UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 30, 1997

MEMORANDUM TO: Chairman Jackson
Commissioner Diaz
Commissioner Dicus
Commissioner McGaffigan

FROM: L. Joseph Callan
Executive Director for Operations

SUBJECT: FOLLOWUP ACTIVITIES ON THE SPENT FUEL POOL ACTION PLAN

In a memorandum to the Commission dated July 26, 1996, the staff reported the findings from the Spent Fuel Pool (SFP) action plan. In that memorandum, the staff concluded that existing structures, systems and components related to the storage of irradiated fuel provide adequate protection for public health and safety. Concurrent with activities associated with the SFP action plan, the staff performed an independent review of all operating reactor licensees and found that each licensee was operating its spent fuel storage system in compliance with its operating license or would be before the next refueling outage. The results of this compliance review are documented in a memorandum to the Commission dated May 21, 1996. Notwithstanding these findings, the staff proposed to perform plant-specific evaluations or regulatory analyses to determine whether safety enhancement backfits could be justified at certain plants. The purpose of this memorandum is to report the results of the plant-specific evaluations and regulatory analyses performed for this study.

On February 28, 1997, the staff informed the Commission that our followup activities would also include a review of refueling cavity seals at certain plants. The addition of this review was the result of findings from the Office for Analysis and Evaluation of Operational Data (AEOD) study, "Assessment of Spent Fuel Pool Cooling," dated October 3, 1996.

The staff has completed the plant-specific evaluations and regulatory analyses for the eleven design issues identified in the staff's July 26 report and the memorandum to the Commission dated February 28, 1997. During our review, twelve licensees proposed certain voluntary actions to address the design issues identified in the staff's reports. A list of the licensees and their proposed actions is presented in Table 2 of the attached report. The staff will track the completion of these voluntary actions using the Commitment Tracking System.

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In the July 26 report, the staff concluded that regulatory analyses should be performed for seven design issues to assess whether safety enhancements were warranted. The staff performed probabilistic screening analyses and found that, in most cases, event frequencies for sequences associated with these design issues were sufficiently low that further analyses were not warranted. In one instance where the probabilistic screening criteria was met, the staff performed a deterministic evaluation of the issue using plant-specific information and found that safety enhancements were not warranted. At LaSalle, the staff found unique design and operational features associated with the spent fuel pool cooling systems that require further analysis to determine whether safety enhancements are warranted. The staff concluded that, based on the results of these probabilistic evaluations and with the exception of the outstanding issues at LaSalle, safety enhancements at plants with these seven design issues could not be justified and no further actions will be taken. The staff also gathered and reviewed additional information about the four remaining design issues to determine the need for safety enhancements. Based on a review of this additional information, the staff determined that safety enhancements at these plants are not justified and that no further analysis is required. Details of the staff's evaluations for all issues can be found in the attached report.

Other actions identified in the staff's July 26 report to address spent fuel storage issues, which include rulemaking and revising staff guidance for SFP evaluations, are still under development. The staff has issued SECY-97-168, "Issuance for Public Comment of Proposed Rulemaking Package for Shutdown and Fuel Storage Pool Operation," requesting Commission approval to release for public comment the proposed rule on shutdown operations. Revision of the staff's SFP evaluation guidance documents will be completed by October 1998, as described in our response to the Staff Requirements Memorandum dated October 2, 1996.

Attachment: Report On Followup Actions From the Spent Fuel Storage Pool Action Plan

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REPORT ON FOLLOWUP ACTIONS FROM THE SPENT FUEL STORAGE POOL ACTION PLAN

1.0 BACKGROUND

The NRC staff developed and implemented a generic action plan for ensuring the safety of spent fuel storage pools in response to two separate postulated event sequences involving the spent fuel pools (SFPs) at two plants. The principal safety concerns addressed by the action plan involve the potential for a sustained loss of SFP cooling and the potential for a substantial loss of spent fuel coolant inventory that could expose irradiated fuel.

The first postulated event sequence was reported to the NRC staff in November 1992 by two engineers, who formerly worked under contract for the Pennsylvania Power and Light Company (PP&L). In the report, the engineers contended that the design of the Susquehanna station failed to meet regulatory requirements with respect to sustained loss of the cooling function to the SFP that could result from a loss-of-coolant accident (LOCA) or a loss of offsite power (LOOP). The heat and water vapor added to the reactor building atmosphere by subsequent SFP boiling could cause failure of accident mitigation or other safety equipment and an associated increase in the consequences of the initiating event. Using probabilistic and deterministic methods, the staff evaluated these issues as they related to Susquehanna and determined that public health and safety were adequately protected on the basis of existing design features and operating practices at Susquehanna. However, the staff also concluded that a broader evaluation of the potential for this type of event to occur at other facilities was justified.

The second postulated event sequence was based on an actual event that occurred at Dresden 1, which is permanently shutdown. This plant experienced containment flooding because of freeze damage to the service water system inside the containment building on January 25, 1994. Commonwealth Edison reported that the configuration of the spent fuel transfer system between the SFP and the containment similarly threatened SFP coolant inventory control. At Dresden Unit 1, portions of the spent fuel transfer system piping inside the containment could have burst due to freezing at an elevation that would drain the spent fuel coolant to a level below the top of stored irradiated fuel in the SFP. A substantial loss of SFP coolant inventory could lead to such consequences as high local radiation levels due to loss of shielding, unmonitored release of radiologically contaminated coolant, and inadequate cooling of stored fuel. The staff concluded that the potential for this type of event to occur at other facilities should be evaluated.

Finally, the action plan itself called for a review of events related to wet storage of irradiated fuel. From the review of events related to wet storage of irradiated fuel and information from the two postulated event sequences that prompted development of the action plan, the staff identified areas to evaluate for further regulatory action. Design information to support the SFP action plan's evaluation was developed through four onsite assessments, a safety analysis report review for several operating reactors, and the staff's survey of refueling practices completed in May 1996.

Because the safety of fuel storage in the SFP is principally determined by coolant inventory, coolant temperature, and reactivity, the staff divided its evaluation into those areas. Coolant inventory affects the capability to cool the stored fuel, the degree of shielding provided for the operators, and the consequences of postulated fuel handling accidents. Coolant temperature affects operator performance during fuel handling, control of coolant chemistry and radionuclide concentration, generation of thermal stress within structures, and environmental conditions surrounding the SFP. SFPs are designed to maintain a substantial reactivity margin to criticality under all postulated storage conditions. In order for operators to promptly identify unsuitable fuel storage conditions, the spent fuel storage facility must have an appropriate means to notify operators of changes to the conditions in the SFP.

The report detailing the resolution of the SFP action plan was issued in a memorandum to the Commission dated July 26, 1996. Three courses of action were identified to address the concerns raised in the report: (1) plant-specific evaluations and regulatory analyses for safety enhancement backfits, (2) rulemaking, and (3) revision of staff guidance for SFP evaluation. Staff actions to address rulemaking and revision to guidance documents are still under development. The staff has issued SECY-97-168, "Issuance for Public Comment of Proposed Rulemaking Package for Shutdown and Fuel Storage Pool Operation," requesting Commission approval to release for public comment the proposed rule on shutdown operations. Revision of the staff's SFP evaluation guidance documents will be completed by October 1998, as described in our response to the Staff Requirements Memorandum dated October 2, 1996.

Concurrent with the SFP action plan, the staff conducted a compliance review of all licensees' spent fuel storage activities. The results were documented in a memorandum to the Commission dated May 21, 1996. At the time of the review, all plants were found to be in compliance with their licensing basis, or would be before their next refueling outage. The staff also concluded that SFP system design features and licensee operating practices were adequate in assuring protection for public health and safety. However, instances of incomplete or inaccurate documentation in licensee Final Safety Analysis Reports (FSAR) were identified. The staff is developing specific enforcement guidance to address these instances of non-compliance regarding licensees' FSARs.

