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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 133 TO FACILITY OPERATING LICENSE NO. NPF-2

AND AMENDMENT NO. 125 TO FACILITY OPERATING LICENSE NO. NPF-8

SOUTHERN NUCLEAR OPERATING COMPANY, INC., ET AL.

JOSEPH M. FARLEY NUCLEAR PLANT, UNITS 1 AND 2

DOCKET NOS. 50-348 AND 50-364

1.0 INTRODUCTION

By letter dated June 30, 1997, as supplemented by letter of September 25, 1997, Southern Nuclear Operating Company, Inc. (SNC), et al., submitted a request for changes to the Joseph M. Farley Nuclear Plant (FNP), Units 1 and 2, Technical Specifications (TS) to allow credit for soluble boron in the spent fuel pool criticality analyses. These criticality analyses were performed using the methodology developed by the Westinghouse Owners Group (WOG) and described in WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology." The September 25, 1997, letter provided additional and clarifying information that did not change the scope of the June 30, 1997, application and the initial proposed no significant hazards consideration determination.

The proposed changes add two new Technical Specifications and associated Bases and revise the Design Features section to make the changes necessary to credit soluble boron in the fuel storage criticality analyses. The proposed changes are described below:

Revisions to the Table of Contents: The Table of Contents is revised to include two additional Technical Specifications, "Fuel Storage Pool Boron Concentration," Sections 3/4.7.13 and 3/4.7.14 for Units 1 and 2, respectively, and "Fuel Assembly Storage," Sections 3/4.7.14 and 3/4.7.15 for Units 1 and 2, respectively. These TS are being added to support crediting soluble boron in the fuel storage pool criticality analyses. The Table of Contents is also revised to include two additional Technical Specification Bases, "Fuel Storage Pool Boron Concentration," B 3/4.7.13 and B 3/4.7.14 for Units 1 and 2, respectively, and "Fuel Assembly Storage," B 3/4.7.14 and B 3/4.7.15 for Units 1 and 2, respectively. These Bases are being added to support crediting soluble boron in the fuel storage pool criticality analyses.

Addition of Technical Specifications 3/4.7.13 and 3/4.7.14 (Unit 1), and 3/4.7.14 and 3/4.7.15 (Unit 2): Two Technical Specifications are being added to credit soluble boron in the fuel storage pool criticality analyses and specify enrichment and burnup requirements. These Technical Specifications are "Fuel Storage Pool Boron Concentration," Sections 3/4.7.13 and 3/4.7.14 for Units 1 and 2, respectively, and "Fuel Assembly Storage," Sections 3/4.7.14 and 3/4.7.15 for Units 1 and 2, respectively.

TS 5.6.1.1: Design Features, Section 5.6.1.1 is revised to change the 0.95 K_{eff} requirement from "when flooded with unborated water" to "when flooded with water borated to 400 ppm," and add a requirement to maintain K_{eff} less than 1.0 when flooded with unborated water, and to add the fuel allowable storage configurations of all cell, 2-out-of 4, and burned/fresh storage. In addition, since the revised criticality analyses support the use of all types of Westinghouse fuel at FNP for up to 5.0 nominal weight percent (w/o), a single enrichment limit of 5.0 w/o for all fuel types is used. The enrichment limit for Westinghouse fuel with standard fuel assembly diameter (e.g., LOPAR) remains 4.25 w/o for the new fuel pit storage racks (Section 5.6.1.2). For Unit 1, a special configuration is established for fuel damaged during operation with baffle jetting.

TS 5.6.1.2: Section 5.6.1.2 is revised to change the nomenclature for fuel stored in the new fuel pit storage racks from "LOPAR fuel assemblies" to "fuel assemblies with Standard Fuel Assembly fuel rod diameter" and from "OFA or VANTAGE-5 fuel assemblies" to "fuel assemblies with Optimized Fuel Assembly fuel rod diameter."

