50-219

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

September 23, 1996

Mr. Michael B. Roche
Vice President and Director
GPU Nuclear Corporation
Oyster Creek Nuclear Generating Station
Post Office Box 388
Forked River, New Jersey 08731

SUBJECT: RESOLUTION OF SPENT FUEL STORAGE POOL SAFETY ISSUES: ISSUANCE OF FINAL REPORT, OYSTER CREEK NUCLEAR GENERATING STATION (TAC NO. M88094)

Dear Mr. Roche:

The Nuclear Regulatory Commission staff recently completed a detailed review of spent fuel storage pool safety issues. The results of the staff's review are documented in a report to the Commission which is enclosed for your information. In the report, the staff concludes that existing structures, systems, and components related to the storage of irradiated fuel provide adequate protection of public health and safety.

Notwithstanding this finding, the staff has also identified certain design features that reduce the reliability of spent fuel pool decay heat removal, increase the potential for loss of spent fuel coolant inventory, or increase the potential for consequential loss of essential safety functions at an operating reactor. The staff intends to conduct plant-specific regulatory analyses to evaluate potential safety enhancement backfits pursuant to 10 CFR 50.109(a)(3) at a number of operating plants that possess one or more of these design features.

Although Oyster Creek Nuclear Generating Station is not identified for a plant-specific safety enhancement backfit analysis by the staff, it is requested that you review the enclosed report for applicability to your facility and consider actions, as appropriate, related to the design of spent fuel pool decay heat removal systems at your facility. This letter does not require any response.

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If you have any questions regarding this matter, please do not hesitate to contact Ronald B. Eaton at (301) 415-3041.

Sincerely,

(Original Signed By)

Ronald B. Eaton, Senior Project Manager
Project Directorate I-2
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Docket No. 50-219

Enclosure: Memo to the Commission, from J. Taylor, "Resolution of Spent Fuel Storage Pool Action Plan Issues," dated July 26, 1996

cc w/enclosure: See next page

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cc w/enclosure: See next page

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

July 26, 1996

MEMORANDUM TO: Chairman Jackson
Commissioner Rogers
Commissioner Dicus

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: RESOLUTION OF SPENT FUEL STORAGE POOL ACTION PLAN ISSUES

In a meeting with Chairman Jackson on February 1, 1996, regarding spent fuel pool issues, the staff committed to prepare a course of action for resolving significant issues developed through the staff's Task Action Plan for Spent Fuel Storage Pool Safety. The significant issues examined within the framework of that plan were the reliability of spent fuel pool decay heat removal and the maintenance of an adequate spent fuel coolant inventory in the spent fuel pool. The staff was also directed to identify plant-specific and generic areas for regulatory analyses in support of further regulatory action.

The staff has completed its review and evaluation of design features related to the spent fuel pool associated with each operating reactor. Details of the staff's review and evaluation are presented in the attached report. The staff classified operating reactors on the basis of specific design features associated with the spent fuel pool in the following areas: coolant inventory control, coolant temperature control, and fuel reactivity control.

In comparing design features with NRC design requirements and guidance, the staff determined that design features related to coolant inventory control and reactivity control were more consistent with NRC guidance than were design features associated with coolant temperature control. The staff concluded that coolant inventory control design features were more consistent with present guidance because the staff had issued explicit guidance for prevention of coolant inventory loss in the form of design criteria before it issued most construction permits for currently operating reactors. These criteria are documented in plant specific AEC Design Criteria in each affected facility's safety analysis report; in the General Design Criteria of Appendix A to 10 CFR Part 50, which became effective in 1971; and in Safety Guide 13 (now Regulatory Guide 1.13), "Spent Fuel Storage Facility Design Basis," which was issued in March 1971. The staff concluded that reactivity control provisions are consistent because nearly all operating reactors have increased their spent fuel pool storage capacity since the NRC issued specific guidance for reactivity control, and such increases involve design and analysis of new fuel storage racks for criticality prevention. Conversely, the NRC staff did not issue specific guidance on the design of spent fuel pool cooling systems until the issuance of the Standard Review Plan (NUREG-75/087) in 1975, which was

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Attachment 1

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after the issuance of most construction permits for currently operating reactors, and spent fuel storage capacity increases have seldom involved a sufficient increase in decay heat generation that an expanded cooling system was warranted.

The staff has found that existing structures, systems, and components related to storage of irradiated fuel provide adequate protection for public health and safety. Protection has been provided by several layers of defenses that perform accident prevention functions (e.g., quality controls on design, construction, and operation), accident mitigation functions (e.g., multiple cooling systems and multiple makeup water paths), radiation protection functions, and emergency preparedness functions. Design features addressing each of these areas for spent fuel storage have been reviewed and approved by the staff. In addition, the limited risk analyses available for spent fuel storage suggest that current design features and operational constraints cause issues related to spent fuel pool storage to be a small fraction of the overall risk associated with an operating light water reactor. Notwithstanding this finding, the staff has reviewed each operating reactor's spent fuel pool design to identify strengths and weaknesses, and to identify potential areas for safety enhancements.

The staff plans to address certain design features that reduce the reliability of spent fuel pool decay heat removal, increase the potential for loss of spent fuel coolant inventory, or increase the potential for consequential loss of essential safety functions at an operating reactor. We intend to pursue regulatory analyses for safety enhancement backfits on a plant-specific basis pursuant to 10 CFR 50.109 at the small number of operating reactors possessing each particular identified design feature. The specific plans for safety enhancement backfits and their bases are described in the attached report. Because of the relatively low safety significance of these issues, the staff recognizes that some, or all, of these potential enhancements may not pass the backfit tests.

The staff will provide the attached report to the licensees of all operating reactors. The staff intends to request that those licensees identified in the report for plant-specific regulatory analysis verify the applicability of the staff's findings and conclusions. The staff will also request that licensee's provide, on a voluntary basis, their perspective on the potential increase in the overall protection of public health and safety and information regarding the cost of potential modifications to address the design features identified in the staff report. Staff reviews of potential plant-specific or generic backfits will be appropriately coordinated with the Committee to Review generic Requirements (CRGR).

The staff also plans to address issues relating to the functional performance of spent fuel pool decay heat removal, as well as the operational aspects related to coolant inventory control and reactivity control, through expansion of the proposed, performance-based rule, "Shutdown Operations at Nuclear Power Plants" (10 CFR 50.67), to encompass fuel storage pool operations.

Concurrent with the regulatory analyses for the potential safety enhancements, the staff will develop guidance for implementing the proposed rule for fuel storage pool operations at nuclear power plants. The staff will also develop plans to improve existing guidance documents related to design reviews of spent fuel pool cooling systems. In addition, the staff will issue an information notice as a mechanism for distributing information in areas where regulatory analyses do not support rulemaking or plant-specific backfits.