On February 10, 1996, the Executive Director for Operations directed the Office for Analysis and Evaluation of Operational Data (AEOD) to perform an independent study of the likelihood and consequences of an extended loss of spent fuel pool cooling. The report included a review of the potential for and the consequences of SFP coolant inventory loss due to the failure of the refueling cavity seal. The results of the AEOD study were reported to the Commission in a memorandum dated October 3, 1996. Office of Nuclear Reactor Regulation (NRR) staff reviewed the results of the AEOD study and concluded that they were consistent with the findings of the SFP action plan. However, NRR decided to expand the scope of their SFP action plan followup activities to include a new category for the review of refueling cavity seals. In a memorandum dated February 28, 1997, the staff informed the Commission that additional information regarding the refueling cavity seal designs at certain plants would be gathered to determine whether additional regulatory actions were warranted.

This report provides the results of the plant-specific evaluations and regulatory analyses performed for the 11 design features identified in the July 26 report and the staff's followup memorandum dated February 28, 1997. Overall, 48 of the 108 operating reactors have at least 1 of the following 11 design features of concern:

(1) Absence of Passive Antisiphon Devices on Piping Extending Below the Top of the Stored Fuel

(2) Transfer Tube(s) Within the SFP Rather Than a Separate Transfer Canal

(3) Piping Entering the Pool Below the Top of the Stored Fuel

(4) Limited Instrumentation for Loss-of-Coolant Events

(5) Absence of Leak Detection Capability or Absence of Isolation Valves in Leakage Detection System Piping

(6) Shared Systems and Structures at Multi-Unit Sites

(7) Absence of Onsite Power Supply for Systems Capable of SFP Cooling

(8) Limited SFP Decay Heat Removal Capability

(9) Infrequently Used Backup SFP Cooling Systems

(10) Limited Instrumentation for Loss-of-Cooling Events

(11) Refueling Cavity Seals with Pneumatic Components

Table 1 contains a list of the categories evaluated for this followup activity, the type of evaluation performed (i.e., regulatory analysis or evaluation), the plants identified for each category, and the source document of the design concern (i.e., NRR SFP action plan or the AEOD study on SFP cooling).

2.0 STAFF'S REVIEW OF SFP ISSUES RESULTING FROM THE SPENT FUEL STORAGE ACTION PLAN AND THE AEOD STUDY OF SFP COOLING

The staff sent copies of the resolution of the spent fuel storage action plan to each of the plants identified in the July 26 report and offered these licensees an opportunity to address the issues related to their plants. Most of the licensees took the opportunity to respond to the request. Some licensees informed the staff that they have taken or plan to take voluntary actions that would eliminate the need to conduct the proposed regulatory analysis. Other licensees provided additional information about the design and operation of their plant to address the issues. The staff considered all of the licensees' responses in its evaluation.

Review Methodology

The staff conducted a review for each category in the July 26 report and for the refueling cavity seal issue identified in the staff's memorandum to the Commission dated February 28, 1997. For each review, the staff either: (1) evaluated the licensees' voluntary actions as they applied to the design feature of concern for those licensees committing to voluntary actions, (2) performed a plant-specific screening analysis (probabilistic analysis) as a first step in the regulatory analysis process to determine whether safety enhancements could be justified, or (3) gathered additional information and evaluated the need for further regulatory analysis.

In each of the 11 categories identified for this study, the staff selected one or two plants as the lead plants for that category's review. The lead plant selection was based on plant design. For those plants undergoing regulatory analysis, the lead plant represented the most rigorous tests for the safety enhancement backfit. For those categories requiring further evaluation, plants with the "worst-case" example of the design feature of concern were selected for each category. Lead plants were also selected on the basis that their design features were representative of all plants in their category so that decisions based on the analysis of these lead plants could then be applied to all other plants in the category. If for some reason, a lead plant was eliminated from a category due to voluntary actions by the licensee or through a review of additional information, the next lead plant was selected on the same basis from the remaining plants in that category. If the results of the screening evaluation of a lead plant indicated the need for further regulatory action, additional plants in that category would also be screened.

Plants Taking Voluntary Actions

In response to the staff's July 26 report on the resolution of the SFP action plan, several licensees informed the staff that they intended to perform certain voluntary actions to address the issues identified for their plants (See Table 2). The staff reviewed the proposed actions by the licensees and determined whether the actions addressed the design features of concern. In some cases, the proposed actions by licensees eliminated the need for further regulatory actions for certain categories. The staff will track the licensee's voluntary actions using the Commitment Tracking System to ensure the underlying issue is resolved in a timely manner.

Plant-Specific Regulatory Analysis

The staff's July 26 report concluded that plant-specific regulatory analysis should be performed for seven categories of design issues to determine whether a safety enhancement backfit was warranted. For these categories, a probabilistic analysis was performed as a screening criteria to determine the likelihood of attaining certain predesignated endstates. The staff visited seven plants, the lead plants for 5 of the 7 regulatory analysis categories, to gather plant-specific design and operational information to be used in the probabilistic analyses. For the other two regulatory analysis categories, one issue was resolved solely through voluntary actions by the licensees and the other issue was resolved by performing a probabilistic analysis using information already available to the staff.

Regulatory analyses were performed by first conducting a screening analysis using plant-specific design and operational information. Two endstates were chosen to test the design features under evaluation. For inventory control analyses, an endstate corresponding to a SFP level one foot above the top of the SFP rack was used. For issues related to SFP boiling, an endstate corresponding to sustained boiling in the SFP for greater than 8 hours was used. These endstates chosen for this evaluation represent conservative points in the event sequences where public health and safety was assured (i.e., several magnitudes above the point of exposing fuel or causing a safety system degradation). The endstates were also chosen to be consistent with previous models used by the staff to evaluate SFP events (see the staff's safety evaluation of SFP issues at the Susquehanna plant, dated June 19, 1995).

The staff used probabilistic analyses to determine the frequency of these endstates for the lead plants in each category. An endstate frequency greater than 1×10^{-5}/yr indicated the need to perform further analysis of the design feature, including sensitivity analyses, value-impact analyses, or a deterministic evaluation of the plant's response to the event sequence. An endstate frequency less than 1×10^{-6}/yr indicated that the probability of the event occurring was low and that a safety enhancement could not be justified. For endstates in the range between 10^{-6}/yr and 10^{-5}/yr, engineering judgement based on the margin available was used to determine whether further analysis was necessary.

Plants Requiring Further Evaluation

As a result of the staff's July 26 report and the review of the AEOD study of SFP cooling, the staff identified four categories where further evaluation of certain design features was required to determine whether additional regulatory action was warranted. For the plants in these categories, the staff gathered plant-specific information from the licensees through site visits, information requests, telephone conferences, and by reviewing archived information at the NRC. On the basis of these reviews, the staff made case-by-case determinations regarding the need for further regulatory action.

3.0 RESULTS

3.1 Inventory Control Issues

3.1.1 Absence of Passive Antisiphon Devices on Piping Extending Below the Top of the Stored Fuel

SFPs at four plants (Turkey Point 3 and 4, Robinson, and Davis-Besse) lacked antisiphon devices for piping that could, through improper operation of the system, reduce coolant inventory to a level that provides insufficient shielding and eventually expose the stored fuel. In all cases, the piping is a drain path from the lower portion of the SFP that is no longer used by the licensees. Licensees provide protection against a siphoning event by providing locked-closed valves, providing a low-level alarm, and establishing operator actions to stop the siphon flow and add makeup water. The staff believed that a design modification to introduce passive antisiphon protection for the SFP could be easily implemented at the plants currently lacking this protection. The staff planned to perform a regulatory analysis to determine whether such design modifications could be justified.