Addition of Bases for Technical Specifications 3/4.7.13 and 3/4.7.14 (Unit 1), and 3/4.7.14 and 3/4.7.15 (Unit 2): Two Technical Specification Bases are being added to credit soluble boron and note that no credit is taken for the presence of Boraflex absorber in the fuel storage pool criticality analyses. These Technical Specifications Bases are "Fuel Storage Pool Boron Concentration," B 3/4.7.13 and B 3/4.7.14 for Units 1 and 2, respectively, and "Fuel Assembly Storage," B 3/4.7.14 and B 3/4.7.15 for Units 1 and 2, respectively.

The following section provides the staff's evaluation of the criticality aspects and boron dilution analyses of the FNP proposed TS changes.

2.0 EVALUATION

The FNP spent fuel storage racks were analyzed using the Westinghouse methodology, which has been reviewed and approved by the NRC [Newmyer, W. D., "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," Westinghouse Electric Corporation, WCAP-14416-NP-A, Rev. 1, November 1996]. This methodology takes partial credit for soluble boron in the fuel storage pool criticality analyses and requires conformance with the following NRC acceptance criteria for preventing criticality outside the reactor:

(1) k_{eff} shall be less than 1.0 if fully flooded with unborated water, which includes an allowance for uncertainties at a 95% probability, 95% confidence (95/95) level as described in WCAP-14416-NP-A; and

(2) k_{eff} shall be less than or equal to 0.95 if fully flooded with borated water, which includes an allowance for uncertainties at a 95/95 level as described in WCAP-14416-NP-A.

The analysis of the reactivity effects of fuel storage in the FNP spent fuel racks was performed with the three-dimensional Monte Carlo Code, KENO-Va, with neutron cross sections generated with the NITAWL-II and XSDRNPM-S Codes using the 227 group ENDF/B-V cross-section library. Since the KENO-Va Code package does not have burnup capability, the depletion analyses and the determination of small reactivity increments, due to manufacturing tolerances, were made with the two-dimensional transport theory code, PHOENIX-P, which uses a 42 energy group nuclear data library. The analytical methods and models used in the reactivity analysis have been benchmarked against experimental data for fuel assemblies similar to those for which the FNP racks are designed and have been found to adequately reproduce the critical values. This experimental data is sufficiently diverse to establish that the method bias and uncertainty will apply to rack conditions which include close proximity storage and strong neutron absorbers. The staff concludes that the analysis methods used are acceptable and capable of predicting the reactivity of the FNP storage racks with a high degree of confidence.

The FNP spent fuel storage racks have previously been qualified for storage of various Westinghouse 17 x 17 fuel assembly types with maximum enrichments up to 5.0 w/o U-235. The maximum enrichment is based on a nominal value of 4.95 w/o U-235 plus a manufacturing tolerance of 0.05. The spent fuel rack Boraflex absorber panels were considered in this previous analysis. Because of the Boraflex deterioration that has been observed in many spent fuel pools, the FNP spent fuel storage racks have been reanalyzed neglecting the presence of Boraflex to allow storage of all 17 x 17 fuel assemblies with nominal enrichments up to 5.0 w/o U-235 (enrichment tolerance of ± 0.05 w/o U-235) using credit for checkerboarding, burnup, burnable absorbers, and soluble boron.

The moderator was assumed to be pure water at a temperature of 68°F and a density of 1.0 gm/cc and the array was assumed to be infinite in lateral extent. Uncertainties due to tolerances in fuel enrichment and density, storage cell inner diameter, storage cell pitch, stainless steel thickness, assembly position, calculational uncertainty, and methodology bias uncertainty were accounted for. These uncertainties were appropriately determined at the 95/95 probability/confidence level. A methodology bias (determined from benchmark calculations) as well as a reactivity bias to account for the effect of the normal range of spent fuel pool water temperatures (50°F to 180°F) were included. These biases and uncertainties meet the previously stated NRC requirements and, therefore, are acceptable.

