residential	87,500	17,000	19.4%
One- and two- family dwellings	16,900	3,000	17.8%
Apartments	50,000	10,000	20.0%
Hotels and Motels	12,900	2,000	15.5%
Department Stores	28,700	6,000	20.9%
Offices	10,700	2,000	18.7%
Industrial Facilities	4,100	1,000	24.4%
Manufacturing Facilities	49,800	13,000	26.1%
Storage Properties	9,000	3,000	33.3%
Total All Uses	273,400	53,000	19.4%

While property loss and life loss are greatly reduced in buildings protected with an automatic sprinkler system, the sprinkler system alone is not providing the entire increased protection.

Summary

While NFPA fire data clearly demonstrates that property loss and life loss are reduced in buildings protected throughout with an automatic sprinkler system, the same data indicates that sprinklers fail to operate 1 in every 6 fires that are large enough to activate a sprinkler. The previously stated limitations would indicate that the number is not perfect. It has been stated that unreported fires may increase the reliability of automatic sprinkler systems. However, no data has been presented to support that claim. It is not uncommon in the U.S. for the applicable building or fire code to require that the water flow alarm from an automatic sprinkler system automatically transmit an alarm to an alarm receiving facility. This should have the affect of increasing the percentage of fires reported to fire departments in buildings protected with an automatic sprinkler system.

If it is assumed, as Ramachandran did, that 33% of the fires are not reported to the fire department and that the sprinkler system operated properly in all of those fires, the failure rate would be adjusted to 1 in every 9 fires. Using the data from the earlier NFPA

report[7], if one assumes that 8% of the failures are due to fires originating in nonsprinklered spaces within a building that is partially sprinklered, the failure rate would be adjusted to 1 in every 6.5 fires. Combining both adjustments, fires not reported to the fire department and fires occurring in nonsprinklered spaces, the failure rate would be adjusted to 1 in every 10 fires. It should be noted that these adjustments are included merely to address the potential impact of unreported fires and partial sprinkler systems and are without any statistical support from the data base from which the 1 in every 6 fires has been derived.

It should also be noted that the 1 in every 6 fires does not include performance reliability. The data in Table 2 only addresses the operational reliability of automatic sprinkler systems. While a failure rate of 1 in every 6 fires appears to be contrary to what has historically been reported, it should be noted that 6 studies reported in Table 1, including studies by Factory Mutual and the Oregon State Fire Marshal, report similar values for the reliability of automatic sprinkler systems. Whether one is convinced that the operational reliability of automatic sprinkler systems is 84% (fails once in every 6 fires) or some other value, the NFPA data seems to indicate that the commonly stated reliability of automatic sprinkler systems in the range of 96% (fails once in every 25 fires) is overstating the operational reliability of sprinkler systems and therefore overstating the overall reliability of sprinkler systems. It should also be noted that even if the reliability of sprinkler systems is 84%, automatic sprinkler systems have still had a dramatic impact on reducing life and property loss from fire.

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