The licensees in this category took the opportunity to address this issue in their responses to the NRC. Each licensee provided similar testimony as to why a loss-of-inventory event through this piping should be considered a low likelihood event. The piping at each plant is seismically qualified up to the first isolation valve and exposed to a benign environment and the isolation valve in the piping is normally locked closed and not included in any plant operating procedures. In addition, at the plants reviewed for this category, the lower suction piping connects to the normal suction line for the SFP cooling system which terminates six to twenty feet above the top of the spent fuel racks providing siphon protection if a siphon event occurred. The upper isolation valve on the normal suction line would also have to be mispositioned to threaten the stored fuel, further reducing the probability of a siphon event occurring.

Regardless, the licensees in this category informed the staff that they are making voluntary modifications to their plants to further reduce the likelihood of an inadvertent inventory loss. The modifications to the SFP cooling systems include removing the valve and blanking the pipe or permanently locking closed and removing the valve operator from the piping of concerns. Other controls, for example, tagging the locking devices to alert operators to their significance, are planned to prevent operators from misaligning the valves.

On the basis of these voluntary actions, further regulatory actions are not warranted. The staff will continue to follow the progress of the voluntary actions for the licensees in this category until they are completed.

3.1.2 <u>Transfer Tube(s) Within the SFP Rather Than a Separate Transfer Canal</u>

Transfer tubes are normally open during refueling operations. When these openings are below the top of the stored fuel without a passive design feature to ensure adequate coverage of the stored fuel (e.g., a weir located between the transfer tube and the stored fuel), any drain path from the refueling cavity has the potential to reduce coolant inventory in the SFP to an extent that the stored fuel could be exposed to air. Licensees with SFPs that do not have these passive design features currently provide protection against loss-of-inventory events in the SFP from leakage in the refueling cavity through level alarms, closure of the fuel transfer tube blank flange during reactor operations, and operator actions to isolate the leakage and add makeup water. During the staff's review, which was conducted as part of the SFP action plan, the staff concluded that the relative rarity of a fuel transfer system lacking passive design features to prevent the uncovery of the stored fuel warranted a more detailed review of the system design and the administrative controls at these plants. The staff performed a probabilistic analysis of this issue to determine whether further regulatory analysis would be needed.

SFP designs at five plants (Oconee 1, 2, 3, Crystal River 3, and Maine Yankee) have fuel transfer tubes that enter directly into the pool below the level of the stored fuel with no passive design feature to separate the fuel transfer tube from the stored fuel. Of the five plants, the staff chose to perform this assessment at Oconee because the single SFP that services Units 1 and 2 has four fuel transfer tubes, increasing the frequency of operations with the transfer tube open and maximizing the flow rate out of the pool through the tubes should a large leak or other coolant diversion event occur somewhere in the refueling cavity or the reactor vessel. The staff considered the design of this spent fuel storage system to be a "worst case" compared with the other plants in this category.

The staff conducted a site visit to Oconee to collect plant-specific information regarding the design of the Units 1 and 2 SFP and refueling cavities. This information was used to develop a plant-specific probabilistic analysis to determine the extent to which the Oconee plant design affected the potential for a loss-of-coolant inventory event. The staff considered normal and refueling system configurations in its assessment and estimates for the likelihood for relevant pipe breaks, seismic events, and operator errors.

The staff's assessment found that even with four fuel transfer tubes penetrating directly into the SFP below the level of the stored fuel, because of the minimal amount of piping available to fail and the availability of the transfer tube isolation valve to isolate leaks, the frequency of events resulting in the uncovery of the fuel was estimated to be less than 1×10^{-6}/yr. The probabilistic analysis quantified the frequency of each sequence that led to the endstate resulting in SFP coolant one foot above the top of stored fuel. As a result of the low likelihood that the fuel could be uncovered, the staff considers this design feature to be of relatively low risk-significance. On the basis of this finding, no further regulatory action will be taken on this issue for any of the plants in this category.

3.1.3 Piping Entering the Pool Below the Top of the Stored Fuel

In addition to having transfer tubes that enter directly into the SFP, the three units at Oconee have an interfacing system, a portion of the standby shutdown facility (SSF), that connects to the transfer tube. The normal alignment of the transfer tube during reactor operations is to have the transfer tube isolation valve open to allow the interfacing system to draw water from the SFP under emergency conditions (a blank flange is installed on the transfer tube to maintain containment integrity and to prevent leakage from the SFP). This fuel transfer tube arrangement is unique to Oconee. Pipe breaks or misalignment of the valves supporting the SSF has the potential to drain coolant from the SFP to such an extent that fuel could be exposed to air. The licensee provides protection against events involving this piping through seismic qualification requirements, design features such as a normally closed valve on each SSF line, direct level indication in the SFP, and training operators to take appropriate actions (e.g., isolate the leakage and add makeup water). However, the staff concluded that a safety enhancement modification involving this piping or other spent fuel storage systems may be justified to ensure adequate protection of the stored fuel. A probabilistic analysis of this issue was performed to determine whether further regulatory analysis would be needed.

In the assessment described in Section 3.1.2 of this report, the staff considered the reactor coolant makeup piping that is part of Oconee's SSF. That assessment led the staff to conclude that the piping penetrating the SFP below the stored fuel is of low risk significance. The staff found that loss-of-coolant-inventory events involving the fuel transfer tube and interfacing piping that result in a SFP level one foot above the top of the fuel storage racks had a frequency of less than 1×10^{-6}/yr.

Therefore, as a result of this estimate of the low likelihood of a significant coolant inventory loss in the SFP due to this design feature and consistent with the findings of Section 3.1.2 of this report, the staff considers that further regulatory actions are not warranted.

3.1.4 Limited Instrumentation for Loss-of-Coolant Events

Some facilities have limited instrumentation to reliably alert operators to a loss-of-SFP coolant inventory. Direct SFP level instrumentation is not available to operators at certain plants as an indication of a loss-of-coolant event. Operators use related alarms (e.g., a loss-of-SFP cooling alarm or an alarm for low levels in the SFP cooling surge tanks), operating procedures, and direct observation to provide protection against loss-of-coolant events. The staff performed a probabilistic analysis of this issue to determine whether any safety enhancement backfits to improve the SFP level monitoring capability could be justified under the current guidance.

Seven plants (Big Rock Point, Dresden 2 and 3, Peach Bottom 2 and 3, and Hatch 1 and 2) do not have direct level indication in their SFPs. In response to the staff's task action plan, four of the seven plants are taking voluntary actions to address this issue. At Peach Bottom 2 and 3, the licensee is installing level switches in the SFP that will provide low level alarms locally and in the control room. At Dresden 2 and 3, the licensee is adding administrative controls to site procedures to locally monitor pool level during periods when forced cooling is secured or when AC power is lost. With the SFP cooling system operable at Dresden, level in the SFP can be monitored using the alarms associated with the SFP cooling system.

The staff selected four plants, Hatch 1 and 2 and Dresden 2 and 3, to evaluate whether limited level instrument affected the safe storage of spent fuel. The staff made site visits to these plants to gather plant-specific design information to be used in the probabilistic analysis. Hatch and Dresden were selected because they were representative of all plants in this category. Due to the design of the SFP and associated cooling systems of the plants in this category, conclusions based on the analyses performed for the Hatch and Dresden plants were considered to be applicable to all plants in this category. The staff performed a probabilistic analysis of event sequences dependent on SFP level indication to determine whether a safety enhancement backfit could be justified.

The staff found that for the four plants modeled for this analysis, the total endstate frequency for all sequences resulting in a SFP level one foot above of the top of the spent fuel racks was less than 1×10^{-6}/yr. The analysis took loss-of-cooling sequences without makeup water into consideration, as well as pipe breaks and flow diversions. This low frequency indicates that additional analysis concerning direct SFP level indication would not be cost beneficial. Therefore, the staff will not pursue further regulatory action on this issue for any plants in this category.

