IPEEE Fire Review

TR-112933

Final Report, June1999

EPRI Project Manager
R. P. Kassawara

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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Science Applications International Corporation
4920 El Camino Real
Los Altos, California 94022.

Principal Investigators
B. Najafi
K. M. Bateman
W. J. Parkinson
J. A. Lee
R. G. Rehwoldt

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REPORT SUMMARY

Plant-specific examinations of fire vulnerabilities have been completed for all operating U.S. plants in response to Nuclear Regulatory Commission's Generic Letter 88-20, Supplement 4, "Individual Plant Examination of External Events for Severe Accident Vulnerabilities." This report compiles and summarizes results of these examinations as documented in the original submittals and provides generic lessons and insights.

Background

The United States Nuclear Regulatory Commission (USNRC) issued Supplement 4 to Generic Letter 88-20 in June 1991. This letter requested each U.S. nuclear plant licensee to perform an IPEEE to identify any vulnerabilities to severe accidents and to report its results to the Commission together with any licensee-determined plant improvements and corrective actions. The NRC's stated purpose in these Individual Plant Examination for External Events (IPEEE) reviews is for each licensee to develop an appreciation of severe accident behavior; understand the most likely severe accident sequences that could occur at its plant under full power operating conditions; gain a qualitative understanding of the overall likelihood of core damage and radioactive material release; and, if necessary, reduce the overall likelihood of core damage and radioactive material releases by modifying hardware and procedures to help prevent or mitigate severe accidents. Each U.S. plant conducted a plant-specific examination of fire induced vulnerabilities in response to this request.

Objectives

To create a database of information from IPEEE fire submittals; to use the database to develop insights into fire risk analysis technology and application of this technology to nuclear power plant fire protection; and, to develop insights on plant fire protection design and operation that industry can use to deal with resolution of generic issues.

Approach

The project team collected a library of original utility fire IPEEE submittals from the NRC's Public Document Room (PDR) and summarized it. The team reviewed these submittals to show overall trends in fire risk technology and to focus the level of future detailed reviews. Insights and conclusions were drawn where they could be substantiated by the level of data taken from the submittals.

Results

This report presents a number of trends and observations from a compilation of fire IPEEE submittals. However, this exercise has shown that in drawing generic conclusions it is absolutely necessary to understand the underlying assumptions used in each of the reviews in order to avoid misinterpretation. Nevertheless, the process has proved to be a powerful tool in helping to gain insights into plant-specific fire protection elements and an integrated picture of the safety benefit of various program elements. Key results include compilation of core damage frequencies by review method, plant vintage, and type—as well as significant risk contributors by plant area. Insights include the following:

- About a third of the plants reported fire risk contribution (core damage frequency) greater than internal events risk.
- Plant-unique characteristics, such as plant type or operational data, show small variations (for example, less than a factor of two higher for pre-Appendix R versus post-Appendix R plants).
- Control rooms and switchgear rooms are primary contributors to fire risk, while turbine buildings and cable spreading rooms are secondary contributors to fire risk at most plants.
- Only two utilities reported vulnerabilities associated with fire, but nearly a third of the utilities have recommended or instituted some form of plant improvement.

The primary lesson drawn from review of the results (and limited review of their bases) is that conclusions and insights from the fire IPEEEs may be influenced more by key assumptions—for example, characteristics of the pilot fire or recovery of post-fire safe shutdown functions—than by plant design and operation or even the methodology (FIVE vs. FIRE PRA). The state of fire risk technology lends itself to larger variability in assumptions than those used in internal event probabilistic risk assessments (PRAs). This is reflected in the variability of fire CDFs versus internal event CDFs.

EPRI Perspective

Over the past decade, EPRI has aggressively pursued development and application of data, methods, and tools to meet the needs of the fire protection community in electric power utilities. EPRI developed the fire risk analysis methods and collected the data the commercial nuclear industry has used in response to Generic Letter 88-20, supplement 4. As a result, seventy (70) individual plant examinations for internal fires were completed. To evaluate the effectiveness of its fire risk analysis methods, EPRI performed this review with a goal toward future improvements. Maturity of fire risk analysis data, methods, and tools is the key in promoting application of risk to fire protection. Detailed review of the fire IPEEEs is needed to determine how to reach an acceptable level of maturity in fire risk methods.

Keywords

Fire risk
Fire protection
Fire IPEEE

ABSTRACT

In June of 1991, NRC issued Supplement 4 to the Generic Letter 88-20 (Ref 1) requesting all nuclear power reactor facilities in the United States to perform an Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, including an assessment of fire-induced core damage risk. Seventy (70) examinations were completed and submitted for the NRC review in response to this request.

Over the past decade Electric Power Research Institute (EPRI) has been developing the data, methods and tools that have been used extensively in these examinations. As the result, EPRI has undertaken the Fire IPEEE Insights project with the following objectives:

1. To gain generic insights into fire risk analysis technology, and the application of this technology in nuclear power plant fire protection, and

2. To gain insights on plant fire protection design and operation that are of value to the industry in dealing with resolution of generic issues.

This report documents development of a library of initial utility fire IPEEE submittals. A limited review of these submittals was conducted to draw insights where they could be supported by the results and study assumptions.

In general, the results of these evaluations point to a number of trends. These trends are evident in a significant number of submittals and include:

- About one third of plants reported fire risk, (core damage frequency) higher than the internal events risk.

- Methods and assumptions are a bigger contributor than plant design and operation,

- Control Room and Switchgear Rooms are primary contributors to fire risk, and

- Many plants instituted plant improvements based on insight gained even when they identified no vulnerability.

Use of the results presented in this report beyond the above observations should take into consideration the scope and objectives of this project since they are influenced by the method and assumptions used and by the rigor of the analysis. In general, quantitative conclusions or comparisons need to consider the underlying assumptions and be confirmed against the insights gained from the plant-specific analyses.

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INTRODUCTION

1.1 Background

In June of 1991, the Nuclear Regulatory Commission (NRC) issued Supplement 4 to Generic Letter 88-20 (Ref.1) requesting all nuclear power reactor facilities in the United States to perform an Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, including an assessment of fire-induced core damage risk. The objectives of the program were stated as:

1. To develop an appreciation of severe accident behavior,

2. To understand the most likely severe accident sequences that could occur at a plant under full power operating condition,

3. To gain a qualitative understanding of the overall likelihood of core damage and radioactive material release, and

4. If necessary, to reduce the overall likelihood of core damage and radioactive material release by modifying hardware and procedures that would help prevent or mitigate severe accidents.

Nearly all plants have completed their IPEEEs and they are currently under various stages of review by the NRC. In February of 1998, the staff made available a draft of their preliminary insights gained from the review of the first twenty-four IPEEE submittals (Ref.2)

In a letter dated August 31, 1992, the NRC Chairman informed the President of the United States of the NRC's plans to pursue rulemaking with regard to Appendix R. The general consensus is that the new regulatory approach should be "performance-based," and NRC management actively encourages wider use of performance-based approaches. In response to the staff's SECY-96-134 (Ref.3), the Commission directed the NRC staff to:

1. Develop a plan for transitioning fire protection regulations to a more risk-informed and performance-based structure;

2. Address probabilistic uncertainty explicitly;

3. Consider inspection and enforcement consistent with preliminary commission views on risked-informed, performance-based regulation;

4. Consider preliminary IPEEE insights;

5. Address status of existing exemptions; and

6. Continue interaction with industry.

In June 1997, the NRC staff presented its plan to the commissioners for this transition in SECY 97-127 (Ref.4) which called for completion of a rulemaking plan by June of 1998. In September of 1997 the Commission issued a response, directing the staff to finalize the research and study by the end of 1997 and provide the Commission with a schedule for the expedited rulemaking. In addition, the Commission directed the staff to solicit industry feedback on their interest in a new rule.

In response, Nuclear Energy Institute (NEI) conducted a survey of all Chief Nuclear Officers of operating nuclear power plants concerning the proposed rulemaking and communicated the following industry position to the staff.

- A new rule is not desired, nor necessary to assure or improve safety;

- Further development of risk and performance bases should support changes in guidance to existing regulation;

- Changes to regulation or supporting guidance must allow adequate time for completion of support elements such as IPEEE, FPFI, NFPA efforts; and

- Industry will participate actively in any changes to rule or supporting guidance.

In March of 1998, the staff presented the following options to the commission in SECY 98-058 after receiving feedback from NEI, National Fire Protection Association (NFPA), NIRS, and UCS.

Option 1 Develop a performance-based, risk-informed fire protection regulation, on an expedited schedule, to replace the existing regulation.

Option 2 Defer rulemaking until the NFPA and the industry develop a performance-based, risk-informed consensus standard for fire protection for nuclear power plants.

Option 3 Maintain the existing fire protection regulation and guidance.

The staff recommended that option 2 be adopted. On June 30, 1998, the NRC provided its response in an SRM, which approved the staff's recommendation to defer rulemaking while NFPA develops the performance-based, risk-informed consensus standard (NFPA-805) (Ref.5).

To support the increased NRC and industry interest in risk-informed approaches in resolving fire protection issues, EPRI has been engaged in evaluation and enhancement of the fire technology. In December of 1997, EPRI developed a plan for assessment of technology requirements for realization of performance-based, risk-informed fire protection at nuclear power plants (Ref.6). One element of this plan includes review of the fire IPEEEs to develop insights.

1.2 Objectives

The objective of EPRI's Fire IPEEE Insights project is twofold:

1. To gain generic insights into fire risk analysis technology, and the application of this technology in nuclear power plant fire protection, and

2. To gain insights on plant fire protection design and operation that are of value to the industry in dealing with resolution of generic issues.

1.3 Scope and Limitations

The review of the fire IPEEEs is planned in two phases. The objectives of this effort were to collect information and provide a top-level review to show trends, gain insights and help define the nature of any additional review needed to achieve the objectives of the project. This was accomplished by completing the following activities:

1. Acquiring copies of the Fire IPEEE submittals available through the NRC Headquarters Public Document Room (PDR) as of September 1998;

2. Developing and populating a database for recording the information contained in the submittals; and

3. Performing a limited analysis of the data, identifying trends and preliminary lessons learned.

The conclusions presented in this report should be viewed in context with the limited depth of the review. Limitations include the following:

- The review is solely based on information as it was reported in the submittals. For example, if a licensee reported using the FIVE methodology but deviated from FIVE,

the reviewer recorded the submittal as using the FIVE methodology. An independent review to ensure consistency was not performed.

- This initial review focused only on four factors; namely: analysis methods, reactor type, plant operational date, and significant plant locations. The limited scope of the preliminary review permitted reviewers to investigate only a few combinations of factors. For example, this review investigated how the average calculated core damage frequencies (CDFs) for the significant location compare based on the methods used. Because methodology differences appear to be important, differences appearing to be attributable to a specific factor may in reality be strongly influenced by method.

- The review is based primarily on information from summary and results sections of the submittals (that is, Sections 1, 2, 6, 7 and 8 as delineated in NUREG-1407, Table C-1) (Ref.7) supplemented by a selected review of the Internal Fire Analysis (Section 4) as necessary. All licensees generally followed the recommended format of NUREG-1407.

Information not available in the submittals may have a significant influence on the outcome. For example, the submittals report only limited information addressing the plant systems credited in the studies. Some studies may credit only the Appendix R systems for which cable location information was readily available from a safe shutdown analysis. Others may have expended additional effort to locate cables for non-safe shutdown systems. Crediting different or additional means of safe shutdown is likely to impact both the total calculated CDF and the ranking of risk significant contributors or locations.

In order to go beyond the top level nature of this investigation, more detailed review of the IPEEEs is necessary. Such in-depth review would provide insights which can be used to improve fire risk methods and to support resolution of generic fire protection issues.

