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ENCLOSURE

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION  
RELATING TO TOPICAL REPORT WCAP-14416-P  
"WESTINGHOUSE SPENT FUEL RACK CRITICALITY ANALYSIS METHODOLOGY"  
WESTINGHOUSE ELECTRIC CORPORATION

1.0 INTRODUCTION

In a submittal of July 28, 1995 (Ref. 1), the Westinghouse Owners Group (WOG) requested U.S. Nuclear Regulatory Commission (NRC) review and approval of topical report WCAP-14416-P, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," June 1995 (Ref. 2). The report presents the current Westinghouse methodology for calculating the effective multiplication factor,  $k_{eff}$ , of spent fuel storage racks in which no credit is taken for soluble boron except under accident conditions. The report also presents a new proposed procedure for crediting soluble boron in the spent fuel pool water when performing storage rack criticality analysis for Westinghouse fuel storage pools. A revision to the methodology was submitted on October 23, 1996 (Ref. 28), based on recommendations by the NRC Committee to Review Generic Requirements (CRGR).

General Design Criterion (GDC) 62 (Ref. 3) states that "criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations." The NRC has established a 5-percent subcriticality margin ( $k_{eff}$  no greater than 0.95) to comply with GDC 62 (Ref. 4). All of the applicable biases and uncertainties should be combined with  $k_{eff}$  to provide a one-sided, upper tolerance limit on  $k_{eff}$  such that the true value will be less than the calculated value with a 95-percent probability at a 95-percent confidence level (Ref. 5). The proposed new methodology would permit the use of spent fuel pool soluble boron to offset these uncertainties to maintain  $k_{eff}$  less than or equal to 0.95. However, the spent fuel rack  $k_{eff}$  calculation would remain less than 1.0 (subcritical) when flooded with unborated water with a 95-percent probability at a 95-percent confidence level.

2.0 SUMMARY OF THE TOPICAL REPORT

Section 1.0 of the report is an introduction, stating the purpose of the report and summarizing the individual sections. Section 2.0 explains the computer codes used in the evaluation of the spent fuel rack  $k_{eff}$  calculations and presents benchmark results. In Section 3.0, the assumptions used to model the spent fuel storage racks and the reactivity effects of biases and uncertainties are presented. Section 4.0 discusses reactivity equivalencing

methods that credit fuel assembly burnup and integral fuel burnable absorbers (IFBA). Section 5.0 describes postulated accidents that are considered in the spent fuel rack criticality analysis. Section 6.0 of the report, in conjunction with the supplement (Ref. 28), defines how credit for spent fuel pool soluble boron will be applied in the reactivity calculations.

### 3.0 TECHNICAL EVALUATION

The Westinghouse spent fuel rack criticality analysis methodology presented in WCAP-14416-P, and modified by Reference 28, provides a detailed description of both the current methodology, which has been used for many years by Westinghouse to calculate the reactivity of spent fuel storage racks, and a proposed new methodology with which partial credit for soluble boron in the pool water would be taken. The review of the proposed new methodology, given in Section 3.7 below, focused on the approximations and assumptions used as well as on revised technical specifications and analysis of dilution events required when crediting boron. The following evaluation is based on the material presented in the topical report, supplementary information (Ref. 28), discussions with Westinghouse staff, and responses to our requests for additional information (Refs. 14 and 26).

#### 3.1 Computer Code Methods and Benchmarking

Reactivity calculations for the spent fuel storage racks are performed with the KENO-Va (Ref. 6) three-dimensional Monte Carlo computer code. A 227 energy group cross section library is created by NITAWL-II (Ref. 7) and XSDRNPM-S (Ref. 8) from ENDF/B-V data (Ref. 9). This method has been used to analyze a set of 32 low-enriched, water-moderated,  $\text{UO}_2$  critical experiments to establish a method bias and uncertainty (Refs. 10, 11, 12, 13). These experiments cover a range of enrichments varying from 2.35 weight percent (w/o) to 4.31 w/o  $\text{U}^{235}$  separated by various materials ( $\text{B}_4\text{C}$ , borated aluminum, stainless steel, water) at fuel rod spacings from 0 to 6.56 cm. These experiments simulate current PWR spent fuel storage racks as realistically as possible with respect to parameters important to reactivity such as enrichment, assembly spacing, and neutron absorber worth. In response to a staff question (Ref. 14), WOG stated that no significant biases or trends were observed as a function of lattice or fuel parameters, including enrichment. The staff concludes that the KENO-Va benchmarking data is sufficiently diverse to establish that the method bias and uncertainty will apply to spent fuel storage rack conditions similar to those currently in use containing fuel rod enrichments up to 5.0 w/o  $\text{U}^{235}$ .