The enrichment required to maintain k_{eff} less than 1.0 with all cells filled with Westinghouse 17 x 17 fuel assemblies and no soluble boron in the pool water was found to be 2.15 w/o U-235. This resulted in a nominal k_{eff} of 0.96231. The 95/95 k_{eff} was then determined by adding the temperature and methodology biases and the statistical sum of independent tolerances and uncertainties to the nominal k_{eff} values, as described in Reference 2. This resulted in a 95/95 k_{eff} of 0.99201. Since this value is less than 1.0 and was determined at a 95/95 probability/confidence level, it meets the NRC criterion for precluding criticality with no credit for soluble boron and is acceptable.

Soluble boron credit is used to provide safety margin by maintaining k_{eff} less than or equal to 0.95 including 95/95 uncertainties. The soluble boron credit calculations assumed the all cell storage configuration moderated by water borated to 200 ppm. As previously described, the individual tolerances and uncertainties, and the temperature and methodology biases were added to the calculated nominal k_{eff} to obtain a 95/95 value. The resulting 95/95 k_{eff} was

0.90920 for fuel enriched to 2.15 w/o U-235. Since k_{eff} is less than 0.95 with 200 ppm of boron and uncertainties at a 95/95 probability/confidence level, the NRC acceptance criterion for precluding criticality is satisfied. This is well below the minimum spent fuel pool boron concentration value of 2000 ppm required by TS 3.7.13 and is, therefore, acceptable.

The concept of reactivity equivalencing due to fuel burnup was used to achieve the storage of fuel assemblies with enrichments higher than 2.15 w/o U-235 for the all cell storage configuration. The NRC has previously accepted the use of reactivity equivalencing predicated upon the reactivity decrease associated with fuel depletion. To determine the amount of soluble boron required to maintain $k_{eff} \leq 0.95$ for storage of fuel assemblies with enrichments up to 5.0 w/o U-235, a series of reactivity calculations were performed to generate a set of enrichment versus fuel assembly discharge burnup ordered pairs, which all yield an equivalent k_{eff} when stored in the FNP spent fuel storage racks. These are shown in TS Figure 3.7-1 and represent combinations of fuel enrichment and discharge burnup which yield the same rack k_{eff} as the rack loaded with 2.15 w/o fuel (at zero burnup). Uncertainties associated with burnup credit include a reactivity uncertainty of 0.01 Δk at 30,000 MWD/MTU applied linearly to the burnup credit requirement to account for calculational and depletion uncertainties and 5% on the calculated burnup to account for burnup measurement uncertainty. The NRC staff concludes that these uncertainties conservatively reflect the uncertainties associated with burnup calculations and are acceptable. The amount of additional soluble boron, above the value required above, that is needed to account for these uncertainties is 200 ppm. This results in a total soluble boron credit of 400 ppm for the all cell configuration. This is well below the minimum spent fuel pool boron concentration value of 2000 ppm required by TS 3.7.13 and is, therefore, acceptable.

A criticality analysis was performed for a 2-out-of-4 checkerboard storage configuration of 5.0 w/o U-235 assemblies in unborated water. This resulted in a 95/95 k_{eff} of 0.94285 and indicated that, for this configuration, soluble boron was not required to maintain $k_{eff} \leq 0.95$ and there is no burnup requirement for fuel enriched to 5.0 w/o U-235 or less.

The final configuration analyzed consisted of a burned/fresh checkerboard arrangement of a 2 x 2 matrix of cells containing three low-enriched fuel assemblies with initial nominal enrichments no greater than 1.6 w/o U-235 and one high-enriched assembly no greater than 3.9 w/o U-235. This configuration resulted in a 95/95 k_{eff} of 0.99415 in unborated water, thereby meeting the subcriticality acceptance criterion of less than 1.0 with no credit for boron. The amount of soluble boron required to maintain $k_{eff} \leq 0.95$ was 200 ppm, which resulted in a 95/95 k_{eff} of 0.94025.

Storage of assemblies with enrichments higher than 1.6 w/o U-235 low-enriched assemblies in the burned/fresh checkerboard configuration was determined using burnup reactivity equivalencing. Combinations of initial fuel enrichment and discharge burnup which yield the same storage rack k_{eff} as the rack containing 1.6 w/o U-235 assemblies at zero burnup (TS Figure 5.6-1) required an additional 150 ppm of boron to account for the uncertainties associated with burnup credit.

