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1CAN100601

October 4, 2006

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: Supplement to License Amendment Request to Support the Use of Metamic® Poison Insert Assemblies in the Spent Fuel Pool
Arkansas Nuclear One, Unit 1 (ANO-1)
Docket No. 50-313
License No. DPR-51

REFERENCES: 1. Letter to the NRC dated July 27, 2006, "License Amendment Request to Support the Use of Metamic® Poison Insert Assemblies in the Spent Fuel Pool" (1CAN070603)

Dear Sir or Madam:

Pursuant to 10 CFR 50.90, Entergy Operations, Inc. (Entergy) requested an amendment to the Arkansas Nuclear One, Unit 1 (ANO-1) Technical Specification (TS) 3.7.14, Spent Fuel Pool Concentration, TS 3.7.15, Spent Fuel Pool Storage, and TS 4.3, Fuel Storage (Reference 1).

On August 31, 2006, Holtec International identified an error in the criticality safety evaluation that was included in the original submittal. In the criticality calculations for the ANO-1 fuel racks, the material composition for spent fuel is transferred between the CASMO depletion code and the Monte Carlo (MCNP4a) criticality code using an automated process (script). When the script generated for the ANO-1 project was reviewed for use in another project, it was determined that the script contained a typographical error that affected the oxygen atom density in the spent fuel. As a result, the density of all actinides and fission products were underestimated by about 3% in the MCNP4a calculations. The consequence is a slight under prediction of the k-effective in the analysis; reducing margin. The reduction in margin affects the proposed analysis for the ANO-1 spent fuel pool and has no impact on the current criticality analysis. According to the vendor, the script is new and its use limited to two analyses; ANO-1 SFP and another commercial nuclear facility. The error was documented in the ANO corrective action program (CR-ANO-1-2006-1178).

The correction resulted in a slightly higher minimum burnup requirement for the fuel assemblies that are stored in Regions 1 and 2 of the spent fuel pool and reflected in TS 3.7.15-1. In addition, the minimum boron concentration required to ensure K-effective remains ≤ 0.95 (TS 4.3.1.1.b) was changed. This number was slightly lower than the previously submitted value due to the statistical characteristics of the MCNP4a criticality code.

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During the initial rework of the poison panel assemblies (PIAs), it was determined that minor weld changes to the top and bottom of the PIA and inconsequential material changes to the bottom were needed. This results in slight wording changes in the summary of the structural considerations. The original structural analysis remains bounding. In addition, a typographical error is corrected.

Attached are the corrected pages only. Revision bars mark the changes. Please remove the designated pages from the original submittal and insert the corrected pages as follows:

- Attachment 1 – pages 3, 5, 17, and 18
- Attachments 2 and 3 - pages 3.7.15-2 and 4.0-3
- Attachment 4 – page B 3.7.14-1 and B 3.7.15-1
- Attachment 5 - pages 4-3, 4-4, 4-21, 4-24, 4-25, 4-26, 4-27, 4-28 (text roll-over only), 4-29 (text roll-over only) 4-39, 4-40, 4-43, 4-44, 4-47, 4-48, 4-52, 4-53, 4-61, 4-62, 4-63, and 4-64
- Attachment 6 – pages 16, 25, 27, 46, 49, and 50

There is no change to the originally submitted no significant hazards considerations or commitments.

Entergy requests approval of the proposed amendment by February 1, 2007, in order to support insertion of the Metamic® PIAs prior to the spring 2007 refueling outage. Once approved, the amendment shall be implemented within 60 days. Although this request is neither exigent nor emergency, your prompt review is requested.

If you have any questions or require additional information, please contact Dana Millar at 601-368-5445.

I declare under penalty of perjury that the foregoing is true and correct. Executed on October 4, 2006.

