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January 26, 1988

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Subject: Catawba Nuclear Station, Units 1 and 2
Docket Nos. 50-413 and 50-414
Technical Specification Amendment
Reload Fuel Enrichment Upgrade

Gentlemen:

Please find attached a revised Criticality Analysis for the Catawba Fuel Storage Facility concerning the Technical Specification amendment request to upgrade reload fuel enrichments which was submitted to the NRC per my September 8, 1987 letter.

The analysis was revised to correct inconsistencies in the number of significant figures used to report results and values in calculations. In the enclosed revision, numerical quantities are consistently reported to five decimal places. It should be noted that this is an administrative change which does not affect the results or conclusions in the original submittal.

This proposal involves a revision to a previous amendment request. Accordingly, no license fee is required. As previously indicated in my September 8, 1987 letter, it is requested that approval of the proposal be granted prior to July 1, 1988 in view of planned reload designs and schedules.

Pursuant to 10 CFR 50.91(b)(1), the appropriate South Carolina State Official is being provided a copy of this revision to the previous amendment request.

Very truly yours,

Hal B. Tucker

Hal B. Tucker

JGT/1270/sbn

Attachment

IE26
1/1

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ATTACHMENT 2A

CRITICALITY ANALYSES FOR THE CATAWBA
FUEL STORAGE FACILITIES

CRITICALITY ANALYSES FOR THE CATAWBA FUEL STORAGE FACILITIES

1.0 CATAWBA NEW FUEL VAULT ANALYSIS

1.1 CRITICALITY DESIGN CRITERIA

Criticality of fuel stored in the new fuel vault is prevented by the design of the storage racks which maintain a minimum separation between stored fuel assemblies.

The design of the new storage facility is based on the criteria presented in Catawba FSAR Section 9.1.1.1. The design basis for preventing criticality in the new fuel vault is taken from ANSI N18.2-1973, Section 5.7.4.1, which states:

> "The design of spent fuel storage racks and transfer equipment shall be such that the effective multiplication factor will not exceed 0.95 with new fuel of the highest anticipated enrichment in place assuming flooding with pure water. The design of normally dry new fuel storage racks shall be such that the effective multiplication factor will not exceed 0.98 with fuel of the highest anticipated enrichment in place assuming optimum moderation."

The following accidents are considered in the criticality design of the new fuel storage vault:

(A) Flooding: complete immersion of the entire array in pure, unborated full density water.

(B) Envelopment of the entire array in a uniform density aqueous foam of optimum moderation density (that density which maximizes the reactivity of the array).

Accidents resulting in an increase in k-eff because of geometrical changes of the racks are not considered credible due to the following design bases:

(A) The new fuel racks are designed to withstand normal operating loads as well as SSE seismic loads meeting ANS Safety Class 3 and AISC requirements.

(B) The new fuel storage racks are located in the New Fuel Storage Buildings which protect the racks from weather conditions and external forces such as those resulting from tornado or wind loads.

The nominal center-to-center spacing of 21 inches is sufficient to meet the criticality criteria of ANSI N18.2-1973 under the postulated conditions of complete flooding with unborated water or an optimum moderator. The racks are designed to prevent the insertion of fuel between the storage positions.

1.2 FACILITY DESCRIPTION

Each unit of the Catawba Station has an independent new fuel storage system. The New Fuel Storage Buildings are Seismic Category I, reinforced concrete structures. The structures are designed to withstand static and SSE seismic loads as well as tornado generated missile impact loads. The New Fuel Storage Racks are contained entirely within the structure and further segregated from other equipment and operations by a reinforced concrete wall.

New fuel for each unit may be stored in the Spent Fuel Pool or stored dry in racks which are bolted to the floor of the New Fuel Storage Buildings. The new fuel racks are designed to accommodate 98 fuel assemblies for each unit at a nominal center-to-center spacing of 21 inches. Only 92 of these racks may actually be used because six (6) are inaccessible with the overhead crane. Storage cells are formed by 1/8 inch nominal thickness, minimum cell wall thickness 0.12 inches, type 304 stainless steel that completely encloses the fuel on four sides, whereas the supporting racks are fabricated from painted carbon steel conforming to AISC tolerances and specifications.