Attachment: Plan for Resolving Spent Fuel Storage Pool Action Plan Issues

PLAN FOR RESOLVING SPENT FUEL STORAGE POOL ACTION PLAN ISSUES

1.0 INTRODUCTION

The NRC staff developed and implemented a generic action plan for ensuring the safety of spent fuel storage pools in response to two postulated event sequences involving the spent fuel pool (SFP) at two separate 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 (see attached safety evaluation for additional details). 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 shut down. 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 this review 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 this 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.

ATTACHMENT

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. Spent fuel storage pools 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.

2.0 REGULATORY FRAMEWORK FOR SPENT FUEL POOL STORAGE

The NRC acceptance criteria for the design of structures, systems, and components related to the SFP has evolved from case-by-case reviews for early plants to the present guidance of the Standard Review Plan (SRP) - NUREG-0800 - and regulatory guides, and the requirements of the General Design Criteria (GDC) of Appendix A to 10 CFR Part 50, as implemented by 10 CFR 50.34. In addition, the increased use of high density storage racks to expand onsite irradiated fuel storage capability has required nearly all operating reactor licensees to request license amendments related to fuel storage. Consequently, the design of certain structures, systems, and components related to the SFP may vary among a group of plants, depending on the stage of evolution of acceptance criteria developed by the staff and the deviations from these criteria the staff found acceptable.

The Atomic Energy Commission (AEC) developed design criteria in the mid-60s that were used as guidance in evaluating plant design. These criteria were continually revised so that a consistent basis for acceptable design practices for the SFP was not established. As an example, Criterion 25 from a version of the AEC design criteria dated November 5, 1965, stated:

> The fuel handling and storage facilities must be designed to prevent criticality and to maintain adequate shielding and cooling under all anticipated normal and abnormal conditions, and credible accident conditions. Variables upon which the health and safety of the public depend must be monitored.

These AEC design criteria evolved into the GDC presented in Appendix A to 10 CFR Part 50, which the AEC issued in 1971. Criterion 61 of the GDC requires, in part, that the fuel storage system be designed with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal and be designed to prevent significant reduction in coolant inventory under accident conditions. Criterion 62 provides requirements for prevention of criticality, and Criterion 63 specifies requirements for systems to monitor fuel storage systems.

In 1970, the AEC developed and began issuing safety guides to make available specific methods acceptable to the staff for implementing regulations. Regulatory Guide 1.13 (formerly Safety Guide 13), "Spent Fuel Storage Facility Design Basis," was used as guidance in the licensing evaluation of many spent fuel storage facilities. Regulatory Guide 1.13 described an acceptable method of implementing General Design Criterion 61 in order to:

(1) Prevent loss of water from the fuel pool that would uncover fuel.

(2) Protect fuel from mechanical damage.

(3) Provide the capability for limiting the potential offsite exposures in the event of a significant release of radioactivity from the fuel.

Regulatory Guide 1.13 has no specific guidance for evaluating criticality prevention measures or SFP cooling system design features.

The SRP gives specific acceptance criteria derived from applicable GDC and other NRC regulations, and a method acceptable to the staff to demonstrate compliance with those acceptance criteria for various structures, systems, and components at commercial light water reactors. The SRP was first issued in 1975 as NUREG-75/087, and NUREG-0800 was issued in 1981. The SRP is not a substitute for NRC regulations, and compliance is not a requirement. However, 10 CFR 50.34 requires applications for light water reactor operating licenses and construction permits docketed after May 17, 1982, to include an evaluation of the facility against the SRP. Although currently operating reactors all had construction permits before 1982, the staff used the SRP in evaluating operating license applications for facilities that began commercial operation after 1982. Because compliance with the specific acceptance criteria in the SRP is not a requirement, use of the SRP in evaluating operating license applications does not mean that each reactor beginning commercial operation satisfies each acceptance criterion in the SRP. Rather, the staff used the SRP acceptance criteria as an aide in determining the acceptability of a structure, system, or component.

Detailed NRC guidance for evaluating the design of SFP storage facilities and the design of the SFP cooling and cleanup system is in SRP Sections 9.1.2 and 9.1.3, respectively. The acceptance criteria in SRP Section 9.1.2 relate to the SFP structural considerations for coolant inventory control, reactivity control criteria, and monitoring instrumentation. The acceptance criteria in SRP Section 9.1.3 relate to the SFP cooling system considerations for coolant inventory control and coolant temperature control. Both SRP sections reference Regulatory Guide 1.13 for specific criteria related to coolant inventory control.

Because of the unlikely prospects for successful reprocessing of civilian reactor fuel, the NRC developed Multi-Plant Action (MPA) A-28, "Increase in Spent Fuel Pool Storage Capacity," to address continued on-site storage of spent fuel. The staff developed a task action plan in the late 1970's to resolve MPA A-28. This action plan resulted in the development of guidance to address the increased number of SFP modifications involving replacement of low density fuel storage racks with high density fuel storage racks. Operating reactor licensees pursued these modifications because, at the time many operating reactor spent fuel storage areas were designed, offsite storage and reprocessing of spent fuel was expected to limit the need for onsite storage.

On April 14, 1978, the NRC staff issued a letter to all power reactor licensees that forwarded the NRC guidance on SFP modifications. The guidance, entitled "Review and Acceptance of Spent Fuel Storage and Handling Applications," gave (1) guidance on the type and extent of information needed by the NRC staff to perform the review of proposed modifications to an operating reactor spent fuel storage pool and (2) the acceptance criteria to be used by the NRC staff in authorizing such modifications. The review areas addressed by this guidance included prevention of criticality, prevention of mechanical damage to fuel, and adequacy of cooling for the increased fuel storage capacity.

The actions recommended to resolve the action plan issues for MPA A-28 were to revise the NUREG-75/087 version of SRP Section 9.1.3 and the 1975 version of Regulatory Guide 1.13. Although revisions to Regulatory Guide 1.13 were developed that expanded the scope of the document to address SFP cooling and reactivity control, the revised version was not issued for comment. Minor revisions to SRP Section 9.1.3 were incorporated in the NUREG-0800 version in 1981.