Storage of assemblies with enrichments higher than 3.90 w/o U-235 high-enriched assemblies in the burned/fresh checkerboard configuration was determined by crediting the reactivity decrease associated with the addition of integral fuel burnable absorbers (IFBAs). IFBAs consist of neutron absorbing material applied as a thin ZrB_2 coating on the outside of the UO_2 pellet. As with burnup credit, for IFBA credit reactivity equivalencing, a series of reactivity calculations are performed to generate a set of IFBA rod number versus initial enrichment ordered pairs, which all yield the equivalent k_{eff} when the fuel is stored in the burned/fresh checkerboard configuration analyzed for the FNP spent fuel racks. Uncertainties associated with IFBA credit include a 5% manufacturing tolerance and a 10% calculational uncertainty on the B-10 loading of the IFBA rods. The staff finds these uncertainties adequately conservative and acceptable. The amount of additional soluble boron needed to account for these uncertainties is 50 ppm. Therefore, with the above reactivity equivalencing, fuel assemblies with nominal enrichments up to 5.0 w/o U-235 can be stored in the burned/fresh checkerboard configuration by taking credit for a total additional amount of soluble boron of 200 ppm. When added to the 200 ppm required without reactivity equivalencing, this results in a total boron requirement of 400 ppm, which is equivalent to the amount required for the all cell storage configuration. This is well below the minimum spent fuel pool boron concentration value of 2000 ppm required by TS 3.7.13 and is, therefore, acceptable.

As an alternative method for determining the acceptability of fuel assembly storage based on IFBA loading, the infinite multiplication factor, k_∞, was used as a reference reactivity value. When k_∞ is used as a reference reactivity point, the need to specify an acceptable enrichment versus number of IFBA rods correlation is eliminated. Fuel assemblies with a reference k_∞ of 1.455 in the FNP core geometry at 68°F have been shown to result in a maximum $k_{eff} \leq 0.95$ when stored in the FNP spent fuel storage racks. Therefore, the fourth assembly in the burned/fresh checkerboard configuration must have an initial nominal enrichment less than or equal to 3.9 w/o U-235, or satisfy a minimum IFBA requirement for higher initial enrichments to maintain the reference fuel assembly k_∞ less than or equal to 1.455 at 68°F in the FNP core geometry.

Criticality analyses were also performed for special configurations including the storage of 11 damaged fuel assemblies in the FNP spent fuel storage racks. The Unit 1 spent fuel pool contains 11 damaged assemblies nominally enriched to 3.0 w/o U-235 occupying a space of 12 contiguous storage cells and surrounded by empty cells as shown in TS Figure 5.6-6. The analyses have shown that the storage configuration for the 11 damaged assemblies is less reactive than the previously evaluated all cell storage configuration and is, therefore, acceptable.

Although most accidents will not result in a reactivity increase, two accidents can be postulated for each storage configuration which would increase reactivity beyond the analyzed conditions. The first would be a loss of fuel pool cooling system and a rise in pool water temperature from 180°F to 240°F. The second would be a misload of an assembly into a cell for which the restrictions on location, enrichment, or burnup are not satisfied. Calculations have shown that the misload assembly accident for a 2-out-of-4 checkerboard configuration results in the highest reactivity increase. The reactivity increase requires an additional 850 ppm of soluble boron to maintain $k_{eff} \le 0.95$. However, for such events, the double contingency principle can be applied. This states that the assumption of two unlikely, independent, concurrent events is not required to ensure protection against a criticality accident. Therefore, the minimum amount of boron required by TS 3.7.13 (2000 ppm) is more than sufficient to cover any accident and the presence of the additional boron above the concentration required for normal conditions and reactivity equivalencing (400 ppm maximum) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