To minimize the statistical uncertainty of the KENO-Va calculations, at least 100,000 neutron histories are accumulated in each calculation. Experience has shown that this number of histories is sufficient to assure convergence of KENO-Va reactivity calculations. In addition, edits from the KENO-Va calculations provide a visual inspection of the overall convergence of the results.

A method bias of 0.0077 results from the comparison of KENO-Va calculations with the average measured experimental  $k_{\text{eff}}$ . The standard deviation of the bias value is 0.00136  $\Delta k$ . The 95-percent probability/95-percent confidence

level (95/95) one-sided tolerance limit factor for 32 values is 2.20 (Ref. 15). Thus, there is a 95-percent probability with a 95-percent confidence level that the uncertainty in reactivity due to the method is not greater than  $0.0030 \Delta k$  ( $2.20 \times 0.00136$ ).

The PHOENIX-P (Ref. 16) transport theory computer code is used to determine reactivity changes due to possible variations (tolerances) in material characteristics and mechanical dimensions in the fuel assembly and spent fuel racks, changes in pool conditions such as temperature and soluble boron, and fuel burnup. PHOENIX-P is a depletable, two-dimensional, multigroup, discrete-ordinates transport theory code that uses a 42 energy group nuclear data library.

PHOENIX-P has been compared with critical experiments (Refs. 17, 18, 19, 20). The PHOENIX-P reactivity predictions agree very well with the critical experiments, showing no significant bias or trends as a function of lattice or fuel parameters. The range of lattice parameters and configurations in the critical experiments encompassed present fuel storage configurations as realistically as possible.

PHOENIX-P has also been compared with isotopic measurements of fuel discharged from Yankee Core 5 (Ref. 21). The PHOENIX-P predictions agree very well with measurements for all measured isotopes throughout the burnup range.

Based on the above, we conclude that the analysis methods described are acceptable and capable of predicting the reactivity of PWR spent fuel storage racks containing assemblies with maximum fuel rod enrichments of 5.0 w/o  $U^{235}$  with a high degree of confidence.

### 3.2 KENO-Va Reactivity Calculations

KENO-Va is used to establish a nominal reference reactivity, using fresh (unirradiated) fuel assemblies and nominal rack dimensions, that satisfies the 0.95  $k_{eff}$  acceptance criterion. The following assumptions are used in the calculation:

- (1) The nominal spent fuel rack storage cell dimensions are used.
- (2) Fuel assembly parameters for all assembly types considered for storage in the spent fuel pool are evaluated. These parameters include number of fuel rods per assembly, fuel rod clad material, fuel rod clad outer diameter, fuel rod clad thickness, fuel pellet outer diameter, fuel pellet density, fuel pellet dishing factor, fuel rod pitch, control rod guide tube material, number of guide tubes, guide tube outer diameter, guide tube thickness, instrument tube material, number of instrument tubes, instrument tube outer diameter, and instrument tube thickness.
- (3) The nominal fresh fuel enrichment loaded into each fuel pin is modeled. The pin locations within a fuel assembly with multiple enrichments are considered, if applicable. The maximum fuel rod enrichment loaded into the fuel rods is limited to 5.0 w/o  $U^{235}$ .

- (4) The nominal values for theoretical density and dishing fraction of the fuel pellets are modeled.
- (5) If axial blankets are modeled, the length and enrichment of the blanket fuel pellets are considered.
- (6) No amount of  $U^{234}$  or  $U^{236}$  is modeled in the fuel pellet.
- (7) No amount of material from spacer grids or spacer sleeves is modeled in the fuel assembly.
- (8) No amount of burnable absorber poison material is modeled in the fuel assembly.
- (9) No amount of fission product poison material is modeled in the fuel assembly.
- (10) The moderator is pure water (no boron) at a temperature of 68°F and a density of 1.0 gm/cc.
- (11) If credit is taken for any fixed neutron-absorbing poison material panels present (except Boraflex), they are modeled using the as-built or manufacturer-specified poison material loadings and dimensions. Because of the significant Boraflex deterioration observed in some spent fuel racks, additional conservative assumptions are required for racks containing Boraflex as neutron absorber. These assumptions are not part of this technical review but will be reviewed on a case-by-case basis.
- (12) If all storage cells are not loaded with the same fuel assembly type and enrichment, the specific storage configuration will be modeled. Different types of configurations include checkerboard patterns, empty cell locations, specific pool configurations, and other layouts as defined.

