UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
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NRC REGULATORY ISSUE SUMMARY 2005-05
REGULATORY ISSUES REGARDING CRITICALITY ANALYSES FOR SPENT FUEL POOLS AND INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS

ADDRESSEES

All operating and decommissioning pressurized water reactor (PWR) facilities.

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to advise addressees regarding potential inconsistencies between the regulatory bases of their spent fuel pools (SFPs) and independent spent fuel storage installations (ISFSIs). The regulatory basis for many licensees' spent fuel pools is Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.68, "Criticality accident requirements." The regulatory basis for ISFSI licenses is 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste."

Specifically, the NRC is issuing this RIS to —

(1) alert addressees to findings at PWR facilities suggesting that the spent fuel pool licensing and design bases and applicable regulatory requirements may not be met during loading, unloading, and handling of dry casks in the spent fuel pools;

(2) emphasize the importance of maintaining subcritical conditions for spent fuel storage in moderated environments; and

(3) encourage addressees to review the current spent fuel pool and ISFSI licensing and design bases at their facilities to ensure compliance during dry cask loading, unloading, and handling operations.

BACKGROUND INFORMATION

Several provisions of the NRC regulations and licensees' plant operating licenses (technical specifications) pertain to spent fuel pool criticality. The NRC regulations for preventing spent fuel pool criticality include the general design criteria for nuclear power plants (10 CFR Part 50, Appendix A) and 10 CFR 50.68, while 10 CFR 70.24, "Criticality accident requirements," contains requirements for detection of a SFP criticality event.

Appendix A to 10 CFR Part 50 and the plant safety analyses require or commit licensees to design and test safety-related structures, systems, and components (SSCs) to provide adequate assurance that they can perform their safety functions. The NRC staff applies these criteria to plants with construction permits issued on or after May 21, 1971, and to plants whose licensees have committed to them. With respect to spent fuel pool criticality, the applicable General Design Criterion (GDC) is GDC 62, "Prevention of criticality in fuel storage and handling." GDC 62 states: "Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by the use of geometrically safe configurations." As written, GDC 62 emphasizes the prevention of an inadvertent criticality in the spent fuel pool as opposed to detection and mitigation. The preferred method of prevention is the use of geometrically safe configurations.

Subsection 70.24(a) of 10 CFR 70.24, states that each licensee authorized to possess special nuclear material in excess of certain defined quantities must maintain in each area in which such licensed special nuclear material is handled, used, or stored, a monitoring system capable of detecting a criticality that produces either (1) a defined absorbed dose or (2) a specific radiation level. The date of the facility's licensing determines whether the dose or radiation level requirements apply. In the mid-1990s the nuclear industry and NRC staff determined that a number of facilities had not maintained a criticality-monitoring system in accordance with the requirements of 10 CFR 70.24. Recognizing that numerous licensees were out of compliance with 10 CFR 70.24 due to a regulatory oversight in the issuance of their operating licenses and realizing that the system required by 10 CFR 70.24 emphasized detection of a criticality event rather than prevention, the staff issued Information Notice (IN) 97-77, "Exemption from the Requirements of Section 70.24 of Title 10 of the Code of Federal Regulations." IN 97-77 provided staff criteria for evaluating exemptions from 10 CFR 70.24. The staff's seven criteria, if satisfied, ensured that a licensee complied with GDC 62. The criteria emphasized prevention of spent fuel pool criticality rather than detection. Most licensees followed this approach and the staff issued a number of exemptions to 10 CFR 70.24 based on the criteria in IN 97-77.