In order to prevent an undesirable increase in reactivity, the boundaries between the different storage configurations were analyzed. The interface requirements are shown in TS Figures 5.6-3 through 5.6-6. The TS changes proposed as a result of the revised criticality analysis are consistent with the changes stated in the NRC Safety Evaluation (SE) for WCAP-14416-P. Westinghouse submitted a revised Topical Report, WCAP-14416-NP-A, Rev. 1, which incorporated the changes stated in the NRC SE. Also, since the staff disagreed with the proprietary finding of the original WCAP-14416-P, Westinghouse's revised topical report was submitted as a nonproprietary version. Based on this consistency with the approved methodology and on the above evaluation, the staff finds these TS changes acceptable. The proposed associated Bases changes adequately describe these TS changes and are also acceptable.

The licensee also performed a boron dilution analysis, in accordance with the NRC SE of the WOG methodology described in WCAP-14416-NP-A, to ensure that sufficient time is available to detect and mitigate the dilution prior to exceeding the design basis k_{eff} of 0.95. Potential events were quantified to show that sufficient time will be available to enable adequate detection and suppression of any dilution event.

Deterministic dilution event calculations were performed for FNP to define the dilution times and volumes and compared to the dilution sources available. The licensee determined that 480,000 gallons are necessary to dilute the spent fuel pool volume of 300,000 gallons from the minimum TS boron concentration of 2000 ppm to a soluble boron concentration where k_{eff} of 0.95 would be approached (400 ppm). The various events that were considered included dilution from the demineralized water system, fire protection system, reactor makeup water tank, chemical and volume control system blender and other events that may affect the boron concentration of the pool, such as seismic events, random pipe breaks, and loss of offsite power.

The most limiting event was determined to be a random break in the fire protection piping. The fire protection lines provide the largest flow rate of the possible dilution sources. Additionally, the fire protection tanks, which contain 600,000 gallons, are the only tanks with more than the required volume (480,000 gallons) to dilute the spent fuel pool to 400 ppm. This random break event is more limiting than a seismic event because the fire protection lines at FNP are seismically qualified and, the fire protection flow rate is larger than the combined flow rate from nonseismic piping. A break in the fire protection line would take approximately 4 hours at a rate of 2000 gpm to dilute the spent fuel pool to 400 ppm. The spent fuel pool level alarms at FNP are battery powered and therefore, provide a high level of availability. Alarms for the fire pump and low fire protection tank level would provide additional indication to the operators. It is reasonable to expect that the large volume of water added to the spent fuel pool due to this dilution event would be detected by alarms or plant personnel and terminated prior to reaching 400 ppm.

Other sources at FNP require tanks to be replenished and/or longer than 8 hours to dilute the spent fuel pool to 400 ppm. The replenishment of the tanks would provide another indication to alert plant personnel of the event. Personnel perform rounds in the spent fuel pool area once every 8 hours. They are instructed to check the temperature and level of the pool, and the condition of the area. A dilution that would not significantly increase the spent fuel pool level or is a low flow leak may not be readily detected by plant personnel. The licensee proposed a TS surveillance requirement of sampling every 7 days. This is sufficient to detect low flow dilution sources, such as a component cooling water leak, and is consistent with the standard technical specifications for Westinghouse plants. The staff finds the 7-day surveillance requirement to be acceptable.

The licensee's evaluation concluded that an unplanned or inadvertent event that would result in the dilution of the spent fuel pool boron concentration from 2000 ppm to 400 ppm is not a credible event. After review, the staff finds that a boron dilution event to 400 ppm is unlikely and the licensee's boron dilution analysis is acceptable. The staff finds that the combination of the TS-controlled boron concentration and the 7-day sampling requirement, alarms, operator rounds, and other administrative controls should adequately detect and mitigate a dilution event prior to k_{eff} reaching 0.95 (400 ppm). Therefore, the analysis and proposed technical specification controls are acceptable for the boron dilution aspects of the request.

Additionally, the criticality analysis for the spent fuel storage pool show that k_{eff} remains less than 1.0 at a 95/95 probability/confidence level even if the pool were completely filled with unborated water. Therefore, even if the spent fuel storage pool were diluted to 0 ppm, the fuel is expected to remain subcritical.