The nominal fuel cell interior dimension is nine inches square with all interior edges finished to a minimum 1/16 inch radius of chamfer. If chamferred, all intersecting edges are blended. All interior surfaces which may come in contact with the fuel assemblies are smooth and clean of all weld spatter, dirt, and grease. Design conditions that could cause hang-up during insertion or withdrawal of fuel assemblies have been avoided.

General arrangement diagrams of the Unit 1 New Fuel Storage Buildings and racks are provided in Catawba FSAR Figures 9.1.1-1 and 9.1.1-2 (Attachments 1 and 2, respectively). Unit 2 facilities are a mirror image of Unit 1 facilities.

1.3 CRITICALITY ANALYSIS METHOD

The analysis method which ensures the criticality safety of fuel assemblies in the new fuel storage racks uses the Criticality Analysis Sequence No. 2 (CSAS2) and the 123GROUPGMTH master cross-section library included in the SCALE-3 system of codes (Reference 1). CSAS2 consists of two cross-section processing codes (NITAWL and BONAMI), a 1-D transport code for cell-weighting cross-section data (XSDRNPM), and a 3-D monte-carlo code (KENO-IV) for calculating the effective multiplication factor for a system.

CSAS2 and 123GROUPGMTH cross-sections are operational on the Duke Fairview IBM computer system. A set of 40 critical experiments have been analyzed using the CSAS2/123GROUPGMTH reactivity calculation method to demonstrate its applicability to criticality analysis and to establish method bias and variability. The experiments analyzed represent a diverse group of water moderated, oxide fuel arrays separated by various materials (stainless steel, Boral, water, etc.) that are representative of LWR shipping and storage conditions, including the Catawba new and spent fuel storage racks. The set of 40 critical experiments analyzed using the above method are summarized in Table 1.

The average K-eff of the benchmarks is 0.99512 with a standard deviation of 0.00545 ΔK. The 95/95 one-sided tolerance limit factor for 40 values is

2.13. Therefore, there is a 95 percent probability at 95 percent confidence level that the uncertainty in reactivity, due to the method, is not greater than 0.01161 ΔK.

1.4 CRITICALITY EVALUATION

A number of criticality analyses considering a full loading of either Westinghouse 17x17 Standard (STD) or Optimized (OFA) fuel assemblies are performed using aqueous moderator densities ranging from 0.05 to 1.0 gm/cc. Evaluating neutron multiplication over this range of moderator densities is necessary to demonstrate compliance with the design basis for preventing criticality in the new fuel vault as provided by ANSI N18.2-1973, Section 5.7.4.1.

The following assumptions were used in the criticality evaluation:

1) Fuel assembly parameters modeled in each case are summarized in Table 2.

2) Credit is taken for the inherent neutron absorption in full length structural materials as allowed by ANSI N18.2-1973.

3) No burnable poisons, control rods, or supplemental neutron poisons are assumed to be present.

4) Effects of reflectors other than water are included if their neglect would have been nonconservative. This includes the storage vault's concrete walls, ceiling, and floor.

5) All assemblies are assumed to be 4.1 w/o U-235 enriched and unirradiated. This worst-case enrichment assumption allows for a specified maximum nominal enrichment of 4.0 w/o U-235 with an enrichment tolerance of $\leq \pm 0.1$ w/o U-235.

6) The new fuel storage vault is conservatively modeled as an infinite series of 2 infinite rows of 12 foot high fuel assemblies in minimal thickness SS304 cell enclosures.

7) Each fuel assembly is treated as a heterogeneous system with the fuel pins, control rod guide tubes, and instrumentation thimble guide tube modeled explicitly.

8) Mechanical uncertainties and biases due to construction tolerances are considered by using worst-case conditions. Uncertainties considered include cell I.D., center-to-center spacing, and cell enclosure thickness.

In order to address accidents involving flooding of the new fuel storage facilities with full density and optimum density unborated water, eighteen (18) criticality analyses are performed for each fuel type considered (i.e., Westinghouse 17x17 STD and OFA fuel types.) The 18 analyses performed for each fuel type case use aqueous moderator densities ranging from 0.02 to 1.0 gm/cc.