Using these assumptions, the spent fuel rack  $k_{eff}$  is calculated with KENO-Va to show that  $k_{eff}$  is less than or equal to 0.95 with no credit for soluble boron. A temperature bias, which accounts for the normal operational temperature range of the spent fuel pool water, and the method bias, determined from the benchmarking calculations, are included. In addition, if neutron absorber panels are used, a reactivity bias is added to correct for the modeling assumption that individual  $B^{10}$  atoms are homogeneously distributed within the absorber material rather than clustered around each  $B_4C$  particle. The staff concludes that these assumptions tend to maximize the rack reactivity and are, therefore, appropriately conservative and acceptable.

### 3.3 PHOENIX-P Tolerance/Uncertainty Calculations

PHOENIX-P is used to calculate the reactivity effects of possible variations in material characteristics and mechanical/manufacturing dimensions. The following tolerances and uncertainties are considered:

- (1) Enrichment tolerance of  $\pm 0.05$  w/o  $U^{235}$  about the nominal fresh reference enrichments
- (2) Variation of  $\pm 2.0\%$  about the nominal reference  $UO_2$  theoretical density
- (3) Variation in fuel pellet dishing fraction from 0% to twice the nominal dishing
- (4) Tolerance about the nominal reference storage cell inner diameter, center-to-center pitch, and material thickness
- (5) Tolerances about the nominal width, length, and thickness of neutron absorber panels
- (6) Tolerances about the nominal poison loading of the neutron absorbing panels, if the nominal poison loading assumed in the KENO-Va model is not the minimum manufacturer-specified loading
- (7) Asymmetric positioning of fuel assemblies within the storage cells

The manufacturing tolerance uncertainties are based on the reactivity difference between nominal and maximum tolerance values and, therefore, meet the 95/95 probability/confidence level requirement. These uncertainties are combined statistically with the 95/95 calculation uncertainty on the KENO-Va nominal reference  $k_{eff}$  and the 95/95 methodology uncertainty ( $0.0030 \Delta k$ ) in the benchmarking bias determined for the KENO-Va methodology. The methodology benchmarking bias of  $0.0077 \Delta k$ , the water temperature bias, and the  $B^{10}$  self-shielding bias, if applicable, are included in the final  $k_{eff}$  summation before comparison against the  $0.95 k_{eff}$  limit. The following formula is used to determine the 95/95  $k_{eff}$  for the spent fuel storage racks:

$$k_{eff} = k_{nominal} + B_{method} + B_{temp} + B_{self} + B_{uncert}$$

where:

- $k_{nominal}$  = nominal conditions KENO-Va  $k_{eff}$
- $B_{method}$  = method bias determined from benchmark critical comparisons
- $B_{temp}$  = temperature bias
- $B_{self}$  =  $B^{10}$  self-shielding bias, if applicable

$$B_{uncert} = \sqrt{\sum (\text{tolerance}_i \dots \text{or} \dots \text{uncertainty}_i)^2}$$



The staff concludes that the final  $k_{eff}$  calculated using the above methodology will satisfy the NRC guidance that the fuel storage rack reactivity be less than or equal to 0.95 when fully flooded with unborated water, including all appropriate uncertainties at the 95/95 probability/confidence level (Refs. 4, 5). Therefore, the documented methodology is acceptable.

### 3.3 Fuel Assembly Burnup Credit

Reactivity equivalencing is used to allow storage of fuel assemblies with higher initial enrichments (up to 5.0 w/o  $U^{235}$ ) than those found acceptable using the previously described methodology. This concept is predicated upon the reactivity decrease associated with fuel depletion. For burnup credit, a series of reactivity calculations are performed with PHOENIX-P to generate a set of initial enrichment versus fuel assembly discharge burnup ordered pairs that all yield an equivalent  $k_{eff}$  (no greater than 0.95) when fuel assemblies are stored in the spent fuel storage racks.

