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Aging Assessment for Active Fire Protection Systems

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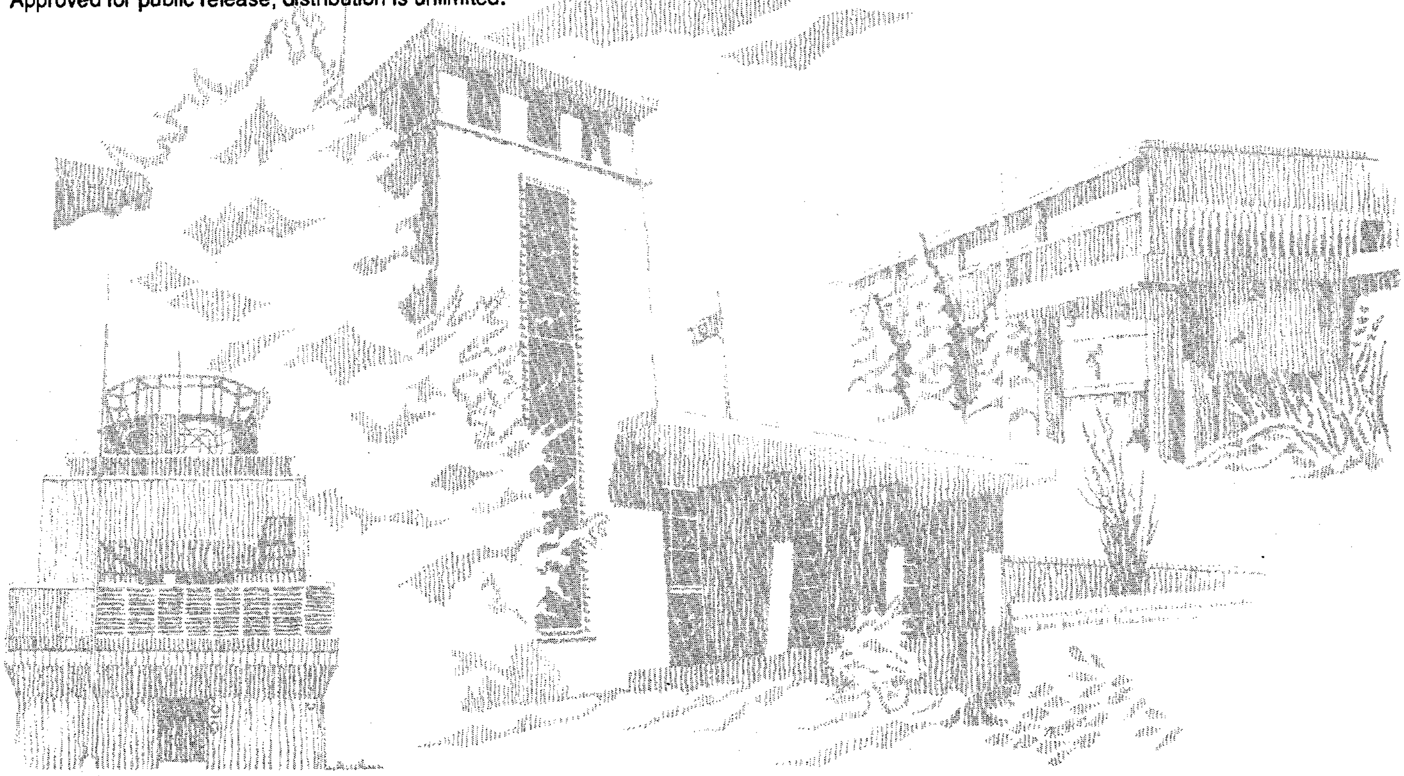

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AGING ASSESSMENT FOR ACTIVE FIRE PROTECTION SYSTEMS

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Abstract

This study assessed the impact of aging on the performance and reliability of active fire protection systems including both fixed fire suppression and fixed fire detection systems. The experience base shows that most nuclear power plants have an aggressive maintenance and testing program and are finding degraded fire protection system components before a failure occurs. Also, from the data reviewed it is clear that the risk impact of fire protection system aging is low. However, it is assumed that a more aggressive maintenance and testing program involving preventive diagnostics may reduce the risk impact even further.

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The authors would like to acknowledge Jack Haugh of the Electric Power Research Institute (EPRI) for his cooperation and review regarding NSAC 179L. We would also like to acknowledge the review and guidance of Christina Antonescu of the United States Nuclear Regulatory Commission, Office of Research.

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EXECUTIVE SUMMARY

This study assessed the impact of aging on the performance and reliability of active fire protection systems (FPSs), including both fixed fire suppression and fixed fire detection systems. From the review of the data, it is clear that most FPS failures are discovered during testing and maintenance activities and not when the FPS is required to actuate. Most of the aging-related failures came from FPS pumps, smoke detectors, and fire doors. The FPS pumps failed for a number of different reasons, including battery and shaft seal failure. The smoke detector failures were a result of both aging and increased sensitivity from an accumulation of dust and dirt. The fire doors that failed were mostly in a high-traffic area.

The reliability of FPSs was also examined for both nuclear and non-nuclear applications. Historically, water-based systems at nuclear power plants are generally assumed to have a 96% reliability as in, for example, the NUREG-1150 and NUREG/CR-4840 studies. This compares with Department of Energy (DOE) experience of 98.3%. None of these studies attempted to identify the contribution of aging to the probability of failure. The experience documented by DOE should closely mirror that of nuclear power plants, given the similarity of requirements for testing and maintaining FPSs. However, the experience base for nuclear power plants is not as comprehensive or as well studied as the DOE experience. In addition, an Electric Power Research Institute (EPRI) report (NSAC-179L) presents fire suppression system reliability values which are utilized in EPRI's fire methodology plant screening guide, FIVE (Fire-Induced Vulnerability Evaluation), and which are very similar to the NUREG/CR-4840 values. Given that the non-nuclear industry's testing and maintenance programs are generally less comprehensive than those of the nuclear power industry, one could assume that the reliability for the nuclear industry should be at least comparable (95% reported by National Fire Protection Association (NFPA) and 99.1% reported by an Australian-New Zealand study [Automatic Fire Sprinkler Performance in Australia and New Zealand, H.W. Maryatt]), if not better. Clearly, this assumption is dependent on the attention and importance given to testing and maintenance at individual nuclear power plants. The lack of FPS failure data and a comprehensive study of FPS reliability at nuclear power plants makes it difficult to make a direct comparison with the non-nuclear industry.

The discovery or occurrence of most of the significant FPS failures during testing and maintenance activities and not on demand demonstrates the existence of an aggressive testing and maintenance program at most nuclear power plants. However, it is assumed that a more aggressive testing and maintenance program involving preventive diagnostics might flag age-related FPS problems before they are found either during testing and maintenance or on demand. In closing, although there has not been a quantitative estimate of the risk due to age-related FPS failures, it is clear from the data on both FPS failure and reliability that the risk impact is low. Further, current fire risk assessment practices generally include sufficient margin in system reliability estimates to take into account the age-related failures which have been observed. Adding predictive diagnostics to the maintenance program could reduce this already low risk even further.