The K-eff for a full loading of new fuel in the new fuel storage racks are calculated in each fuel type/moderator density case as follows:

$$K_{eff} = K_N + B_{mech} + B_{meth} + [(Ks_n)^2 + (Ks_{mech})^2 + (Ks_{meth})^2]^{1/2}$$

where:

K_N	=	nominal case K_{eff} calculated by KENO-IV = Table 3.
B_{mech}	=	bias to account for mechanical tolerances which can increase K_{eff} above the nominal case values.
	=	0.00000 ΔK (mechanical tolerances are considered by using worst-case conditions in the nominal case KENO-IV models).
B_{meth}	=	method bias as determined by benchmark critical experiments.
	=	0.00488 ΔK
Ks_n	=	95 percent probability, 95 percent confidence level uncertainty in the nominal case K_{eff}.
	=	Table 3 Standard Deviations x 2.0.
Ks_{mech}	=	95 percent probability, 95 percent confidence level uncertainty in mechanical tolerance bias.
	=	0.00000 ΔK (mechanical tolerances are considered by using worst-case conditions in the nominal case KENO-IV models).
Ks_{meth}	=	95 percent probability, 95 percent confidence level uncertainty in the method bias.
	=	0.01161 ΔK

Substituting calculated values results in final rack K-eff values which include all biases and uncertainties as required by ANSI/ANS-57.2-1983, Section 6.4.2.2.1 for demonstrating compliance with criticality design criteria. Criticality analysis results are summarized graphically in Figures 1 and 2 for Westinghouse 17x17 STD and OFA fuel types, respectively. Figures 1 and 2 show nominal K-eff values calculated in each fuel type/moderator density case as well as error bars which include the calculational biases and 95/95 uncertainties discussed above.

1.5 NEW FUEL VAULT ANALYSIS RESULTS AND CONCLUSIONS

The criticality analysis results illustrated by Figures 1 and 2 demonstrate that 4.1 w/o U235 enriched Westinghouse STD and OFA fuel can be safely stored in the Catawba new fuel storage vaults in accordance with ANSI N18.2-1973, Section 5.7.4.1 criteria.

2.0 CATAWBA SPENT FUEL STORAGE RACK ANALYSIS

2.1 CRITICALITY DESIGN CRITERIA

Criticality of fuel stored in the spent fuel pool is prevented by the design of the storage racks which maintain a minimum separation between stored fuel assemblies.

The design of the spent fuel storage facility is based on criteria presented in Catawba FSAR Section 9.1.2.1. The design basis for preventing criticality in the spent fuel pool is taken from ANSI N210-1976 and ANSI N18.2-1973, Section 5.7.4.1, which states:

> "The design of spent fuel storage racks and transfer equipment shall be such that the effective multiplication factor will not exceed 0.95 with new fuel of the highest anticipated enrichment in place assuming flooding with pure water. The design of normally dry new fuel storage racks shall be such that the effective multiplication factor will not exceed 0.98 with fuel of the highest anticipated enrichment in place assuming optimum moderation."

Postulated accident conditions do not result in an increase in K-eff values beyond those calculated for the infinite array in the normal design basis analyses.

Accidents considered include: 1) loss of spent fuel pool cooling, 2) the sliding of free standing rack modules such that peripheral cells of two rack modules have C-C spacings below those assumed in normal design basis analyses, and 3) the dropping of fuel assemblies on top of a rack module or lowering of a fuel assembly by the side of a rack module in a non-storage location. Cask drop accidents are not analyzed for criticality consequences since the dropping of a cask into the fuel storage areas at Catawba is precluded by design features and cask handling procedures.

2.2 FACILITY DESCRIPTION

Each unit of the Catawba Station has an independent spent fuel storage system. The Fuel Handling System associated with the pool is discussed in Catawba FSAR Section 9.1.4, and Spent Fuel Cooling System is presented in Section 9.1.3. Radiation shielding and monitoring are presented in Catawba FSAR Sections 12.1 and 11.4, respectively. There are sufficient fuel storage racks to accommodate the number of fuel assemblies discharged from approximately 19 normal Catawba refueling cycles plus one complete Catawba core. Provisions are also made to store control rods and burnable poison rods. The dimensions and location of the fuel pool are included on Catawba FSAR Figures 9.1.2-2 and 9.1.2-3 (Attachments 3 and 4, respectively). For location of the fuel pool in the station complex, see Catawba FSAR Figures 1.2.2-3 and 1.2.2-4. Major components, piping, valves and instrumentation in contact with the fuel pool water are stainless steel. The fuel pools, transfer canals, and cask pits are lined with stainless steel plate. This fuel pool liner plate is designed, fabricated, and installed as a nuclear safety related, QA Condition 1 system.