2

INFORMATION COLLECTION AND FIRE IPEEE DATABASE

2.1 Information Collection

The PDR manages a comprehensive collection of unrestricted documents related to NRC licensing proceedings and other significant decisions and actions. The computerized, on-line Bibliographic Retrieval System (BRS) includes extensive indices to the collection and an on-line ordering module for the placement of orders for the reproduction and delivery of specific documents. The BRS can be accessed on-site in the PDR located at 2120 L Street, NW, Washington, D.C. or off-site via the Internet.

A literature search of the BRS was performed to locate *Individual Plant Evaluation of External Events (IPEEE) reports* which licensees of nuclear power plants conducted in response to U.S. NRC Generic Letter 88-20, Supplement 4, NRC's *Requests for Additional Information (RAI)*, and utility *RAI responses*. The IPEEE documents were identified and retrieved by searching through a series of fields used to categorize BRS documents. Examples of searchable BRS fields used to locate the IPEEE documents are listed below.

Table 2-1
Database Fields

Field Name	Full Field Name	Description of Field
ACN	Accession Number	A unique 10-digit document ID. Documents were ordered according to their CAN number
DATE	Date	Date of document. The lower bound was Generic Letter 88-20, Supplement 4 issuance date of June 1991
DKT	Docket Number	A number assigned to an NRC license.
DTC	Document Type Code	The document type in code format. For example: IPE-Individual Plant Examination (of External Events) OUT – Outgoing Correspondence, to identify an RAI INC – Incoming Correspondence, to identify an RAI response
KEY	Key Terms	Terms from controlled vocabulary or taken from the document description. For example: IPE, IPEEE, and fire.

The literature search produced seventy-three IPEEE submittal reports and Requests for Additional Information (RAIs) on fifty-seven submittals [1].

2.2 Fire IPEEE Database

Once the IPEEE documents were in hand, reviewers extracted the meaningful information and entered it into a database. For ease of data collection, the database is structured into five sections. The sections are designated as Results, Design, Fire Modeling, Hazards, and Summary. The Results section captures information such as the reported core damage frequency (CDF), significant locations, significant systems, and study insights. The Design section captures information such as operational date, reactor type, NSSS vendor, and BWR class. The Fire Modeling section captures such analysis inputs as cable damage criteria, automatic and manual suppression failure probabilities, and the role of walkdowns in determining input for the study. The Hazards section captures information such as the fire model used, heat release rates, damage threshold criteria, non-suppression failure probabilities, and fire brigade response times. The Summary section captures information such as the submittal date, methodology, project team, IPEEE assumptions and questions asked by the NRC in requests for additional information (RAIs). Figure 2-1 illustrates the structure of the database.

The seventy-three IPEEE submittals included in this report represent sixty-eight nuclear plant sites [2] and a total of one hundred and six units. This Project focused on capturing summary and results data for all one hundred and six units, rather than collecting in-depth information on any one unit. This allowed a broad overview analysis of the data, focused on the overall fire CDF distribution, the percent contribution of fire to total core damage frequency, the locations reported to be significant contributors, and the influence of operational date and method.

[1] Four plants were not included in the Phase I review: a BWR-Mk which is currently not operating and did not submit an IPEEE; a BWR-Mark I shut down in 1995; a PWR shut down in 1996; and a BWR due to shut down in 2000, whose submittal was limited to a comparison of the fire portion of the 1981 PRA analysis to the FIVE methodology.

[2] Two PWRs (PWR/W-4 Loop #16 and PWR/W-4 Loop #17) which are located at the same site but are operated by different utilities, were considered to be separate sites.

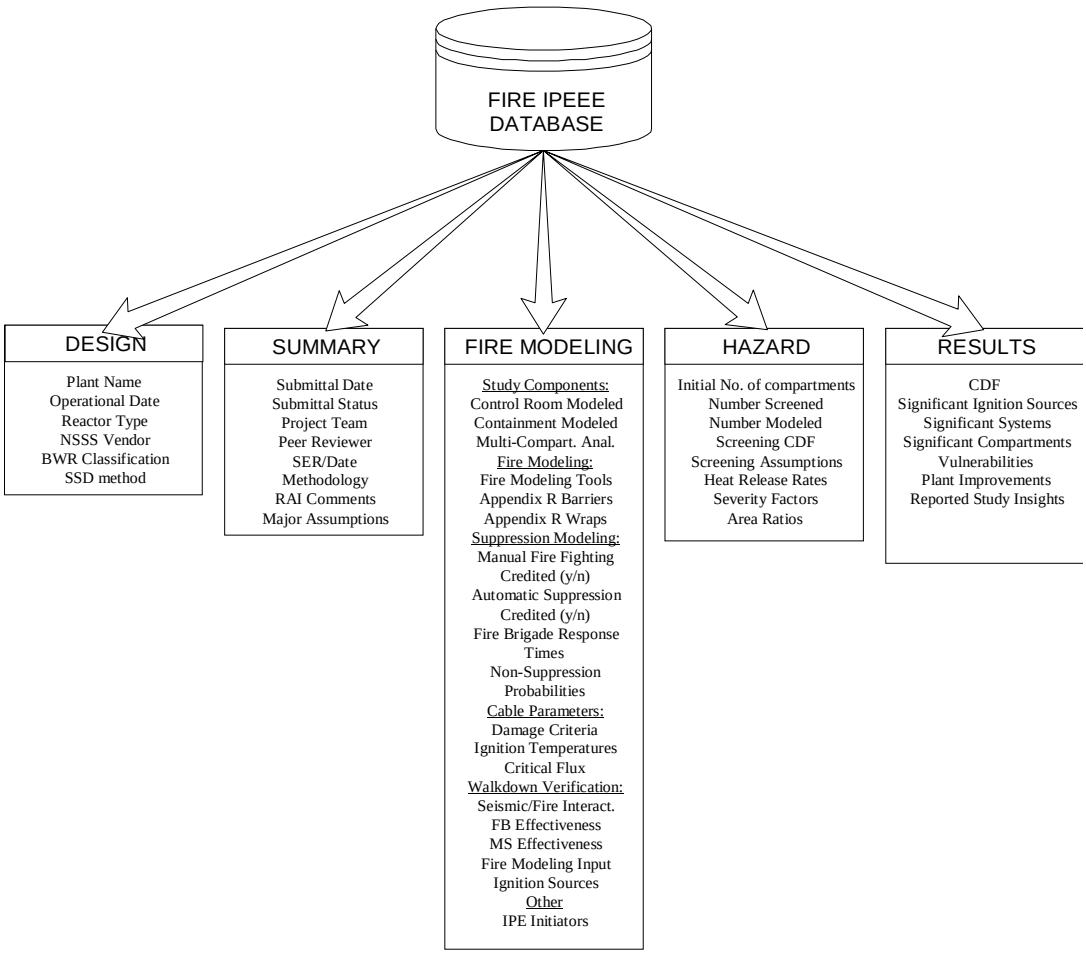

Figure 2-1
Structure of the EPRI Fire IPEEE Insights Database

3

SUMMARY OF FINDINGS

The purpose of this review was to derive an overall perspective of the fire risk at commercial nuclear plants, as it is reflected in their fire IPEEE submittals. A number of trends, both quantitative and qualitative, are observed from these submittals, and are presented here. The interpretation of these trends is limited to clearly justifiable results. This review provides the following important observations:

- Fire is reported, in these submittals, to be an important contributor to risk for most nuclear plants. About one-third of the plants reported a fire contribution equal to or greater than internal events risk. There are two outliers for fire risk (1E-9 and 5E-3). Both are BWRs.

- Plant unique characteristics, as measured by plant type (BWR or PWR), and pre- versus post- Appendix R operational dates, show small variations (excluding the outliers), i.e., less than a factor of 2 higher on average for pre- versus post-Appendix R plants.

- Control rooms and switchgear rooms are the primary contributors to fire risk at most plants. Turbine buildings and cable spreading rooms are the secondary contributors to fire risk.

- Only three submittals reported vulnerabilities associated with fire but nearly a third of the studies recommended or instituted some form of plant improvement ranging from procedure changes (e.g., improved fire brigade drills based on important fire scenarios) to physical plant modifications.

One conclusion is evident from the level of detail presented in the submittals. The results, conclusions and insights of the fire IPEEEs may be more influenced by the by key assumptions, e.g., characteristics of the pilot fire or recovery of post-fire safe shutdown functions, than by plant design and operation or even the methodology (i.e., FIVE vs. Fire PRA). The state of fire risk technology lends itself to larger variability in assumptions than those used in internal events PRAs. This is reflected in the variability of the fire CDFs versus the internal events CDFs.

In summary, this review points to a number of trends in the results and conclusions of the fire IPEEE submittals. These are discussed throughout this report. However, use of

these results should take into consideration the scope and objectives of this project. In general, quantitative conclusions or comparisons need to consider the underlying assumptions and be confirmed against the insights gained from the plant-specific analyses.

Based on the lessons learned from this project, future work (Phase II) would include a detailed review process to investigate the impact of methodology and key assumptions, plant fire protection design and operation, significant fire risk contributions and how they impact the conclusions from a generic viewpoint. The results of this investigation would be documented to:

- Derive generic insights on fire protection design and operation to support use of the fire risk in resolution of issues; and

- Help development of fire technology for use in plant support.

Phase II would also include insights on NRC positions gained from study of RAIs resulting from NRC review of the IPEEE fire submittals.

4

ANALYSIS OF THE AGGREGATE DATA

Total fire core damage frequencies were reported (or estimated from reported information) for 102 of the 106 units represented in the available submittals. One submittal reported results for two units (BWR 4/Mk II #1 and BWR 4/Mk II #2) qualitatively, without including either a total fire CDF for the plant or CDFs for the unscreened locations. Several submittals reported fire CDFs for significant contributors, but did not report a total fire CDF for the plant. For purposes of this review, if no total fire CDF was available in the submittal report, one was estimated based on information available in the study. Some multi-unit plants performed separate studies for each unit, but combined the results into one submittal, reporting a separate total fire CDF for each unit. Finally, many multi-unit plants performed one study applicable to two or three units, reporting one single-unit fire CDF. In this latter case, this database reports each unit as having the same single-unit fire CDF and top two significant locations. Still others prepared separate submittals for each unit. For consistency in handling the data, this review treated all core damage frequencies as unit fire CDFs.

The following sections provide discussion of the fire IPEEE results using these comparisons:

1. Fire risk (i.e., CDF) and comparison to internal events risk;
2. Differences due to methodology used (i.e., FIVE, fire PRA or a combination of both);
3. Differences between reactor types (BWRs and PWRs);
4. Differences between pre- and post- Appendix R units; and
5. Potentially risk-significant plant locations.

4.1 Fire-Induced Risk

Figure 4-1 provides a histogram of fire CDFs and Internal Events CDFs [3] (Ref.8). Figure 4-2 provides a histogram showing the ratio of fire CDFs to internal events CDFs. Examination of these figures prompts the following observations:

- There are two outliers (4 units) for fire CDF (1E-9 and 5E-3). Both are BWRs.
- The remaining ninety-eight units reported fire CDFs between 1.61E-07 and 4.04E-04, a spread of about 3 orders of magnitude. The spread for internal events is about 2 orders of magnitude.
- The mean internal event risk over all plants is 1.5 times the mean fire risk over all plants.
- About one-third of the units reported fire-induced CDF to be equal to or greater than internal events CDF.

These observations yield the conclusion that fire risk is a significant contributor to overall risk. As will be discussed in Section 4.2 however, choice of methodology appears to be a significant factor in this finding.

4.2 Fire Risk Analysis Methodology

The results and conclusions of the fire IPEEEs are greatly influenced by the method and assumptions used. This review identified the fire risk analysis method as reported in the submittals. The studies submitted by September 1998 reported using any one of the following methodologies:

1. Fire Induced Vulnerability Evaluation (FIVE) screening methodology (Ref.9).
2. Various fire PRA methods, such as EPRI's Fire PRA Implementation Guide (Ref.10), NUREG/CR-4840 (Ref.11), and NUREG-2300 (Ref.12).