The CINDER computer code (Ref. 22) was used to determine the most reactive time after reactor shutdown of an irradiated fuel assembly. CINDER is a point-depletion code that has been widely used and accepted in the nuclear industry to determine fission product activities. The fission products were permitted to decay for 30 years after shutdown and the fuel reactivity was found to reach a maximum at approximately 100 hours. At this time, the major fission product poison,  $Xe^{135}$ , has nearly completely decayed away. Therefore, the most reactive time for an assembly after shutdown of the reactor can be conservatively approximated by removing the  $Xe^{135}$ .

An uncertainty associated with the depletion of the fuel assembly and the reactivities computed with PHOENIX-P is accounted for in determining the reactivity equivalence limits. This uncertainty is based on the PHOENIX-P comparisons to the measured isotopics from the Yankee Core 5 experiments and is used to account for any depletion history effects or calculational uncertainties not included in the depletion conditions that are used in PHOENIX-P. The staff concludes that this uncertainty, which increases linearly with burnup from 0 at 0 burnup to  $0.02 \Delta k$  at an assembly average burnup of 60,000 MWD/MTU, is conservative and acceptable.

The effect of axial burnup distribution on fuel assembly reactivity has been evaluated by modeling depleted fuel in both two dimensions and three dimensions. These evaluations show that axial burnup effects can cause assembly reactivity to increase at burnup-enrichment combinations greater than 40,000 MWD/MTU and 4.0 w/o  $U^{235}$ . Westinghouse has stated that this effect will be accounted for as an additional bias if burnup credit limits reach these combinations.

An additional conservatism is that the depletion calculations do not take credit for effects, such as  $Pu^{241}$  decay and  $Am^{241}$  growth, that are known to substantially reduce reactivity during long-term storage. However, the staff does not consider this to be a requirement.

The staff concludes that adequate conservatism has been incorporated in the methodology used to determine burnup credit.

### 3.4 Integral Fuel Burnable Absorber (IFBA) Credit

Another reactivity equivalencing technique for storage of fuel enrichments greater than those allowed by the previous methodology is based on the reactivity decrease associated with the addition of integral fuel burnable absorbers (IFBA) to Westinghouse fuel. IFBAs consist of neutron-absorbing material applied as a nonremovable thin zirconium diboride ( $ZrB_2$ ) coating on the outside of the  $UO_2$  pellet. PHOENIX-P is used to generate a set of initial assembly enrichment versus number of IFBA rods per assembly ordered pairs that all yield the equivalent  $k_{eff}$  (no greater than 0.95) when fuel assemblies are stored in the spent fuel storage racks. The following assumptions are used for the IFBA rod assemblies in the PHOENIX-P calculations:

- (1) The fuel assembly is modeled at its most reactive point in life. This includes any time in life when the IFBA has depleted and the fuel assembly becomes more reactive.
- (2) The  $B^{10}$  loading for each IFBA rod, determined from Westinghouse IFBA design specifications for the given fuel assembly type, is the minimum standard loading offered by Westinghouse for that fuel assembly type.
- (3) The IFBA  $B^{10}$  loading is reduced by 5 percent to account for manufacturing tolerances and by an amount which corresponds to the minimum absorber length offered for the given fuel assembly type (e.g., a 144-inch fuel length with a minimum absorber length of 108 inches would result in a 25 percent IFBA  $B^{10}$  loading).

A calculational uncertainty of approximately 10 percent is included in the development of the IFBA requirements by adding an additional number of IFBA rods to each data point. To demonstrate that reactivity margin exists in the IFBA credit limit to accommodate future changes in IFBA patterns, calculations are also performed with nonstandard IFBA patterns. If a future change is made to the standard IFBA pattern designs, the reactivity difference between the new patterns and the old patterns will be calculated in order to assess the impact on both core reactivity and spent fuel rack IFBA credit limits.

The staff concludes that adequate conservatism has been incorporated in the methodology for determining IFBA requirements and that assemblies that comply with the enrichment-IFBA requirement curve developed by this methodology will have a  $k_{eff}$  no greater than 0.95 when placed in the spent fuel pool storage racks.