The spent fuel assemblies are held in a vertical position by the spent fuel pool storage racks. The fuel assemblies are supported within the fuel storage racks by a stainless steel plate located six inches above the fuel pool floor. Openings are provided that allow coolant water to flow through the rack and up around the fuel assembly. A lead-in assembly is provided at the top of each rack to guide fuel into its proper storage location.

The fuel racks are designed as free standing, self-supporting, independent modules which stand on the fuel pool floor. There are spaces available for the potential storage of 1418 fuel assemblies per unit. Spent fuel storage cell general arrangement is provided in Catawba FSAR Figure 9.1.2-7 (Attachment 5). Spent fuel storage rack plans and details are provided by Catawba FSAR Figures 9.1.2-1 and 9.1.2-8 (Attachments 6 and 7). Unit 2 facilities are a mirror image of Unit 1 facilities.

2.3 CRITICALITY ANALYSIS METHOD

The analysis method which ensures the criticality safety of fuel assemblies in the spent fuel storage racks is the same as used in the Catawba New Fuel Storage Rack Analysis described previously in Section 1.3 of this summary.

2.4 CRITICALITY EVALUATION

2.4.1 NORMAL STORAGE

This section presents the analyses which demonstrate the acceptability of storing up to 4.0 w/o enriched Westinghouse STD or OFA fuel in the Catawba spent fuel storage racks under normal conditions. A nominal case model for each fuel type is described, and a neutron multiplication factor, K-eff, for each nominal model in presented. Construction tolerances and assembly positioning effects are addressed and uncertainties which are to be applied to the nominal calculated K-eff values are presented. The final K-eff values produced represent maximums with a 95 percent probability at a 95 percent confidence level as required by ANSI/ANS-57.2-1983 to demonstrate criticality safety.

The following assumptions were used in the criticality evaluation:

1) Fuel assembly parameters modeled in each case are summarized in Table 2.

2) Credit is taken for the inherent neutron absorption in full length structural materials as allowed by ANSI N18.2-1973.

3) No burnable poisons, control rods, or supplemental neutron poisons are assumed to be present.

4) All assemblies are assumed to be unirradiated 4.05 w/o U-235 enriched Westinghouse STD or OFA type. This worst case assumption allows for a specified maximum nominal enrichment of 4.0 w/o U-235 with an enrichment tolerance of $\leq \pm 0.05$ w/o U-235.

5) The spent fuel storage array is conservatively modeled as infinite in lateral and axial extent.

6) Geometrical and material uncertainties due to mechanical tolerances are treated by either using worst-case configuration or by performing sensitivity calculations and obtaining appropriate uncertainty values. The uncertainties considered include:

   - Stainless steel cell wall thickness
   - Center-to-center spacing
   - Cell ID
   - Cell blowing
   - Assembly positioning

7) Each fuel assembly is treated as a heterogeneous system with the fuel pins, control rod guide tubes, and instrument guide tube modeled explicitly.

8) The moderator is pure, unborated full density water.

Table 4 provides the nominal dimensions and tolerances of the unit cell model illustrated in Figure 3. Figure 4 illustrates the unit cell model complete with the KENO-IV box type orientations used to model the fuel assembly in the unit cell.

2.4.1.1 Westinghouse Standard Type (STD) Fuel

This section describes the nominal model and addresses the uncertainties and biases for an infinite array of Westinghouse 17x17 STD fuel assemblies completely enclosed in 1/4" thick, full length stainless steel cells representative of the Catawba spent fuel storage racks under normal conditions.

NOMINAL CASE

Referring to Figures 3 and 4, and Tables 1 and 4, the following zones are modeled explicitly in the nominal case CSAS2 analysis:

(a) The 0.25" thick cell enclosure

(b) The 0.3225" O.D. fuel pellets (264 rods)

(c) The 0.374" O.D. fuel rod clad (264 rods)

(d) The void gap between the fuel pellets and clad

(e) The 0.474" O.D. guide tubes (24 tubes)

(f) The 0.48" O.D. instrument tube

The nominal case CSAS2 calculation in which 30,476 neutron histories were followed, resulted in a K-eff of 0.93086 with a 95 percent probability/95 percent confidence level uncertainty of +/- 0.00798.