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[3] There is not a one-to-one correspondence between the units included in the data sets for fire and internal events CDFs. Four units (BWR 4/Mk II #1, BWR 4/Mk II #2, BWR 4/Mk I #12 and BWR 4/Mk I #13) for which fire CDF was not available, are not included in the fire CDF histogram. Similarly, three units (BWR 4/Mk I #2, BWR 4/Mk II #1, and BWR 4/Mk II #2) for which an internal events CDF was not available, are not included in the internal events histogram. Nevertheless, we do not believe these omissions significantly alter the observations and insights drawn from the comparison. The internal events CDF for the two units (BWR 4/Mk II #3 and BWR 4/Mk II #4) is not reported in the reference document. An internal events CDF was estimated based on information provided in the IPEEE report indicating that the fire CDF for these two units is approximately 10% of the internal events CDF.

3. A combination of FIVE screening and detailed analysis of the unscreened locations, using one or more fire PRA techniques.

4. One study reported "Spatial Interaction" as the methodology used for fire IPEEE.

Thirty-eight of the 106 units in the data set reported using the FIVE method for fire risk analysis. Thirty units used a combination of FIVE and fire PRA methods; and thirty-one used primarily fire PRA methods. Figure 4-3 provides a histogram of fire CDF by method. Examination of this figure produces the following observations:

- There is a noticeable difference in the mean fire CDF values for different methods, approximately an order of magnitude. However, if the outliers are removed, this difference reduces to about a factor of five.

- On average, IPEEE evaluation using FIVE (either FIVE or a combination of FIVE and fire PRA) produced similar fire risk estimates. Studies that reported using fire PRA methods generally produced lower fire risk values, by roughly a factor of four.

Besides being more conservative in general, the FIVE method appears to distinctly influence whether or not fire risk is larger than internal event risk. Table 4-1 illustrates this tendency.

Table 4-1
Fraction of Units Using FIVE, fire PRA or a Combination of FIVE and Fire PRA, Whose Fire CDF is 1/4, 1/3, or 1/2 of Total CDF.

	Fraction of units using:		
where:	Fire PRA	FIVE + Fire PRA	FIVE
Fire CDF >1/4 of Total CDF	34%	55%	74%
Fire CDF > 1/3 of Total CDF	25%	48%	58%
Fire CDF >1/2 of Total CDF	16%	34%	37%

Only eight of thirty-two units (25%) using the fire PRA method reported a fire CDF that was more than one-third of the total CDF. However, fourteen out of twenty nine (48%) of those using FIVE + fire PRA, and twenty-two out of thirty-eight (58%) using FIVE, reported a fire CDF one-third or more of the total CDF.

The fact that FIVE (a screening methodology) generally produces more conservative results is likely the result of two assumptions made by FIVE that are typically less restrictive in fire PRA:

1. FIVE typically credits only safe shutdown systems, while fire PRA studies tend to credit additional plant systems if unaffected by the fire (e.g., offsite power);

2. FIVE applies the results of the most limiting scenario to the entire zone (i.e., if one ignition source in the zone is found capable of causing damage, all ignition sources in the zone are assumed to cause damage). Typically, a fire PRA assesses damage and consequences for each ignition source (or group of ignition sources) separately.

4.3 Reactor Type

Figure 4-4 compares fire CDFs for BWRs and PWRs. Ignoring the outliers, the range of values is broader for PWRs (about three orders of magnitude) than for BWRs (about two orders of magnitude). However, mean CDFs for BWRs and PWRs are similar, the mean CDF for PWRs being about 20% higher than for BWRs.

4.4 Pre-vs. Post- Appendix R Units

Appendix R to 10CFR50 (Ref.13) was published on November 19, 1980 and became effective ninety days later on February 17, 1981. Appendix R established prescriptive requirements for fire protection in U.S. nuclear power plants. This regulation became directly applicable to plants licensed prior to January 1, 1979, and is regarded as a physical backfit for those plants.

A comparison of fire-induced risk results was made to determine the impact on plant fire risk, if any, of different approaches for meeting the requirements of Appendix R. Figure 4-5 provides a histogram of fire CDFs for units starting operation prior to or after January 1, 1979. About half of the units in the data set started operation prior to January 1, 1979, and about half started after January 1, 1979. Examination of Figure 4-5 prompts the observation that the average (mean) fire CDF for units starting operation prior to January 1, 1979 is more than eight times greater than the fire CDF for units starting operation after January 1, 1979. However, the difference is due almost entirely to the outliers (the difference is about 1.8 times after removing the outliers).

4.5 Significant Fire Risk Contributors

Nearly all submittals reported the fire risk in terms of unscreened fire locations (most using the FIVE screening criteria of 1E-6 for screening locations and 1E-7 for containment bypass scenarios). This section discusses risk-significance in terms of plant locations. The most significant locations and their CDF contributions were reported for

ninety-eight of the 106 units in the data set [4]. Figure 4-6 and Figure 4-7 provide histograms comparing fire CDFs and percent contributions, respectively, for the most significant categories of locations. Examination of the figures prompts the following observations:

- Switchgear rooms were identified as significant more than any other location (fifty-one times, including the Limerick units, which did not report CDFs for significant locations). However, (ignoring the outliers, defined in Note 10), the average CDF attributable to switchgear rooms ranks fifth.

- Control rooms were identified as one of the two most significant locations less often than switchgear rooms. Ignoring the outliers, the average CDF for control rooms ranks first.

- Cable spreading rooms rank fourth, both in terms of the number of times they are identified as one of the two most significant compartments and in terms of their average compartment CDF.

- Turbine Buildings have the highest compartment CDF and were identified as one of the two most significant locations twenty-two times. However, four of the significant locations identified as turbine building locations are associated with a single plant. These four entries also have the highest CDF contributions. Treating these four entries as outliers, Turbine Buildings rank fifth in terms of the number of times they are reported as significant and third in terms of their average compartment CDF.

Figure 4-8 depicts the percentage of times that a location is indicated as the highest contributor to CDF, while Figure 4-9 depicts the percentage of times that a location is indicated as the second highest contributor to CDF. Control rooms are reported to be the most significant almost one-third of the time, but only about 10% of the time are they reported to be second most significant. Switchgear rooms are reported to be most significant about one-fourth of the time, and second most significant almost one-third of the time. Cable spreading rooms are reported to be most significant less than 10% of the time, and second most significant about one-fifth of the time. Turbine Buildings are reported in either category less than 15% of time. Other locations such as pump rooms, electrical equipment rooms (e.g., batteries, battery chargers, inverters, relay cabinets), yard areas, cable tunnels and diesel generator rooms make up the remainder, about one-fourth of both the highest and second highest contributors.

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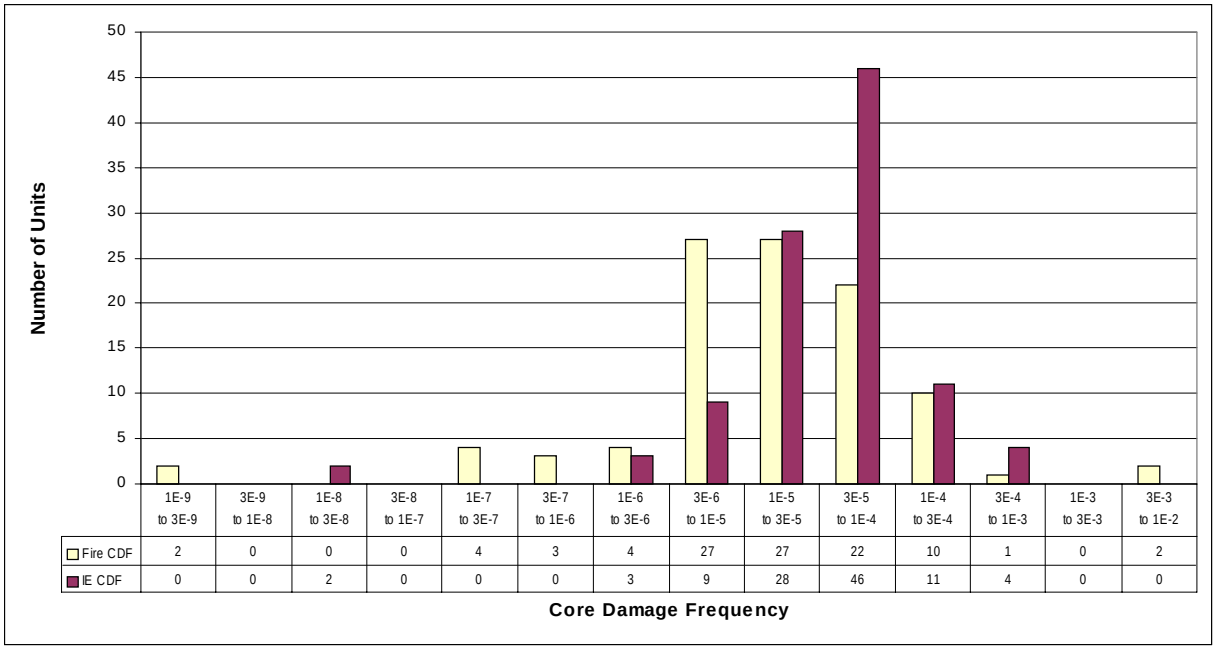
[4] BWR 4/Mk II #1 and BWR 4/Mk II # reported significant locations, but did not report the corresponding CDF contributions. BWR 4/Mk I # 12 and BWR 4/Mk I # 13 reported significant locations, but did not report CDF contributions for all locations (the Control Room was discussed qualitatively). Therefore, we were unable to determine the relative ranking. Four units (BWR 4/Mk II #3, BWR 4/Mk II #4, BWR 5/Mk II #3 and BWR 5/Mk II #4) did not report significant locations.

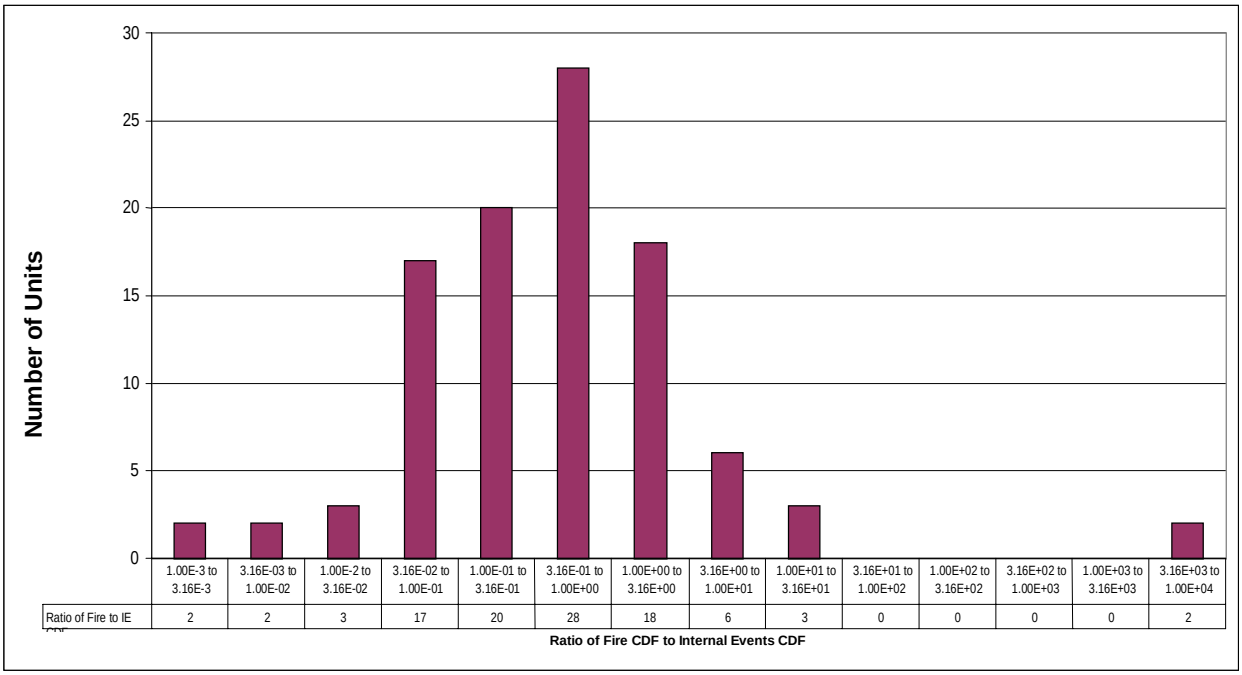


	Fire CDF	*IE CDF*
Mean	1.46E-04	6.74E-05
Median	1.73E-05	4.63E-05
Minimum	1.30E-09	1.30E-08
Maximum	5.40E-03	4.62E-04
5th Percentile	2.44E-07	3.72E-06
95th Percentile	2.21E-04	2.37E-04
Count	102	103

Figure 4-1
Fire and Internal Events CDFs Histogram[5]

[5] The following table compares the statistical data for Figure 4-1 after removing outliers. (Two unit CDFs >3E-3 and two unit CDFs <3E-9 could be considered outliers in the fire CDF data; two unit CDFs <3E-8 could be considered outliers in the internal events CDF data.)