### 3.5 Infinite Multiplication Factor

An alternative method for determining the acceptability of fuel storage in a specific spent fuel rack is based on a PHOENIX-P calculation of the infinite multiplication factor ( $k_{\infty}$ ) for a fuel assembly in the reactor core geometry as a reference point. The fuel assembly model is based on a unit assembly configuration (infinite in the lateral and axial dimensions) in reactor geometry and is modeled at its most reactive point in life and moderated by

pure water (no boron) at a temperature of 68°F with a density of 1.0 g/cc. A 0.01  $\Delta k$  reactivity bias is added to this reference  $k_{\infty}$  to account for calculational uncertainties. The spent fuel storage rack is then modeled with these assemblies to ensure that the storage rack reactivity will be no greater than 0.95.

The staff concludes that fuel assemblies that have a reference  $k_{\infty}$  less than or equal to the value calculated with the above assumptions and methodology will have a  $k_{\text{eff}}$  no greater than 0.95 when placed in the spent fuel pool storage racks.

### 3.6 Postulated Accidents

The criterion that  $k_{\text{eff}}$  be no greater than 0.95 exists even for postulated accidents. Two types of accidents that can occur in a spent fuel storage rack may cause a reactivity increase: (1) a fuel assembly misplacement and (2) a pool water temperature change. However, for any of these accidents, the double contingency principle (Ref. 23) can be applied. According to this principle, it is unnecessary to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accidents, the presence of soluble boron in the pool water can be assumed as a realistic initial condition since assuming its absence would be a second unlikely event. PHOENIX-P boron worth calculations are used to determine the amount of soluble boron required to offset the highest reactivity increase caused by any postulated accident and to maintain  $k_{\text{eff}}$  less than or equal to 0.95, which is also the staff's acceptance criterion for accident conditions.

### 3.7 Soluble Boron Credit Methodology

In the proposed methodology for performing spent fuel rack reactivity calculations with credit for soluble boron in the pool water, a 95/95 rack  $k_{\text{eff}}$  is first calculated which remains below 1.0 (subcritical) with no soluble boron credit. This  $k_{\text{eff}}$  calculation uses the same assumptions described in Section 3.2 above, including the assumption of no soluble boron in the pool water. As previously described, a temperature bias, a method bias, a  $B^{10}$  self-shielding bias, and the 95/95 uncertainties associated with the calculation uncertainty, the methodology uncertainty in the benchmarking bias, and the manufacturing tolerances are included in the  $k_{\text{eff}}$  calculation.

The final equation for determining the  $k_{\text{eff}}$  requirement is

$$k_{\text{eff}} = k_{\text{nominal}} + B_{\text{temp}} + B_{\text{method}} + B_{\text{self}} + B_{\text{uncert}} < 1.0$$

where:

$k_{\text{nominal}}$  = nominal condition KENO-Va  $k_{\text{eff}}$

$B_{\text{temp}}$  = temperature bias for normal operating range



$B_{\text{method}}$  = method bias from benchmark critical comparisons

$B_{\text{self}}$  =  $B^{10}$  self shielding bias

$$B_{\text{uncert}} = \sqrt{\sum (\text{tolerance}_i \dots \text{or} \dots \text{uncertainty}_i)^2}$$

To determine the amount of soluble boron required to maintain  $k_{\text{eff}} \leq 0.95$ , KENO-Va is used to establish a nominal reference  $k_{\text{eff}}$  and PHOENIX-P is used to evaluate the reactivity effects of possible variations in material characteristics and mechanical manufacturing dimensions. These calculations contain the same assumptions, biases, tolerances, and uncertainties previously described except for the assumption regarding the moderator soluble boron concentration. Borated water is assumed instead of pure water. The tolerance calculations are, therefore, performed assuming the presence of soluble boron. The final 95/95  $k_{\text{eff}}$  calculation is determined as described in Section 3.2 above and must be less than or equal to 0.95 with allowances for biases, tolerances, and uncertainties including the presence of the determined concentration of soluble boron.

For enrichments higher than those assumed in the  $k_{\text{eff}}$  calculation, reactivity equivalencing methodologies are used to determine burnup or IFBA credit. However, the maximum fuel rod enrichment is limited to 5.0 w/o  $U^{235}$ . Soluble boron credit is used to offset the uncertainties associated with each of these equivalencing methodologies, as appropriate.