1. INTRODUCTION

This study involved assessing the impact of aging on the performance and reliability of active fire protection systems (FPSs), including both fixed fire suppression and fixed fire detection systems. As part of this study, both nuclear and non-nuclear industry data were investigated. Valuable insights were obtained from a Department of Energy (DOE) study (Ref. 1). To obtain industry insights, organizations such as the National Fire Protection Association (NFPA), The Electric Power Research Institute (EPRI), the Factory Mutual Research Corporation (FMRC), and other fire safety/protection organizations and professionals were contacted. The results of these efforts were limited by the scarcity of research on FPS aging. However, insights from these contacts are discussed in Section 5.0.

The initial step in this study involved reviewing nuclear power plant data, starting with a review of pertinent Licensee Event Reports (LERs) obtained through the Nuclear Operations Analysis Center at Oak Ridge National Laboratory. In addition, Sandia's Fire Event Database (Ref. 2) and EPRI's Fire Event Database (Ref. 3) were reviewed for fire protection system events related to aging. Section 2 presents the results of this data search and review. Section 3.0 presents a discussion of FPS reliability for nuclear power plants, DOE, and non-nuclear industry applications. Section 4.0 presents a discussion of the codes and standards applicable to nuclear power plants, including NFPA and Nuclear Regulatory Commission (NRC) guidance. Section 5.0 summarizes this investigation into FPS aging, provides insights, and suggests improvements to anticipate potential FPS failures and minimize the risk from aging.

As part of this study, it was desired to obtain and evaluate information on EPRI-sponsored efforts in FPS aging and reliability. This study reviewed a report (Ref. 4) prepared by EPRI to be used in conjunction with the Fire-Induced Vulnerability Evaluation (FIVE) (Ref. 5) methodology for analyzing the fire vulnerability of nuclear power plants. The EPRI report provides a database on FPS reliability, including data from nuclear and non-nuclear sources, and a spectrum of FPS ages. Some of the sources of data include FMRC, EPRI, the U.S. Navy, and others. Reliability is described by type of FPS (i.e., Halon, CO_2, wet pipe, etc.). The EPRI report was obtained and reviewed, and the results are included in Section 3.2.

2. NUCLEAR INDUSTRY DATA

To estimate the frequency of fire protection system failures which could be attributed to aging, Licensee Event Reports (LERs) for the period 01/79 to 12/93 were searched for events involving the failure of a fire protection/detection system component. This search identified 2167 LERs to review for their applicability to FPS age-related failures. These LERs were obtained from the Nuclear Operations Analysis Center at Oak Ridge National Laboratory. In addition, the Sandia Fire Event Database and the EPRI Fire Event Database were reviewed for aging-related FPS failures. Table 1 provides a summary of the types and numbers of age-related fire protection system failures found in the LER search, the Sandia Fire Event Database, and the EPRI Fire Event Database. A total of 119 events were determined to be aging-related failures or unknown failures which could be related to age of the system. The specific causes of the failures, along with frequently occurring nonage-related events, are discussed in further detail below. Although the scope of this task did not include nonage-related FPS problems, the non-aging FPS events were significant enough in number to require a brief discussion. This can be found in Sections 2.1 and 2.2. Sections 2.3 through 2.9 present discussions of the age-related FPS failures. Appendix A provides details on the specific events summarized in Table 1.

2.1 LERs Related to Failure to Perform or Maintain a Fire Watch

Based on the significant number of LERs related to the failure to perform or maintain a fire watch, it was decided to briefly mention this widespread and recurring problem. Upon review of the 2167 LERs, it was apparent a that number of the utilities do not understand the fire protection requirements with respect to the plant technical specifications and the limiting conditions for operation. As a result, a large percentage of the LERs reviewed were associated with a failure to perform or establish an appropriate fire watch. These events occurred when an FPS in a given area was found to be inoperable or intentionally made inoperable for activities such as maintenance, or when inadequate fire barriers(i.e., doors) or seals were discovered. For most of these events, the failure to establish a fire watch was not due to an age-related failure of a FPS. In these events, a continuous or periodic fire watch must be implemented; however, on numerous occasions the fire watches were not established or the frequency of the fire watch was inadequate or not maintained. Most of the LERs could be attributed to a lack of understanding of the limiting conditions for operation in the event of the degradation of a fire protection/detection system.

Table 1. FPS Age-Related Failures

Component Failure	Number of Failures
FPS pump (electric or diesel)	37
Fire barriers	7
Fire detectors	35
Fire doors	16
FPS piping/sprinkler heads	14
Miscellaneous	10

2.2 Events Related to Inadequacy of Fire Barriers

An additional type of FPS failure found in significant numbers in the LERs which for the most part was not applicable to aging is the failure or inadequacy of fire barriers. Most of these events were found during routine plant walkdowns or during scheduled fire barrier inspections. The largest source of reporting was from construction or modification activities during which fire barriers were improperly sealed during installation or resealed following maintenance activity. There were a few barrier failure events which were attributed to aging; these are discussed in the following sections.

2.3 Smoke Detector-Related Events

There were a significant number of age-related events (22) in which smoke detectors went off and could not be reset because of increased sensitivity, dust/dirt accumulation or high humidity. However, of the events where there was a malfunction caused by dirt or dust, it is not clear if all of them can be attributed to aging. Some of the events occurred after activity in the area which increased airborne dust. The events which could be attributed to aging involved the increased sensitivity of the detector. These events were consistently described as related to aging phenomenon. The events related to high humidity are difficult to avoid unless the type of detector is changed or if the event was due to unusual circumstances. The events related to dirt /dust accumulation are almost unavoidable in high traffic areas. If it is important to avoid spurious actuations of smoke detectors, an aggressive program (especially in high-traffic areas) to periodically clean and check the detectors must be implemented on a frequency based on plant experience with such actuations. Current maintenance activities may not be frequent enough for high-traffic areas or areas with a potential for high airborne dirt/dust accumulation. This may be an area where performance-based inspections could reduce the number of failures.

There were a few additional events related to the failure of a fire-indicating unit which controlled the alarm/trip functions of the smoke detectors; in these cases the failure could be attributed to aging of the component. There was one event in which 6 of 10 smoke detectors in one fire zone failed due to corrosion from an unknown source.

2.4 FPS Electric and Diesel Pumps

In the review of the LERs, it was found that the majority of age-related failures of a FPS came from failures of the diesel or electric fire pump (37 events). However, only one of these failures could be classified as failure on demand during the required actuation of a FPS; the rest (36) were failure on demand during periodic testing or when the running pump was switched to perform maintenance. There were 7 events in which the starting batteries failed as a result of age or frequent testing and the diesel fire pump did not start on demand. The remaining 30 events were due to various age-related failures, including the following:

- Three-phase motor contactor worn
- Worn shaft seal on pump casing
- Pressure switch failure
- Broken fuel line
- Voltage regulator

Unfortunately, unless an aggressive preventive maintenance program is implemented, most of these failures will not be found until the end of life for the failed component. Although plants are required to have a backup pumping source for the FPS water supply, an additional random failure in combination with an age-related failure could result in a total loss of FPS water for at least the time required to line up an additional source of water. A maintenance program based on predictive diagnostics of critical FPS pumping components could significantly reduce the probability of losing both FPS pumping sources. Similar efforts for diesel generators have greatly improved their reliability.