Sincerely,

Thomas A. Marlow

TAM/DM

Attachments:
1. Analysis of Proposed Technical Specification Change
2. Proposed Technical Specification Changes (mark-up)
3. Proposed Technical Specification Changes (revised)
4. Changes to Technical Specification Bases Pages (For Information Only)
5. Spent Fuel Pool Racks Modifications with Poison Material Inserts in ANO Unit 1
6. Structural/Seismic Considerations for Addition of Metamic Panels to the Flux Traps of Two Spent Fuel Racks at ANO-1

cc: Dr. Bruce S. Mallett
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U. S. Nuclear Regulatory Commission
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Attachment 1

1CAN100601

Analysis of Proposed Technical Specification Change

Region 1 loading restrictions will be reflected in Table 3.7.15-1 as follows:

Region 1 - Minimum Burnup Requirements at
Varying Initial U-235 Enrichment and Cooling Time (Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	2.3	9.2	15.5	22.1	27.7	33.0	39.0
5	2.2	8.7	14.8	21.1	26.7	31.1	37.1
10	2.1	8.3	14.0	20.0	25.6	29.8	35.3
15	2.0	8.1	13.6	19.4	25.3	29.1	34.0
20	2.0	8.0	13.5	19.0	24.6	28.6	33.3

The criticality analysis also results in changes to the current loading restrictions imposed on the Region 2 racks and reflected in current Figure 3.7-15-1. The current figure will be deleted and new loading restrictions will be reflected in Table 3.7.15-1 for Region 2, as follows:

Region 2 - Minimum Burnup Requirements at
Varying Initial U-235 Enrichment and Cooling Time
(Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	4.5	11.7	18.7	25.7	30.6	36.9	42.8
5	4.2	11.0	17.6	24.2	29.1	34.4	40.7
10	4.0	10.6	16.7	23.0	28.1	33.0	38.6
15	4.0	10.1	15.9	22.4	27.4	31.8	37.4
20	4.0	9.8	15.7	21.8	26.8	31.2	36.4

Note 1 associated with the two tables will be added stating:

> "Linear interpolation between burnups for a given cooling time is allowed. However, linear interpolation between cooling times is not allowed, therefore the cooling time of a given assembly must be rounded down to the nearest cooling time."

Note 2, which is also associated with Regions 1 and 2, will be added to state the following:

> "When it is necessary to store fuel assemblies in Region 1 or Region 2 that do not meet the burnup versus U-235 enrichment restrictions, fuel assemblies, including fresh or irradiated fuel assemblies with a maximum U-235 enrichment of 4.95 wt%, may be stored in a 2 x 2 checkerboard (i.e., 2 assemblies and 2 empty cells) arrangement."

A portion of the SFP racks in Region 2 will be modified by the installation of Metamic® PIAs. This will result in the creation of a new Region 3 that will include loading restrictions which will be reflected in Table 3.7.15-1 as follows:

SR 3.7.15.2	Verify Metamic properties are in accordance with, and are maintained within the limits of, the Metamic Coupon Sampling Program.	In accordance with the Metamic Coupon Sampling Program.

Technical Specifications 4.3.1, Criticality

ANO-1 TS 4.3.1.1 a defines a maximum U-235 enrichment of 4.1 wt%. The proposed change will allow the maximum U-235 enrichment to be 4.95 wt%.

ANO-1 TS 4.3.1.1 b defines that k_{eff} (the effective neutron multiplication factor) will be maintained less than or equal to 0.95 if the spent fuel pool racks are fully flooded with unborated water. The criticality analysis, as allowed by 10 CFR 50.68, will credit boron (444 parts per million (ppm)) to assist in maintaining $k_{eff} \leq 0.95$ during normal operating conditions.

TS 4.3.1.1 c will be added, which will describe that a k_{eff} less than 1.0 will be maintained when the pool is flooded with unborated water. The addition of TS 4.3.1.1 c will result in the currently designated TSs 4.3.1.1 c, d, and e to be re-indexed as TSs 4.3.1.1 d, e, and f, respectively.

Current ANO-1 TS 4.3.1.1 d and TS 4.3.1.1 e define loading restrictions for Regions 1 and 2. These will be modified in accordance with the changes proposed to TS 3.7.15 and as follows (current TS 4.3.1.1 d is reflected as "e" and current TS 4.3.1.1 e is reflected as "f" below):

e. New or partially spent fuel assemblies stored in accordance with Table 3.7.15-1 in the spent fuel pool storage racks;

f. New or partially spent fuel assemblies with cooling times, U-235 enrichment or discharge burnup in the unacceptable range of Table 3.7.15-1 for fuel stored in either Region 1 or Region 2 may be stored in a 2 x 2 checkerboard configuration (i.e., 2 assemblies and 2 empty cells); and

To describe the design features of Region 3, TS 4.3.1.1 g will be added and will state:

g. Neutron absorber (Metamic) installed between fuel assemblies in the Region 3 racks.