Postulated accidents are considered in the same manner as discussed in Section 3.6 except that the previously determined amount of soluble boron for the 95/95  $k_{\text{eff}}$  calculation, plus the amount determined for the reactivity equivalencing calculation, if required, is assumed present. The results of PHOENIX-P calculations of the reactivity change due to the presence of soluble boron are used to determine the amount of soluble boron required to offset the maximum reactivity increase caused by postulated accident conditions.

The final soluble boron credit requirement is determined from the following summation:

$$SBC_{\text{TOTAL}} = SBC_{95/95} + SBC_{\text{RE}} + SBC_{\text{PA}}$$

where:

$SBC_{\text{TOTAL}}$  = total soluble boron credit requirement (ppm)

$SBC_{95/95}$  = soluble boron credit required for 95/95  $k_{\text{eff}}$  less than or equal to 0.95 (ppm)

$SBC_{RE}$  = soluble boron credit required for reactivity  
equivalencing methodologies (ppm)

$SBC_{PA}$  = soluble boron credit required for  $k_{eff}$  less than or  
equal to 0.95 under accident conditions (ppm)

Thus the total soluble boron credit requirement will maintain the spent fuel rack  $k_{eff}$  less than or equal to 0.95 with a 95-percent probability at a 95-percent confidence level.

The total soluble boron required to maintain  $k_{eff}$  less than or equal to 0.95 is normally well below the large amount of soluble boron which is typically in spent fuel pool water. Therefore, a significant margin to criticality would generally still exist. However, a boron dilution analysis will be performed for each plant requesting soluble boron credit to ensure that sufficient time is available to detect and mitigate the dilution before the 0.95  $k_{eff}$  design basis is exceeded and submitted to the NRC for review (Ref. 29). The analysis should include an evaluation of the following plant-specific features:

1. Spent Fuel Pool and Related System Features
  - a) dilution sources
  - b) dilution flow rates
  - c) boration sources
  - d) instrumentation
  - e) administrative procedures
  - f) piping
  - g) loss of offsite power impact
2. Boron Dilution Initiating Events (including operator error)
3. Boron Dilution Times and Volumes

#### 4.0 SUMMARY AND CONCLUSIONS

The topical report WCAP-14416-P and supporting documentation provided in References 14, 26 and 28 have been reviewed in detail. A major portion of this review focused on a proposed new methodology whereby partial credit could be taken for soluble boron in the spent fuel pool to meet the NRC-recommended criterion that the spent fuel rack multiplication factor ( $k_{eff}$ ) be less than or equal to 0.95, at a 95-percent probability, 95-percent confidence level.

The staff concludes that the proposed new methodology for soluble boron credit is acceptable for the following reasons:

- (1) Uncertainties in mechanical tolerances and storage rack dimensions are determined at the 95-percent probability, 95-percent confidence level and are incorporated in a conservative direction.
- (2) Conservative uncertainties are incorporated for depletion calculations.

- (3) A substantial margin to criticality would be available since the spent fuel rack  $k_{eff}$  will be less than or equal to 0.95, at a 95-percent probability, 95-percent confidence level, with an amount of soluble boron significantly less than that amount normally available in the pool.
- (4) The fuel rack  $k_{eff}$  will remain less than 1.0 (subcritical), at a 95-percent probability, 95-percent confidence level, even with no soluble boron in the spent fuel pool, thereby conforming to Criterion 62, "Prevention of criticality in fuel storage and handling" of Appendix A to 10 CFR Part 50.

The staff concludes that the methodology documented in WCAP-14416-P and Reference 28 can be used in licensing actions with the following provisions which are stated in WCAP-14416-P and Reference 28:

- (1) If axial and planar variations of fuel assembly characteristics are present, they should be explicitly addressed, including the locations of burnable absorber rods.
- (2) The maximum fuel rod enrichment shall be limited to 5.0 w/o  $U^{235}$ .
- (3) The spent fuel storage racks should be assumed to be infinite in lateral extent or surrounded by a water reflector and concrete or structural material as appropriate to the design. The fuel may be assumed to be infinite in the axial dimension, or the effect of reflector on the top and bottom of the fuel may be evaluated.
- (4) If credit for the reactivity depletion due to fuel burnup is taken, operating procedures should include provision for independent confirmation of the fuel burnup, either administratively or experimentally, before the fuel is placed in burnup-dependent storage cells.
- (5) A reactivity uncertainty due to uncertainty in the fuel depletion history effects and depletion calculations should be included.
- (6) A correction for the effect of the axial distribution in burnup should be determined and added to the reactivity calculated for uniform axial burnup distribution if it results in a positive reactivity effect.