2.5 Fire Barrier or Fire Seal Failure

While many events associated with failure of fire barrier systems were identified, only a very small number of these events (7) appear to be age-related. Three of these involved the failure of fire barriers or door seals due to age-related phenomena. In addition, two of these three events involved potential deficiencies from construction activities, and the third (door seal failure) had management deficiencies as a contributing factor. One of the seven events involved a design deficiency in the control room door seals. In the remaining three events, a fire damper failed to close. In two of these events the fire damper was stuck because there was debris in the track. No root cause was found for the damper that failed to close upon actuation of the Halon FPS.

2.6 Fire Doors

Eighteen LERs involved fire door problems that may have been related to age. Two of the events involved degraded seals on the control room doors and in the remaining sixteen a fire door failed because of aging or high use (i.e., worn hinges, latch). The failure of a fire door may be a violation of a Technical Specifications requirement, depending on the configuration of the fire zone being protected (FPS present, equipment in the area). Such failures may also provide a path for the spread of fire or fire products (smoke and heat) beyond a single fire area. This situation also requires a fire watch until the door is repaired. An aggressive program to track all the fire doors at a plant site and their inspection would be necessary to prevent such problems. However, it is equally important, and potentially more cost effective, to stress to plant personnel the importance of fire doors and the need for prompt notification of any deficiency.

2.7 FPS Piping and Nozzles

Fourteen events involved the failure or partial failure of a water-based FPS system because rust and scale buildup caused a blockage or because the piping wall was corroded. In one event, the entire FPS water main was lost because two carbon steel tension tie bolts were corroded. One of the fourteen events involved a pinhole leak in a 3-inch fire protection line caused by corrosion that pitted the wall. In twelve of the fourteen events, the FPS nozzles were plugged by rust and scale. A more aggressive maintenance program to flush out the FPS lines might have prevented the plugging of the nozzles. However, if only the end nozzle in the line is opened as required by current procedures, debris may be lodged in the nozzles upstream of the opened nozzle. It is important to note that the plugging of the nozzles did not in any case involve 100% blockage; therefore partial FPS coverage was available.

2.8 Miscellaneous FPS Aging Failures

The FPS failures that fall into this category cover all age-related failures not discussed in the previous sections. Nineteen events were categorized as miscellaneous FPS failures. Examples of the types of failures are:

Solenoid valve failure
CO_2 discharge timer
Circuit card/board failure
Relay coils
Failed capacitor

2.9 FPS Aging-Related Events Obtained from Sandia Fire Event Database and EPRI Fire Event Database

This section presents additional age-related failures found in the review of the Sandia Fire Event Database and EPRI Fire Event Database. Five additional events not found in the LER search which could be interpreted as age-related were identified. A total of 454 events in the Sandia Fire Event Database and 772 events in the EPRI Fire Event Database were screened. These age-related failures are included in Appendix A and are summarized as follows:

The first event involved a fire in a cooling tower. The fire was extinguished by plant personnel, with extensive damage to the tower. The sprinkler system deluge valve was not effective in extinguishing the fire. The exact failure mode is unknown.

The second event involved the failure of a panel alarm buzzer relay in a fire detection instrumentation panel, causing a fire. The panel was de-energized and fire detectors in the switchgear rooms, battery room, diesel generator area, and diesel fuel storage area were rendered inoperable.

The third event involved the overheating and failure of a fire pump engine and its failure to trip. The root cause for this event was a broken fan belt.

The fourth event involved the rupture of the Division I diesel generator fuel line, resulting in a fire near the left bank turbocharger. The fire protection system deluge valve failed to open automatically as designed. The valve was forced open by a mechanic. The root cause of the deluge valve failure was not reported.

The fifth event involved the failure of a deluge valve in the diesel generator area, which was attributed to rough mating surfaces between the valve latch and the clapper.

2.10 Summary

The experience indicates that the most common failures encountered are the failure of the FPS pumping source (diesel or electric pump). Most of these failures were aging-related and in most cases a redundant pumping source was available. This type of event is reportable because of the loss of redundancy in FPS pumping capabilities. Although periodic testing and maintenance usually identify FPS pump failures, only through trending and preventive diagnostics can FPS pumping-related failures be predicted and effectively eliminated. The second most common failure encountered was the spurious actuation or failure of smoke detectors to reset because of either aging and increased sensitivity, or an accumulation of dirt and dust. The third most common failure was fire door failure caused by aging or high use and traffic. Although this type of failure requires the spread of smoke or fire to an adjacent fire zone to be significant, it is a technical specification violation and requires a fire watch until it is corrected. For both the detector and fire door failures, an aggressive maintenance program tracking these types of failures and implementing preventive or corrective measures should ensure that there is limited recurrence or none. The following section uses this experience base and other FPS experience to characterize FPS reliability for both nuclear and non-nuclear applications.

3. RELIABILITY OF FIRE PROTECTION SYSTEM

This section presents a summary of FPS reliability from four different sources (nuclear power plant, NFPA non-nuclear, DOE, and Australia-New Zealand experience). Although some of the reliability data are not directly applicable to nuclear power plant FPS installations, insights can be gained from the experience of other industries and government agencies. Specifically, the work most applicable to nuclear power plant experience is the DOE reliability study, which provides data that are directly comparable to nuclear power plant performance when considering the level of inspection, testing, and maintenance that both DOE and NRC require. The first study presented is that for nuclear power plants and is based on data from the United States and abroad. The NFPA general industry data are presented next, followed by the DOE and Australian-New Zealand data.

3.1 Nuclear Power Plant FPS Reliability

In reference 6, failure rates (on demand) for three types of fire system (water deluge, CO_2 and Halon) are presented which were based on a literature review (Refs. 7 - 10). Table 2 lists the failure probabilities given a demand for the three system types. Based on this literature search, best-estimate values for system reliability for water, Halon and CO_2 were taken to be 96%, 94%, and 96% respectively.

It is assumed that the FPS failure rates were based upon data in the referenced sources, which include nuclear power plants of various ages. Inherently this includes data from FPS with a spectrum of ages and therefore includes to some degree the effect of FPS aging. Without a detailed look at the data used to estimate these failure rates in conjunction with plant specific testing and maintenance programs, it would be difficult to assess the contribution of aging to the failure rates in Table 2.

Table 2. Automatic Suppression System Failure Rates (On Demand)

System	Failure Rate	NUREG/CR-4840
Water deluge	0.049 (Ref. 7)	
	0.038 (Ref. 10)	0.04
	0.0063 (Ref. 8)	
Halon	0.20 (Ref. 7)	
	0.059[1]	0.06
	0.0536 (Ref. 10)	
CO_2	0.116 (Ref. 7)	
	0.04 (Ref. 9)	0.07
	0.002 (Ref. 8)	

3.2 EPRI FPS Reliability Estimates

This section presents a brief summary of EPRI's report NSAC-179L, "Automatic and Manual Suppression Reliability Data for Nuclear Power Plant Fire Risk Analyses."[2] The intent of the EPRI report, as stated in the abstract, is twofold: "1) to provide reliability data for Fire Risk Assessments (FRAs) and for EPRI's Fire-Induced Vulnerability Evaluation (FIVE) Methodology; and 2) to provide a better understanding of the reasons for conflicting reliability estimates that have been used in past FRAs."