3.1.5 Absence of Leak Detection Capability or Absence of Isolation Valves in Leakage Detection System Piping

Coolant inventory loss is not easily isolated following events that breach the SFP liner at facilities that do not provide a method of isolating the liner leakoff system. The limited flow area through leak detection system telltale drains, the low leak rate through the seismically designed concrete structure, controls on movement of heavy loads over the fuel pool, and operator actions (to plug leak detection system drains and add makeup) provide protection at these plants. The staff noted in its report on the resolution of the SFP task action plan that insufficient information was available at the time of the review to evaluate the makeup capability relative to credible leakage through the SFP liner.

Five plants were identified as having an SFP liner leakoff system that lacks a method for isolating a leak (Salem 1 and 2, DC Cook 1 and 2), or as having a liner that does not include a leakoff system (Indian Point 2). Two additional plants (Zion 1 and 2) that do not have liner leakoff isolation capability were identified after the publication of the July 26 report on the resolution of the SFP action plan. A review of the design information for each plant regarding credible leakage and makeup capability was performed by the staff to confirm that this issue had been addressed for these plants. The staff found that for all plants in this category, licensees have performed the necessary evaluations to ensure the available makeup rate to the SFP exceeds the leakage rate for credible leakage scenarios.

On the basis of this assessment, the staff has determined that no further regulatory action is warranted on this issue for any plants in this category.

3.1.6 SFP Loss of Inventory Through Failure of the Refueling Cavity Seal

During refueling operations, refueling cavity seals form a watertight boundary between the reactor vessel and the refueling cavity. The seal is established and the refueling cavity is flooded so that the spent fuel can be transported safely from the reactor vessel to the SFP. Failure of this seal during refueling operations could dramatically lower the inventory level in the SFP.

The staff focused this review on boiling-water reactors (BWRs) with refueling cavity seals that contain pneumatic components. The staff selected BWRs because the refueling cavity is isolated from the SFP through the use of a gate that must be put in place with a building crane. Conversely, pressurized-water reactors transport spent fuel from the refueling cavity to the SFP through a transfer tube that contains a valve that can be closed in the event of a leak. Sudden gross leakage at a BWR, though unlikely, would be difficult to isolate before a significant level decrease would occur in the SFP. In addition, because pneumatic seals must have reliable air supplies to keep the seal from deflating and leaking, it is more likely that a significant leak would occur at plants that have pneumatic seals compared to plants with mechanical seals.

Of the five BWRs with pneumatic refueling cavity seals, three plants (Limerick 1 and 2 and Nine Mile Point 2) were selected for this evaluation. The staff reviewed previous licensing information to determine whether these seals were susceptible to gross leakage or failure that could threaten stored fuel indicating the need for further regulatory actions. Our review focussed on the design of the seal rather than its installation and testing because the seal must be installed and the cavity flooded to the level of the SFP before the refueling cavity is aligned with the SFP. This substantially reduces the risk of a seal failure that has been installed or tested incorrectly affecting the safety of the stored fuel. The cavity seals at the remaining two plants (Susquehanna 1 and 2) were extensively reviewed and accepted by the staff as documented in NUREG/CR-4525, "Closeout of IE Bulletin 84-03: Refueling Cavity Water Seal," dated June 1990, and are similar in design to the seals installed at Limerick 1 and 2.

In response to a refueling cavity seal event at Haddam Neck in 1984, the staff issued Office of Inspection and Enforcement Bulletin (IEB) 84-03, "Refueling Cavity Water Seal." Licensees were required to evaluate the potential for a failure of a refueling cavity seal and provide a summary report to the NRC. IE Information Notice 84-93, "Potential for Loss of Water From the Refueling Cavity," was issued late in 1984 to highlight events in which two failures of pneumatic seals had the potential to drain the refueling cavity. A temporary instruction was also developed in late 1984 to provide guidance for performing reviews and inspections regarding utility responses to IEB 84-03.

The staff issued the findings from IEB 84-03 in NUREG/CR-4525 (June 1990). The study found that the Limerick 1 and 2 refueling cavity seal design uses two pneumatic seals, with keepers (to prevent seal displacement even with a loss of air pressure), one located above the other, in a narrow, fixed outer annulus. The outer annulus is covered with a plate fitted with compressible seals at each edge. The inner seal is a mechanical expandable bellows. Air supplies to the pneumatic seals are redundant. The seals include a leak detection system to alert operators to leakage past the pneumatic components.

Nine Mile Point 2 uses a Presray wedge-type refueling cavity seal design located in a narrow, fixed annular opening. The seal design includes flanges that rest on the edges of the support plates. The annular opening is maintained at a fixed distance to provide interference if the seal becomes dislodged. The corners of the support plates are chamfered at the same angle as the seal so that a wedge effect occurs, becoming tighter as the water pressure above the seal increases. The annulus within which the seal fits extends the full length of the seal thereby preventing the ballooning and hinging of the seal seen at Haddam Neck.

After reviewing the plant designs and supporting documentation submitted by the licensees in response to IEB 84-03, the NRC concluded that the licensees for Limerick 1 and 2 and Nine Mile Point 2 complied with the actions required by the bulletin. The report also came to the following conclusions:

(1) The two major cavity seal leak events at Haddam Neck and Surry 1 were due to design and testing deficiencies unique to each plant.

(2) Most applications of pneumatic seals incorporate the Presray design (e.g., those at Nine Mile Point 2), which uses a solid wedge portion as the primary seal and the inflated portion as the backup seal. The inflated portion acts as the initial sealing mechanism until sufficient head builds up to seal the solid wedge. The success of this design has been adequately demonstrated.

(3) In the few plants with pneumatic seals that do not use the solid wedge design (e.g., Limerick 1 and 2), some other backup means is provided that is obviously adequate or has been tested. For Limerick, this includes a stainless steel coverplate with compressible seals at each edge that covers the refueling cavity seal outer annulus. The coverplate acts to reduce leakage flow through the outer annulus in the unlikely event of a pneumatic seal failure.

In a separate study, the staff issued a generic evaluation of failures of refueling cavity and transfer gate pneumatic seals in NUREG-1353, "Regulatory Analysis for the Resolution of Generic Issue 82, 'Beyond Design Basis Accidents in Spent Fuel Pools,'" dated April 1989. The staff concluded that on the basis of the heightened awareness of refueling cavity seal design, installation, testing and maintenance; of the need for adequate procedures to address seal failures as identified in IEB 84-03; and considering that there is sufficient time available to diagnose a serious seal failure, the best estimate frequency is 3×10^{-8}/reactor-yr of a seal failure resulting in spent fuel damage.

On the basis of the staff's conclusions in NUREG/CR-4525 concerning the acceptability of Nine Mile Point 2 and Limerick 1 and 2 refueling cavity seal designs, this review, and the low probability of a seal failure resulting in spent fuel damage as documented in NUREG-1353, the staff concludes that no further regulatory action is required for the plants in this category.

3.2 Decay Heat Removal Reliability Issues

3.2.1 Shared Systems and Structures at Multi-Unit Sites

At certain multi-unit sites, with one unit being refueled, the decay heat rate in the SFP may be sufficiently high that the pool could reach boiling in a short time following a loss-of-cooling event. Communication between the fuel pool area and areas housing safety equipment supporting the operating unit through shared ventilation systems or shared structures may cause failure or degradation of those systems. Restrictive administrative controls on refueling operations, reliable SFP cooling systems, and operator actions to restore forced cooling and protect essential systems from the adverse environmental conditions that may develop during SFP boiling provide protection at these plants.