BIASES AND UNCERTAINTIES

A method bias and uncertainty has been established as discussed in Section 1.3 of this summary. A statistical bias of +/- 0.00488 and a 95/95 uncertainty of

0.01161 ΔK is associated with the CSAS2 method used. The 95/95 uncertainty in the nominal case analysis is 0.00798 Δ K. In addition to these uncertainties, there are other considerations which may effect the final K-eff value assigned to the array. These considerations are treated as either worst-case in the nominal run or a sensitivity run is performed to determine the ΔK associated with a variable parameter (e.g., enclosure wall thickness.).

The worst-case conditions incorporated in the nominal CSAS2 run are as follows:

(a) All assemblies are assumed to be unirradiated 4.05 w/o U-235 enriched.

(b) Fuel assemblies are modeled in the center of the storage cells. Sensitivity calculations indicate that this is a conservative assumption and may contribute as much as 0.00199 ΔK to the nominal K-eff value depending on how may cells are modeled with the fuel assemblies off-center.

(c) A water density of 1.0 gram/ml is modeled in the nominal case run. Any credible water density decrease from full density will result in a decrease in the calculated K-eff.

(d) Fuel storage cells are modeled uniformly at a center-to-center (C-C) spacing of 13.5". Although a construction tolerance of +/-0.125" on this parameter (not to accumulate) allows groups of four assemblies to be at a reduced C-C spacing of 13.375", sensitivity calculations indicate that the net effect of reducing the spacing on two sides of the unit cell is more than canceled out by the increased spacing resulting on the other two sides. This conservative assumption may contribute as much as 0.00496 ΔK, depending on how may cells are modeled at this reduced groups-of-four spacing.

The following are treated as uncorrelated tolerance uncertainties in the calculation of the final rack K-eff:

(a) The sheet metal from which the storage enclosures are fabricated has a tolerance of +/-0.05". The effect of a reduced wall thickness is determined in conjunction with the effect cell I.D. variability has on the storage array K-eff. The construction tolerance for cell I.D. is +/-0.0625". Sensitivity calculations indicate that a thin wall cell combined with a large cell I.D. assumption can add as much as 0.02191 ΔK to the nominal case K-eff value.

(b) Individual cell bowing is assumed to be as much as 0.25" from vertical. Cell bowing is assumed to occur in conjunction with the reduced C-C spacing tolerance. This assumption yields an array of groups-of-four assemblies at a C-C spacing of 13.25". Sensitivity calculations indicate that groups-of-four assemblies at this reduced C-C spacing can add as much as 0.01214 ΔK to the nominal case K-eff value.

WORST-CASE MAXIMUM RACK K-eff

The worst case maximum rack K-eff is determined by combining the nominal case results with the uncertainties and biases developed from the method benchmark calculations and the sensitivity studies performed for the Catawba spent fuel storage racks. The resulting maximum final K-eff value is accurate with a 95 percent probability at a 95 percent confidence level.

The following equation is used to develop the final K-eff result for the Catawba spent fuel storage racks:

$$K_{eff} = \text{K-nominal} + \text{B-method} + [(\text{ks-nominal})^2 + (\text{ks-method})^2 + (\text{ks-mechanical})^2]^{1/2}$$

Where:

K-nominal	=	Nominal case K-eff = 0.90386
B-method	=	Method bias = .00488
ks-nominal	=	95/95 uncertainty in the nominal case K-eff value = 0.00798 ΔK
ks-method	=	95/95 uncertainty in the method bias =0.01161 ΔK
ks-mechanical	=	95/95 uncertainty resulting from material and construction tolerances = 0.02505 ΔK (or, $[(0.02191)^2 + (0.01214)^2]^{1/2}$

Substituting the appropriate values in order listed:

$$\text{K-eff} = 0.90386 + 0.00488 + [(0.00798)^2 + (0.01161)^2 + (0.02505)^2]^{1/2}$$

$$\text{K-eff} = 0.93748$$

2.4.1.2 Westinghouse Optimized Type (OFA) Fuel

This section describes the nominal model and addresses the uncertainties and biases for an infinite array of Westinghouse 17x17 OFA fuel assemblies completely enclosed in 1/4" thick, full length stainless steel cells representative of the Catawba spent fuel storage racks under normal conditions.