ANO-1 TS 4.3.1.2 a defines a maximum U-235 enrichment of 4.1 wt%. The proposed change will allow the maximum U-235 enrichment to be 4.95 wt%.

ANO-1 TS 4.3.1.2 e references Figure 4.3.1.2-1 which depicts locations in the fresh fuel storage racks in which fuel loading is prohibited. Based on the increase in fuel assembly U-235 enrichment from 4.1 wt% to a maximum U-235 enrichment of 4.95 wt%, two loading pattern configurations will be proposed, which will result in the addition of Figure 4.3.1.2-2. Figure 4.3.1.2-1 will depict the loading pattern associated with fuel assemblies with a maximum U-235 enrichment up to 4.95 wt% and Figure 4.3.1.2-2 will illustrate the loading configuration for fuel

5.7 SFP Structural Integrity for Increased Loads from SFP Racks

An evaluation of the SFP structural integrity for the effects of the increased loads from the SFP racks was performed. The evaluation demonstrated that the structural integrity of the pool structure is maintained.

6.0 REGULATORY ANALYSIS

6.1 Applicable Regulatory Requirements/Criteria

The proposed changes have been evaluated to determine whether applicable regulations and requirements continue to be met. The applicable regulations and requirements used to support the proposed changes and reflection of their continued compliance are included in subsequent attachments to this letter.

Arkansas Nuclear One, Unit 1 (ANO-1) is currently exempt from the requirements of 10 CFR 70.24, *Criticality accident requirements.* The exemption was granted on October 6, 1998 (TAC NOS. MA1278 and MA1279). Upon approval of the proposed change, the exemption to 10 CFR 70.24 will no longer be required. ANO-1 will fully comply with 10 CFR 50.68 paragraph (b) as follows:

50.68(b)(1) - Plant procedures shall prohibit the handling and storage at any one time of more fuel assemblies than have been determined to be safely subcritical under the most adverse moderation conditions feasible by unborated water.

It has been determined that movement of only one fuel assembly at a time assures that subcriticality is maintained under the most adverse moderation conditions feasible by unborated water. ANO fuel handling procedures for the spent fuel pool (SFP) and reactor refueling bridges will exclusively prohibit the movement of more than one fuel assembly over the SFP or the refueling canal. Movement of a fuel assembly using the upender frame is allowed while the fuel handling bridges are moving fuel assemblies because it has been determined that for the worst case geometry the effective neutron multiplication factor (k_{eff}) is less than 0.95 at a 95% probability with a 95% confidence level. The fuel receipt procedure only allows one new fuel assembly to be moved at a time. Only one fuel assembly at a time is procedurally allowed to be moved into a dry fuel storage cask.

Storage of fuel assemblies is procedurally controlled to assure k_{eff} remains below 1.0, at a 95% probability, 95% confidence level, when flooded with unborated water. The storage patterns assure subcriticality under the most adverse moderation conditions by unborated water. The storage patterns will also insure reactivity will not exceed 0.95 at a 95% probability with a 95% confidence level when credit is taken for 444 ppm boron during normal conditions. If a fuel assembly were to be misloaded, reactivity will not exceed 0.95 at a 95% probability with a 95% confidence level when credit is taken 889 ppm boron. For the overly conservative fuel drop accident that assumes the loss of all Metamic®, a boron concentration of 1600 ppm ensures reactivity will not exceed 0.95 at a 95% probability with a 95% confidence level.

50.68(b)(2) - The estimated ratio of neutron production to neutron absorption and leakage (k-effective) of the fresh fuel in the fresh fuel storage racks shall be calculated assuming the racks are loaded with fuel of the maximum fuel assembly reactivity and flooded with unborated water and must not exceed 0.95, at a 95 percent probability, 95 percent confidence level. This evaluation need not be performed if administrative controls and/or design features prevent such flooding or if fresh fuel storage racks are not used.