In 1977, the NRC initiated the Systematic Evaluation Program (SEP) to review the designs of older operating nuclear reactors. Although the staff originally planned to conduct the SEP in several phases, the SEP was conducted in two phases. The first phase involved identification of issues for which regulatory guidance and requirements had changed enough since licensing of the older plants to warrant a re-evaluation of those older operating reactors. In the second phase, the staff re-evaluated 10 of the older operating reactors (7 of which are currently operating) against the guidance and requirements existing at the time of the re-evaluation. From the results of the second phase, the staff identified 27 issues, termed the SEP "lessons learned" issues, that involved some corrective action at one or more of the 10 reactors reviewed in the second phase of the SEP. The staff concluded that these 27 issues would be generally applicable to other older operating reactors that were not reviewed in the second phase of the SEP, and the staff proposed to include these issues in the Integrated Safety Assessment Program (ISAP). However, the ISAP was discontinued after reviews at two pilot plants. The SEP "lessons learned" issues were subsequently tracked as Generic Issue (GI) 156 until resolution of that GI in 1995.

Fuel storage was one of the issues identified in the first phase of the SEP. The purpose of the fuel storage review in the second phase of the SEP was to ensure that new and irradiated fuel are stored safely with respect to criticality prevention, cooling capability, shielding, and structural capability. For the seven currently operating reactors reviewed in the second phase of the SEP, the staff found that irradiated fuel was stored safely at those facilities on the basis of staff reviews conducted in the late 70s or early 80s that approved license amendments for increased spent fuel storage capacity. During the staff's review of the SEP program as part of our action plan for spent fuel storage pool safety, the staff determined that three of the seven license amendments for spent fuel storage capacity increases were approved on the basis of substantial hardware modification to the SFP cooling system. Despite the hardware modifications necessary to satisfy the staff acceptance criteria at the time of the increase in spent fuel storage capacity, the staff did not identify the fuel storage issue as an SEP "lessons learned" issue.

3.0 PARAMETERS AFFECTING THE SAFE STORAGE OF IRRADIATED FUEL

3.1 Coolant Inventory

The coolant inventory in the SFP protects the fuel cladding by cooling the fuel, protects operators by serving as shielding, decreases fission product releases from postulated fuel handling events by retaining soluble and particulate fission products, and supports operation of forced cooling systems by providing adequate net positive suction head. Adequate cooling of the fuel and cladding is established by maintaining a coolant level above the top of the fuel (however, this condition does not ensure that the SFP structure and other non-fuel components will not be degraded by high temperature). A water depth of several feet above the top of irradiated fuel assemblies stored in racks serves as acceptable shielding, but additional water depth is necessary to provide adequate shielding during movement of fuel assemblies above the storage racks and to maintain operator dose as low as is reasonably achievable (ALARA). Consequence analyses for fuel handling accidents typically assume a water depth of 23 feet above the top of irradiated fuel storage racks, and this value is specified as a minimum depth for fuel handling operations in the NRC's Standard Technical Specifications. Because cooling system suction connections to the SFP are typically located well above the top of stored fuel to prevent inadvertent drainage, a substantial depth of water above the top of fuel storage racks is necessary to provide adequate net positive suction head for forced cooling system pumps.

Design features to reduce the potential for a loss of coolant inventory are common. On the basis of the staff's design review, all operating reactors have a reinforced-concrete SFP structure designed to retain their function following the design-basis seismic event (i.e., seismic Category I or Class 1) and a welded, corrosion-resistant SFP liner. Only one operating reactor lacks leak detection channels positioned behind liner plate welds to collect leakage and direct the leakage to a point where it can easily be monitored. Nearly all operating reactors have passive features preventing draining or siphoning of the SFP to a coolant level below the top of stored, irradiated fuel. Excluding paths used for irradiated fuel transfer, passive features at nearly all operating reactors prevent draining or siphoning of coolant to a level that provides inadequate shielding for fuel seated in the storage racks.

In the event that SFP coolant inventory decreases significantly, several indications are available to alert operators of that condition. The primary indication is a low-level alarm. A secondary indication of a loss of coolant level is provided by area radiation alarms. These alarms indicate a loss of shielding that occurs when SFP coolant inventory is lost. Except for the SFP located inside the containment building, the area radiation alarms are set to alarm at a level low enough to detect a loss of coolant inventory early enough to allow for recovery before radiation levels could make such a recovery difficult.

The staff noted five categories of operating reactors that warrant further review based on specific design features that are contrary to guidance in Regulatory Guide 1.13. These categories are described in the next five sections.

3.1.1 Spent Fuel Pool Siphoning via Interfacing Systems

The SFPs serving four operating reactors lack passive anti-siphon devices for piping systems that could, through improper operation of the system, reduce coolant inventory to a level that provides insufficient shielding and eventually exposes stored fuel. These four operating reactors, all issued construction permits preceding the issuance of Safety Guide 13, have piping that penetrates the SFP liner several feet above the top of stored fuel, but the piping extends nearly to the bottom of the SFPs. Because, for each of these reactors, this piping is connected to the SFP cooling and cleanup system through a normally locked closed valve and lacks passive anti-siphon protection, mispositioning of the normally locked-closed valve coincident with a pipe break or refueling water transfer operation could reduce the SFP coolant inventory by siphon flow to a level below the top of the stored fuel.

This concern is related to a 1988 event at San Onofre Unit 2, which involved a partial loss of SFP coolant inventory due to an improper purification system alignment and inadequate anti-siphon protection. The NRC issued Information Notice 88-65, "Inadvertent Drainages of Spent Fuel Pools," to alert holders of operating licenses and construction permits of this event and similar system misalignments. Although the coolant inventory loss at San Onofre Unit 2 was not significant in this instance, the piping extended deep enough in the pool that failure of operator action to halt the inventory loss would have been of concern. Corrective action for this event included removing the portion of piping that extended below the technical specification limit on SFP level and strengthening administrative controls on system alignment.

Reduction in coolant inventory to an extremely low level is unlikely because of the low probability of the necessary coincident events, the long time period necessary for significant inventory loss through small siphon lines, and the many opportunities afforded operators to identify the inventory loss (e.g., SFP low-level alarm, SFP area high-radiation alarms, building sump high-level alarms, observed low level in SFP, and accumulation of water in unexpected locations). However, the staff believes that a design modification to introduce passive anti-siphon protection for the SFP could be easily implemented at the plants currently lacking this protection. Therefore, the staff will conduct a regulatory analysis to determine if such modifications are justified.

3.1.2 Spent Fuel Pool Drainage via the Fuel Transfer System

The SFPs serving five operating reactors contain fuel transfer tubes located at elevations below the top of fuel stored in the SFP racks. These five reactors also held construction permits preceding the issuance of Safety Guide 13. During refueling periods when the blank flange on the containment side of the transfer tube is removed, improper operation of the spent fuel transfer system or the SFP cooling and cleanup system could lead to a loss of coolant inventory from the SFP to the refueling cavity inside the containment through the transfer tube.