	Fire CDF	*IE CDF*
Mean	4.43E-05	7.01E-05
Median	1.73E-05	4.74E-05
Minimum	1.61E-07	1.92E-06
Maximum	4.04E-04	4.62E-04
5th Percentile	5.06E-07	4.30E-06
95th Percentile	2.00E-04	2.40E-04
Count	98	99

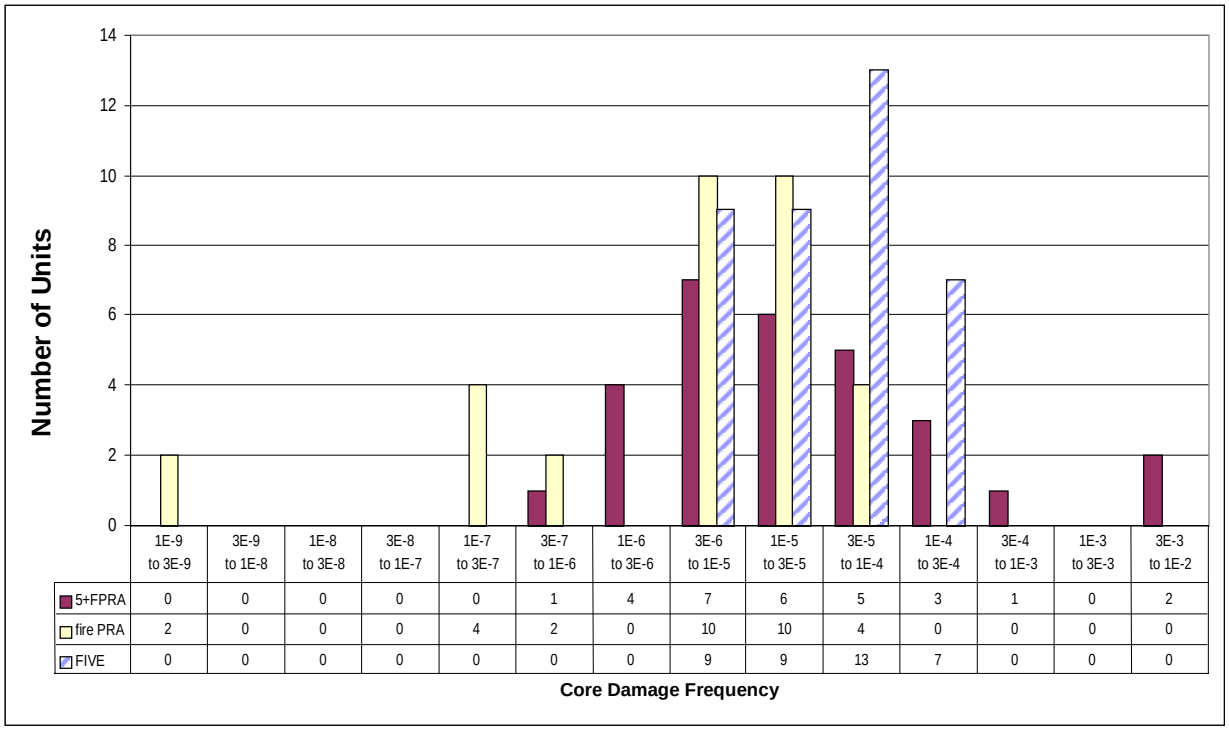


Ratio of Fire to IE CDF	
Mean	89
Median	0.4
Minimum	2.57E-03
Maximum	4.50E+03
5th Percentile	0.012
95th Percentile	8.8
Count	101

Figure 4-2
Histogram Showing Ratio of Fire CDF to Internal Events CDF [6]

[6] The following table provides the statistical data for the histogram in Figure 4-2, after removing outliers. Note 5 identifies the data points considered to be outliers.

Ratio of Fire to IE CDF	
Mean	1.3
Median	0.4
Minimum	2.57E-03
Maximum	15.1
5th Percentile	0.012
95th Percentile	5.3
Count	97

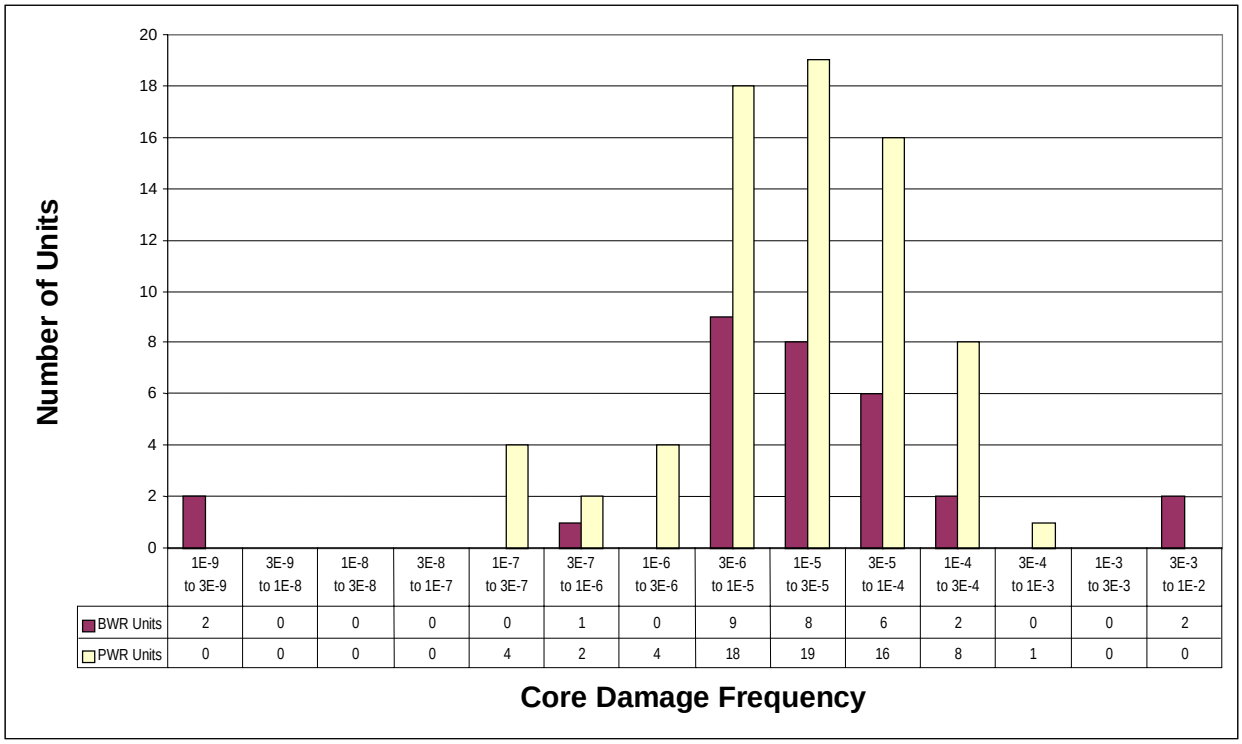


	5+FPRA	*fire PRA*	*FIVE*
Mean	4.12E-04	1.22E-05	5.72E-05
Median	1.78E-05	5.80E-06	3.56E-05
Minimum	1.00E-06	1.30E-09	3.91E-06
Maximum	5.40E-03	5.20E-05	2.00E-04
5th Percentile	2.45E-06	8.12E-08	4.06E-06
95th Percentile	3.04E-03	3.21E-05	2.00E-04
Count	30	31	38

Figure 4-3
Fire CDF Histogram by Method [7]

[7] The following table provides the statistical data for the methods, after removing outliers. Note 5 identifies the data points considered to be outliers.

	5+FPRA	*fire PRA*	*FIVE*
Mean	6.25E-05	1.31E-05	5.72E-05
Median	1.73E-05	7.50E-06	3.56E-05
Minimum	1.00E-06	1.61E-07	3.91E-06
Maximum	4.04E-04	5.20E-05	2.00E-04
5th Percentile	2.44E-06	2.44E-06	2.44E-06
95th Percentile	2.70E-04	2.70E-04	2.70E-04
Count	28	29	38

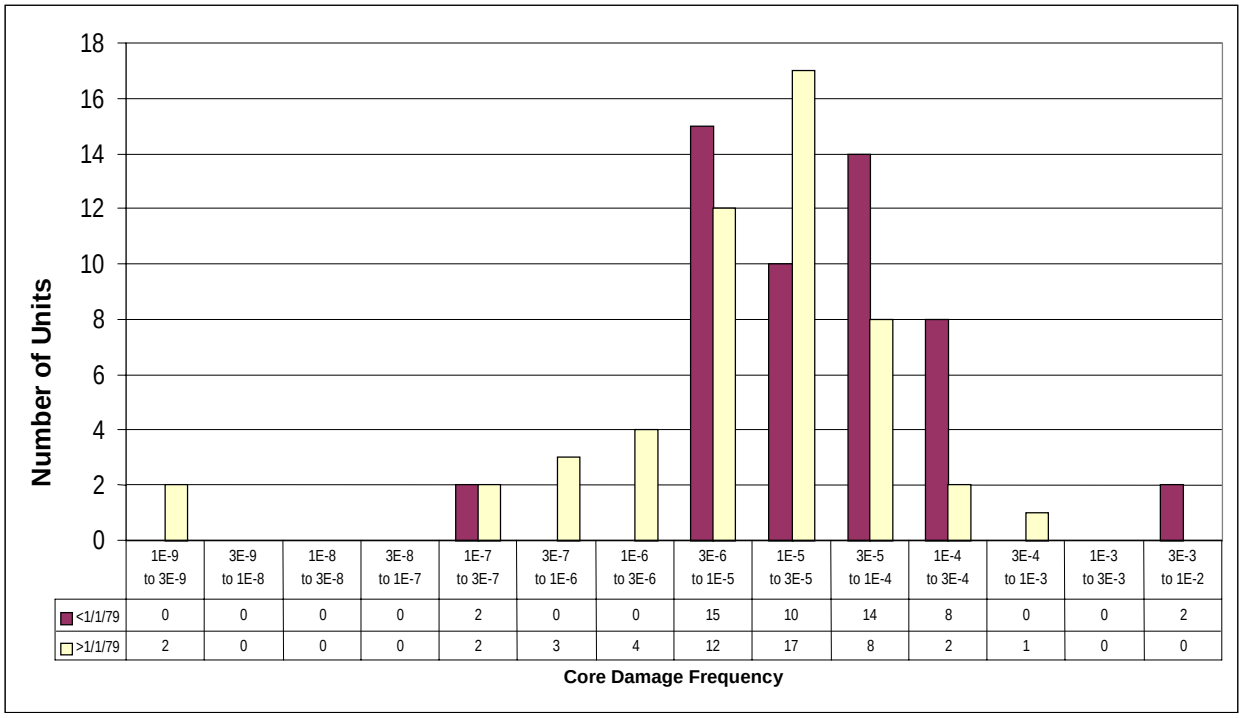


	BWR Units	*PWR Units*
Mean	3.87E-04	4.63E-05
Median	1.88E-05	1.66E-05
Minimum	1.30E-09	1.61E-07
Maximum	5.40E-03	4.04E-04
5th Percentile	4.51E-07	3.82E-07
95th Percentile	2.99E-03	2.00E-04
Count	30	72