Criticality calculations have been performed on the new fuel vault fully loaded with B&W 15x15 fresh fuel assemblies and filled with the most reactive unborated water. The results of these calculations showed that reactivity did not exceed 0.95, at a 95% probability, 95% confidence level.

50.68(b)(3) - If optimum moderation of fresh fuel in the fresh fuel storage racks occurs when the racks are assumed to be loaded with fuel of the maximum fuel assembly reactivity and filled with low density hydrogenous fluid, the k-effective corresponding to this optimum moderation must not exceed 0.98, at a 95 percent probability, 95 percent confidence level. This evaluation need not be performed if administrative controls and/or design features prevent such moderation or if fresh fuel storage racks are not used.

Criticality calculations were performed on the new fuel vault fully loaded with B&W 15 x 15 fresh fuel assemblies and filled with the most reactive low density hydrogenous fluid. The results of these calculations showed that reactivity does not exceed 0.98, at a 95% probability, 95% confidence level. Hydrogenous fluid are not used in the new fuel vault area and they would only be used in the most extreme cases where the use of fire water was not able to contain a fire in the new fuel vault area.

50.68(b)(4) - If no credit for soluble boron is taken, the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with unborated water. If credit is taken for soluble boron, the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity must not exceed 0.95, at a 95 percent probability, 95 percent confidence level, if flooded with borated water, and the k-effective must remain below 1.0 (subcritical), at a 95 percent probability, 95 percent confidence level, if flooded with unborated water.

Soluble boron credit will be taken in the SFP storage racks. The criticality calculations included in the proposed change show that k_{eff} remains below 1.0, at a 95% probability, 95% confidence level, when flooded with unborated water. Reactivity (K_{eff}) will not exceed 0.95 at a 95% probability with a 95% confidence level when credit is taken for 444 ppm boron during normal operations. If a fuel assembly were to be misloaded, reactivity will not exceed 0.95 at a 95% probability with a 95% confidence level when credit is taken 889 ppm boron. For the overly conservative fuel drop accident that assumes the loss of all Metamic®, a boron concentration of 1600 ppm ensures reactivity will not exceed 0.95 at a 95% probability with a 95% confidence level.

50.68(b)(5) - The quantity of SNM, other than nuclear fuel stored onsite, is less than the quantity necessary for a critical mass.

Any quantity of SNM (special nuclear material), other than nuclear fuel, that is received on site is tracked to ensure that the total quantity remains less than that needed to form a critical mass.

Attachment 2

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Proposed Technical Specification Changes (mark-up)

Region 1 - Minimum Burnup Requirements at Varying Initial U-235 Enrichment and Cooling Time (Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	2.3	9.2	15.5	22.1	27.7	33.0	39.0
5	2.2	8.7	14.8	21.1	26.7	31.1	37.1
10	2.1	8.3	14.0	20.0	25.6	29.8	35.3
15	2.0	8.1	13.6	19.4	25.3	29.1	34.0
20	2.0	8.0	13.5	19.0	24.6	28.6	33.3

Region 2 - Minimum Burnup Requirements at Varying Initial U-235 Enrichment and Cooling Time (Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	4.5	11.7	18.7	25.7	30.6	36.9	42.8
5	4.2	11.0	17.6	24.2	29.1	34.4	40.7
10	4.0	10.6	16.7	23.0	28.1	33.0	38.6
15	4.0	10.1	15.9	22.4	27.4	31.8	37.4
20	4.0	9.8	15.7	21.8	26.8	31.2	36.4

Region 3 Loading Restrictions

Unrestricted storage is allowed for fuel assemblies with an initial U-235 enrichment less than or equal to 4.35 wt%.

For fuel assemblies with an initial U-235 enrichment greater than 4.35 wt%, the burnup of at least one fuel assembly in each 2 x 2 section of storage cells is at least 20.1 GWD/MTU.

Note 1: Linear interpolation between burnups for a given cooling time is allowed. However, linear interpolation between cooling times is not allowed, therefore the cooling time of a given assembly must be rounded down to the nearest cooling time.