NOMINAL CASE

Referring to Figures 3 and 4, and Tables 1 and 4, the following zones are modeled explicitly in the nominal case CSAS2 analysis:

(a) The 0.25" thick cell enclosure

(b) The 0.3088" O.D. fuel pellets (264 rods)

(c) The 0.36" O.D. fuel rod clad (264 rods)

(d) The void gap between the fuel pellets and clad

(e) The 0.474" O.D. guide tubes (24 tubes)

(f) The 0.476" O.D. instrument tube

The nominal case CSAS2 calculation in which 30,476 neutron histories were followed, resulted in a K-eff of 0.90676 with a 95 percent probability/95 percent confidence level uncertainty of +/-0.00894.

BIASES AND UNCERTAINTIES

A method bias and uncertainty has been established as discussed in Section 1.3 of this summary. A statistical bias of +.0049 and a 95/95 uncertainty of 0.012 ΔK is associated with the CSAS2 method used. The 95/95 uncertainty in the nominal case analysis is 0.00894 ΔK. In addition to these uncertainties, there are other considerations which may effect the final K-eff value assigned to the array. These considerations are treated as either worst-case in the nominal run or a sensitivity run is performed to determine the ΔK associated with a variable parameter (e.g., enclosure wall thickness).

The worst-case conditions incorporated in the nominal CSAS2 run are as follows:

(a) All assemblies are assumed to be unirradiated 4.05 w/o U-235 enriched.

(b) A water density of 1.0 gram/ml is modeled in the nominal case run. Any credible water density decrease from full density will result in a decrease in the calculated K-eff.

(c) Fuel storage cell C-C spacing is nominally 13.5". Fuel storage cells are modeled in groups-of-four at a reduced C-C spacing of 13.375" to account for the construction tolerance of +/-0.125" on this parameter (non-accumulating). Sensitivity calculations indicate that the net effect of reducing the spacing on two sides of the unit cell and the corresponding increased spacing resulting on the other two sides may contribute as much as 0.00102 ΔK to the nominal K-eff value, depending on how many cells are modeled at this reduced groups-of-four C-C spacing.

The following are treated as uncorrelated tolerance uncertainties in the calculation of the final rack K-eff:

(a) The sheet metal from which the storage enclosures are fabricated has a tolerance of +/-0.05". The effect of a reduced wall thickness is determined in conjunction with the effect cell I.D. variability has on the storage array K-eff. The construction tolerance for cell I.D. is +/-0.0625". Sensitivity calculations indicate that a thin wall cell combined with a reduced cell I.D. assumption can add as much as 0.01989 ΔK to the nominal case K-eff value.

(b) Individual cell bowing is assumed to be as much as 0.25" from vertical. This assumption yields an array of groups-of-four assemblies at a C-C spacing of 13.25". Sensitivity calculations indicate that

this reduced C-C spacing can add as much as 0.01100 ΔK to the nominal case K-eff value.

(c) Eccentric assembly positioning in the cells can result in groups-of-four assemblies being closer in C-C spacing than in the nominal case. Sensitivity calculations indicate that eccentric positioning of fuel assemblies in the cells can add as much as 0.01969 ΔK to the nominal case K-eff value.

WORST-CASE MAXIMUM RACK K-eff

The worst-case maximum rack K-eff is determined by combining the nominal case results with the uncertainties and biases developed from the method benchmark calculations and the sensitivity studies performed for the Catawba spent fuel storage racks. The resulting maximum final K-eff value is accurate with a 95 percent probability at a 95 percent confidence level.

The following equation is used to develop the final K-eff result for the Catawba spent fuel storage racks:

$$K_{eff} = \text{K-nominal} + \text{B-method} + [(\text{ks-nominal})^2 + (\text{ks-method})^2 + (\text{ks-mechanical})^2]^{1/2}$$

Where:

K-nominal	=	Nominal case K-eff = 0.90676
B-method	=	Method bias = 0.00488
ks-nominal	=	95/95 uncertainty in the nominal case K-eff value = 0.00894 ΔK
ks-method	=	95/95 uncertainty in the method bias = 0.01161 ΔK
ks-mechanical	=	95/95 uncertainty resulting from material and construction tolerances = 0.03007 ΔK (or, $[(0.1989)^2 + (0.01100)^2 + (0.01969)^2]^{1/2}$

Substituting the appropriate values in the order listed:

$$\text{K-eff} = 0.90676 + 0.00488 + [(0.00894)^2 + (0.01161)^2 + (0.03007)^2]^{1/2}$$

$$\text{K-eff} = 0.94509$$

2.4.2 ACCIDENT CONDITIONS

Postulated accident conditions will not result in an increase in K-eff values beyond those presented for the infinite arrays in Section 2.4.1 of this summary.