In 1998, the staff published Section 50.68 in Title 10 of the *Code of Federal Regulations* to formally issue the staff criteria from IN 97-77 with minor but notable changes, as regulatory requirements for ensuring subcriticality in spent fuel pools. Part 50 licensees may choose to comply with 10 CFR 50.68 in lieu of installing and maintaining a criticality-monitoring system as required by 10 CFR 70.24 or seeking an exemption from 10 CFR 70.24. A licensee's compliance with 10 CFR 50.68 ensures that an inadvertent criticality in the spent fuel pool is extremely unlikely. Section 50.68 requires that licensees demonstrate that subcritical conditions ($k_{eff} < 1.0$) can be maintained in the spent fuel pool under normal conditions without a soluble boron credit. However, under 10 CFR 50.68, licensees may credit soluble boron both during normal conditions to maintain a 5-percent subcriticality margin (k_{eff} # 0.95) and during accident conditions to maintain the spent fuel pool subcritical ($k_{eff} < 1.0$). Specifically, 10 CFR 50.68(b)(1) states: "Plant procedures shall prohibit the handling and storage at any one time of more fuel assemblies than have been determined to be safely subcritical under the most adverse moderation conditions feasible by unborated water." This requirement assures public health and safety during all fuel handling and storage operations, including cask loading, unloading, and handling, because subcritical conditions are maintained by geometrically safe configurations,in accordance with GDC 62. Therefore, the soluble boron in the spent fuel pool is available to ensure defense-in-depth requirements are satisfied under accident conditions.

Since the issuance of 10 CFR 50.68 in 1998, numerous PWR facilities have requested license amendment changes to take advantage of this new regulation. Many licensees have submitted license amendment requests to rerack the spent fuel pool in accordance with the subcriticality requirements in 10 CFR 50.68. A license amendment which takes credit for the subcriticality margins described in 10 CFR 50.68 invalidates any 10 CFR 70.24 exemption previously granted by the NRC. These licensees have therefore chosen to use the license amendment process to adopt the 10 CFR 50.68 regulatory requirements as their spent fuel pool licensing basis. Likewise, since the 10 CFR 70.24 exemptions, which were issued in accordance with the criteria described in IN 97-77, are based on the design and operation of the spent fuel pool at the time of issuance, changes to the spent fuel pool design and operation, including changes made under the 10 CFR 50.59 process, invalidate the exemption. Therefore, licensees who have either received a license amendment to change the licensing and design basis of the spent fuel pools or made design or operational changes to the spent fuel pools have invalidated their 10 CFR 70.24 exemptions. The staff encourages all licensees to review their current SFP licensing and design bases to ensure continued compliance with NRC regulations.

SUMMARY OF ISSUE

Nuclear reactor plants have storage facilities for the wet storage of spent fuel assemblies. One safety function of the spent fuel pool and storage racks is to maintain the spent fuel assemblies in a safe and subcritical array during all normal storage conditions and credible accident conditions and to provide a safe means to load the assemblies into storage or transportation casks.

The design and operation of PWR spent fuel pools ensure that new and irradiated fuel stored in the pool will remain subcritical under all normal conditions and credible accident conditions. To ensure subcriticality under normal conditions, spent fuel storage racks maintain fuel assemblies in geometrically safe configurations, typically by maintaining adequate spacing between assemblies and incorporating fixed neutron absorbers. The permissible storage configurations, the permitted fuel assembly enrichments, and the fuel and storage rack design specifications are documented in the facility's technical specifications. Additionally, PWR spent fuel pools contain soluble boron that provides defense-in-depth for a variety of credible accident conditions, such as mislocation of a fuel assembly or a dropped fuel assembly, which are part of a facility's licensing and design basis.

Spent fuel pools also contain designated cask pit areas for loading, unloading, and handling storage and transportation casks. Since most PWR spent fuel pools were not designed with the storage capacity necessary for all the spent fuel generated over the full term of the facility's operating license or for the permanent storage of a plant's spent fuel following the cessation of operations, the cask pit area provides plant operators with a safe location to load storage and

transportation casks. Licensees may use NRC-approved storage and transportation casks to remove spent fuel meeting specific criteria from the spent fuel pool, thereby avoiding unnecessary plant shutdowns caused by a lack of storage capacity.

Under 10 CFR Part 72, the NRC issues licenses for ISFSIs and Certificates of Compliance (CoCs) for dry cask storage systems. ISFSIs allow licensees to relocate spent fuel assemblies that satisfy specific-cooling time criteria and other design parameters from the spent fuel pools to dry storage environments. Under a general or specific Part 72 license, a facility may load spent fuel assemblies into storage casks that are subsequently stored in a dry condition on specially designed and fabricated concrete storage pads. With an ISFSI at the site, a plant can maintain sufficient storage space in the spent fuel pool for irradiated fuel removed from the reactor during refueling outages. Without an ISFSI many plants would be required to shut down because of insufficient storage space for irradiated fuel assemblies.