Figure 4-4
Histogram Comparing Fire CDF by Reactor Type [8]

[8] The following table provides the statistical data for reactor type, after removing outliers. Note 5 identifies the data points considered to be outliers

	BWR Units	*PWR Units*
Mean	3.87E-05	4.63E-05
Median	1.88E-05	1.66E-05
Minimum	1.00E-06	1.61E-07
Maximum	2.80E-04	4.04E-04
5th Percentile	3.46E-06	3.82E-07
95th Percentile	2.08E-04	2.00E-04
Count	26	72

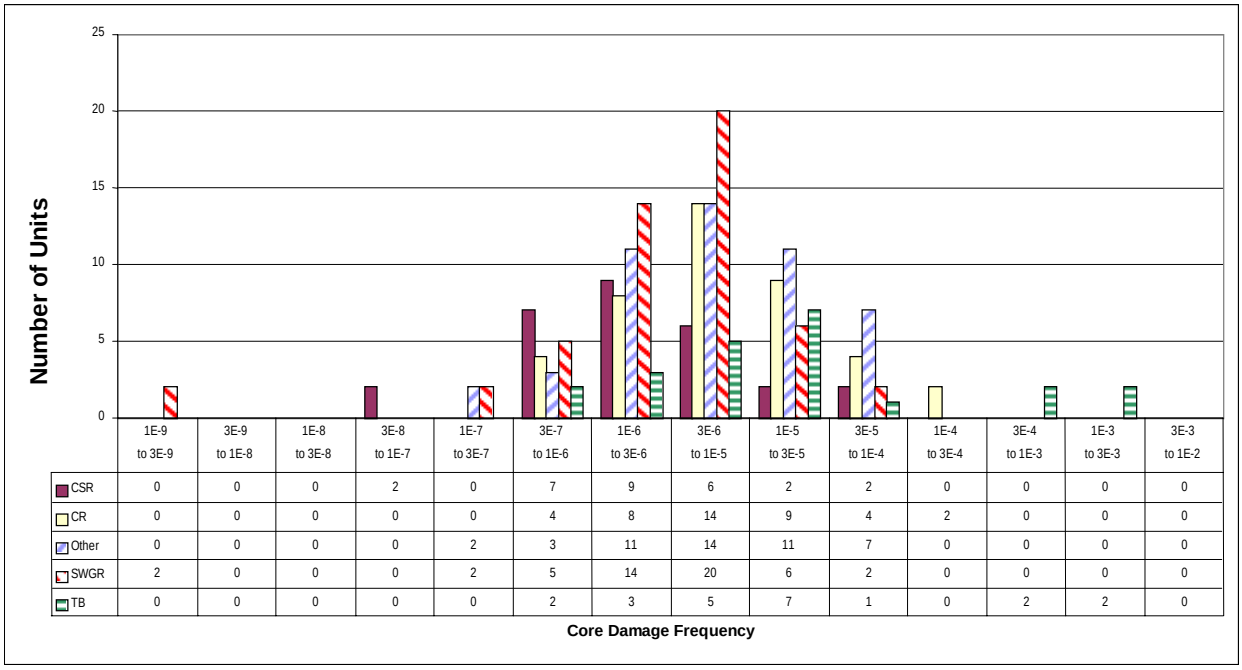


	<1/1/79	*>1/1/79*
Mean	2.63E-04	3.04E-05
Median	2.30E-05	1.05E-05
Minimum	1.61E-07	1.30E-09
Maximum	5.40E-03	4.04E-04
5th Percentile	3.92E-06	2.30E-07
95th Percentile	2.65E-04	1.03E-04
Count	51	51

Figure 4-5
CDF Histogram by Operational Date [9]

[9] The following table provides the statistical data for operational dates, after removing outliers. Note 5 identifies the data points considered to be outliers

	<1/1/79	*>1/1/79*
Mean	5.69E-05	3.16E-05
Median	2.20E-05	1.20E-05
Minimum	1.61E-07	2.30E-07
Maximum	2.80E-04	4.04E-04
5th Percentile	3.91E-06	5.06E-07
95th Percentile	2.13E-04	1.07E-04
Count	49	49



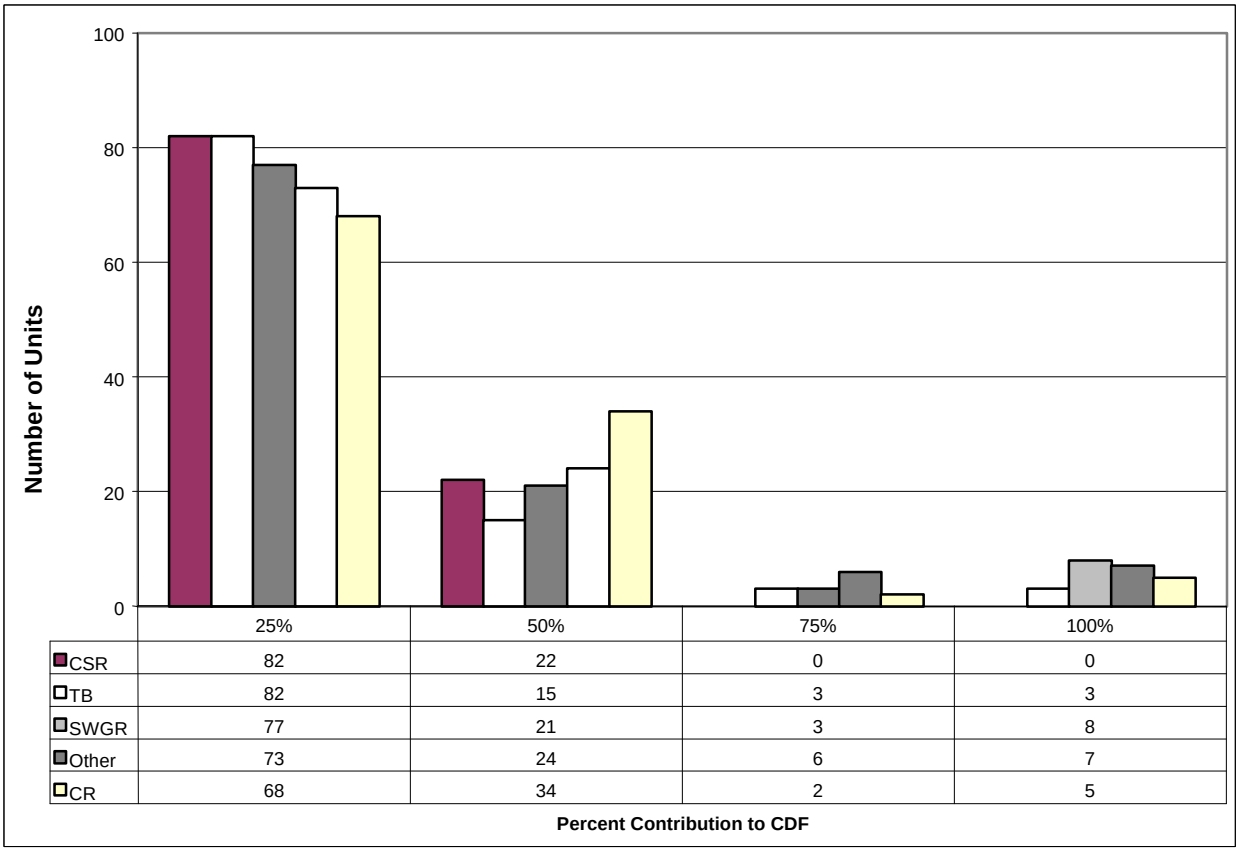
	1E-9 to 3E-9	3E-9 to 1E-8	1E-8 to 3E-8	3E-8 to 1E-7	1E-7 to 3E-7	3E-7 to 1E-6	1E-6 to 3E-6	3E-6 to 1E-5	1E-5 to 3E-5	3E-5 to 1E-4	1E-4 to 3E-4	3E-4 to 1E-3	1E-3 to 3E-3	3E-3 to 1E-2
CSR	0	0	0	2	0	7	9	6	2	2	0	0	0	0
CR	0	0	0	0	0	4	8	14	9	4	2	0	0	0
Other	0	0	0	0	2	3	11	14	11	7	0	0	0	0
SWGR	2	0	0	0	2	5	14	20	6	2	0	0	0	0
TB	0	0	0	0	0	2	3	5	7	1	0	2	2	0

	CSR	*CR*	*Other*	*SWGR*	*TB*
Mean	7.26E-06	2.13E-05	1.49E-05	6.31E-06	3.19E-04
Median	1.78E-06	8.22E-06	5.62E-06	3.36E-06	1.39E-05
Minimum	4.60E-08	5.06E-07	1.29E-07	1.61E-09	7.35E-07
Maximum	7.03E-05	1.90E-04	7.55E-05	3.68E-05	2.91E-03
5th Percentile	1.94E-07	7.01E-07	6.20E-07	1.55E-07	7.70E-07
95th Percentile	4.02E-05	7.41E-05	5.88E-05	2.45E-05	2.69E-03
Count	28	41	48	51	22

Figure 4-6
Significant Locations Histogram [10]

[10] The following table provides the statistical data for the significant locations, after removing outliers. Data points >3E-4 and <3E-9 were considered to be outliers

	CSR	*CR*	*Other*	*SWGR*	*TB*
Mean	7.26E-06	2.13E-05	1.49E-05	6.57E-06	1.33E-05
Median	1.78E-06	8.22E-06	5.62E-06	3.36E-06	8.61E-06
Minimum	4.60E-08	5.06E-07	1.29E-07	1.55E-07	7.35E-07
Maximum	7.03E-05	1.90E-04	7.55E-05	3.68E-05	8.20E-05
5th Percentile	1.94E-07	7.01E-07	6.20E-07	3.34E-07	7.43E-07
95th Percentile	4.02E-05	7.41E-05	5.88E-05	2.53E-05	3.19E-05
Count	28	41	48	49	18



	25%	50%	75%	100%
CSR	82	22	0	0
TB	82	15	3	3
SWGR	77	21	3	8
Other	73	24	6	7
CR	68	34	2	5

Figure 4-7
Histogram of Percent Contribution of Significant Locations [11]

[11] The data on which Figure 4-7 is based includes the outliers.