In addition, as stated in the letter of October 18, 1996, from Westinghouse to the NRC (Ref. 28), the following items will be submitted by all licensees proposing to use the methodology described above:

- (1) All licensees proposing to use the new method described above for soluble boron credit should submit a 10 CFR Part 50.36 technical specification change containing the following:
  - a.  $k_{eff}$  shall be less than or equal to 0.95 if fully flooded with water borated to [1050] ppm which includes an allowance for uncertainties as described in WCAP-14416-P.

- b.  $k_{eff}$  shall be less than 1.0 if fully flooded with unborated water which includes an allowance for uncertainties as described in WCAP-14416-P.
- c. The spent fuel pool boron concentration shall be greater than [2300] ppm and shall be verified at a frequency of [7 days].

Licensees using the Westinghouse Improved Standard Technical Specifications (ISTS) described in NUREG-1431 (Ref. 27), should adopt specification 3.7.16, "Fuel Storage Boron Concentration," and 4.3.1, Fuel Storage-Criticality," as shown in section 5.0 below.

- (2) All licensees proposing to use the new method described above for soluble boron credit should identify potential events which could dilute the spent fuel pool soluble boron to the concentration required to maintain the 0.95  $k_{eff}$  limit (as defined in (1)a above) and should quantify the time span of these dilution events to show that sufficient time is available to enable adequate detection and suppression of any dilution event. The effects of incomplete boron mixing, such as boron stratification, should be considered. This analysis should be submitted for NRC review and should also be used to justify the surveillance interval used for verification of the technical specification minimum pool boron concentration.
- (3) Although Boraflex deterioration is not addressed in this topical report, appropriate analyses are required to account for Boraflex degradation in storage racks that credit the negative reactivity effect of Boraflex. These analyses should be submitted for NRC review.
- (4) Plant procedures should be upgraded, as necessary, to control pool boron concentration and water inventory during both normal and accident conditions.

## 5.0 TECHNICAL SPECIFICATIONS



## 3.7 PLANT SYSTEMS

## 3.7.16 Fuel Storage Pool Boron Concentration

LCO 3.7.16 The fuel storage pool boron concentration shall be  $\geq$  [2300] ppm.

APPLICABILITY: When fuel assemblies are stored in the fuel storage pool and a fuel storage pool verification has not been performed since the last movement of fuel assemblies in the fuel storage pool.

## ACTIONS

| CONDITION  | REQUIRED ACTION  | COMPLETION TIME |
|--|--|-----------------|
| A. Fuel storage pool boron concentration not within limit. | -----NOTE-----<br>LCO 3.0.3 is not applicable.<br>-----  |                 |
|  | A.1 Suspend movement of fuel assemblies in the fuel storage pool.  | Immediately     |
|  | <u>AND</u>   |                 |
|  | A.2.1 Initiate action to restore fuel storage pool boron concentration to within limit.  | Immediately     |
|  | <u>OR</u>  |                 |
|  | A.2.2 Verify by administrative means [Region 2] fuel storage pool verification has been performed since the last movement of fuel assemblies in the fuel storage pool. | Immediately     |

## SURVEILLANCE REQUIREMENTS

| SURVEILLANCE  | FREQUENCY |
|---|-----------|
| SR 3.7.16.1 Verify the fuel storage pool boron concentration is within limit. | [7 days]  |