A key safety objective of storing spent fuel assemblies in spent fuel pools and dry storage casks is maintaining subcritical conditions under both normal and accident conditions. Under 10 CFR 50.68, the NRC regulates spent fuel pools to ensure that subcriticality is maintained through a combination of geometric spacing and fixed neutron absorbers. Although PWR spent fuel pools contain soluble boron, NRC regulations do not credit the boron for maintaining the SFP subcritical ($k_{eff} < 1.0$) under normal conditions. However, 10 CFR 50.68 does permit licensees to credit the SFP soluble boron to demonstrate that a 5-percent subcriticality margin (k_{eff} # 0.95) can be maintained under normal conditions and that the spent fuel pool inventory will remain subcritical ($k_{eff} < 1.0$) under all credible accident conditions. Therefore, the soluble boron provides defense-in-depth during accident conditions to ensure that no individual accident will result in an inadvertent criticality. Under 10 CFR 72.124, "Criteria for nuclear criticality safety," the NRC regulates dry cask storage activities to ensure that subcriticality is maintained during the handling, packaging, transfer, and storage of spent fuel assemblies. The NRC regulations for dry cask criticality prevention rely on favorable geometric configurations and fixed neutron absorbers. However, unlike 10 CFR 50.68, the regulations for criticality prevention in dry casks allow licensees to credit the spent fuel pool soluble boron for maintaining subcritical conditions during cask loading, unloading, and handling operations in the spent fuel pool. Therefore, many cask designs have incorporated soluble boron credit in lieu of a burnup credit as a means of increasing dry cask storage capacity while maintaining subcritical conditions.

During the NRC review of Pacific Gas and Electric Company's (PG&E's) application for a site-specific license for an ISFSI at the Diablo Canyon Power Plant (DCPP), the staff identified regulatory inconsistencies in the licensee's methodologies for the criticality analyses. As permitted by 10 CFR Part 72, PG&E credited the SFP soluble boron, during cask loading, unloading, and handling operations, to ensure subcritical conditions were maintained even if a full load of fresh fuel assemblies is assumed. However, the licensing basis for the DCPP spent fuel pools, 10 CFR 50.68, requires that the pools remain subcritical without soluble boron credit. Since dry casks are loaded and unloaded in the cask pit area of a licensee's spent fuel pool, casks, while they are in the SFP, must meet both the 10 CFR Part 72 and Part 50 requirements for criticality control. Therefore, the soluble boron credit methodology employed by PG&E in its ISFSI application, which also assumes a cask fully loaded with fresh fuel assemblies, was inconsistent with the regulatory and licensing basis for its spent fuel pools.

Based on interactions with the nuclear industry, the NRC has determined that similar regulatory inconsistencies may exist at other PWR facilities. In discussions with the Tennessee Valley Authority (TVA), the staff learned that the same regulatory inconsistency existed at Sequoyah Nuclear Plant (SQN). Since determining that this issue has generic implications, the NRC staff has been in communication with other PWR facilities regarding compliance with 10 CFR 50.68 during dry cask loading, unloading, and handling operations.

The NRC has determined that other PWR facilities may have regulatory inconsistencies similar to those identified at DCPP and SQN. Approximately 50 percent of PWRs are licensed to 10 CFR 50.68, while numerous PWRs utilize cask designs that rely on soluble boron credit in lieu of burnup credit to ensure subcriticality during loading, unloading, and handling operations in the spent fuel pool. Therefore, this regulatory and safety issue currently affects a significant number of PWR facilities and has the potential to affect all PWRs in the future as licensees modify their SFP licensing basis to take advantage of the 10 CFR 50.68 flexibility (described below) and as SFP crowding motivates licensees to implement dry cask storage. The generic applicability of this issue has prompted the issuance of this RIS.