Note 2: When it is necessary to store fuel assemblies in Region 1 or Region 2 that do not meet the burnup versus U-235 enrichment restrictions, fuel assemblies, including fresh or irradiated fuel assemblies with a maximum U-235 enrichment of 4.95 wt%, may be stored in a 2 x 2 checkerboard (i.e., 2 assemblies and 2 empty cells) arrangement.

4.0 DESIGN FEATURES

4.3 Fuel Storage

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 ~~4.1~~ 4.95 weight percent;

b. $k_{eff} \le 0.95$ if fully flooded with 444 ppm of ~~un~~borated water, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

c. $k_{eff} < 1.0$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

~~c~~d. A nominal 10.65 inch center to center distance between fuel assemblies placed in the storage racks;

~~d~~e. New or partially spent fuel assemblies ~~with a discharge burnup in the "acceptable range" of~~ stored in accordance with ~~Figure~~ Table 3.7.15-1 ~~allowed unrestricted storage~~ in ~~either~~ the spent fuel storage racks; ~~Region 1 or Region 2; and~~

~~e~~f. New or partially spent fuel assemblies with cooling times, U-235 enrichment or ~~a~~ discharge burnup in the ~~"~~unacceptable range~~"~~ of ~~Figure~~ Table 3.7.15-1 for fuel assemblies stored in Region 1 or Region 2 may be stored in a 2 x 2~~, or in~~ checkerboard configuration (i.e., 2 assemblies and 2 empty cells); and ~~in Region~~

g. Neutron absorber (Metamic) installed between fuel assemblies in the Region 3 racks.

4.3.1.2 The new fuel storage racks are designed and shall be maintained with:

a. Fuel assemblies having a maximum U-235 enrichment of ~~4.1~~4.95 weight percent;

b. $k_{eff} \le 0.95$ under normal conditions, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

c. $k_{eff} \le 0.98$ with optimum moderation, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

d. A nominal 21 inch center to center distance between fuel assemblies placed in the storage racks; and

e. ~~Ten interior storage cells,~~ Fuel assembly loading prohibited in interior storage cells as shown in Figures 4.3.1.2-1 or 4.3.1.2-2, based on U-235 fuel enrichment.~~, precluded from use during fuel storage.~~

Attachment 3

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Proposed Technical Specification Changes (revised)

Table 3.7.15-1
Loading Restrictions for Spent Fuel Storage Racks

Region 1 - Minimum Burnup Requirements at Varying Initial U-235 Enrichment and Cooling Time (Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	2.3	9.2	15.5	22.1	27.7	33.0	39.0
5	2.2	8.7	14.8	21.1	26.7	31.1	37.1
10	2.1	8.3	14.0	20.0	25.6	29.8	35.3
15	2.0	8.1	13.6	19.4	25.3	29.1	34.0
20	2.0	8.0	13.5	19.0	24.6	28.6	33.3

Region 2 - Minimum Burnup Requirements at Varying Initial U-235 Enrichment and Cooling Time (Notes 1 & 2)

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time (Years)	Minimum Burnup (GWD/MTU)						
0	4.5	11.7	18.7	25.7	30.6	36.9	42.8
5	4.2	11.0	17.6	24.2	29.1	34.4	40.7
10	4.0	10.6	16.7	23.0	28.1	33.0	38.6
15	4.0	10.1	15.9	22.4	27.4	31.8	37.4
20	4.0	9.8	15.7	21.8	26.8	31.2	36.4

Region 3 Loading Restrictions

Unrestricted storage is allowed for fuel assemblies with an initial U-235 enrichment less than or equal to 4.35 wt%.

For fuel assemblies with an initial U-235 enrichment greater than 4.35 wt%, the burnup of at least one fuel assembly in each 2 x 2 section of storage cells is at least 20.1 GWD/MTU.

Note 1: Linear interpolation between burnups for a given cooling time is allowed. However, linear interpolation between cooling times is not allowed, therefore the cooling time of a given assembly must be rounded down to the nearest cooling time.

Note 2: When it is necessary to store fuel assemblies in Region 1 or Region 2 that do not meet the burnup versus U-235 enrichment restrictions, fuel assemblies, including fresh or irradiated fuel assemblies with a maximum U-235 enrichment of 4.95 wt%, may be stored in a 2 x 2 checkerboard (i.e., 2 assemblies and 2 empty cells) arrangement.