Section 1 of NSAC-179L provides an introduction and summary of automatic and manual suppression reliability data, including guidance on the selection and use of fire protection system reliability estimates in FRAs. Although FPS aging is not explicitly discussed, the contribution of aging is inherent in any set of reliability data. In general, the NSAC-179L and the current SNL review provide very similar overall system reliability point estimates. This is not overly surprising in that both studies have identified similar, and often identical, data sources. Another point of

[1] Letter from SAIC Senior Staff Scientist Bill Parkinson to John Lambright, Dated May 3, 1988.
[2] For information regarding the availability of NSAC-179L, contact Robert Kassawara (EPRI) at (415)855-2775.

similarity between the reviews is that both studies highlight aggressive maintenance and testing programs as the most effective means of ensuring high reliability in fire protection systems.

To determine the source(s) of FPS reliability data used in FRAs, seventeen FRAs and two of the most recent FRA methodologies —NUREG/CR-4840 (Procedures for the External Event Core Damage Frequency Analyses for NUREG-1150) and FIVE (Refs. 5 and 6)— were reviewed in NSAC 179L. An assessment of the specific FPS reliability data for each FRA analyzed was included. Based on this review, there appears to be a consensus developing regarding the reliability of automatic suppression systems. The reliability point estimates developed by Sandia National Laboratories and published in NUREG/CR-4840 are presented in Table 2. Although different assumptions were used to determine the reliability of fire suppression systems, the NSAC-179L automatic FPS reliability point estimates, which are used in FIVE, are very similar to the NUREG/CR-4840 values. However, as noted in NSAC-179L, there are two significant differences in the reliability data between NUREG/CR-4840 and FIVE. In FIVE, the design of the automatic detection system is explicitly evaluated. This results in an additional event in the fire event tree that explicitly considers failure of the automatic detection system. In NUREG/CR-4840, detection and suppression are lumped as one event. Second, FIVE divides the water-based systems into two categories: wet pipe systems and deluge or preaction systems. This is done to account for the quality of the available data and the more reliable design of the wet-pipe system.

NSAC-179L also contains a discussion of automatic suppression system reliability for CO_2, Halon, and water-based systems (wet-pipe, deluge, and preaction systems). As stated in Section 3 of NSAC-179L, "This study focused on providing data for systems failing to actuate or operate." For each system type, data sources for automatic suppression system reliability, including the Department of Energy, Australia/New Zealand, high-rise buildings, and Navy experience, were reviewed and evaluated. Each source was reviewed for its applicability to nuclear power plant fire PRAs and the overall quality of the source. The search criteria were: "quality of the data (number of success and failures reported, old vs. current, etc.), types of data (actual fire events vs. test data), completeness (whole suppression system, including detection , vs. suppression only), and industry practices (nuclear plant experience vs. other industry practice)." Each set of data was reviewed against these criteria and the overall quality of the data evaluated. The sources judged to be of highest quality for each suppression system type are identified in NSAC-179L.

One insight that is reported by NFPA and was found to be reflected in the EPRI Fire Event Data Base (FEDB) is that in the case of wet-pipe system failures, for both nuclear (with a limited data set) and non-nuclear data, the dominant cause of failure is human error. Given the volume of data on wet pipe sprinkler experience compared with other systems, it may be that with more operating history, human error will also be found to be a dominant failure mode for other suppression system types.

NSAC-179L also presents a discussion on the reliability of manual suppression. Included is a brief review of values used in fire PRAs and the manual suppression reliability values obtained using the EPRI FEDB (Ref. 3). In summary, it is stated that "Because it provides a much larger and more contemporary database of fire durations and suppression times, the EPRI FEDB can be used to generate a much more complete and realistic set of manual suppression data."

Overall, NSAC-179L provides a valuable review of available data on the reliability of automatic fire protection systems and provide additional confirmation for the reliability estimates in nuclear power plant fire PRAs using the methodology developed in NUREG/CR-4840. However, no information was provided or was available in NSAC-179L relating the reliability of fire protection systems to aging. Although NSAC-179L did not explicitly provide information on FPS aging, some of the data sources referenced in that report —and previously reviewed for this study— did discuss aging, and those insights were separately incorporated into this report.

3.3 NFPA FPS Reliability

The NFPA has tracked sprinkler system failure in general commercial applications. In this context, NFPA defines failure as the failure to suppress or control a fire, rather than as a failure to actuate. Figure 1 and Table 3 present the failure type and the percentage for that failure. Inadequate sprinkler coverage caused 26% of the malfunctions; sprinklers shutoff caused 30% of the failures; inadequate water or line obstruction caused 13% of the malfunctions; building construction caused 13%; inadequate system design 7%, inadequate maintenance 4%, and unknown causes account for 7% of the malfunctions. From this list, 83% of the failures could have been prevented with an aggressive test and maintenance program.

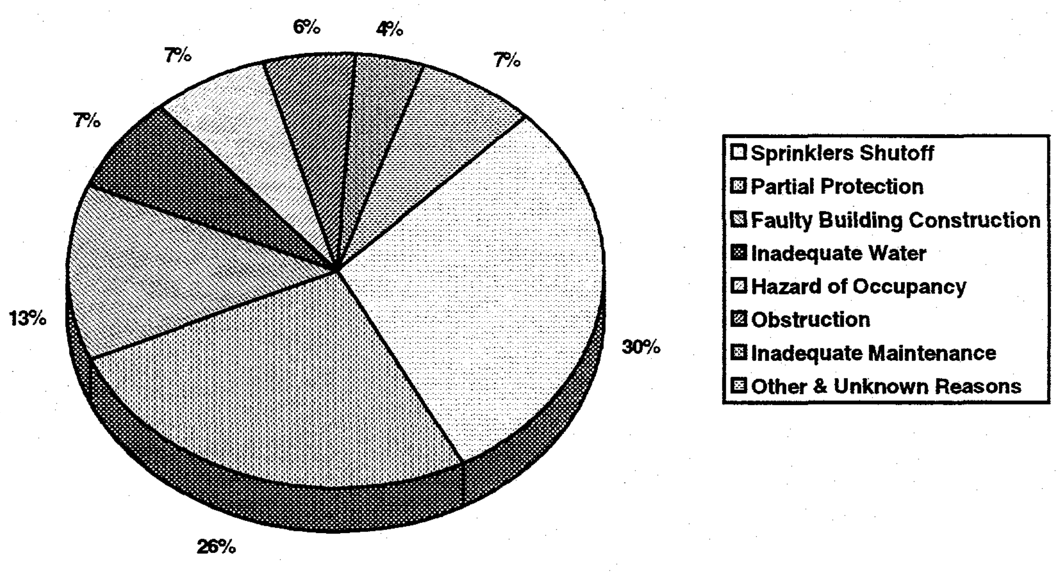

Figure 1 NFPA-Reported Sprinkler Failures (1970 - 1974)

Table 3. NFPA-Reported Sprinkler Failures (%)

Sprinkler Failures	Years 1925 - 1969	Years 1970 - 1974
Sprinklers Shut off	35.4	29.8
Partial protection	8.1	26.1
Faulty building construction	6.0	13.0
Inadequate water	9.9	7.1
Hazard of occupancy	13.5	7.1
Obstruction	8.2	5.6
Inadequate maintenance	8.4	4.0
Other and unknown reasons	10.5	7.3

3.4 DOE Experience

In a report published by the Department of Energy (Ref. 1) titled "Automatic Sprinkler System Performance and Reliability in United States Department of Energy Facilities 1952 - 1980," it is stated that since the inception of the Atomic Energy Commission (AEC) in 1947, the automatic sprinkler system has been accepted as the principal fire protection in all types of facilities. In addition, sprinklers are the most common protection system installed in computer rooms, reactor control rooms, electrical equipment rooms, and areas where the principal hazard is from nuclear criticality or radioactive contamination. Installations at DOE facilities have been based more on hazard analyses, comparable industrial experience, and insurance industry data than on actual DOE facility experience. In 1980 a special effort was undertaken to collect as much information concerning sprinkler operations at DOE facilities as possible. As a result, 600 sprinkler-related incidents were compiled and analyzed for this effort.