This concern is related to a 1984 event at Haddam Neck, which involved a massive loss of water from the reactor refueling cavity inside the containment caused by a failed refueling cavity seal. The spent fuel transfer tube at Haddam Neck, which separates the refueling cavity inside the containment from the SFP in the fuel handling building, enters the SFP at an elevation below the top of the stored fuel, and, had the transfer tube been open at the time of the refueling cavity seal failure, the water loss could have uncovered fuel stored in the SFP. The NRC issued Information Notice 84-93, "Potential for Loss of Water from the Refueling Cavity," to alert holders of operating licenses and construction permits of this event and of similar, but less severe, seal failures.

Since that event, the licensee for Haddam Neck has installed a cofferdam to prevent water loss through the transfer tube to such an extent that fuel could be uncovered and has also improved the design of the refueling cavity seal. With the exception of the five operating reactors with transfer tubes in their associated SFPs, operating reactors have some type of weir that separates the fuel transfer area from the storage area so that loss of coolant inventory through the fuel transfer system to a level below the top of the stored fuel is prevented by design.

A review of refueling cavity seal failure potential by all operating reactor licensees, which was performed in response to NRC Bulletin 84-03, "Refueling Cavity Water Seal," indicated that refueling cavity seal failures were more likely to occur at Haddam Neck than at other operating reactors because of the unique design of the Haddam Neck refueling cavity. The review also found that such failures would likely be less severe at other reactors than at Haddam Neck. Other potential drainage paths (e.g., refueling cavity drains and systems interfacing with the reactor coolant system) have a much lower maximum rate of water loss because of the smaller flow area. Therefore, similar to the loss of coolant inventory scenario by siphoning, water loss from the refueling cavity that exposes fuel in the SFP is unlikely because of the low probability of water loss from the refueling cavity when the transfer tube is open, the long time period necessary for the inventory loss, and the many opportunities for operators to identify the inventory loss. However, the staff concludes that the relative rarity of fuel transfer systems lacking passive design features to prevent uncovery of stored fuel warrants a more detailed review of the design features and administrative controls at the operating reactors that have this characteristic. The staff will perform regulatory analyses at these five reactors to determine if any safety enhancement backfits related to this design feature are justified under current guidance.

3.1.3 Spent Fuel Pool Drainage via Interfacing Systems

Of the five operating reactors associated with SFPs containing fuel transfer tubes at elevations below the top of the stored fuel, three have an interfacing system connected to the transfer tube. This interfacing system is designed to supply purified water from the SFP for reactor coolant pump seal injection during certain low-probability events postulated to occur during reactor operation. Administrative controls maintain the SFP inventory available to supply water to this interfacing system during reactor operation.

The configuration of this system increases the potential for inadvertent drainage that uncovers fuel. The configuration introduces the potential for improper alignment of the interfacing system or failure of the piping for the interfacing system so that coolant inventory is lost; the staff did not find this potential at any other operating reactor. By design, the system withdraws water from the SFP for reactor coolant pump seal injection at a rate that would leave insufficient water for shielding over the stored fuel after 72 hours of operation. The inadvertent drainage of the SFP to a level that would uncover the stored fuel is an unlikely event based on the long time period necessary for the inventory loss and the many opportunities for operators to discover the inventory loss. However, the staff has concluded that a safety enhancement modification to the SFP may be justified to ensure that the fuel remains covered for any potential occurrence involving the interfacing system piping. Therefore, the staff will conduct a regulatory analysis to determine if such a modification is justified.

3.1.4 Absence of a Direct Low Level Alarm

Absence of a direct SFP low level alarm could delay operator identification of a significant loss of SFP coolant inventory. The staff identified one operating reactor that does not have some type of SFP low-level alarm, but that reactor does have control room indication of SFP level and the SFP is inside the containment building. Additionally, six operating reactors have only indirect indication and alarm for a low SFP level. These six reactors have low-level alarms in the SFP cooling system surge tanks and low-discharge-pressure alarms for the SFP cooling system pumps. Surge tanks are used to accommodate movement of large objects, such as spent fuel storage casks, into and out of the SFP and thermal expansion or contraction of the coolant without a large change in coolant level. To accomplish this function, surge tanks are separated from the SFP by a weir slightly below the normal SFP water level, and the SFP cooling system pumps draw water from the surge tanks. With continuous operation of the SFP cooling system pumps, the surge tank low-level alarm is equivalent to the SFP level alarm because the surge tank would rapidly drain once the SFP level decreased below the surge tank entry weir. The SFP cooling system pump low-discharge-pressure alarms would alert the operators to a change in the status of the cooling system pumps. The staff will perform regulatory analyses at these seven reactors to determine if any safety enhancement backfits to improve SFP level monitoring capability are justified under current guidance.

3.1.5 Absence of Isolation Capability for Leakage Collection System

The absence of isolation capability for leakage identification systems could allow water to leak at a rate in excess of make-up capability for certain events that cause failure of the SFP liner. The staff identified four operating reactors with this characteristic, but this item was not included in our previous information collection efforts. However, the staff also has not collected the information necessary to evaluate makeup capability relative to credible leakage through the leakage detection channels. To address this omission, the staff will examine previous licensing reviews to determine if the staff had previously evaluated makeup capability relative to credible coolant inventory loss through the leakage detection channels. Because the four plants identified with this characteristic were not evaluated for inventory control using the SRP guidance, the staff believes that the depth of review for these plants would be indicative of the depth of review at other operating reactors. If this issue has not been previously addressed by the staff at the four operating reactors, the staff will initiate additional information collection activities for this design characteristic and conduct a regulatory analysis to determine if modification to the leakage detection system is justified.

3.2 Coolant Temperature

Coolant temperature has a less direct effect on safe storage of irradiated fuel than coolant inventory. Coolant temperature at the pool surface is limited by evaporative cooling from the free surface of the pool to a value of about 100°C [212°F], and the design of the pool storage racks provides adequate natural circulation to maintain the coolant in a subcooled state at the fuel cladding surface assuming the coolant inventory is at its normal level. Therefore, forced cooling is not required to protect the fuel cladding integrity when adequate water is supplied to makeup for coolant inventory loss. The temperature of the SFP does have an effect on structural loads, the operation of SFP purification systems, operator performance during fuel handling, and the environment around the SFP.