4.0 DESIGN FEATURES

4.3 Fuel Storage

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 4.95 weight percent;

b. $k_{eff} \leq 0.95$ if fully flooded with 444 ppm of borated water, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

c. $k_{eff} < 1.0$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

d. A nominal 10.65 inch center to center distance between fuel assemblies placed in the storage racks;

e. New or partially spent fuel assemblies stored in accordance with Table 3.7.15-1 in the spent fuel storage racks;

f. New or partially spent fuel assemblies with cooling times, U-235 enrichment or discharge burnup in the unacceptable range of Table 3.7.15-1 for fuel assemblies stored in Region 1 or Region 2 may be stored in a 2 x 2 checkerboard configuration (i.e., 2 assemblies and 2 empty cells); and

g. Neutron absorber (Metamic) installed between fuel assemblies in the Region 3 racks.

4.3.1.2 The new fuel storage racks are designed and shall be maintained with:

a. Fuel assemblies having a maximum U-235 enrichment of 4.95 weight percent;

b. $k_{eff} \leq 0.95$ under normal conditions, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

c. $k_{eff} \leq 0.98$ with optimum moderation, which includes an allowance for uncertainties as described in Section 9.6.2.4.3 of the SAR;

d. A nominal 21 inch center to center distance between fuel assemblies placed in the storage racks; and

e. Fuel assembly loading prohibited in interior storage cells as shown in Figures 4.3.1.2-1 or 4.3.1.2-2, based on U-235 fuel enrichment.

Attachment 4

1CAN100601

Changes to Technical Specification Bases Pages
For Information Only

B 3.7 PLANT SYSTEMS

B 3.7.14 Spent Fuel Pool Boron Concentration

BASES

BACKGROUND

As described in the Bases for LCO 3.7.15, "Spent Fuel Pool Storage," fuel assemblies are stored in the spent fuel pool racks in accordance with criteria based on initial U-235 enrichment, cooling time, and discharge burnup. Although the water in the spent fuel pool is normally borated to ≥≥ ~~1600~~ 2000 ppm, the criteria that limit the storage of a fuel assembly to specific rack locations are conservatively developed ~~without~~ taking credit for a boron concentration of 444 ppm in the spent fuel pool water.

The spent fuel storage pool is divided into ~~two~~ three separate and distinct regions as shown in SAR Figure 9-53 which, for the purpose of criticality considerations, are considered as separate ~~pools~~infinite arrays. ~~Region 1 3 is designed to accommodate new fuel with a maximum enrichment of 4.10 5.0 wt% U-235, or spent (irradiated) fuel regardless of the discharge fuel burnup. Region 1 and 2 is are~~The spent fuel pool racks are designed to accommodate fuel of various initial U-235 enrichments ~~which have accumulated minimum burnups~~ within the acceptable domain according to ~~Figure~~ Table 3.7.15-1. Fuel assemblies not meeting the criteria of ~~Figure~~ Table 3.7.15-1 shall be stored in accordance with Specification 4.3.1.1.~~e~~f. ~~The criticality considerations for the cask are the same as required for Region 1 of the spent fuel pool storage locations.~~

The water in the spent fuel storage pool normally contains soluble boron, which results in large subcriticality margins under actual operating conditions. However, the NRC guidelines (10 CFR 50.68) specify that the limiting k_{eff} of ~~0.95~~1.0 be evaluated in the absence of soluble boron. The NRC guidelines also require that the limiting k_{eff} of 0.95 may be evaluated considering soluble boron or the absence of soluble boron. Hence, the design of ~~both~~ the three regions is based on the use of ~~un~~borated water, which maintains each region in a subcritical condition during normal operation with the regions fully loaded. The double contingency principle discussed in ANSI N-16.1-1975 and the April 1978, NRC letter (Ref. 1) allows credit for soluble boron under other abnormal or accident conditions, since only a single accident need be considered at one time. Thus, for accident conditions, the presence of soluble boron in the spent fuel pool water can be assumed as a realistic condition. For example, accident scenarios are postulated which could potentially increase the reactivity and reduce the margin to criticality. To mitigate these postulated criticality related accidents, boron is dissolved in the pool water. Safe operation of the high density storage racks with no movement of assemblies may therefore be achieved by controlling the location of each assembly in accordance with LCO 3.7.15, "Spent Fuel Pool Storage." Prior to movement of an assembly, it is necessary to perform SR 3.7.15.1.