At DOE facilities, the value of automatic sprinkler systems has been confirmed. The report points out the following facts:

The loss from fire in a sprinklered building is about one-fifth of the loss in an unsprinklered building despite that fact that only facilities with potentially low losses do not have sprinklers.

There has been no loss of life caused by fire in a sprinklered DOE building.

The sprinkler system is more than 98% effective in controlling or extinguishing fires.

About one-third of all fires were completely extinguished by a single sprinkler head.

The report also, and maybe more important, discusses the reliability of sprinkler systems. Specifically, the report states that the last bastion of resistance to sprinkler system installations involves fears about their reliability in general, and water damage in particular. The following observations may be the most important to have been drawn from this study:

The chance of a sprinkler head failing is about one in a million per year.

The chance of any damage to, or from, a sprinkler system is about one per year for every 800 systems; and nearly half the incidents were so slight that the damage to, or from, the system was negligible.

Sprinkler systems are more reliable than non-fire protection water systems (e.g., general plumbing). Both the frequency of losses and the mean dollar loss from sprinkler incidents is about 1/2 of that from other water systems.

On the basis of actual experience, the damage resulting from a sprinkler system is less than 1% of the fire damage that will result if the system is not present.

Thorough inspection, test, and maintenance procedures can eliminate most causes of sprinkler failure, in either fire or non-fire situations.

Freezing is the most common cause of all sprinkler system losses, including dry pipe systems.

The wet pipe system is the most effective and reliable type of system

In addition, the DOE indicates that automatic sprinkler systems provide the most vital aspect of the department's fire protection programs: continuity.

In 115 fires involving sprinkler systems in DOE facilities since 1952, the sprinklers were successful in controlling or extinguishing the fire in 113, or 98.3% of the incidents. This compares favorably with the 95% satisfactory performance reported by NFPA (Ref. 11) and is close to the 99.1% favorable experience recorded by the Australian Fire Protection Association (Ref. 12). The DOE report indicates that the agency's experience is closer to the Australian experience than that reported by NFPA for U.S. industry in general. The reasons for this performance parallel those given for the favorable Australia - New Zealand experience. They are summarized as follows:

The reporting is more complete. The report is made up of all fires reported to DOE since 1952. This includes all fires with a fire loss exceeding $50 ($1000 after 1975).

All systems had waterflow alarms. In addition, the majority send an alarm directly to an on-site emergency organization.

Inspection and maintenance of fire protection systems is better than the U.S. average. In addition to the NFPA fire protection standards, some 27 DOE sites have on-site fire and emergency services and nearly all sites that exceed $25 million in replacement value have one or more professional fire protection engineers on staff.

Sprinkler valve controls, including electrical supervision, are probably more extensive and effective at DOE facilities than at average U.S. sprinklered properties.

The average age of DOE sprinklers is probably less than the national average. Only ten of the fires were known to involve old-style (pre-1954) sprinkler heads.

It is also pointed out that while the number of sprinkler events results in less statistical validity than other studies, the experience covers a wide range of installation types and occupancy groups over a considerable number of years. In conclusion, the DOE report states that "the DOE experience is closer to the true performance of sprinkler systems than that reported for the U.S. as a whole and that the Australia - New Zealand experience is closest to the true performance record of automatic sprinkler systems."

The experience documented by DOE should closely mirror that of nuclear power plants, given the similarity of requirements for test and maintenance of FPSs between DOE and the NRC. Also, given that the non-nuclear industry's testing and maintenance programs are generally less comprehensive than those of the nuclear power industry, one could assume that the reliability for the nuclear industry is at least comparable, if not better. Clearly, this assumption is dependent on the attention and importance given to testing and maintenance at individual nuclear power plants. The lack of statistically complete FPS failure data and a comprehensive study on FPS reliability at nuclear power plants makes it difficult to make a direct comparison with the non-nuclear industry.

3.5 Australia - New Zealand FPS Experience

The Australia - New Zealand data indicate the best performance from all of the data sources considered in this section (DOE, NFPA, nuclear power plant). This is attributed to the weekly inspection testing frequency required in Australia and New Zealand. NFPA requirements, as in Section 1-6.1 of NFPA 13A "Inspection, Testing and Maintenance of Sprinkler Systems," states:

"The level of reliability of the protection offered by an automatic sprinkler system is promoted when there is a qualified inspection service. Qualified inspection service should include:

(a) Four visits per year, at regular intervals.

(b) All services indicated in summary Table 7-3 [Table 5 of this report].

(c) The completion of a report form with copies furnished to the property owner."

The difference in automatic suppression system reliability between NFPA and Australia - New Zealand data (95% vs. 99.1%) can, in part, be attributed to the frequency of rigorous inspection and testing in Australia and New Zealand.

4. NUCLEAR POWER PLANT FIRE PROTECTION GUIDELINES

4.1 NRC Requirements

The requirements for fire protection are defined in 10 CFR 50.48, which references Appendix R to 10 CFR 50 and Branch Technical Position, CMEB, 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants." Appendix R to 10 CFR 50 establishes fire protection features required to satisfy Criterion 3 (Fire Protection) of Appendix A to 10 CFR 50. BTP 9.5.1 provides guidelines acceptable to the NRC staff for implementing General Design Criterion 3 (Appendix of 10 CFR 50). These guidelines include acceptance criteria listed in a number of documents, including Appendix R to 10 CFR 50 and 10 CFR 50.48. The purpose of the fire protection is to ensure the capability of shutting down the reactor, maintaining it in a safe shutdown condition, and minimizing radioactive releases to the environment in the event of a fire. Throughout BTP 9.5.1, references to NFPA standards are given as recommended guidance or required compliance. The following section presents a brief overview of the NFPA standards and specifically maintenance requirements.

4.2 National Fire Protection Association Guidance

NFPA defines maintenance as " Repair service, including periodically recurrent inspection and tests, required to keep the protective signaling system and its component parts in an operative condition at all times, together with replacement of the system or of its components when, for any reason, they become undependable or inoperative." A key piece of this definition is "with replacement of the system or of its components when, for any reason, they become undependable or inoperative. " It can and has happened that a component has tested satisfactorily and a moment after the successful test the component entered a degraded mode in which, if it was required for service, would fail. Under this testing approach, such a component would either fail on demand, with potentially risk-significant results, or fail upon its next testing cycle. A fire protection program that includes an aggressive testing and maintenance program satisfying the guidelines presented in the NFPA standards found in Table 4 should minimize the occurrence of

FPS failures on demand. Table 5 presents the minimum inspection, testing, and maintenance frequencies for FPS components found in NFPA 13A. Most recently (1993) NFPA published NFPA 20 (1993), *Standard for the Installation of Centrifugal Fire Pumps.* This rewritten standard should improve FPS pump reliability. There are three main objectives of the rewritten standard. The first is to ensure that the pump will start under any and all conditions. Also, if the pump will not start automatically, there are provisions to override protective devices for manual startup. The second objective is that, after the fire pump start up, the circuits and protective fire pump components will continue operation of the pump as long as water is needed to put out the fire, even if the pump runs itself to destruction. The third objective is to ensure that the installation of the pump is as safe as possible. To that end, fire pump controllers must be listed (certified) for such service.