The staff identified 13 plants at which SFP boiling may affect safety equipment in an adjoining unit through shared systems and structures. The staff reviewed the configuration of each plant in this category and performed a regulatory analysis of three plants (Hatch 1 and Dresden 2 and 3. Hatch 2 is not included in this category because safety equipment required for the safe shutdown of Unit 2 is not affected by boiling of either Unit 1 or 2 SFPs). These plants were selected because they were representative of all 13 plants in this category. The staff conducted site visits to Hatch and Dresden to gather plant-specific information about the design and operation of the spent fuel storage pool and cooling system. This information was used to perform the probabilistic analysis of the event sequences relevant to this design feature.

To assess the effects of SFP boiling on safety equipment at these plants, an estimation of the frequency of sustained pool boiling event was calculated. The staff calculated the frequency of the endstates (i.e., sustained SFP boiling for a minimum of 8 hours, with or without makeup to the SFP) that would have the capability of producing sufficient heat and water vapor to degrade the operating units' safety equipment. The endstates were chosen at points in the event sequences where public health and safety were assured. The staff calculated the frequency for these event sequences as a screening measure for this analysis. A sustained boiling frequency of approximately 10^{-6}/yr was the basis to decide whether to perform further analyses. Sustained boiling frequencies of greater than 1×10^{-5}/yr indicate the need to perform further analyses. However, sustained boiling frequencies of 1×10^{-6}/yr or less indicate that the frequency of these events is sufficiently low that even the lowest cost safety enhancements could not be justified. The staff used engineering judgement to determine whether further analysis was necessary for those sites where the sustained boiling frequency was calculated to be between 10^{-6}/yr and 10^{-5}/yr. Initiating event sequences that were considered in this evaluation included the loss-of-SFP cooling system, seismic events, and loss of offsite power.

The results of the evaluation indicated that there is a low likelihood of events that result in sustained boiling for Dresden 2 and 3. The analyses concluded that the frequency for events resulting in sustained boiling was 4.3×10^{-6}/yr. This low frequency was primarily attributable to the reliability of the systems that provide cooling to the SFP. The Dresden SFP cooling system has pumps that receive power from an emergency onsite power source, and SFP cooling can be supplied from the Shutdown Cooling System which also receives backup power from an emergency onsite source.

In its response to the staff's July 26 report on the resolution of the SFP action plan, the licensee for Dresden provided an analysis of the effects of sustained SFP boiling on safety equipment in shared spaces, indicating that high humidity and temperature could threaten the equipment required to mitigate a loss-of-coolant accident (LOCA) in an operating unit. However, the licensee noted that the SFP cooling systems, which include normal SFP cooling and shutdown cooling in the SFP cooling assist mode, are very reliable because of their redundant power supplies (i.e., two offsite sources, plus five onsite sources). The cooling systems' reliability, combined with the low probability of a concurrent LOCA plus a loss of offsite power event, makes the likelihood of a sustained SFP boiling event that affects safety equipment in the reactor building a low frequency event. The staff reviewed the licensee's evaluation, and based on our own independent probabilistic analysis, agreed with their conclusions.

For Hatch 1 and 2, the sum of event sequences that result in sustained boiling had a frequency of 4.4 x 10^{-4}/yr. Event sequences resulting in evaporative cooling in the SFP was the dominated contributor. Because this frequency exceeded the staff's screening criteria, additional analysis was required.

The staff found that the sustained boiling frequency for Hatch was dominated by an event sequence in which both units are initially operating. During plant operation, the non-safety related Spent Fuel Pool Cooling (SFPC) system provides cooling to the Units 1 and 2 SFPs. The Alternate Decay Heat Removal (ADHR) system, with its normal power supplied by a separate switchyard from the SFPC systems, is also available to provide SFP cooling. With neither unit in refueling, however, ADHR is not required to have its portable backup diesel generator available. An extended loss of offsite power that disables both plant switchyards would render both the SFPC and ADHR systems inoperable. The Residual Heat Removal (RHR) system can be aligned in the Fuel Pool Cooling Assist mode to provide cooling to the stored fuel, but at Hatch, this mode can only be used if the reactor vessel is aligned with the SFP in a refueling configuration. Therefore, fuel pool cooling assist mode of RHR would not be available during an extended loss of offsite power with both units configured for operation.

Several factors affect the probability of a sustained boiling event that were not included in the staff's probabilistic analysis. During normal plant operation, there is a lower decay heat load in the SFP and a longer time-to-boil compared with refueling operations. In the staff's analysis, no credit was given for any contingency actions by the licensee, such as supplying temporary power to the SFP cooling pumps during an extended power outage, or obtaining a portable diesel for the ADHR system, either of which would restore cooling to the SFP. Either of these contingency actions would lower the frequency of a sustained SFP boiling event. The staff calculated the frequency of sustained boiling during refueling at Hatch with a full core offload in one SFP, and with the alternate decay heat removal system in operation including its dedicated diesel generator aligned and ready for use, was approximately 9 x 10^{-6}/yr. This frequency is more consistent with the results found at Dresden. In addition, due to the extended time-to-boil at these lower decay heat loads, critical safety equipment required for safe shutdown of an operating unit should have completed its required safety functions or can be otherwise protected from the effects of the boiling pools before degradation occurs.

Regardless, the staff reviewed the effects of pool boiling on safety equipment located in shared structures. The licensee for Hatch provided an evaluation of the safety-related equipment located on the refueling floor and in the Unit 1 reactor building that could be exposed to high temperature and humidity during a pool boiling event, as well as an evaluation of the effects of flooding due to the spread of condensation throughout these spaces. The temperature and humidity qualification of the equipment was compared with the expected environment for a sustained boiling event in the SFP. Based on the existing environmental qualification of this equipment and the relatively mild environment created by the sustained boiling event, the licensee determined that it was unlikely that any safety equipment required for the safe shutdown of an operating unit would be adversely affected. The licensee also provided an analysis based on conservative assumptions of the effects of flooding due to the condensation of vapor from the boiling SFPs and concluded that adequate equipment was available for the safe shutdown of the plant. The staff reviewed the licensee's evaluations and agreed with their conclusions.

Initially, the staff selected Hatch and Dresden as lead plants for this issue because they were representative of the other plants in this category. During this review, it became apparent that the evaluations for the shared systems and structures issue were complex and plant-specific and that the results of evaluations should not be applied to the other plants in this category without further review. After reviewing the results of the Dresden and Hatch evaluations, the staff determined that plants having SFP cooling systems with backup power from onsite sources have a low likelihood of sustained boiling. Plants without onsite backup power for the SFP cooling system should receive further evaluation to determine the frequency of sustained boiling events.

The staff reviewed design features for the remaining ten plants in this category and found that eight plants have SFP cooling systems with onsite backup power. The two remaining plants (LaSalle 1 and 2) have the capability to supply onsite backup power to the SFP cooling system pumps, however, critical valves within each units' SFP cooling system have control power circuits that are not powered from onsite sources and would fail shut during a loss-of-offsite-power event, rendering the SFP cooling system inoperable.

In their response to the staff's July 26 report, the licensee for LaSalle acknowledged this condition and informed the staff that they are taking voluntary actions to ensure the control circuits in the unit experiencing the loss of offsite power will be supplied power from the other unit's nonsafety-related source. These actions would restore the valves' function in the event of a plant-centered loss of offsite power. However, should a grid-related loss-of-offsite-power event occur, both units' control power circuits would become de-energized disabling both SFP cooling systems. The staff has determined that this configuration, unique to LaSalle, warrants further analysis to determine whether a safety enhancement is warranted.

Based on these findings, the staff has determined that no further regulatory action is warranted for eleven plants in this category. However, for LaSalle 1 and 2, the staff will continue its regulatory analysis to determine whether a plant-specific safety enhancement can be justified.