3.0 STAFF CONCLUSION

On the basis of the staff's preceding evaluation of the criticality aspects of the FNP proposed TS changes, the staff finds the criticality aspects of request are acceptable and meet the requirements of General Design Criterion 62 for the prevention of criticality in fuel storage and handling. The analysis assumed credit for soluble boron, as allowed by WCAP-14416-NP-A, but no credit for the Boraflex neutron absorber panels. The required amount of soluble boron for each analyzed storage configuration is shown in Table 1 on the following page.

The following storage configurations and U-235 enrichment limits for Westinghouse 17 x 17 fuel assemblies were determined to be acceptable.

> Assemblies with initial nominal enrichments no greater than 2.15 w/o U-235 can be stored in any cell location. Fuel assemblies with initial nominal enrichments greater than this and up to 5.0 w/o U-235 must satisfy a minimum burnup requirement as shown in TS Figure 3.7-1.

Assemblies with initial nominal enrichments no greater than 5.0 w/o U-235 can be stored in a 2-out-of-4 checkerboard arrangement.

Assemblies can be stored in a burned/fresh 2 x 2 checkerboard arrangement consisting of three fuel assemblies with an initial nominal enrichment no greater than 1.6 w/o U-235 and one assembly with an initial nominal enrichment no greater than 3.9 w/o U-235. Fuel assemblies with initial enrichments greater than this and up to 5.0 w/o U-235 must satisfy a minimum burnup requirement as shown in TS Figure 5.6-1 (low-enrichment assemblies) or must satisfy a minimum IFBA requirement that maintains a maximum reference fuel assembly k_∞ less than or equal to 1.455 at 68°F (high-enrichment assembly).

TABLE 1

Summary of Soluble Boron Credit Requirements for Farley Units 1 and 2

Storage Configuration	Soluble Boron Required for $k_{eff} \leq 0.95$ (ppm)	Soluble Boron Required for Reactivity Equivalencing (ppm)	Total Soluble Boron Credit Required Without Accidents (ppm)
All Cell Storage	200	200	400
2-out-of-4 Checkerboard	0	0	0
Burned/Fresh Checkerboard	200	150	350

On the basis of the preceding staff's evaluation of the dilution analyses of the FNP proposed TS changes, the staff finds the boron dilution aspects of the proposed FNP license amendments request are acceptable. The TS boron concentration of 2000 ppm and 7-day surveillance requirement and other administrative controls are acceptable to ensure that sufficient time is available to detect and mitigate the dilution prior to exceeding the design basis k_{eff} of 0.95.

3.0 <u>STATE CONSULTATION</u>

In accordance with the Commission's regulations, the State of Alabama official was notified of the proposed issuance of the amendments. The State official had no comments.

4.0 ENVIRONMENTAL CONSIDERATION

The amendments change a requirement with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20 and change surveillance requirements. The NRC staff has determined that the amendments involve no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendments involve no significant hazards consideration, and there has been no public comment on such finding (62 FR 45464 dated August 27, 1997). Accordingly, the amendments meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendments.

5.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendments will not be inimical to the common defense and security or to the health and safety of the public.

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REFERENCES

1. D. Morey, SNC, letter to U. S. Nuclear Regulatory Commission, "Joseph M. Farley Nuclear Plant, Technical Specifications Change Request, Credit For Boron For Spent Fuel Storage," June 30, 1997.

2. D. Morey, SNC, letter to U. S. Nuclear Regulatory Commission, "Joseph M. Farley Nuclear Plant, Credit for Boron for Spent Fuel Storage RAI Responses," September 25, 1997.

3. Newmyer, W. D., "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," Westinghouse Electric Corporation, WCAP-14416-NP-A, Rev. 1, November 1996.

4. T. E. Collins, NRC, letter to T. Greene, WOG, "Acceptance for Referencing of Licensing Topical Report WCAP-14416-P, Westinghouse Spent Fuel Rack Criticality Analysis Methodology," (TAC No. M93254), October 25, 1996.