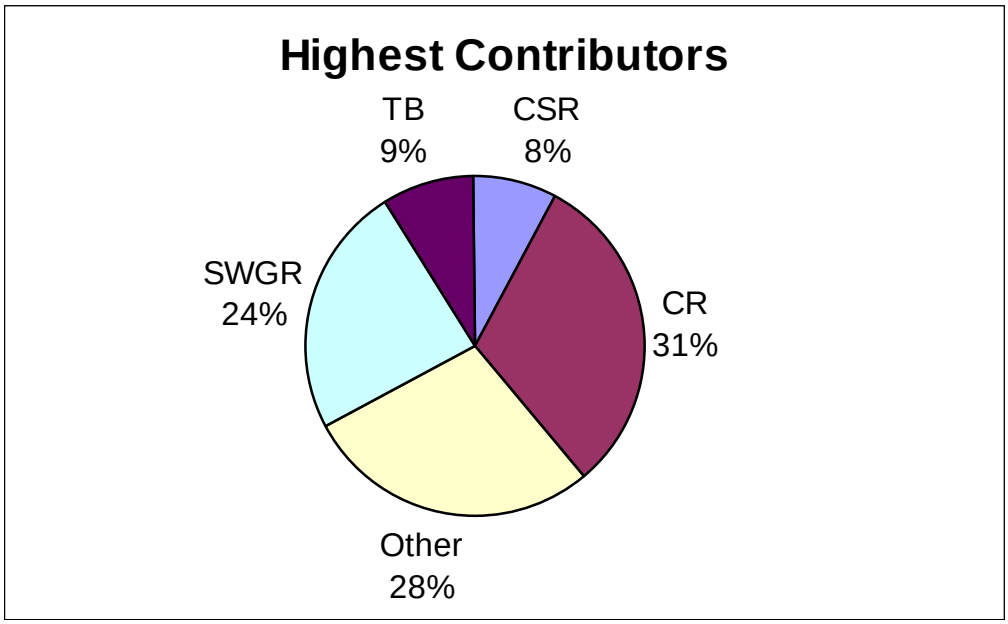


Figure 4-8
Representation of Significant Locations among Highest Contributors [12]

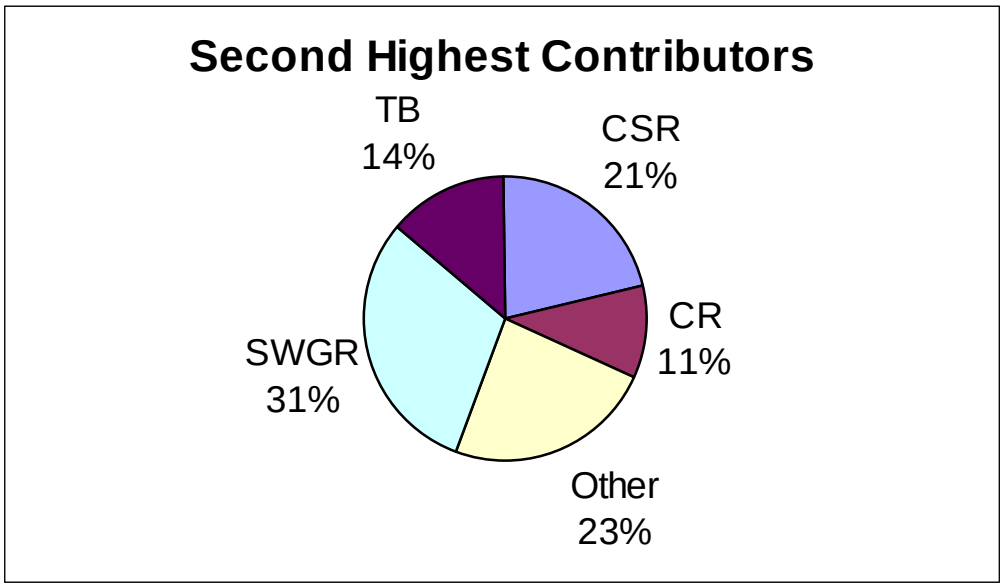


Figure 4-9
Representation of Significant Locations among Second Highest Contributors

[12] Outliers are included in the data on which Figure 4-8 is based.

5

REFERENCES

1. Generic Letter 88-20, Supplement No. 4, "Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities—10 CFR 50.54(f)," June 28, 1991.

2. NUREG-xxxx, "Preliminary Perspectives Gained from Initial IPEEE Submittal Reviews", December 17, 1997.

3. Memorandum to James M. Taylor, from John C. Hoyle, "Staff Requirements — SECY-96-134—Options for Pursuing Regulatory Improvement in Fire Protection Regulations for Nuclear Power Plants."

4. SECY 97-127, "Development of a Risk-Informed, Performance-Based Regulation for Fire Protection at Nuclear Power Plants," dated June 21, 1997.

5. NFPA 805-P, "Light Water Reactor Electric Generating Plants," National Fire Protection Association, (draft, expected official release date is 1/8/99).

6. EPRI TR-108799, "Planning for Risk-Informed/Performance-Based Fire Protection at Nuclear Power Plants."

7. NUREG-1407 "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, June 1991.

8. "Individual Plant Examination Database, " http://www.nrc.gov/NRC/NUREGS/SR1603/index.html

9. EPRI TR-100370, "Fire-Induced Vulnerability Evaluation (FIVE) Methodology Plant Screening Guide," April 1992.

10. W. J. Parkinson, et al., "Fire PRA Implementation Guide," Electric Power Research Institute, Palo Alto, CA, Final Report, December 1995.

11. U. S. Nuclear Regulatory Commission, "Recommended Procedures for the Simplified External Event Risk Analyses for NUREG-1150," Albuquerque, New Mexico: NUREG/CR-4840, Sandia National Laboratories, September 1989.

12. "PRA Procedures Guide", NUREG/CR-2300, January 1983.

13. CFR50, Appendix R, "Fire Protection Program for Nuclear Power Plant Facilities Operating Prior to January 1,1979."

A

SUMMARY OF THE FIRE INDIVIDUAL PLANT EXAMINATION FOR EXTERNAL EVENTS (IPEEE) RESULTS

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/W-4 Loop #1	fire PRA	1.01E-05	4.90E-05	None	None
PWR/W-4 Loop #2	fire PRA	1.01E-05	4.90E-05	None	None
PWR/B&W #1	FIVE	4.20E-05	4.67E-05	None	None
PWR/CE #1	FIVE	3.50E-05	3.40E-05	None	None
PWR/W-3 Loop #1	fire PRA	1.75E-05	2.14E-04	None	None
PWR/W-3 Loop #2	Other	1.05E-05	1.92E-04	None	None
PWR/W-4 Loop #3	5-FPRA	2.50E-06	2.74E-05	None	None
PWR/W-4 Loop #4	5-FPRA	2.40E-06	2.74E-05	None	None
BWR 4/Mk I #1	FIVE	5.25E-06	4.80E-05	None	None
BWR 4/Mk I #2	FIVE	3.92E-06		None	None
BWR 4/Mk I #3	FIVE	3.62E-05	2.70E-05	None	Include response to control room fires in Severe Accident Mgmt Guidelines Evaluate adequacy of current procedures and training
BWR 4/Mk I #4	FIVE	3.62E-05	2.70E-05	None	Include response to control room fires in Severe Accident Mgmt Guidelines Evaluate adequacy of current procedures and training
PWR/W-4 Loop #5	5-FPRA	3.10E-06	3.09E-05	None	None
PWR/W-4 Loop #6	5-FPRA	3.00E-06	3.09E-05	None	None
PWR/W-4 Loop #7	FIVE	8.88E-06	5.85E-05	None	Update prefire plans

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/CE #2	5-FPRA	7.29E-05	2.40E-04	Not reported	Revised procedures and operator training for placing CR and CSR ventilation in recirculation. Revised procedures for restoring CSR and switchgear rooms ventilation following an inadvertent Halon system actuation. Changes to Fire Fighting Strategies for yard areas and Turbine Building Evaluation of switchgear room ventilation systems to determine whether procedure changes are required to either prevent loss of ventilation or to restore ventilation.
PWR/CE #3	5-FPRA	9.60E-05	2.40E-04	Not reported	Revised procedures and operator training for placing CR and CSR ventilation in recirculation. Revised procedures for restoring CSR and switchgear rooms ventilation following an inadvertent Halon system actuation. Changes to Fire Fighting Strategies for yard areas and Turbine Building Evaluation of switchgear room ventilation systems to determine whether procedure changes are required to either prevent loss of ventilation or to restore ventilation.
PWR/W-4 Loop #8	fire PRA	4.69E-06	5.80E-05	None	None
PWR/W-4 Loop #9	fire PRA	4.69E-06	5.80E-05	None	None
BWR 6/Mk III #1	fire PRA	3.30E-06	2.60E-05	None	None
PWR/W-4 Loop #10	fire PRA	2.10E-05	5.72E-05	None	None
PWR/W-4 Loop #11	fire PRA	2.10E-05	5.72E-05	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
BWR 4/Mk I #5	5-FPRA	9.00E-06	7.97E-05	Div I Ess SWGR 1F Room Div II Ess SWGR 1G Room Control Room and SAS Corridor SW Pump Room	Alternate location for control of swyd breakers, or a pre-planned recover/repair action for control of swyd breakers Alternate source of SW
PWR/B&W #2	fire PRA	5.20E-05	1.53E-05	None	Thermo-Lag issues still being considered
PWR/B&W #3	5-FPRA	1.71E-05	6.60E-05	None	Will review fire response procedures
PWR/W-4 Loop #12	fire PRA	2.73E-05	8.80E-05	None	Procedure change to trip RCPs in the event of a fire in CR cabinet fire resulting in loss of CCW or ASW systems.
PWR/W-4 Loop #13	fire PRA	2.73E-05	8.80E-05	None	Procedure change to trip RCPs in the event of a fire in CR cabinet fire resulting in loss of CCW or ASW systems.
PWR/W-4 Loop #14	fire PRA	1.61E-07	6.26E-05	None	None
PWR/W-4 Loop #15	fire PRA	1.61E-07	6.26E-05	None	None
BWR 3/Mk II#1	5-FPRA	2.50E-04	1.85E-05	None	Evaluate procedure revisions and Isolation Condenser unavailability due to maintenance for feasibility of cost effective changes Implement Severe Accident Management Guidelines
BWR 3/Mk II #2	5-FPRA	2.80E-04	1.85E-05	None	Evaluate procedure revisions and Isolation Condenser unavailability due to maintenance for feasibility of cost effective changes Implement Severe Accident Management Guidelines

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
BWR 4/Mk I #6	FIVE	1.10E-05	7.84E-06	Not reported	Optimization of River Water maintenance outage time Staging or readying of fire hoses during RW maintenance outage to maintain level in RHRSW pump wet pits using the fire protection system.
BWR 4/Mk I #7	fire PRA	7.50E-06	2.23E-05	None	None
BWR 4/Mk I #8	fire PRA	5.40E-06	2.36E-05	None	None
BWR 4/Mk I #9	FIVE	1.70E-05	5.70E-06	None	Fire Brigade drills in the vicinity of critical control room cabinets
PWR/CE #4	fire PRA	2.74E-05	1.36E-05	None	Procedure revision in progress
PWR/W-2 Loop #1	5-FPRA	6.40E-05	8.74E-05	None	Fuses will be installed on control circuits routed in the screen house associated with the functioning of 4160 VAC circuit breakers 52/17SS and 52/18SS. The fuses will be designed to open if grounding occurs. A procedural enhancement is under consideration to provide for local recovery of pressurizer heater operation. A procedural enhancement is under consideration to insert a warning that MOV 857B may need to be locally closed. Additional installation of sealed containers for transient combustible storage in the auxiliary building basement is being considered. A modification to reduce the potential for spurious opening of MOVs 850A and 850B due to hot shorting is being considered. Installation of a local pressure gauge to permit RWST level measurements is being considered.
BWR 6/Mk III #2	fire PRA	8.76E-06	1.72E-05	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/W-3 Loop #7	5-FPRA	2.22E-04	3.20E-04	None	None
BWR 4/Mk I #10	FIVE	8.10E-05	4.63E-05	None	None
PWR/W-4 Loop #16	5-FPRA	1.80E-05	3.13E-05	None	None
PWR/W-4 Loop #17	5-FPRA	5.64E-05	4.40E-05	None	None
BWR 4/Mk I #11	fire PRA	2.00E-05	1.92E-06	None	None
PWR/W-3 Loop #3	FIVE	1.60E-04	1.30E-04	None	Committed to procedural enhancements
PWR/W-3 Loop #4	FIVE	1.23E-04	1.30E-04	None	Committed to procedural enhancements
PWR/W-2 Loop #2	5-FPRA	9.80E-05	6.65E-05	None	None
BWR 5/Mk II #3	fire PRA	3.21E-05	4.74E-05	None	None
BWR 5/Mk II #4	fire PRA	3.21E-05	4.74E-05	None	None
BWR 4/Mk II #1	FIVE		4.30E-06		
BWR 4/Mk II #2	FIVE		4.30E-06		
PWR/CE #5	FIVE	4.20E-05	7.40E-05	Many	Improve guidance for manual actions in procedures. Plant procedures require H2 supply be isolated. Additional qualified ventilation added to the EFW Pump Room. Develop accident management guidelines for severe fires. Improve AFW reliability.
PWR/W-4 Loop #18	fire PRA	2.30E-07	4.00E-05	None	None
PWR/W-4 Loop #19	fire PRA	2.30E-07	4.00E-05	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/CE #6	FIVE	6.30E-06	3.42E-05	None	None
PWR/W-4 Loop #20	fire PRA	4.90E-06	5.61E-05	None	None
BWR 3/Mk I #1	5-FPRA	7.80E-06	2.60E-05	None	None
BWR 2/Mk I #1	5-FPRA	2.00E-05	5.50E-06	Not reported	Operator training in use of N1-SOP-14 - Loss of Instrumentation
BWR 5/Mk II #1	5-FPRA	1.00E-06	3.10E-05	None	None
PWR/W-3 Loop #5	FIVE	3.91E-06	7.16E-05	None	Procedure enhancements
PWR/W-3 Loop #6	FIVE	4.08E-06	7.16E-05	None	Procedure enhancements
PWR/B&W #4	fire PRA	5.80E-06	2.30E-05	None	Improvements to the fire protection system program and systems, summarized as follows: • Revisions to the pre-fire plan and updating of fire protection drawings • Physical changes to improve seismic adequacy of flammable combustible storage and a revision to the transient combustible control procedures; • Specific improvements to suppression and detection systems; • Specific improvements to fire protection barriers; and • Recommendation to provide work force advisors to the fire brigade.