3.2.2 Absence of Onsite Power Supply for Systems Capable of SFP Cooling

A sustained loss of offsite power at plants without an onsite power supply for SFP cooling may lead to departure from subcooled decay heat removal in the fuel pool, increased thermal stress in pool structures, loss of coolant inventory, increased levels of airborne radioactivity, and adverse environmental effects in areas communicating with the SFP area. Operator actions to align a temporary power supply from an onsite source or establish alternate cooling such as feed and bleed using a diesel-powered pump, high temperature alarms, filtered ventilation, and separation and isolation of areas containing equipment important to safety from the SFP area provide protection at these plants. To address this category, the licensee's capability to supply onsite power to the SFP cooling system relative to the time available for recovery actions was evaluated relative to the risks of a loss of all cooling.

Seven plants (Surry 1 and 2, Prairie Island 1 and 2, ANO 2, and Zion 1 and 2) were identified in the staff's report on the resolution to the SFP action plan as not having onsite power available to a system available to cool the SFP. Licensees for four of the plants (Surry 1 and 2 and Prairie Island 1 and 2), notified the staff of their intentions to install backup power to their SFP cooling system pumps from an onsite source. Of the three plants remaining, the staff selected Zion 1 and 2 for review because it was representative of the remaining plant in this group.

During initial licensing, the staff reviewed the design of plants without backup power to the SFP cooling system pumps and found that the use of evaporative cooling as a backup method for SFP cooling was acceptable, provided sufficient makeup was available to maintain SFP coolant inventory. Although evaporative cooling is an available method of backup SFP cooling at these plants, it has never been used. Operating the SFP at elevated temperatures for evaporative cooling results in some adverse consequences that do not otherwise affect the safety of the stored fuel. These consequences include the inability to operate the SFP cleanup system, effects on plant operations resulting from high temperature and humidity in the spent fuel building, and long-term effects of elevated SFP temperature on the pool's concrete structure.

In response to the resolution of the SFP action plan, the licensee for Zion 1 and 2 provided an analysis that concludes that an extended loss of offsite power event combined with a failure to establish makeup to the SFP is a low probability event. The licensee calculated the frequency of this event sequence to be 2.1×10^{-6}/yr. Their evaluation did not credit their operators with any extraordinary actions, such as connecting emergency power to the SFP cooling pumps, even though sufficient time may be available to perform such actions. If the probability of a failure to connect emergency power to the pumps were considered, the licensee estimated the frequency of this event sequence to be less than 1×10^{-6}/yr.

The staff reviewed the licensee's evaluations and performed independent calculations which confirmed the licensee's conclusions for Zion. The staff found that the low frequency of an extended loss of offsite power combined with a failure to establish makeup to the SFP was primarily based on the reliability of the SFP makeup systems and the low non-recovery probability for loss of offsite power. The staff reviewed the design of the remaining plant in this category, ANO 2, and concluded that, due to the similarity in the design of the systems that support the storage of spent fuel, the results of the probabilistic analysis performed for Zion are representative of ANO 2.

On the basis of the low likelihood of a sustained loss of offsite power, the redundant makeup systems available to compensate for a boiling event, and the design of the spent fuel storage systems that have been analyzed for boiling, the staff has determined that no further regulatory action for any plants in this category is warranted.

3.2.3 Limited SFP Decay Heat Removal Capability

Assuming a full core discharge at an equivalent time after reactor shutdown during a period of peak ultimate heat sink temperature, some plants have higher SFP equilibrium design temperatures and shorter design recovery times than other similar plants. Licensees use administrative controls on refueling operations to ensure that spent fuel temperatures are controlled within the appropriate limits. The staff has previously reviewed and approved the designs of these systems, however, the relatively high equilibrium design temperatures and short recovery times compared with other similar plants indicated the need for further review. The staff examined the administrative controls with respect to SFP temperature and available recovery time to determine the need for further actions.

The staff identified four plants (Indian Point 2 and 3, Salem 1 and 2) that have SFP cooling systems with limited decay heat removal capabilities. The staff reviewed design calculations; normal, abnormal and emergency operating procedures; and annunciator response procedures and held discussions with the licensee's SFP cooling system engineers to determine how these systems are actually operated compared with the assumptions and calculations used for their design.

Most spent fuel storage systems include a cooling system with a relatively large heat capacity designed to maintain the SFP temperature below 150 °F under all offload conditions, including the failure of a single active component. The four plants included in this category have relatively low cooling capacities. Under design conditions, which include the maximum decay heat load possible, ultimate heat sink temperature at its maximum design temperature, and the failure of a single active component, the SFP equilibrium temperature was calculated as high as 205 °F. Higher equilibrium temperatures in the SFP limit the capability of the licensee to operate the SFP cleanup system and reduce the available time operators have to make provisions to add makeup water to the pool in the event of a sustained loss of cooling. High SFP temperatures also create operational problems for operators during refueling because of the high temperature and humidity in the fuel building.

The staff reviewed operating practices and procedures from three of the four plants (Salem 1 and 2, Indian Point 2) in this category to determine whether additional administrative controls were warranted. The staff also conducted telephone interviews with site personnel to determine the actual operating conditions under which refuelings are conducted.

Based on the conversations with the licensees contacted for this issue, administrative controls are used to limit the temperature in the SFP. The licensees indicated that pool temperature at these sites have been consistently maintained below SFP cooling system alarm setpoints, normally less than 130 °F, even under full core offload conditions.

Each licensee has procedures that direct their operators to take actions early in loss-of-cooling events to ensure temperature limits in the SFP are not exceeded. SFP high temperature alarms are typically set well below design and licensing limits to allow operators sufficient time to address any degraded conditions. Procedures require operators to take action to isolate the SFP cooling purification system and resolve the cooling inadequacy as SFP temperatures approach alarm setpoints. In some cases, operators are required to align makeup water to the pool if cooling is lost for an extended period, well in advance of pool boiling. The staff found that requiring operators to take mitigative actions to restore cooling at temperatures well below design temperatures, and make preparations to add makeup water early in a loss-of-cooling event ensures that operators will have sufficient time to establish makeup and reduces the likelihood that boiling could occur without makeup water available.

Both licensees interviewed for this issue took additional measures that ensure significant margin to SFP temperature design limits. Though not required, these licensees typically perform their refuelings in colder months to take advantage of the additional cooling from low ultimate heat sink temperatures. Although system design calculations at one plant in this category indicated that the SFP temperature could exceed 180 °F under design conditions with a full core offload, the practice of offloading when ultimate heat sink temperatures are low enables the licensee to maintain the SFP temperature below 125 °F. In addition, preventive maintenance and repairs to the cooling system are typically performed just before the refueling outage when the SFP decay heat load is low so that system malfunctions are minimized during refueling. These practices and others are not exclusive to the licensees in this category but are commonly used throughout the industry to minimize risk during shutdown operations.

In addition, the staff is currently developing a proposed rule for shutdown operations that would provide clarification and improvements in the way licensees provide administrative control over the management of decay heat.

On the basis of our review of these plant-specific practices and procedures regarding the management of decay heat during shutdown operations, and due to the staff's current actions regarding the development of proposed shutdown regulations, the staff has determined that there is no need to pursue further regulatory analysis for any of the plants in this category.

3.2.4 <u>Infrequently Used Backup SFP Cooling Systems</u>

Infrequently operated backup cooling systems are relied on at plants in this category more than other similar plants because of the absence of an onsite power supply for the primary SFP cooling system or the low relative capacity of the primary cooling system. Administrative controls on refueling operations and availability of backup SFP cooling capability ensure that adequate cooling is available for the spent fuel. The staff examined the administrative controls on the availability of the backup cooling systems during refueling and technical analyses demonstrating the capability of these backup systems to determine the need for further regulatory analyses.

The staff performed a plant-specific review of this issue for four plants (Dresden 2 and 3, and Hatch 1 and 2). These plants were selected because they were determined to be representative of the six other plants in this category. These plants use a permanently installed backup system to augment SFP cooling during periods of high decay heat in the pool or during periods of maintenance when SFP cooling or other support systems are unavailable. Because these backup systems normally perform other functions or are staged in dry layup, the staff reviewed the licensees' administrative procedures for the control and use of these systems. In addition, the staff verified the capability of one backup system to perform its function as described in the licensee's final safety analysis report (FSAR).