The above standards provide a framework for a successful fire protection program. However, the NFPA standards alone are not enough to ensure that in the event of a fire the capability to shut down the reactor, maintain it in a safe shutdown condition, and minimize radioactive releases to the environment is present. Nuclear power plants must have a comprehensive fire protection program which begins with FPS design and ends with an aggressive inspection, testing, and maintenance program.

Table 4. National Fire Protection Association Standards

NFPA Standard	Title	Comments
12 Section 1-11	Carbon Dioxide Extinguishing Systems	Inspection, maintenance, and Instructions
12B Section 1-11	Halon 1211 Fire Extinguishing Systems	Inspection, maintenance, and instructions
12A Section 1-11	Halon 1301 Fire Extinguishing Systems	Inspection, maintenance, and instructions
13 Section 1-5	Standard for the Installation of Sprinkler Systems	Maintenance
13A	Recommended Practice for the Inspection, Testing, and Maintenance of Sprinkler Systems	
15 - Ch 6	Standard for Water Spray Fixed Systems for Fire Protection	Periodic testing and maintenance
16 Ch 6	Deluge Foam-Water Sprinkler and Foam-Water Spray Systems	Periodic testing
16 Ch 7	Deluge Foam-Water Sprinkler and Foam-Water Spray Systems	Maintenance
20 Ch. 11	Centrifugal Pumps	Acceptance, operation, and maintenance
72A Ch. 2	Standard for Local Protective Signaling Systems	
72B	Standard on Auxiliary Protective Signaling Systems	
72C	Standard for Remote Station Protective Signaling Systems	
72D	Standard for Proprietary Protective Signaling Systems	
72E Ch. 8	Standard on Automatic Fire Detectors	Inspections, tests, and maintenance

Table 5. FPS Minimum Inspection, Testing, and Maintenance

FPS Component	Activity	Frequency	NFPA 13A Section
Flushing piping	Test	5 years	5-4.2
Fire department connections	Inspection	Monthly	2.8
Control valves	Inspection	Weekly - sealed	2-7.1.4
	Inspection	Monthly - locked	2-7.1.4
	Inspection	Monthly - tamper	2-7.1.4
	Maintenance	Yearly	2-7.1.8
Indicator post valve	Test	Quarterly	2-7.3.1
Valves in roadway boxes	Test	Quarterly	2-7.4.1
Main drain	Flow test	Quarterly	2-6.1
Open sprinklers	Test	Annual	5-11.1
Pressure gage	Calibration	5 years	4-4.2
Sprinklers	Test	50 years	3-3.3
Sprinklers-high temperature	Test	5 years	3-3.1
Sprinklers-residential	Test	20 years, then 10-year intervals	3-3.4
Water flow alarms	Test	Quarterly	4-5.3, 4-7.1, 4-12.3
Preaction/deluge detection systems	Test	Semiannually	4-12.3
Preaction/deluge systems	Test	Annually	4-12.1
Hydrants	Inspection	Monthly	2-5.1
	Test (open and close)	Annually	2-5.3
	Maintenance	Semiannually	2-5.2
Antifreeze solution	Test	Annually	4-7.3
Cold weather valves	Open and close	Fall - close, spring - open	4-7.2
Dry/preaction/deluge systems	Air and water pressure inspection	Weekly	4-8.2.4
	Enclosure	Daily - cold weather	4-8.2.5
	Priming water level	Quarterly	4-8.2.1

Table 5. FPS Minimum Inspection, Testing, and Maintenance (Continued)

FPS Component	Activity	Frequency	NFPA 13A Section
Low-point drains	Test	Fall	4-8.2.6
Dry pipe valves	Trip test	Annual - Spring	1-6.1
Dry pipe valves	Full flow trip	3 years - Spring	4-8.4
Quick-opening devices	Test	Semiannually	4-11.1
Gravity tank - water level	Inspection	Monthly	2-2.1
Gravity tank - heat	Inspection	Daily - cold weather	2-2.2
Gravity tank - condition	Inspection	Biannual	NFPA 22
Pressure tank - water level and pressure	Inspection	Monthly	2-3.1
Pressure tank - heat enclosures	Inspection	Daily - cold weather	2-3.7
Pressure tank - condition	Inspection	3 years	2-3.2
Pump	Test flow	Annually	2-4.2.5
Engine drive	Test operate	Weekly	2-4.2.1
Motor drive	Test operate	Monthly	2-4.2.1
Steam drive	Test operate	Weekly	NFPA 21

5. INSIGHTS

The intent of this work was to determine whether age-related failures of FPSs in nuclear power plants are a significant risk and, if they are, how the risk can be minimized.

First, based on the FPS aging-related failures found in the data search, there does not appear to be an aging problem of FPSs at nuclear power plants. Fire suppression and detection systems have failed on occasion, but the data suggest that most failures related to aging are encountered first with an aggressive inspection, testing, and maintenance program. Also, aging effects are more singularly dependent on the environment in which the fire suppression or detection components are located, and this fact must be factored into the test, maintenance, and inspection activities.

One approach which would further minimize FPS aging problems is performance-based FPS inspection, testing, and maintenance. An extensive review of aging-related failures of FPSs has revealed a few potential problem areas. However, experience shows that a factor contributing to these problem areas is the frequency of FPS testing activities. For example, the monthly startup of the diesel-driven pump stresses and ages the pump since the diesel engine is designed for continuous, not cyclical operation. This suggests that performance-based FPS inspection, testing, and maintenance might merit further discussion. This performance-based program could be set up to test 20% of a given system or systems per year with a 5-year frequency to test all components. During testing, if failure occurs, one can modify the testing to identify any common mode failures and check all similar components. This approach would lessen the burden for those plants with an aggressive maintenance program and identify any problem areas for those plants with similar components.

Another approach that may point to problems before they occur is predictive diagnostics, which anticipates future performance and identifies the cause of the decrease in performance. Some aging-related failures can appear as random failures if predictive diagnostics are not used. For automatic fire suppression systems, there are typically two types of failures: random and age-related. Typical random failures can be minimized by good design and frequent inspections. Age-related failures can be averted with predictive diagnostics. Components have been known to test satisfactorily and shortly after the test enter a degraded mode in which if they were required for service they would fail. Thus, such a component would either fail on demand, with potentially significant risk or fail on its next testing cycle. Since aging-related FPS failures can be characterized by decreases in performance that develop slowly, one could use these data to predict failure before it occurs. Examples of these types of failures include a gradual loss of battery power caused by chemical action and internal resistance, loss of flow capacity in the water pipe, and stuck valves because of corrosion and buildups of mineral deposits. Predictive diagnostics would use performance data to predict a failure before it becomes a problem. Age-related failures are predictable and preventable if the performance decrement can be measured. This performance measurement should be built into the FPS component to allow the condition to be assessed at a glance. Any performance decrement would be noted and diagnostics initiated to determine the cause.