3.2.1 Structural Considerations

The SFP structure is evaluated to ensure that its structural integrity and leak tightness are retained under various operating, accidental, and environmental loadings. The reinforced concrete SFP walls and floors are required to withstand the loadings without exceeding the corresponding allowables set forth in the American Concrete Institute Code requirements for Nuclear Structures (ACI 349) as modified by Regulatory Guide 1.142. Appendix A, "Thermal Consideration," of ACI 349 limits the long-term temperature exposure of concrete surfaces to 150° F, and short term exposures temperature (under accident conditions) to 350° F. It permits long term temperature exposures higher than 150° F, provided tests are performed to evaluate reductions in the concrete strengths and elastic modulus, and these reductions are applied to design allowables. During the approval of Amendments related to reracking of SFPs, the staff reviews the structural, thermal and seismic loadings on the SFPs and the proposed storage racks to ensure their compliance with the regulatory provisions (relevant SRPs and Regulatory Guides).

Under normal operating conditions (including that associated with reactor refueling activities), the regulatory provisions ensure that the sustained concrete surface temperatures are below 150° F. However, during a rise in the SFP bulk temperature due to temporary loss of forced cooling, the low thermal diffusivity of concrete and the large thermal capacity of the SFP concrete cause the temperature distribution within the concrete structure to change slowly after a rise in the temperature. Evaporative cooling of the pool limits the maximum temperature attainable at the concrete surface following a temporary loss of forced cooling. Thus, the concrete material properties will not be affected due to a temporary rise in SFP bulk temperature above 150° F.

The inside surfaces of the concrete walls and floors of the SFP are provided with a leak tight and corrosion resistant (generally stainless steel) liner. The liner is anchored to the concrete walls and floor by means of structural shapes and/or headed studs. The liner between the anchors could move away from the walls and the floor under differential temperature effects on the walls, floor, and the liner. In most cases, the liner ductility and anchor strength would accommodate such differential temperature effects. However, some construction features of the liner and its anchorage could give rise to high stress concentrations and liner weld failure under high temperature exposures. Such failure, if they should occur would be localized, and would be detected during maintenance, and/or by the leakage detection system (see Section 3.1.5).

Therefore, it is reasonable to conclude that if thermal loads on pool structure are limited and their effects monitored as discussed above, no significant structural degradation of the SFP structure is likely to occur.

3.2.2 Coolant Purification

Temperature also has an indirect effect on fuel integrity and radiological conditions. All SFPs use an ion exchange and filtration processes to maintain the purity of the coolant. The chemical contaminants in the coolant affect the corrosion resistance of components in the fuel pool and the activity of the coolant. However, the ion exchange resins may degrade at temperatures above 60°C [140°F], and the degradation can cause the release of previously absorbed impurities in addition to reducing the effectiveness of the resin. Some SFP purification subsystems operate using water from the outlet of the SFP heat exchanger, which protects the ion exchange resin in these subsystems from high pool temperature. The purification subsystems for other SFPs must be isolated to protect the resin when pool temperature is high.

Prolonged isolation of the purification subsystem creates the potential for increased operator exposure from radionuclide accumulation in the pool coolant and increased corrosion from impurities that accumulate in the coolant. However, chemical and radiological monitoring of SFP water is routinely specified in each facility's safety analysis report and operating procedures. Such monitoring ensures that the coolant is maintained sufficiently pure to avoid excessive accumulation of radionuclides or chemical impurities in the SFP coolant.

3.2.3 Fuel Handling

Lastly, SFP temperature affects operator performance during fuel handling. A pool temperature above 37°C [100°F] can lead to frequent operator rotation during fuel movement to prevent heat stress, and higher pool temperatures can result in fogging on the operating floor that interferes with an operator's ability to observe fuel assembly position. To avoid these problems, most operating reactor licensees have implemented administrative controls to maintain pool temperature in a range that does not hinder operator performance.

3.2.4 Environmental Effects of High Temperature in the SFP

At very high temperatures in the SFP, the evaporative cooling that occurs on the pool surface can add a significant amount of latent heat and water vapor to the atmosphere of the building surrounding the SFP. Depending on the ventilation system design and capability, the added heat and water vapor could increase building temperature and condensation on equipment. The higher temperature and condensation could impair the operation of essential safety systems.

The staff has extensively evaluated this issue at one operating reactor site, Susquehanna. The deterministic analysis of Susquehanna indicated that systems used to cool the spent fuel storage pool were adequate to prevent unacceptable challenges to the safety related systems needed to protect public health and safety during and following design basis events. The probabilistic review at Susquehanna indicated that event sequences leading to a sustained loss of SFP cooling have a low frequency of occurrence. In particular, the staff found that loss of operator access to SFP cooling system components, which was a principal contention of the report filed pursuant to 10 CFR Part 21 regarding loss of SFP cooling at Susquehanna, is not a significant contributor to the frequency of sustained loss of SFP cooling events because the probability of severe core damage that has the potential to deny operator access to the building housing the SFP is very low. The staff recognized that the mechanisms by which the operators would be unable to provide cooling to the SFP were not limited to the design basis events and operator access considerations. Therefore, the staff modeled other event sequences leading to SFP boiling. The staff concluded that, even with consideration of the additional event sequences, loss of SFP cooling events presented a challenge of low safety significance to the plant.

On the basis of deterministic and probabilistic evaluations at Susquehanna, the staff concluded that this concern can be adequately addressed through provision of a reliable SFP cooling system or through administrative controls that extend the time available to institute recovery actions following a loss of cooling. The reliability of the SFP cooling function at each operating reactor is dependent on the design of the SFP cooling system and each licensee's administrative controls on availability of systems capable of cooling the SFP. The time available for recovery action following a loss of SFP cooling is dependent on the initial temperature of the SFP coolant, the decay heat rate of the stored fuel, and the available passive heat sinks. Because the decay heat rate within the SFP is at least an order of magnitude higher during refueling operations involving a full-core discharge than during reactor operation and because refueling is a controlled evolution, administrative controls on refueling operations affect the time available for recovery following a loss of SFP cooling.

Through the extensive evaluation of Susquehanna, the NRC staff identified certain design characteristics that increase the probability that an elevated SFP temperature will interfere with the safe operation of a reactor either at power or shutdown. The first characteristic is an open path from the area around the SFP to areas housing safety systems. This path may be through personnel or equipment access ports, ventilation system ducting, or condensate drain paths. Without an open path, the large surface area of the enclosure around a SFP would allow water vapor to condense and return to the SFP and allow heat to be rejected through the enclosure to the environment without affecting reactor safety systems. The second characteristic is a short time for the SFP to reach elevated temperatures. The time for the SFP to reach an elevated temperature is affected by initial temperature, coolant inventory, and the decay heat rate of irradiated fuel. On the basis of operating practices and administrative limits on SFP temperature, the NRC staff has determined that short times to reach elevated temperatures are credible only when nearly the entire core fuel assembly inventory has been transferred to the SFP and the reactor has been shut down for a short period after extended operation at power.