The staff found that the licensees reviewed for this study manage decay heat using an outage safety assessment in a manner consistent with NUMARC 91-06, "Guidelines for Industry Actions To Assess Shutdown Management." Outage safety assessments provide methods for documenting the availability of systems and components that provide adequate core and fuel pool cooling, provide emergency power supplies, and provide containment. Systems available to provide primary and backup SFP cooling are identified to the operational staff through this assessment and are updated as conditions change throughout the outage period.

The staff also found that systems relied upon to provide augmented cooling to the SFP under the high heat load conditions associated with refueling at the plants in this category were aligned, inspected, and tested before the licensee began the transfer of fuel assemblies. Often these systems require spool-pieces or special system alignments to provide this cooling function. Requirements to prepare these backup systems for use were contained in the appropriate refueling procedures.

However, at one site, the licensee found that the backup cooling system could not provide the required flow rate to the SFP as described in the FSAR. The licensee performed an operability determination to verify that the actual flow of the backup cooling system would provide sufficient cooling to keep the stored fuel below its temperature limits under design conditions. The licensee found that the original design calculations were conservative and that the actual system flow rate provides sufficient cooling to the stored fuel under design conditions. The licensee plans to update its FSAR with the latest design parameters and the results of the updated calculations, as appropriate.

On the basis of the staff's findings that the backup cooling systems are used regularly during refueling outages, the systems are aligned and tested by administrative procedures before the commencement of fuel offload, and administrative controls are in place to manage decay heat during refuel periods, the staff has determined that no further regulatory action is required on this issue.

3.2.5 Limited Instrumentation for Loss of Cooling Events

The capability of instrumentation to alert operators to a sustained loss of SFP cooling is limited at certain plants. Fuel storage pools at most sites have direct temperature indication. However, some sites rely on temperature indication in the SFP cooling and cleanup system (SFPCCS) to provide an indication of the temperature of the coolant in the pool. A loss of flow in the SPFCCS would prevent operators from monitoring the temperature of the pool and could lead to delays in identifying a loss-of-cooling event. Related alarms, along with operating procedures, and operator identification would provide protection for the stored fuel if a loss-of-cooling event occurred. The staff evaluated this issue to determine whether additional instrumentation or operational controls were warranted on a safety enhancement basis at these plants.

The staff identified 10 plants (ANO 1, Big Rock Point, Brunswick 1 and 2, Cooper, Hatch 1 and 2, LaSalle 1 and 2, and Millstone 1) that had limited temperature instrumentation for loss-of-cooling events and selected the Hatch facility for this assessment because the Hatch plant configuration was representative of the other plants in this category and it also had other design features being evaluated as part of this study. The staff visited the site to document the instrumentation and procedures available to the operators to control and monitor cooling of the stored fuel in the SFP so that they could be used to construct a plant-specific probabilistic analysis. This information was used to assess the effects of having limited temperature indication during loss-of-cooling events.

The probabilistic analysis performed at Hatch indicated a low likelihood of sustained loss-of-cooling events and loss-of-inventory events. The staff found no indication that the lack of direct temperature indication significantly increased the likelihood associated with identifying or mitigating loss-of-cooling events in the SFP. Alternate instrumentation available to operators provides indication and alarm (e.g., SFP cooling and cleanup temperature indication). Administrative controls that are put in place when SFP cooling is secured or becomes otherwise disabled (e.g., installing temporary temperature indication in the pool if cooling is lost for a significant period) provide adequate information to operators concerning the status of pool cooling.

On the basis of the available alternate instrumentation, administrative controls, and the low frequency of loss-of-cooling events and loss-of-inventory events associated with the lack of direct temperature instrumentation for the SFP, the staff has determined that further regulatory actions on this issue are not warranted.

4.0 SUMMARY

The staff has completed its actions to perform plant-specific evaluations and regulatory analyses of issues that were identified in the resolution of the SFP action plan and the AEOD study on SFP cooling and provides the following summary of issues and resolutions.

In their response to the staff's report dated July 26, 1996, 12 licensees volunteered to perform actions ranging from procedural changes to plant modifications. A list of these licensees and their proposed actions is presented in Table 2. The staff reviewed the licensees' voluntary actions and agreed that they address the issues identified in the staff's July 26 report for their respective plants. The staff will track the licensees' actions using the Commitment Tracking System to ensure the underlying issue is resolved in a timely manner.

For the four plants in the category "Absence of Passive Antisiphon Devices on Piping Extending Below the Top of the Stored Fuel," the proposed actions by these licensees, which include modifications to the plants (e.g., valve removal or installation of a permanent locking device) and administrative controls that further reduce the probability that these valves could be inadvertently operated, resolve the staff's concerns on this issue. Therefore, no further regulatory action is warranted.

For the categories "Transfer Tube(s) Within the SFP Rather Than a Separate Transfer Canal," and "Piping Entering the Pool Below the Top of the Stored Fuel," Oconee was evaluated because it has the most transfer tubes penetrating the SFPs, and is the only site that has an interfacing system. The results of the staff's probabilistic analysis indicated a low likelihood (less than 1×10^{-6}/yr) that stored fuel could become uncovered, indicating that this design feature is of relatively low risk-significance. On this basis, no further regulatory action will be taken for the plants in this category.

The staff's evaluation of the "Limited Instrumentation for Loss-of-Coolant Events " and "Limited Instrumentation for Loss of Cooling Events," determined that no event sequence resulted in a SFP level one foot above the top of the fuel storage racks with a frequency greater than 1×10^{-6}/yr, and there was no indication that the lack of direct temperature indication significantly increased the likelihood associated with identifying or mitigating loss-of-cooling events in the SFP. Also, alternate instrumentation and administrative controls are available to operators to provide information concerning the status of pool cooling. Therefore, no further regulatory actions will be taken for the plants in these categories.

For the five plants in the category of "Absence of Leak Detection Capability or Absence of Isolation Valves in Leakage Detection System Piping," the staff found that the licensees performed the necessary evaluations to ensure that the available makeup rate to the SFP exceeded the leakage rate for credible leakage scenarios. Therefore, no further regulatory action is warranted.

The category entitled "SFP Loss of Inventory Through Failure of the Refueling Cavity Seal" was added to this study as a result of AEOD's review of SFP cooling. The staff evaluated the design and licensing of three BWR refueling cavity seals, and found that no further regulatory action is warranted regarding this design feature. The staff based this finding on the staff's conclusions in NUREG/CR-4525 concerning the acceptability of the refueling cavity seal designs at Nine Mile Point 2 and Limerick 1 and 2, the results of this review, and the low probability of a seal failure resulting in spent fuel damage as documented in NUREG-1353.

The staff performed regulatory analyses for three of thirteen plants in the category "Shared Systems and Structures at Multi-Unit Sites," and reviewed the designs of the other ten plants to ensure that the results of the regulatory analysis were applicable to these plants. The staff found that at plants where the systems cooling the SFP have backup power from onsite sources, there is a low likelihood of events that result in the sustained boiling of the SFP. Because Hatch does not supply backup power from an onsite source to their available SFP cooling systems during normal plant operation, the staff evaluated the effects of sustained boiling on equipment required for the safe shutdown of the reactor. The staff found that the qualification of this equipment exceeded the expected environment created by boiling in the SFP and that potential flooding caused by condensation would not threaten any vital equipment. During the review of the remaining plants in this category, the staff determined that LaSalle 1 and 2 may experience sustained boiling during certain loss-of-offsite-power events, and that further evaluation is necessary to determine whether a plant-specific safety enhancement is warranted. For the other eleven plants in this category, the staff has determined that further evaluation is not warranted.