5.1 Conclusions

The experience base shows that most nuclear power plants have an aggressive maintenance and testing program and are finding degraded FPS components before a failure occurs. However, the database also shows that there are going to be age-related failures of FPS components. The question is whether such failures will pose significant risk. The impact of these failures can vary. For example, if a smoke detector actuates and cannot be reset because of increased sensitivity caused by aging, a fire detection signal could be masked by the failed detector. This could result in, at a minimum, a delay in the response to a fire. Also, the plugging of FPS nozzles by rust and scale buildup could prevent the automatic extinguishment of a fire and require manual fire-fighting efforts. However, it is important to note that the plugging of the nozzles did not, in any case, involve 100% blockage; therefore there was partial FPS coverage.

The discovery or occurrence of most of the significant FPS failures during testing and maintenance activities and not on demand demonstrates the existence of an aggressive testing and maintenance program at most nuclear power plants. However, it is assumed that a more aggressive testing and maintenance program involving preventive diagnostics might flag age-related FPS problems before their occurrence either during testing and maintenance or on demand. In closing, although there has not been a quantitative estimation of the risk due to age-related FPS failures, it is clear from the FPS failure and reliability data that the risk impact of FPS aging is low. In general, current maintenance practices are adequately identifying aging degradation. Further, the system reliability estimates currently used in fire risk assessments already account for FPS aging-related failures. Changes to the maintenance program with predictive diagnostics could reduce this already low risk even further.

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APPENDIX A

AGE-RELATED FIRE PROTECTION SYSTEM FAILURES

Age-Related Fire Protection System Failures

Fire Pumps					
Plant	Plant Type	LER #	FPS Component	Failure	Failure Mode
Humboldt Bay	BWR	133/80-007	Diesel FPS pump	Pump pulley flange	Aging
Humboldt Bay	BWR	133/82-003	Fire pump #3	Stator grounded	Aging
Humboldt Bay	BWR	133/85-002	Fire Pump #2	Throttle linkage	Aging
Big Rock Point	BWR	155/82-031	Electric fire pump	3 phase motor contactor worn	Aging
Connecticut Yankee	PWR	213/88-016	Diesel fire pump	Pump shaft seal	Aging
Nine Mile Point	BWR	220/81-014	Diesel fire pump	Pressure switch failure	Aging
Quad Cities 1	BWR	254/82-022	Diesel fire pump	Wear rings failure	Aging
Quad Cities 1	BWR	254/83-042	Diesel fire pump	Battery bank A failure	Aging
Salem 1	PWR	272/80-035	Diesel fire pump	Bearing	Unknown
Salem 1	PWR	272/80-061	Fire pump #2	Failed alternator	Unknown
Salem 1	PWR	272/81-088	Fire pump #2	Battery cable cracked and arcing	Aging
Salem 1	PWR	272/82-019	Fire pump #2	Failed voltage regulator	Aging
Salem 1	PWR	272/82-027	Fire pump #2	Damaged flywheel	Unknown
Salem 1	PWR	272/82-055	Fire pump #1	Failed fuse on #1 battery charger	Aging
Salem 1	PWR	272/83-064	Diesel fire pump	Fuel oil pressure gauge hose ruptured	Aging
Salem 1	PWR	272/83-067	Diesel fire pump	Control rod shaft seal leak due to bushing wear	Aging
Salem 1	PWR	272/83-069	Fire pump #2	Failed pressure detector	Aging
Pilgrim 1	BWR	293/80-066	Diesel fire pump	Broken cable in governor assembly	Aging
Pilgrim 1	BWR	293/83-055	Diesel fire pump	Battery failure	Aging
Arkansas Nuclear 1	PWR	313/82-028	Diesel fire pump	Battery Bank B failure	Aging
Three Mile Island 2	PWR	320/81-008	Diesel fire pump	Battery Bank A failure	Aging
Duane Arnold	BWR	331/84-033	Electric fire pump	Tech spec flow requirements	Unknown
Duane Arnold	BWR	331/85-046	Electric fire pump	Worn pump shaft sleeve	Aging
Fitzpatrick	BWR	333/80-033	Diesel fire pump	Cooling HX failure	
Fitzpatrick	BWR	333/93-006	Fire pumps 76P-1 & 76P-2	Inadequate pump discharge pressure & engine overheating	Unknown
Beaver Valley	PWR	334/80-030	Diesel fire pump	Fan belt slipping and brittle	Aging (?)
Beaver Valley	PWR	334/80-052	Diesel fire pump	Fuel oil filter clogged	Aging (?)
Beaver Valley	PWR	334/80-059	Diesel fire pump	Starter motor failure	Aging
Beaver Valley	PWR	334/87-004	Diesel fire pump	Degraded batteries	Aging
North Anna 1	PWR	338/85-006	Diesel fire pump	Coolant hose ruptured	Aging

Age-Related Fire Protection System Failures

North Anna 1	PWR	338/86-010	Diesel fire pump	Starter motor & battery bank	Excessive starting
Davis Besse 1	PWR	346/80-070	Diesel fire pump	Failure of fuel shutoff solenoid valve	Unknown
		367/80-054	Diesel fire pumps	Lack of lubrication & failed voltage regulator	Unknown
McGuire 1	PWR	369/81-194	Fire pump C	Burned contacts in the starting contactor	High cycling
La Salle 1	BWR	373/82-001	Diesel fire pump	Broken speed cable	Aging
La Salle 1	BWR	373/82-024	Diesel fire pump	Broken flexible fuel line	Aging
La Salle 1	BWR	373/85-046	Fire pump B	Alternator belt broke	Aging

FPS Piping/Heads					
Plant	Plant Type	LER #	FPS Component	Failure	Failure Mode
Humboldt Bay	BWR	133/Form 24	Fire water system	Corrosion failure of 2 carbon steel bolts	Aging/Environment
San Onofre 1	PWR	206/85-016	7 spray nozzles of hydrogen seal oil deluge FPS	Plugged by rust	Unknown
San Onofre 1	PWR	206/88-021	8 of 33 nozzles in containment FPS	Plugged by rust (open nozzle design)	Unknown
San Onofre 1	PWR	206/89-???	20 of 78 nozzles	Plugged due to corrosion	Unknown
Browns Ferry 1	BWR	259/82-064	FPS water supply	Due to slit and clams in the inline strainer the FPS water supply did not meet tech specs	Unknown
Browns Ferry 2	BWR	260/82-029	Fire protection line	Pinhole leak due to through wall pitting corrosion attact	Unknown
Cook 1	PWR	315/81-009	8 of 72 spray nozzles for ESF vent	Plugged with welding slag, rust & bits of paper	Unknown
Cook 2	PWR	316/81-008	8 of 72 & 14 of 72 spray nozzles for ESF vent	Plugged with welding slag, rust & bits of paper	Unknown
Three Mile Island 2	PWR	320-82-016	18 of 90 Aux Bldg filter cabinet sprinkler heads	Clogged due to debris	Unknown
Sequoyah 1	PWR	327/91-009	FPS sprinkler heads	Degraded due to internal piping corrosion deposits, incrustation, river sediment	Unknown
Fitzpatrick	BWR	333/81-052	Spray nozzles for SGTS	Plugged w/ rust	Unknown
Beaver Valley 1	PWR	334/80-034	50% of sprinkler nozzles for suppl. leak collection & release system	Plugged w/ rust	Unknown
Beaver Valley 1	PWR	334/86-005	45 of 90 spray nozzles	Clogged w/ charcoal & white scale	Unknown
Beaver Valley 1	PWR	334/87-021	34 of 90 spray nozzles	Clogged w/ charcoal & white scale	Unknown