These conditions establish the third design characteristic, which is a reactor site with multiple operating units sharing structures and systems related to the SFP. At a single-unit site, large coolant inventories in the SFP and in the reactor cavity act as a large passive heat sink for irradiated fuel during fuel transfer. When the entire core fuel assembly inventory has been transferred to the SFP at a single-unit site, safety systems associated with the reactor are not essential because no fuel remains in the reactor vessel. Multi-unit sites with no shared structures can be treated as a single-unit site. At a multi-unit site with shared structures, a short time to reach an elevated temperature can exist in the SFP associated with a reactor in refueling while safety systems in communication with the area around that SFP are supporting operation of another reactor at power.

When these three design characteristics coexist at a single site, one SFP could reach an elevated temperature in a short time (i.e., between 4 and 10 hours) after a sustained loss of cooling, the heat and water vapor could propagate to systems necessary for shutdown of an operating reactor, and these systems could subsequently fail while needed to support shutdown.

The staff has determined through its survey of SFP design features that these three design characteristics coexist at no more than seven operating reactor sites in addition to Susquehanna. The staff determined through its review of design information and operational controls that immediate regulatory action is not warranted on the basis of the capability of available cooling systems, the passive heat capacity of the SFP, and the operational limits imposed by administrative controls at these seven sites. In making this determination, the staff considered the findings from its review of this issue at Susquehanna. Nevertheless, the staff will conduct detailed reviews to identify enhancements to refueling procedures or cooling system reliability that are justified based on the reduced potential for SFP conditions to impact safety systems supporting an operating reactor at these seven sites.

3.2.5 Cooling System Reliability and Capability

The SFP cooling system reliability and capability affect the ability of the licensee to maintain SFP temperature within an appropriate band. Through its survey of operating reactors, the staff identified some commonality with respect to control of the cooling system, but substantial variation in the design of fuel pool cooling systems with respect to reliability and capability.

The large, passive heat sink provided by the SFP coolant reduces the significance of a short-term loss of cooling by providing ample time for operator diagnosis of problems and implementation of corrective action. Consequently, SFP cooling systems are typically aligned, operated, and controlled by manual actions. Most plants have SFP cooling system pump controls only at local control stations near the pumps.

The staff identified a wide range of SFP cooling system configurations. The least reliable configuration consisted of a single-train system with no backup system capable of providing SFP cooling. This system was designed with two 50-percent flow-capacity pumps supplying a single heat exchanger. The electrical distribution system serving this reactor was not configured to supply onsite power to the SFP cooling pumps. At the other end of the range, the SFP cooling system consisted of two redundant, high-capacity, safety-grade trains of cooling. The primary SFP cooling system was supported by the safety-grade shutdown cooling system, which was capable of being aligned to cool the SFP.

The staff analyzed design information collected during the survey to determine the susceptibility of SFP cooling systems to a sustained loss of SFP cooling. Specifically, the staff examined the minimum design capacity of the system with no failures, the capacity of the system assuming long-term failure of a single pump, the capacity assuming a LOOP, the passive thermal capacity of the SFP, and the availability of a large-capacity backup system. In order to have a consistent basis for comparison, the staff developed a numerical rating for each reactor based on a ratio of heat removal capacity under limiting conditions relative to the rated thermal power of each reactor.

On the basis of design information collected through the staff's survey effort and onsite assessment visits, the staff identified events that are most likely to lead to extended reductions in SFP cooling capability. Because the SFP cooling systems typically do not maintain train separation in control cabinets and power cable raceways, events such as fires or internal floods may cause a complete loss of SFP cooling. Also, the primary SFP cooling systems often are designed such that their cooling capacity would be eliminated during a LOOP. However, operators are more likely to recover from minor electrical and control system failures by rerouting power cables and bypassing control cabinets than they are to recover from mechanical failures requiring a unique part for repair in the time available before the SFP reaches elevated temperatures. On this basis, the staff concludes that the operating reactors identified with relatively low cooling capacity that lack redundancy of mechanical components are more likely to experience elevated SFP temperatures than those reactors with greater SFP cooling capacity or mechanical component redundancy. Similarly, those reactors without an onsite source of power to a system capable of cooling the SFP are more likely to experience elevated SFP temperatures than reactors having a cooling system designed to be powered from an onsite power source. However, once again, the long period of time available for operator diagnosis of a problem and identification of appropriate corrective action reduces the level of risk from elevated SFP temperatures.

The staff noted that the SFPs for all but seven operating reactors are capable of being cooled by a system powered from an onsite source without special reconfiguration of the electrical distribution system. However, nine of the operating reactors with onsite power available to a system capable of cooling the SFP rely on backup SFP cooling using a mode of the reactor shutdown cooling system. This mode of system operation often requires significant realignment for fuel pool cooling.

The staff concluded that all SFPs associated with U.S. operating reactors can withstand, without bulk boiling in the SFP, a long-term loss of one SFP cooling system pump or cooling water system (i.e., service water or closed cooling water system) pump and maintain 50 to 100 percent of full decay heat removal capability using redundant or installed spare pumps. However, with reduced cooling capability, the rate of water vapor production from the SFP may be significant for operating reactors with lower heat removal capability under certain conditions.

To address concerns with the reliability and capability of SFP cooling systems, the staff will conduct evaluations and regulatory analyses at selected operating reactors. The first category of operating reactors are those seven operating reactors lacking a design capability to supply onsite power to a system capable of cooling the SFP. The staff will examine the capability to supply onsite power to the SFP cooling system relative to the time available for recovery actions based on procedural controls to determine the need for regulatory analyses. The second category of operating reactors are operating reactors identified with low primary SFP cooling system cooling capacity relative to potential spent fuel decay heat generation that have no backup cooling capability. The staff will examine the administrative controls with respect to SFP temperature and available recovery time at four operating reactors with low SFP cooling capacity to determine the need for regulatory analyses. The final category of operating reactors are those reactors reliant on infrequently operated backup SFP cooling systems to address long-term LOOP events and mechanical failures. The staff will examine administrative controls on the availability of the backup cooling systems during refueling and technical analyses demonstrating the capability of these backup systems to cool the SFP at the ten operating reactors in this category to determine the need for further regulatory analyses.