Accidents considered include: 1) loss of spent fuel pool cooling, 2) the sliding of free standing rack modules such that peripheral cells of two racks modules have C-C spacings below those assumed in normal storage analyses, and

3) the dropping of fuel assemblies on top of a rack module or lowering of a fuel assembly by the side of a rack module in a non-storage location. Case drop accidents are not analyzed for criticality consequences since the dropping of a cask into the fuel storage areas at Catawba is precluded by design features and cask handling procedures.

LOSS OF COOLING

The loss of spent fuel pool cooling with a decay heat load present in the pool would result in lower moderator densities than assumed in the normal storage analyses. This would result in a lowering of storage array reactivity.

Optimum moderation is not a concern in the spent fuel storage pool since the moderator densities required for this effect (<0.4 grams/ml) are lower than would be credible in the pool. Since the fuel pool is supplied with redundant, safety related coolant makeup systems, the fuel will always be covered by saturated water at > or = to 1 ATM.

SLIDING OF RACK MODULES

Since the storage rack modules are free standing, it is possible two racks may slide due to seismic forces resulting in reduced C-C spacing for fuel cells stored in peripheral locations. However, the Catawba pools will contain approximately 2000 ppm boron and the double contingency principle ANSI-N16.1-1975 may be applied for this accident. This principle states that two unlikely, independent, concurrent events need not be considered to ensure protection against a criticality accident (i.e., rack sliding need not be assumed concurrent with loss of pool boration).

Calculations indicate that 2000 ppm boron present in the fuel pool coolant would reduce the nominal case K-eff values presented in Section 2.4.1 by approximately 0.23 ΔK. Therefore, the rack K-eff is easily held below 0.95 since any reactivity increase resulting from reduced peripheral cell C-C spacings would be much less than the negative worth of the dissolved boron.

DROPPED FUEL ASSEMBLIES

A dropped fuel assembly resting on top of a storage rack will not result in an increase in the K-eff values presented in Section 2.4.1 since 1) the normal condition K-eff calculations assume infinite axial fuel length, 2) the rack structure would provide some amount of water separation between the active fuel regions of the dropped and stored assemblies, and 3) the upper end fittings of stored fuel assemblies are not modeled in normal condition K-eff calculations and would contribute negative reactivity to this postulated configuration relative to the normal case. In any case, a dropped fuel assembly resting on top of a full storage rack will not result in a K-eff value greater than the 0.95 criteria since the double contingency principle could be applied to take credit for dissolved boron for this accident condition.

Similarly, dropping or lowering a fuel assembly in a non-storage location beside a rack module will not result in a K-eff value greater than the 0.95 criterion. As in the postulated sliding rack module accident case, the double contingency principle could be applied to take credit for dissolved boron in this case. The approximately 0.23 ΔK negative reactivity provided by 2000 ppm

boron would more than compensate for the additional reactivity added by a fuel assembly being present at some reduced C-C spacing on the periphery of a rack module.

2.5 RESULTS AND CONCLUSIONS

The calculated worst-case K-eff values for the two fuel types analyzed in this calculation are as follows:

WESTINGHOUSE 17x17 STD FUEL: K-eff = 0.93748

WESTINGHOUSE 17x17 OFA FUEL: K-eff = 0.94509

These calculated maximum K-eff values are valid for the specified fuel types for up to 4.05 w/o enrichment. These calculated values include geometrical and material uncertainties and biases at a 95 percent probability, 95 percent confidence level, as required by ANSI/ANS-57.2-1983, to demonstrate criticality safety. The uncertainties considered include:

- Stainless steel cell wall thickness
- Center-to-center spacing
- Cell ID
- Cell bowing
- Assembly positioning

As specified by ANSI N18.2-1973 and ANSI N210-1976, the maximum K-eff value in the spent fuel pool shall be less than 0.95, including all uncertainties, under all conditions. The analyses presented in this summary demonstrates that this criterion is met.

3.0 REFERENCES

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