Age-Related Fire Protection System Failures

Detectors					
Plant	Plant Type	LER #	FPS Component	Failure	Failure Mode
Turkey Point 4	PWR	251/80-013	Smoke detectors	Corrosion of unknown source	
Palisades	PWR	255/87-010	Water flow switch	Aging	
Palisades	PWR	255/87-013	Water flow switch	Aging	
Browns Ferry 1	BWR	259/80-041	Smoke Detector	Increased sensitivity due to aging	
Browns Ferry 1	BWR	259/81-002	Smoke Detector	Increased sensitivity due to aging	
Browns Ferry 1	BWR	259/81-088	Smoke Detector	Increased sensitivity due to aging	
Browns Ferry 1	BWR	259/82-009	Smoke Detector	Increased sensitivity due to aging	
Browns Ferry 1	BWR	259/82-085	Smoke detector	Increased sensitivity due to aging	
Oconee 3	PWR	287/80-016	Smoke detector (?)	Dirt buildup	
Oconee 3	PWR	287/80-016	Smoke detector (?)	Dirt buildup	
Pilgrim 1	BWR	293/80-015	Heat detector	Failure to actuate CO2 system	
Three Mile Island 2	BWR	320/82-013	Smoke detectors	Transformer malfunction failed fire indicating unit	
Fitzpatrick	BWR	333/81-076	Smoke Detector	Multiplexer transmitter failure	
Davis Besse	PWR	346/80-026	Smoke detectors	Dirty contacts	
San Onofre 2	PWR	361/83-107	Flame detector	Faulty circuit card	
McGuire 1	PWR	369/83-074	Smoke detector	Dust accumulation	
McGuire 1	PWR	369/83-094	Smoke detector	Dust accumulation	
McGuire 1	PWR	369/83-119	Smoke detectors	Invalid fire alarm due to dirt accumulation	
McGuire 2	PWR	370/83-013	Smoke detector	Dust accumulation	
McGuire 2	PWR	370/83-024	Smoke detector	Dust accumulation	
McGuire 2	PWR	370/83-030	Smoke detector	Dust accumulation	
McGuire 2	PWR	370/83-058	Smoke detector	Dust accumulation	
McGuire 2	PWR	370/83-066	Smoke detector	Dust accumulation	
McGuire 2	PWR	370/83-081	Smoke detector	Dust accumulation	
Susquehanna 1	BWR	387/90-001	Fire detection	Inoperable transponder cards	
Summer 1	PWR	395/83-017	Smoke detectors	Printed control circuit board	
Summer 1	PWR	395/83-020	Detectors in 5 zones	Blown fuse	
Summer 1	PWR	395/83-072	Smoke detectors	Printed control circuit board	
Lacrosse	BWR	409/82-002	Smoke detector (?)	Dirt buildup	
Grand Gulf 1	BWR	416/82-061	Smoke Detector	Dust accumulation	
Grand Gulf 1	BWR	416/82-065	Smoke Detector	Dust accumulation	
Grand Gulf 1	BWR	416/82-066	Smoke Detector	Dust accumulation	
Grand Gulf 1	BWR	416/82-119	Smoke Detector	Dust accumulation	

			Smoke Detector	Multiplexer transmitter failure	
			Heat detectors	CO_2 sys failed to actuate due to pneumatic devices mech. bound	

Age-Related Fire Protection System Failures

Fire Door					
Plant	Plant Type	LER #	FPS Component	Failure	Failure Mode
Surry 1	PWR	280/83-040	Fire Door Hinges	Aging	
Pilgrim 1	BWR	293-83-041	Fire Door Hinges	Aging	
Cook 2	PWR	316/82-043	Fire Door Latch	Aging	
Hatch 1	BWR	321/82-052	Fire Door (?)	Aging	
Hatch 1	BWR	321/83-120	Fire Door (?)	Aging	
North Anna 1	PWR	338/80-095	Fire Door Latch	Aging (Heavy Use)	
North Anna 1	PWR	338/82-007	Fire Door Latch	Aging (Heavy Use)	
North Anna 2	PWR	339/82-012	Fire Door Latch	Aging (Heavy Use)	
North Anna 2	PWR	339/83-022	Fire Door Latch	Aging (Heavy Use)	
Davis Besse 1	PWR	346/83-006	Fire Door Latch	Aging (Heavy Use)	
Davis Besse 1	PWR	346/86-027	Fire Doors	Aging (Heavy Use)	
Farley 1	PWR	348/89-001	Fire Doors	Aging (Heavy Use)	
Farley 1	PWR	348/89-002	Fire Doors	Aging (Heavy Use)	
San Onofre 2	PWR	361/90-001	Fire Doors (Latch)	Aging (Heavy Use)	
Arkansas Nuclear 2	PWR	368/84-029	Fire Doors (Latch)	Aging (Heavy Use)	
Arkansas Nuclear 2	PWR	368/85-007	Fire Doors (Latch)	Aging (Heavy Use)	

Fire Barriers					
Plant	**Plant Type**	**LER #**	**FPS Component**	**Failure**	**Failure Mode**
Palisades	PWR	255/83-069	Fire Barrier	Construction & time	Aging (?)
Three Mile Island 2	PWR	320/83-021	Fire Barrier	Construction & time	Aging (?)
Mcguire 1	PWR	369/87-026	Control room door seals	Degradation & management deficiency	Aging (?)
Mcguire 1	PWR	369/88-022	Fire damper	Failed to close when tested	Unknown
Summer 1	PWR	395/83-129	Fire dampers	Debris on track & wiring	Unknown
Wash. Nuclear 2	BWR	397/83-008	Fire damper	Binded in track	Unknown
Wolf Creek 1	PWR	482/87-009	Control room door seals	Design deficiency	Design

Miscellaneous					
Plant	Plant Type	LER #	FPS Component	Failure	Unknown
Palisades	PWR	255/81-021	Fire alarms	Relay coils	Unknown
Browns Ferry 1	BWR	259/83-052	FPS	Failed relay	Unknown
Indian Point 3	PWR	286/80-007	Deluge valve	Dirty contacts	Unknown
Pilgrim 1	BWR	293/80-035	Fire alarm annunciation	Capacitor failure	Unknown
Cook 1	PWR	315/83-035	Deluge valves	Time delay circuit boards (actuation signal was initiated)	Unknown
Mcguire 1	PWR	369/83-106	Fire alarm circuit board	Corrosion due to moisture	Unknown
Grand Gulf 1	BWR	416/83-126	Deluge valve	Rough mating surface of latch & clapper	Unknown
		Form 648	Halon system	Failed control board	Unknown
		Form 459	CO2 system	Dirty contacts on pilot control solenoid valve	Aging
		Form 474	CO2 system	Scale & corrision on solenoid valve	Aging

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