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/B&W #5	fire PRA	5.80E-06	2.30E-05	None	Improvements to the fire protection system program and systems, summarized as follows: • Revisions to the pre-fire plan and updating of fire protection drawings • Physical changes to improve seismic adequacy of flammable combustible storage and a revision to the transient combustible control procedures; • Specific improvements to suppression and detection systems; • Specific improvements to fire protection barriers; and • Recommendation to provide work force advisors to the fire brigade.
PWR/B&W #6	fire PRA	5.80E-06	2.30E-05	None	Improvements to the fire protection system program and systems, summarized as follows: • Revisions to the pre-fire plan and updating of fire protection drawings • Physical changes to improve seismic adequacy of flammable combustible storage and a revision to the transient combustible control procedures; • Specific improvements to suppression and detection systems; • Specific improvements to fire protection barriers; and • Recommendation to provide work force advisors to the fire brigade.
BWR 2/Mk I #2	FIVE	7.70E-06	3.69E-06	None	None
PWR/CE #7	FIVE	2.00E-04	5.07E-05	None	Operator training for manual actions credited
PWR/CE #8	FIVE	8.67E-05	9.00E-05	None	None
PWR/CE #9	FIVE	8.67E-05	9.00E-05	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/CE #10	FIVE	8.67E-05	9.00E-05	None	None
BWR 4/Mk I #12	FIVE	1.57E-05	5.53E-06	None	Revise procedures Enhance control of transient combustibles Upgrade fire compartment barriers Create transient-free zones FB training Modify OSP control Automate existing suppression system
BWR 4/Mk I #13	FIVE	1.57E-05	5.53E-06	None	Revise procedures Enhance control of transient combustibles Upgrade fire compartment barriers Create transient-free zones FB training Modify OSP control Automate existing suppression system
BWR 6/Mk III #3	FIVE	3.14E-05	1.32E-05	None	None
BWR 3/Mk I #2	5-FPRA	2.20E-05	5.80E-05	None	None
PWR/W-2 Loop #3	FIVE	5.11E-05	1.15E-04	None	4 improvements listed but not credited 2 new diesels new control system for AF Pumps revise procedure for CR fire evaluate CR smoke detectors
PWR/W-2 Loop #4	FIVE	5.11E-05	1.15E-04	None	4 improvements listed but not credited 2 new diesels new control system for AF Pumps revise procedure for CR fire evaluate CR smoke detectors

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/W-2 Loop #5	FIVE	6.30E-05	5.00E-05	none	none
PWR/W-2 Loop #6	FIVE	6.30E-05	5.00E-05	none	none
BWR 3/Mk I #3	5-FPRA	5.40E-03	1.20E-06	Use of non-IPEE qualified cables Human factors in the safe shutdown procedures Use of opposite unit equipment for SSD Proximity of the same unit redundant divisions Stripping of circuits in anticipation of spurious actuation	IPEEE task force to implement an action plan to evaluate vulnerabilities, review options and recommend a course of action Procedure and hardware changes to ensure adequate isolation of RWCU high/low pressure interface Hardware and procedural changes to address a potential hot short failure Resolution of cable discrepancies Correction of administrative deficiencies Implementation of an interim alternate shutdown method
BWR 3/Mk I #4	5-FPRA	5.20E-03	1.20E-06	Use of non-IPEE qualified cables Human factors in the safe shutdown procedures Use of opposite unit equipment for SSD Proximity of the same unit redundant divisions Stripping of circuits in anticipation of spurious actuation	IPEEE task force to implement an action plan to evaluate vulnerabilities, review options and recommend a course of action Procedure and hardware changes to ensure adequate isolation of RWCU high/low pressure interface Hardware and procedural changes to address a potential hot short failure Resolution of cable discrepancies Correction of administrative deficiencies Implementation of an interim alternate shutdown method
BWR 6/Mk III #4	fire PRA	2.25E-05	1.55E-05	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/W-4 Loop #21	FIVE	2.30E-05	6.25E-05	None	Transient fire controls in TB added and proceduralized
PWR/W-4 Loop #22	FIVE	2.30E-05	6.35E-05	None	Transient fire controls in TB added and proceduralized
PWR/CE #11	FIVE	1.60E-05	3.00E-05	None	3 procedure changes
PWR/CE #12	FIVE	1.60E-05	3.00E-05	None	3 procedure changes
PWR/W-4 Loop #23	5-FPRA	1.20E-05	6.70E-05	None	None
PWR/W-4 Loop #24	FIVE	1.56E-05	1.70E-04	None	None
PWR/W-4 Loop #25	FIVE	1.56E-05	1.70E-04	None	None
PWR/W-3 Loop #8	5-FPRA	8.00E-06	7.00E-05	None	None
PWR/W-4 Loop #26	fire PRA	5.06E-07	4.27E-05	None	None
PWR/W-4 Loop #27	fire PRA	5.06E-07	4.27E-05	None	None
PWR/CE #13	FIVE	1.90E-04	2.30E-05	None	None
PWR/CE #14	FIVE	1.20E-04	2.60E-05	None	None
PWR/W-3 Loop #9	FIVE	6.30E-06	7.40E-05	None	None
PWR/W-3 Loop #10	FIVE	6.30E-06	7.40E-05	None	None
BWR 4/Mk II #3	fire PRA	1.30E-09	1.30E-08	None	None
BWR 4/Mk II #4	fire PRA	1.30E-09	1.30E-08	None	None
PWR/B&W #7	Other	2.16E-05	4.49E-05	None	None
PWR/W-3 Loop #11	FIVE	2.00E-04	4.62E-04	None	None

Unit	Method	Fire CDF	Internal Events CDF (Ref.1)	Reported Vulnerabilities	Plant Improvements
PWR/W-3 Loop #12	FIVE	2.00E-04	4.62E-04	None	None
BWR 4/Mk I #14	5-FPRA	3.80E-05	4.30E-06	None	Include the top 6" of the north wall in the lower NE ECCS Corner room in the plant fire barrier inspection program Enhance inspection and maintenance of vertical cable tray fire stops at each floor in the Reactor Building Perform periodic fire prevention inspections of the Reactor Building and Control Building on a monthly basis Relocate or otherwise protect the control cables for Vernon Tie Breakers 3V, 4V and 3V4 in the east and west Switchgear Rooms from fires that are likely to damage offsite power control cables.
PWR/W-3 Loop #13	5-FPRA	4.04E-04	2.00E-04	None	None
PWR/CE #15	5-FPRA	7.00E-06	1.70E-05	None	Evaluate adding fire wrap to the B chilled water cables in the vicinity of the A chiller
PWR/W-4 Loop #28	FIVE	5.88E-06	3.30E-04	None	None
BWR 5/Mk II #2	5-FPRA	1.75E-05	1.75E-05	Not reported	None
PWR/W-4 Loop #29	5-FPRA	7.59E-06	4.20E-05	None	None
PWR/W-4 Loop #30	5-FPRA	5.13E-06	4.00E-06	None	None

Reference

1 “Individual Plant Examination Database”, http://www.nrc.gov/NRC/NUREGS/SR1603/index.html.

B

RISK SIGNIFICANT PLANT LOCATIONS

Unit	Most Significant Location	% Contri-bution	Second Most Significant Location	% Contri-bution
PWR/W-4 Loop #1	Control Room	16%	Switchgear Room	12%
PWR/W-4 Loop #2	Control Room	16%	Switchgear Room	12%
PWR/B&W #1	Turbine Building	21%	Battery Room, South	16%
PWR/CE #1	Turbine Building	50%	Cable Spreading Room	16%
PWR/W-3 Loop #1	Cable Spreading Room	27%	Cable Tunnel	24%
PWR/W-3 Loop #2	Control Room	18%	Cable Tunnel	13%
PWR/W-4 Loop #3	Auxiliary Building	72%	Cable Spreading Room	22%
PWR/W-4 Loop #4	Auxiliary Building	72%	Cable Spreading Room	22%
BWR 4/Mk I #1	Yard Area Fires	15%	Turbine Building	14%
BWR 4/Mk I #2	Yard Area Fires	20%	Turbine Building	19%
BWR 4/Mk I #3	Control Room, AW Area	53%	North Central Area	9%
BWR 4/Mk I #4	Control Room, AW Area	53%	North Central Area	9%
PWR/W-4 Loop #5	Auxiliary Building	82%	Switchgear Room	11%
PWR/W-4 Loop #6	Auxiliary Building	82%	Switchgear Room	11%
PWR/W-4 Loop #7	Control Room	30%	Switchgear Room	26%
PWR/CE #2	Control Room	36%	Turbine Building	24%
PWR/CE #3	Control Room	36%	Turbine Building	24%
PWR/W-4 Loop #8	Pump Room, KC	80%	Cable Room	15%
PWR/W-4 Loop #9	Pump Room, KC	80%	Cable Room	15%
BWR 6/Mk III #1	Control Room	37%	Div I Safety Switchgear room	24%
PWR/W-4 Loop #10	Control Room	43%	Train A Elec. Equip. Area	8%

Unit	Most Significant Location	% Contri-bution	Second Most Significant Location	% Contri-bution
PWR/W-4 Loop #11	Control Room	43%	Train A Elec. Equip. Area	8%
BWR 4/Mk I #5	Control Room	40%	Switchgear Room	29%
PWR/B&W #2	Battery Charger Room	29%	Switchgear Bus Room, 4160V ES 3A	14%
PWR/B&W #3	No. 1 Low Volt. Swgr Room	35%	High Volt. Swgr Room B	30%
PWR/W-4 Loop #12	Cable Spreading Room	37%	Control Room	33%
PWR/W-4 Loop #13	Cable Spreading Room	37%	Control Room	33%
PWR/W-4 Loop #14	MCC Room	96%	Switchgear Room Cable Vault	1%
PWR/W-4 Loop #15	MCC Room	96%	Switchgear Room Cable Vault	1%
BWR 3/Mk II#1	U2/3 Control Room Bkup HVAC Equip. Area	25%	U2/3 SBGT & TBCCW Hx Area	23%
BWR 3/Mk II #2	U2/3 SBGT & TBCCW Hx Area	21%	U3 West Corridor and Trackway	19%
BWR 4/Mk I #6	Switchgear Room, Div I 4kV	53%	Switchgear Room, Div II 4kV	47%
BWR 4/Mk I #7	Cable Spreading Room	26%	Switchgear Room 1G, 4kV	19%
BWR 4/Mk I #8	Switchgear Room 2G, 4kV	20%	Switchgear Room 2E, 4kV	16%
BWR 4/Mk I #9	Switchgear Room, Div 1	26%	Control Room	25%
PWR/CE #4	Control Room	30%	AFW and Air Compressor Area	22%
PWR/W-2 Loop #1	Aux. Building Mezzanine	18%	Control Room	17%
BWR 6/Mk III #2	Control Room	44%	Div 1 Switchgear Room	11%
PWR/W-3 Loop #7	Battery Room	34%	Transformer Yard	7%
BWR 4/Mk I #10	Control Room	31%	Switchgear Room	16%
PWR/W-4 Loop #16	Control Room	38%	Cable Spreading Room	23%
PWR/W-4 Loop #17	Switchgear Room, 480V	62%	Cable Spreading Room	12%
BWR 4/Mk I #11	Cable Spreading Room	33%	Control Room	15%
PWR/W-3 Loop #3	AB 4160V Swgr Room, Train A	23%	Control Room	19%