3.2.6 Absence of Direct Instrumentation for Loss of the SFP Cooling Function

Inadequate SFP cooling can be indicated by a high SFP temperature alarm, a SFP cooling system low flow alarm, a cooling system high temperature alarm, or a

SFP cooling system pump low discharge pressure alarm. The staff's survey results indicate that ten operating reactors lack a direct-reading high SFP temperature alarm to identify a sustained loss of SFP cooling and, of those ten reactors, one lacks any associated alarms for a loss of cooling. Because the associated alarms provide annunciation of SFP cooling problem at nine of the operating reactors, because the SFP for the tenth operating reactor is located inside primary containment where equipment is qualified for harsh environments, and because routine operator monitoring also has the potential to detect a loss of the SFP cooling function, the staff determined that immediate regulatory action was not warranted. However, the staff will examine these reactor sites further to determine if additional instrumentation or operational controls are warranted on a safety enhancement basis.

3.3 Fuel Reactivity

All irradiated fuel storage racks are designed to maintain a substantial shutdown reactivity margin for normal and abnormal storage conditions. The NRC staff acceptance criterion for all storage conditions, including abnormal or accident storage conditions (e.g., fuel handling accident, mispositioned fuel assembly, or storage temperature outside of normal range), is a very high confidence that the effective neutron multiplication factor is 0.95 or less. Every licensee is required to maintain this shutdown reactivity margin as a design feature technical specification or as a commitment contained in each licensee's safety analysis report. The NRC staff has accepted credit taken for the negative reactivity introduced by soluble boron in abnormal or accident storage conditions where dilution of the boron concentration would not be a possible outcome of the abnormal or accident condition alone.

3.3.1 Solid Neutron Absorbers

To maintain a substantial shutdown reactivity margin in a regular array of fuel assemblies, the storage geometry, the neutron absorption characteristics of the storage array, and the reactivity and position of fuel assemblies in the array are controlled. Reliance on geometry alone results in a low-density storage configuration. No operating reactor currently uses only low-density storage in its associated SFP. Intermediate storage density can be achieved by either special construction of the storage racks to form "flux traps" or by controlling the position and reactivity of fuel stored in the rack. The reactivity of each fuel assembly is typically determined by its initial enrichment in the uranium-235 isotope, its integrated irradiation (burnup), and its integral burnable neutron poison inventory. The highest density fuel storage has been achieved through the use of solid neutron absorbers as integral parts of the storage racks.

All solid neutron absorbers used at U.S. operating reactors utilize the high neutron absorption cross-section of the boron-10 isotope. Boron held in a silicon-rubber matrix (Boraflex) is the most common solid neutron absorber, followed by an aluminum/boron carbide alloy (Boral). Boron carbide clad in a metal sheathing is the next most common neutron absorber. Borated stainless steel pins are in use at one SFP associated with an operating reactor. The SFP storage racks associated with 14 of 109 U.S. operating reactors contain no solid neutron absorbers. The remaining SFPs use one or more of the solid neutron absorbers identified above to achieve higher storage density.

Because boron-10 is consumed by the interaction with neutrons, storage racks containing neutron absorbers are designed assuming a finite neutron irradiation and, therefore, a finite operating life. Other mechanisms that deplete the boron-10 inventory in the storage racks can reduce the operating life of the storage racks under design storage conditions. Although the SFP environment is relatively benign for most of the neutron absorbers in use, Boraflex has been observed to degrade by two mechanisms (1) gamma irradiation-induced shrinkage and (2) boron washout following long-term gamma irradiation combined with exposure to the wet pool environment. In addition to issuing three information notices regarding Boraflex degradation, the NRC staff issued Generic Letter (GL) 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks," on June 26, 1996. This GL requires licensees using Boraflex in their spent fuel storage racks to submit information to the NRC staff regarding their plans to address potential degradation of Boraflex material. This action on Boraflex is outside the staff's action plan activities.

A review of neutron absorber performance as part of the action plan for spent fuel storage pool safety indicates that degradation in neutron absorption performance has not been observed in materials other than Boraflex. Some neutron absorbing panels have been observed to swell due to gas accumulation within the cladding material, but this effect has not degraded neutron absorption performance.

3.3.2 Soluble Boron

Soluble boron is used in pressurized water reactors (PWRs) to control reactor coolant system reactivity. Because the SFP interfaces with the reactor coolant system during refueling, an adequate boron concentration must be maintained in the SFP to preclude inadvertent dilution of the reactor coolant system. In addition, the boron concentration maintained in PWR SFPs is also credited with mitigating reactivity transients caused by abnormal or accident fuel storage conditions. The NRC staff found that soluble boron concentration was adequately controlled by administrative controls or technical specifications at PWRs.

4.0 PLANNED ACTIONS

The staff has identified three courses of action to address the areas described in Section 3.0. These courses of action are (1) plant-specific evaluations or regulatory analyses for safety enhancement backfits, (2) rulemaking, and (3) revision of staff guidance for SFP evaluation. In addition, the staff will issue an information notice as a mechanism for distributing information in areas where regulatory analyses do not support rulemaking or plant-specific backfits.

4.1 Plant Specific Evaluations and Regulatory Analyses

The staff has identified several areas for additional plant-specific evaluation. The bases for these additional reviews was described in Section 3.0. The staff has identified specific operating reactors in each of the following categories for further evaluation:

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

The specific operating reactors in each category are named in the following summaries. Each summary also describes existing design features at the named reactors and other capabilities that limit the risk from each identified concern.

Inventory Control Issues

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

Plants:	Davis-Besse, Robinson, and Turkey Point 3 & 4
Concern:	Misconfiguration of system has the potential to syphon coolant to such an extent that fuel could be exposed to air.
Current Protection:	Locked closed valve on line at level of pool liner penetration, liner penetration well above top of stored fuel, low level alarm, and operator action (stop syphon flow and add make-up water)
Action:	Regulatory analysis to assess potential enhancements

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

Plants:	Crystal River, Maine Yankee, and Oconee 1, 2, & 3
Concern:	Transfer tubes are normally open during refueling operations. When these openings are below the top

of stored fuel, any drain path from the refueling cavity has the potential to reduce coolant inventory to an extent that stored fuel could be exposed to air.

Current Protection: Low-level alarm, blank flange closure during reactor operation, and operator action (stop drainage and add makeup water)

Action: Regulatory analysis to assess potential enhancements

3. Piping Entering Pool Below Top of Stored Fuel

Plants: Oconee Units 1, 2, & 3

Concern: Pipe break or misconfiguration of piping supporting the standby shutdown facility (SSF) at Oconee has potential to drain coolant to such an extent that fuel could be exposed to air. [The SSF at Oconee uses SFP coolant as a supply of reactor coolant pump seal water for certain low-probability events. The supply pipe for the SSF is a 3 inch diameter, seismically-qualified pipe that ties into a transfer tube for each unit. The Oconee safety analysis report states that the transfer tube gate valve is normally open during reactor operation to support SSF initiation.]