## 4.0 DESIGN FEATURES

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### 4.3 Fuel Storage

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#### 4.3.1 Criticality

- 4.3.1.1 The spent fuel storage racks are designed and shall be maintained with:
- a. Fuel assemblies having a maximum U-235 enrichment of [4.5] weight percent;
  - b.  $k_{eff} < 1.0$  if fully flooded with unborated water which includes an allowance for uncertainties as described in WCAP-14416-P;
  - c.  $k_{eff} \leq 0.95$  if fully flooded with water borated to [1050] ppm which includes an allowance for uncertainties as described in WCAP-14416-P;
  - [d. A nominal [9.15] inch center to center distance between fuel assemblies placed in [the high density fuel storage racks];]
  - [e. A nominal [10.95] inch center to center distance between fuel assemblies placed in [low density fuel storage racks];]
  - [f. New or partially spent fuel assemblies with a discharge burnup in the "acceptable range" of Figure [3.7.17-1] may be allowed unrestricted storage in [either] fuel storage rack(s); and]
  - [g. New or partially spent fuel assemblies with a discharge burnup in the "unacceptable range" of Figure [3.7.17-1] will be stored in compliance with the NRC approved [specific document containing the analytical methods, title, date, or specific configuration or figure].]

6.0 REFERENCES

- 1) Newton, R.A. (WOG), letter to Document Control Desk (NRC), Westinghouse Owners Group Transmittal of Reports: WCAP-14416-P (Proprietary) and WCAP-14417-NP (Non-proprietary) Entitled "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," OG-95-062, July 28, 1995.
- 2) Newmyer, W.D., "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," WCAP-14416-P, June 1995.
- 3) Code of Federal Regulations, Title 10, Part 50, Appendix A, Criterion 62, "Prevention of Criticality in Fuel Storage and Handling."
- 4) U.S. Nuclear Regulatory Commission, Standard Review Plan, Section 9.1.2, NUREG-0800, July 1981.
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August 12, 1996

MEMORANDUM TO: Edward L. Jordan, Chairman  
Committee to Review Generic Requirements

FROM: Frank J. Miraglia, Deputy Director  
Office of Nuclear Reactor Regulation

SUBJECT: CREDIT FOR SOLUBLE BORON IN PWR SPENT FUEL POOLS

REFERENCES: 1. Letter from R.C. Jones (NRC) to R.A. Newton, Chairman,  
Westinghouse Owners Group, "Acceptance for Referencing of  
Licensing Topical Report WCAP-14416-P, 'Westinghouse Spent  
Fuel Rack Criticality Analysis Methodology'"

2. WCAP-14416-P, "Westinghouse Spent Fuel Rack Criticality  
Analysis Methodology," June 1995

The Office of Nuclear Reactor Regulation (NRR) is proposing (Ref. 1) to accept the Westinghouse Owners Group (WOG) methodology for crediting the soluble boron in Westinghouse-designed spent fuel pools (Ref. 2). The basis for this acceptance is that a significant margin to criticality would still be available and, thus, the probability of an inadvertent criticality in the spent fuel pool would not be increased to any appreciable extent. In fact, the new methodology would still require subcriticality even if no soluble boron were present. The large reactivity margin available in the soluble boron in the spent fuel pool water could be used by licensees to design spent fuel storage racks with expanded storage capacity.

The staff considers this a relaxation of our existing position, which only allows credit for soluble boron under accident conditions. The CRGR charter requires review of proposed relaxations or decreases in current requirements which affect such a generic group of plants. Therefore, we are requesting CRGR review of the attached package.

Attachment 1 is the staff Safety Evaluation Report (Ref. 1). Attachment 2 contains copies of Topical Report WCAP-14416-P (Ref. 2). Please note that Westinghouse has reclassified the report as nonproprietary. Attachment 3 is the response to the questions contained in Section IV.B of the CRGR Charter. We will work with your staff to schedule a meeting on this subject after the Committee has reviewed the enclosed package. The staff considers this to be Category 2.

Attachments:

1. WCAP-14416-P SER
2. Topical Report WCAP-14416-P (non-proprietary)
3. Response to CRGR Charter Questions

\* See previous concurrence

#96-070

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|------|-----------|-----------|-----------|----------|--------|----------|----------|
| OFC  | SRXB:DSSA | SRXB:DSSA | D:DSSA    | TSB:ADPR | OGC    | ADT:NRR  | DT:NRR   |
| NAME | LKOPP*    | RJONES*   | GHOLAHAN* | CGRIMES* |        | ATHADANI | MIRAGLIA |
| DATE | 6/13/96   | 6/20/96   | 6/20/96   |          | 1/2/96 |          |          |

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