Unit	Most Significant Location	% Contri-bution	Second Most Significant Location	% Contri-bution
PWR/W-3 Loop #4	AB 4160V Swgr Room, Train A	23%	Control Room	19%
PWR/W-2 Loop #2	AFW Pump A Room	54%	AFW Pump B Room	30%
BWR 5/Mk II #3	Not reported		Not reported	
BWR 5/Mk II #4	Not reported		Not reported	
BWR 4/Mk II #1	Switchgear Room, 13.2 kV	Not reported	Unit 1 Static Inverter	Not reported
BWR 4/Mk II #2	Switchgear Room, 13.2 kV	Not reported	Unit 1 Static Inverter	Not reported
PWR/CE #5	Control Room	29%	Turbine Building	20%
PWR/W-4 Loop #18	Vital I&C Battery Area	56%	Cable Room	20%
PWR/W-4 Loop #19	Vital I&C Battery Area	56%	Cable Room	20%
PWR/CE #6	Auxiliary Building	44%	Turbine Building	26%
PWR/W-4 Loop #20	Charging and CC Pumps Area	22%	Cable Spreading Room	20%
BWR 3/Mk I #1	Control Room	19%	Turbine Building El 932'	16%
BWR 2/Mk I #1	Turbine Building El. 261 South	65%	Cable Spreading Area	10%
BWR 5/Mk II #1	Control Room	100%	None	0%
PWR/W-3 Loop #5	Switchgear Room, Emergency	84%	Cable Vault & Tunnel	12%
PWR/W-3 Loop #6	Switchgear Room, Emergency	84%	Cable Vault & Tunnel	12%
PWR/B&W #4	Turbine Building	100%	None	
PWR/B&W #5	Turbine Building	100%	None	
PWR/B&W #6	Turbine Building	100%	None	
BWR 2/Mk I #2	Switchgear Room	42%	Cable Spreading Room	21%
PWR/CE #7	Turbine Building	41%	Control Room	19%
PWR/CE #8	Switchgear Room, Train A ESF	24%	Turb. Bldg, lower levels, west end	17%
PWR/CE #9	Switchgear Room, Train A ESF	24%	Turb. Bldg, lower levels, west end	17%
PWR/CE #10	Switchgear Room, Train A ESF	24%	Turb. Bldg, lower levels, west end	17%

Unit	Most Significant Location	% Contri-bution	Second Most Significant Location	% Contri-bution
BWR 4/Mk I #12	Note 1	24%	Note 1	20%
BWR 4/Mk I #13	Note 1	24%	Note 1	20%
BWR 6/Mk III #3	Control Room	34%	Switchgear Room, Div 2	
BWR 6/Mk III #3	Control Room	34%	Switchgear Room, Div 2	34%
BWR 3/Mk I #2	Switchgear/Ld Ctr Room B	28%	Switchgear/Ld Ctr Room A	14%
PWR/W-2 Loop #3	Gas Turbine Building	40%	Diesel Generator Room G02	11%
PWR/W-2 Loop #4	Gas Turbine Building	40%	Diesel Generator Room G02	11%
PWR/W-2 Loop #5	Auxiliary Building, ground floor area	44%	Switchgear Room	14%
PWR/W-2 Loop #6	Auxiliary Building, ground floor area	44%	Switchgear Room	14%
BWR 3/Mk I #3	Turbine Bldg Ground Floor	52%	Turbine Bldg Mezzanine Level	10%
BWR 3/Mk I #4	Turbine Bldg Ground Floor	56%	Turbine Bldg Mezzanine Level	10%
BWR 6/Mk III #4	Control Room	22%	Switchgear Room, Div. 1 Standby	21%
PWR/W-4 Loop #21	Relay Room	31%	Control Room	30%
PWR/W-4 Loop #22	Relay Room	31%	Control Room	30%
PWR/CE #11	Switchgear Room 2A	21%	Switchgear Room 2B	18%
PWR/CE #12	Switchgear Room 2A	21%	Switchgear Room 2B	18%
PWR/W-4 Loop #23	Control Room	35%	PCC pump area	26%
PWR/W-4 Loop #24	Auxiliary Building	74%	ERCW	21%
PWR/W-4 Loop #25	Auxiliary Building	74%	ERCW	21%
PWR/W-3 Loop #8	Switchgear Room B	50%	Switchgear Room	33%
PWR/W-4 Loop #26	Control Room	100%	None	
PWR/W-4 Loop #27	Control Room	100%	None	

Note 1 The BWR/Mk I #12 submittal reported seven significant locations, but reported CDF contributions for only six. The Control Room was reported to be significant but was only discussed qualitatively. It was therefore not possible to rank the control room with respect to the other compartments.

Unit	Most Significant Location	% Contri-bution	Second Most Significant Location	% Contri-bution
PWR/CE #13	Control Room	39%	Cable Spreading Room	37%
PWR/CE #14	Control Room	49%	Cable Spreading Room	47%
PWR/W-3 Loop #9	Switchgear Room, Emergency	67%	Switchgear Room	31%
PWR/W-3 Loop #10	Switchgear Room, Emergency	67%	Switchgear Room	31%
BWR 4/Mk II #3	Not reported		Not reported	
BWR 4/Mk II #4	Not reported		Not reported	
PWR/B&W #7	Inverter Room, West	27%	Switchgear Room, 1E	23%
PWR/W-3 Loop #11	Control Room	95%	Cable Spreading Room	1%
PWR/W-3 Loop #12	Control Room	95%	Cable Spreading Room	1%
BWR 4/Mk I #14	Cable Vault	26%	West Switchgear Room	16%
PWR/W-3 Loop #13	IB-3, Intermediate Bldg	12%	IB-22.2, Intermediate Bldg.	5%
PWR/CE #15	Control Room	31%	Chiller Room	29%
PWR/W-4 Loop #28	Control Room	12%	Corridor	9%
BWR 5/Mk II #2	Control Room	48%	Turbine Generator Corridor	17%
PWR/W-4 Loop #29	Train A ESF Switchgear Room	34%	Train B ESF Switchgear Room	28%
PWR/W-4 Loop #30	Cable Spreading Room, Unit 1 outer	22%	Cable Spreading Room, Unit 2 outer	22%
PWR/W-4 Loop #31	Cable Spreading Room, Unit 1 outer	22%	Cable Spreading Room, Unit 2 outer	22%

C

DESIGN INFORMATION

Unit	Operational Date
PWR/W-4 Loop #1	Jun-87
PWR/W-4 Loop #2	May-89
PWR/B&W #1	Dec-74
PWR/CE #1	Mar-80
PWR/W-3 Loop #1	Oct-76
PWR/W-3 Loop #2	Nov-87
PWR/W-4 Loop #3	Jul-88
PWR/W-4 Loop #4	Oct-88
BWR 4/Mk I #1	Mar-75
BWR 4/Mk I #2	Mar-77
BWR 4/Mk I #3	Mar-77
BWR 4/Mk I #4	Nov-75
PWR/W-4 Loop #5	Sep-85
PWR/W-4 Loop #6	Aug-87
PWR/W-4 Loop #7	Apr-85
PWR/CE #2	May-75
PWR/CE #3	Apr-77
PWR/W-4 Loop #8	Jun-85
PWR/W-4 Loop #9	Aug-86
BWR 6/Mk III #1	Apr-87
PWR/W-4 Loop #10	Aug-90
PWR/W-4 Loop #11	Aug-93
BWR 4/Mk I #5	Jan-74

Unit	Operational Date
PWR/B&W #2	Mar-77
PWR/B&W #3	Apr-77
PWR/W-4 Loop #12	Nov-84
PWR/W-4 Loop #13	Mar-86
PWR/W-4 Loop #14	Aug-75
PWR/W-4 Loop #15	Aug-78
BWR 3/Mk II#1	Jun-70
BWR 3/Mk II #2	Nov-71
BWR 4/Mk I #6	Feb-75
BWR 4/Mk I #7	Dec-75
BWR 4/Mk I #8	Sep-79
BWR 4/Mk I #9	Jan-88
PWR/CE #4	Sep-73
PWR/W-2 Loop #1	Jul-70
BWR 6/Mk III #2	Jul-85
PWR/W-3 Loop #7	Mar-71
BWR 4/Mk I #10	Dec-86
PWR/W-4 Loop #16	Aug-74
PWR/W-4 Loop #17	Aug-76
BWR 4/Mk I #11	Jul-75
PWR/W-3 Loop #3	Dec-77
PWR/W-3 Loop #4	Jul-81
PWR/W-2 Loop #2	Jun-74
BWR 5/Mk II #3	Jan-84
BWR 5/Mk II #4	Oct-84
BWR 4/Mk II #1	Feb-86
BWR 4/Mk II #2	Jan-90
PWR/CE #5	Dec-72
PWR/W-4 Loop #18	Dec-81
PWR/W-4 Loop #19	Mar-84
PWR/CE #6	Dec-75

Unit	Operational Date
PWR/W-4 Loop #20	Apr-86
BWR 3/Mk I #1	Jun-71
BWR 2/Mk I #1	Dec-69
BWR 5/Mk II #1	Apr-88
PWR/W-3 Loop #5	Jun-78
PWR/W-3 Loop #6	Dec-80
PWR/B&W #4	Jul-73
PWR/B&W #5	Sep-74
PWR/B&W #6	Dec-74
BWR 2/Mk I #2	Dec-69
PWR/CE #7	Dec-71
PWR/CE #8	Jan-86
PWR/CE #9	Sep-86
PWR/CE #10	Jan-88
BWR 4/Mk I #12	Jul-74
BWR 4/Mk I #13	Dec-74
BWR 6/Mk III #3	Nov-87
BWR 3/Mk I #2	Dec-72
PWR/W-2 Loop #3	Oct-70
PWR/W-2 Loop #4	Mar-73
PWR/W-2 Loop #5	Dec-73
PWR/W-2 Loop #6	Dec-74
BWR 3/Mk I #3	Feb-73
BWR 3/Mk I #4	Mar-73
BWR 6/Mk III #4	Jun-86
PWR/W-4 Loop #21	Jun-77
PWR/W-4 Loop #22	Oct-81
PWR/CE #11	Feb-82
PWR/CE #12	Nov-82
PWR/W-4 Loop #23	Aug-90
PWR/W-4 Loop #24	Jul-81

Unit	Operational Date
PWR/W-4 Loop #25	Jun-82
PWR/W-3 Loop #8	Jan-87
PWR/W-4 Loop #26	Aug-88
PWR/W-4 Loop #27	Jun-89
PWR/CE #13	Dec-76
PWR/CE #14	Aug-83
PWR/W-3 Loop #9	Dec-72
PWR/W-3 Loop #10	May-73
BWR 4/Mk II #3	Jun-83
BWR 4/Mk II #4	Feb-85
PWR/B&W #7	Sep-74
PWR/W-3 Loop #11	Dec-72
PWR/W-3 Loop #12	Sep-73
BWR 4/Mk I #14	Nov-72
PWR/W-3 Loop #13	Jan-84
PWR/CE #15	Sep-85
PWR/W-4 Loop #28	May-96
BWR 5/Mk II #2	Dec-84
PWR/W-4 Loop #29	Sep-85
PWR/W-4 Loop #30	Dec-73
PWR/W-4 Loop #31	Sep-74