Current Protection: Seismic qualification of piping, normally closed valves on line, low level alarm, and operator action (stop drainage flow and add make-up water)

Action: Regulatory analysis to assess potential enhancements

4. Limited Instrumentation for Loss of SFP Coolant Events

Plants: Big Rock Point, Dresden 2 & 3, Peach Bottom 2 & 3, and Hatch 1 & 2

Concern: Insufficient instrumentation to reliably alert operators to a loss of SFP coolant inventory or a sustained loss of SFP cooling.

Current Protection: Related alarms, operating procedures, and operator identification

Action: Regulatory analysis to assess potential enhancements

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

Plants: D. C. Cook 1 & 2, Indian Point 2, and Salem 1 & 2

[possibly others - leak detection system drain isolation information was not part of design survey - staff will conduct further review of other sites]

Concern: Coolant inventory loss is not easily isolated following events that breach the SFP liner.

Current Protection: Limited flow area through leak detection system tell-tale drains, low leak rate through concrete structure, controls on movement of loads over fuel pool, and operator action (plug leak detection system drains and add make-up)

Action: Further Evaluation of Condition

Decay Heat Removal Reliability Issues

6. Shared Systems and Structures at Multi-Unit Sites

Plants: Calvert Cliffs 1 & 2, D. C. Cook 1 & 2, Dresden 2 & 3, Hatch 1 (Hatch 2 lower levels are a separate secondary containment zone), LaSalle 1 & 2, Point Beach 1 & 2, and Quad Cities 1 & 2

Concern: With one unit in refueling, the decay heat rate in the SFP may be sufficiently high that the pool could reach boiling in a short period of time following a loss of cooling. 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.

Current Protection: 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

Action: Regulatory analysis to assess potential enhancements

7. Absence of On-site Power Supply for Systems Capable of SFP Cooling

Plants: ANO 2, Prairie Island 1 & 2, Surry 1 & 2, and Zion 1 & 2

Concern: A sustained loss of offsite power at plants without an on-site 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.

Current Protection: Operator action (align a temporary power supply from an on-site source or establish alternate cooling such as feed and bleed using diesel powered pump), high temperature alarm, filtered ventilation, and separation/isolation of areas containing equipment important to safety from the SFP area

Action: Regulatory analysis to assess potential enhancements

8. Limited SFP Decay Heat Removal Capability

Plants: Indian Point 2, Indian Point 3, and Salem 1 & 2

Concern: Assuming a full core discharges at an equivalent time after reactor shutdown during a period of peak ultimate heat sink temperature, these plants will have higher SFP equilibrium temperatures and shorter recovery times than other similar plants.

Current Protection: Administrative controls on refueling operations

Action: Evaluation of administrative controls

9. Infrequently Used Backup SFP Cooling Systems

Plants: Browns Ferry 2 & 3, Davis-Besse, Dresden 2 & 3, Fermi, Fitzpatrick, Hatch 1 & 2, and WNP-2

Concern: These plants are more reliant on infrequently operated backup cooling systems than other similar plants because of the absence of an onsite power supply for the primary SFP cooling system or low relative capacity of the primary cooling system.

Current Protection: Administrative controls on refueling operations and availability of backup SFP cooling capability

Action: Evaluation of capability to effectively use backup system

10. Limited Instrumentation for Loss of Cooling Events

Plants: ANO-1, Big Rock Point, Brunswick 1 & 2, Cooper, Hatch 1 & 2, LaSalle 1 & 2, and Millstone 1

Concern: Instrumentation to alert operators to a sustained loss of SFP cooling is limited in capability.

Current Protection: Related alarms at most of above reactors, operating procedures, and operator identification

Action: Regulatory analysis to assess potential enhancements

4.2 Implementation of the Shutdown Rule for Spent Fuel Pool Operations

The primary benefit of including SFP operations in the shutdown rule is the establishment of clear and consistent performance standards for forced cooling of the SFP. Existing design features and operational controls provide assurance that a substantial shutdown reactivity margin will be maintained within the SFP. Similarly, common SFP design features have resulted in a low probability of a significant loss of SFP coolant inventory. Those facilities that lack specific design features are best examined on a plant-specific basis to determine if any enhancements to operating procedures or modifications to structures or systems are warranted.

A performance-based shutdown rule addressing SFP cooling would establish a consistent level of safety with specific performance goals. Those reactors with more capable cooling systems and those licensees that more carefully plan refueling cycles would benefit from increased maintenance flexibility during refueling outages. This approach is more appropriate from a safety standpoint than is the current situation of applying stringent design basis limits to reactors with more capable cooling systems.

4.3 Revision of Staff Guidance

The staff will develop guidance supporting implementation of the Shutdown Rule for SFP shutdown operations. The staff will also develop revisions to Regulatory Guide 1.13 and SRP Section 9.1.3. Regulatory Guide 1.13 will be expanded to include guidance related to design performance of SFP cooling systems, and SRP Section 9.1.3 will be revised to be consistent with that regulatory guide.

5.0 CONCLUSIONS

The staff has found that existing structures, systems, and components related to the storage of irradiated fuel provide adequate protection for public health and safety. Protection has been provided by several layers of defenses that perform accident prevention functions, accident mitigation functions, radiation protection functions, and emergency preparedness functions. Design features addressing each of these areas for spent fuel storage have been reviewed and approved by the staff. In addition, the limited risk analyses available for spent fuel storage suggest that current design features and operational constraints cause issues related to SFP storage to be a small fraction of the overall risk associated with an operating light water reactor. Notwithstanding this finding, the staff has reviewed each operating reactor's spent fuel pool design to identify strengths and weaknesses, and to identify potential areas for safety enhancements.

The staff plans to address issues relating to the functional performance of SFP decay heat removal, as well as the operational aspects related to coolant inventory control and reactivity control, through expansion of the proposed, performance-based rule for Shutdown Operations at Nuclear Power Plants (10 CFR 50.67) to encompass fuel storage pool operations.

The staff also plans to address certain design features that reduce the reliability of SFP decay heat removal, increase the potential for loss of spent fuel coolant inventory, or increase the potential for consequential loss of essential safety functions at an operating reactor. We intend to pursue regulatory analyses for safety enhancement backfits on a plant-specific basis pursuant to 10 CFR 50.109 at the operating reactor sites possessing one or more of these design features.

Concurrent with the regulatory analyses for the potential safety enhancements, the staff will develop guidance for implementing the proposed rule for fuel storage pool operations at nuclear power plants. The staff will also develop plans to improve existing guidance documents related to SFP storage.