The staff found that no further regulatory action was necessary for the category "Absence of Onsite Power Supply for Systems Capable of SFP Cooling" on the basis of the low likelihood of a sustained loss of offsite power, the redundant and reliable makeup systems available to compensate for a boiling event, and the design of the spent fuel storage systems that have been analyzed for boiling.

For the four plants that have SFP cooling systems under the category "Limited SFP Decay Heat Removal Capability," the staff found that there is no need to perform any further regulatory analysis based on existing licensee practices and procedures for managing decay heat in the SFP. Even though the plants in this category are susceptible to relatively high SFP temperatures due to the design of their spent fuel storage systems, the staff found these licensees employ practices to limit the SFP temperatures to below the SFP cooling system alarm setpoints which are set significantly below design limits and have administrative controls in place to add makeup water early in a loss-of-cooling event. The staff is also in the process of formulating regulations to clarify and improve the way licensees manage decay heat during shutdown operations.

Four plants were evaluated under the category "Infrequently Used Backup SFP Cooling Systems." The staff found that these backup cooling systems are used regularly during refueling outages, that the systems are aligned and tested by administrative procedures before the commencement of fuel offload, and that administrative controls used manage decay heat during refuel periods. At one dual unit site, however, the staff found that the backup system could not provide the cooling flow rate described in the FSAR. The licensee has performed the necessary calculations to ensure the system is capable of providing adequate cooling to the SFP and will update their FSAR. Based on these findings, the staff found no need to pursue further regulatory action.

The staff has completed its actions to perform the evaluations and regulatory analyses identified in our July 26 report to the Commission on resolution to the SFP action plan. Other planned actions identified in resolution to the SFP action plan report, which include rulemaking and revising the staff guidance for SFP evaluations, are still under development. The staff has issued SECY-97-168, "Issuance for Public Comment of Proposed Rulemaking Package for Shutdown and Fuel Storage Pool Operation," requesting Commission approval to release for public comment the proposed rule on shutdown operations. Revision of the staff's SFP evaluation guidance documents will be completed by October 1998, as described in our response to the Staff Requirements Memorandum dated October 2, 1996.

TABLE 1
SFP DESIGN FEATURES IDENTIFIED IN THE JULY 26 REPORT

Category	Review	Plant	Source
Absence of Passive Antisiphon Devices on Piping Extending Below the Top of the Stored Fuel	Regulatory Analysis	Robinson, Davis-Besse, Turkey Point	NRR
Transfer Tube(s) Within the SFP Rather Than a Separate Transfer Canal	Regulatory Analysis	Oconee*, Crystal River, Maine Yankee	NRR
Piping Entering the Pool Below the Top of the Stored Fuel	Regulatory Analysis	Oconee*	NRR
Limited Instrumentation for Loss-of-Coolant Events	Regulatory Analysis	Dresden*, Hatch*, Big Rock Point, Peach Bottom	NRR
Absence of Leak Detection Capability or Absence of Isolation Valves in Leakage Detection System Piping	Additional Information	Indian Point 2, Salem, D.C. Cook	NRR
Shared Systems and Structures at Multi-Unit Sites	Regulatory Analysis	Dresden*, Hatch 1*, Calvert Cliffs, D.C. Cook, LaSalle, Point Beach, Quad Cities	NRR
Absence of Onsite Power Supply for Systems Capable of SFP Cooling	Regulatory Analysis	Zion, ANO 2, Prairie Island, Surry	NRR
Limited SFP Decay Heat Removal Capability	Additional Information	Indian Point 2, Salem	NRR
Infrequently Used Backup SFP Cooling Systems	Additional Information	Dresden*, Hatch*, Browns Ferry, Davis-Besse, Fermi, FitzPatrick, WNP-2	NRR
Limited Instrumentation for Loss-of-Cooling Events	Regulatory Analysis	Hatch*, ANO-1, Big Rock Point, Brunswick, Cooper, LaSalle, Millstone	NRR
Refueling Cavity Seals with Pneumatic Components	Additional Information	Limerick, Nine Mile Point 2	AEOD

Notes:

1. The underlined plant(s) was selected as the lead review plant(s) for each category. Design features at these plants represented the most rigorous backfit tests for the regulatory analysis categories. Site visits were conducted at plants designated with an asterisk (*).

2. NRR: Resolution of the Spent Fuel Storage Pool Action Plan Issues, July 26, 1996.
   AEOD: Assessment of Spent Fuel Cooling, October 3, 1996.

TABLE 2
SFP REGULATORY ANALYSIS LICENSEE VOLUNTARY ACTIONS

Plant Name	*SFP Issue (see notes)*	*Voluntary Actions Described in Submittal*
Crystal River	2	Procedural revisions are to be made to assure that fuel transfer canal and fuel transfer tube drain valves are closed and locked prior to removal of fuel transfer covers. Procedures will be revised to specify order of equipment removal for fuel transfer operations
Davis-Besse	1	For issue 1 (siphon), licensee plans to lock closed or remove handwheel from valve to prevent potential misoperation. Licensee feels that back-up systems are adequate.
Dresden 2 and 3	4	Administrative controls to locally monitor SFP level during periods without forced SFP cooling or during a loss of AC power will be included in site procedures.
LaSalle 1 and 2	10	Licensee will either perform a modification to provide control power from either unit's normal offsite power, 6.9 kV supply, or proceduralize a method to restore power to the control circuit in the event of a loss of offsite power.
Oconee 1, 2 and 3	2,3	Licensee has committed to upgrading procedures to clarify event sequences for fuel transfer preparation activities.
Peach Bottom	4	Licensee plans to install low-level switches in the SFP which would alarm locally and provide a general SFP trouble alarm in the main Control Room. Switches to be installed by September 30, 1997.
Prairie Island 1 and 2	7	Licensee has modified the SFP cooling system to include a power supply from an onsite safety-related source.
Robinson	1	Licensee plans to blank the piping from the spent fuel pool to prevent siphoning. Modifications to the piping are expected to be completed by September 1997.
Salem 1 and 2	8	Commitments made in August 2, 1996 letter to develop enhanced administrative controls for SFP Decay Heat Load Management
Surry 1 and 2	7	Surry has changed (lowered) SFP high temp alarm setpoint, added procedural controls to provide further actions to restore SFP cooling in the event of LOOP, and initiated a design change to provide emergency power to SFP cooling pumps. Licensee will notify the staff of the finalization of the design change.
Turkey Point 3 and 4	1	The licensee has welded a chain around the valve in question to permanently lock it shut. In addition there are administrative controls and a tag on the valve which warns that it cannot be opened without the approval of the Plant General Manager and Licensing Manager.
Zion	7	Licensee has committed to modify procedures to more specifically identify the work necessary to provide the temporary power to the SFP Cooling water pumps. In addition, dedicated and staged cabling and other required equipment will be provided. Procedure AOP-6.4 will be revised to account for the removal of the block wall between the Fuel Handling Building and Containment. Licensee maintains that adequate make-up is available to maintain pool level, should maximum leakage occur via the leakage detection system.

Notes:
<u>SFP Issues</u>:
1. Absence of Passive Antisiphon Devices on Piping Extending Below Top of Stored Fuel
2. Transfer Tube(s) Within SFP Rather Than Separate Transfer Canal
3. Piping Entering Pool Below Top of Stored Fuel
4. Limited Instrumentation for Loss of Coolant Events
5. Absence of Leak Detection Capability or Absence of Isolation Valves in Leakage Detection System Piping
6. Shared Systems and Structures at Multi-Unit Sites
7. Absence of On-site Power Supply for Systems Capable of SFP Cooling
8. Limited SFP Decay Heat Removal Capability
9. Infrequently Used Backup SFP Cooling Systems
10. Limited Instrumentation for Loss of Cooling Events