Under 10 CFR 50.68, licensees may credit soluble boron to demonstrate that the spent fuel pool storage racks can maintain a 5-percent subcriticality margin. By permitting a soluble boron credit for normal storage conditions, 10 CFR 50.68 gives licensees more flexibility than was available under 10 CFR 70.24 and 10 CFR 70.24 exemptions, where licensees were required to maintain the 5-percent subcriticality margin without a soluble boron credit. However, a licensee who takes advantage of the greater flexibility of 10 CFR 50.68 must also show that the spent fuel pool will remain subcritical if flooded with unborated water. This second requirement ensures that the full soluble boron concentration is available to prevent credible accidents from resulting in an inadvertent criticality. The staff expects that most licensees will elect to comply with Section 50.68 rather than Section 70.24 because Section 50.68 is more flexible, allowing licensees to increase spent fuel pool storage capacity, while maintaining adequate margins for public health and safety.

In accordance with the NRC's Safety Strategic Goal, "Ensure protection of public health and safety and environment," the NRC staff and licensees must ensure that the NRC's Strategic Outcomes, including No Inadvertent Criticality Events, are satisfied. The NRC has determined that cask designs that rely on soluble boron credit in lieu of taking credit for burnup would enter an unanalyzed condition if flooded with unborated water. Although considered a low probability event, especially considering the short duration of cask loading operations, a boron dilution event in the spent fuel pool can rapidly lower the soluble boron concentration, reducing the subcriticality margin in a fully loaded cask to the point that an inadvertent criticality might occur. A boron dilution event can be initiated by various mechanisms, including either improper controls on normal routine operations (such as adding makeup water to the spent fuel pool), or accidents (such as piping ruptures in the fuel handling building). The portion of the SFP soluble boron concentration that is credited for ensuring subcriticality in the cask would not be available under these conditions to provide defense-in-depth; however adding credit for burnup may provide

defense-in-depth. Analyses performed by PG&E and TVA following identification of this issue showed that more than 60 percent of technical specification soluble boron concentration was credited for maintaining the dry casks subcritical under the most limiting permissible storage conditions, including assuming the cask is fully loaded with fresh fuel assemblies, leaving less than 40 percent of the SFP soluble boron concentration available for preventing an inadvertent criticality during a boron dilution event. These values were cask- and plant-specific and highly dependent on a number of factors, including the SFP technical specification limit on soluble boron concentration, the geometric configuration for spent fuel storage in the cask design, and the fuel assembly design and enrichment. The amount of soluble boron available to provide defense-in-depth during an accident will likely vary from plant to plant because of differences in the cask and fuel design parameters.

The NRC staff has determined that one potential resolution strategy to ensure 10 CFR 50.68 compliance for most licensees affected by this issue is to perform new 10 CFR Part 50 criticality analyses for fuel assemblies loaded into dry storage casks in the spent fuel pool. Licensees can perform these new spent fuel pool criticality analyses on a plant-specific basis and in accordance with previously accepted Part 50 conservatisms and assumptions, such as a permitted burnup credit. A plant-specific burnup credit analysis for dry cask loading, unloading, and handling operations will eliminate the need for a licensee to credit soluble boron, allowing the full SFP boron concentration to be used for defense-in-depth as required by 10 CFR 50.68. Additionally, licensees can choose to use conservative and bounding assumptions previously accepted by the NRC, such as a 5-percent decrement on burnup, in lieu of performing detailed calculations to justify smaller uncertainties and biases in the criticality analyses. Likewise, licensees who have previously submitted license amendments that credited burnup in the SFP criticality analyses can follow their plant-specific methodologies as previously reviewed and approved by the NRC, limiting the amount of reanalysis that must be performed. The staff expects that, if necessary, affected licensees can submit this new criticality analysis as part of a license amendment request to add a technical specification to the site's Part 50 license restricting the minimum burnup of fuel assemblies loaded in a particular cask design.

BACKFIT DISCUSSION

This RIS requires no action or written response and is, therefore, not a backfit under 10 CFR 50.109. Consequently, the staff did not perform a backfit analysis.

FEDERAL REGISTER NOTIFICATION

The staff did not publish a notice of opportunity for public comment in the Federal Register because this regulatory issue summary is informational and requires no action or written response by addressees.

SMALL BUSINESS REGULATORY ENFORCEMENT FAIRNESS ACT OF 1996

The NRC has determined that this action is not a rule and therefore is not subject to the Small Business Regulatory Enforcement Fairness Act of 1996.

PAPERWORK REDUCTION ACT

This RIS does not contain information collections and, therefore, is not subject to the requirements of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.).

CONTACT

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