B.3.7 PLANT SYSTEMS

B 3.7.15 Spent Fuel Pool Storage

BASES

BACKGROUND

The spent fuel assembly storage facility is designed to store either new (nonirradiated) nuclear fuel assemblies, or burned (irradiated) fuel assemblies in a vertical configuration underwater. The spent fuel pool is sized to store 968 fuel assemblies and is connected to a pit for loading shipping or dry fuel storage casks. The spent fuel storage cells are installed in parallel rows with center to center spacing of 10.65 inches in each direction. The cask configuration is in accordance with the cask vendors ~~venders~~ Certificate of Compliance.

The spent fuel storage pool is divided into ~~two~~ three separate and distinct regions as shown in SAR Figure 9-53 which, for the purpose of criticality considerations, are considered as separate pools. Region 1 ~~is designed to accommodate new fuel with a maximum enrichment of 4.10 wt% U-235, or spent (irradiated) fuel regardless of the discharge fuel burnup.~~ and Region 2 ~~is~~ are designed to accommodate fuel of various initial U-235 enrichments which have accumulated minimum burnups within the acceptable domain according to ~~Figure~~Table 3.7.15-1. Fuel assemblies not meeting the ~~criteria~~ acceptable range of ~~Figure~~ Table 3.7.15-1 shall be stored in accordance with paragraph 4.3.1.1.~~e~~f in ~~SAR~~ TS Section 4.3, Fuel Storage. Region 3 is designed to accommodate new fuel with loading restrictions with a maximum initial fuel assembly enrichment of 4.35 or 4.95 wt% U-235 in accordance with Table 3.7.15-1. The supporting analysis included U-235 fuel enrichments of up to 5.0 wt% plus 0.05 wt% for uncertainties (Ref. 5). ~~The criticality considerations for the cask are the same as required for Region 1 of the spent fuel pool storage locations.~~

APPLICABLE SAFETY ANALYSES

Criticality of fuel assemblies in the spent fuel storage rack and casks is prevented by the design of the rack or cask, which limits fuel assembly interaction. ~~This is done by fixing the minimum separation between assemblies and inserting neutron poison between assemblies in Region 1.~~Region 1 and- Region 2 control~~s~~ fuel assembly interaction by fixing the minimum separation between assemblies and by setting U-235 enrichment, ~~and~~ burnup, and cooling time criterion to limit fissile materials. Region 3 controls fuel assembly interaction similar to Region 2 and utilizes Metamic poison panels. ~~This is sufficient to maintain~~ Aa k_{eff} of ≤ 0.95 for spent fuel of original U-235 enrichment of up to 4.~~10wt~~95 wt% is accomplished by taking credit for boron (444 ppm). A k_{eff} of < 1.0 is accomplished when no credit for boron is taken. ~~However, fuel assemblies to be stored in the spent fuel pool Region 2 which do not meet enrichment and burnup criterion must be stored in a checkerboard pattern to maintain a k_{eff} of 0.95 or less. In order to prevent inadvertent fuel assembly insertion into two adjacent storage locations, vacant spaces adjacent to the faces of any fuel assembly which does not meet the Region 2 burnup criteria (unrestricted) are physically blocked before any such fuel assembly is placed in Region 2 (Ref. 1). In addition, the area designated for checkerboard arrangement is divided from the normal storage in Region 2 by a row of vacant storage spaces (Ref. 2.)~~

Required Soluble Boron Concentrations for Accident Conditions

TS 3.7.14 includes the requirement for great than 2000 ppm boron concentration to assure the fuel assemblies will be maintained in a subcritical array with $K_{eff} \leq 0.95$ in the event of a postulated drop accident. Analysis has shown that, during a postulated misplacement accident with the fuel stored within the limits of this specification, that a $K_{eff} \leq 0.95$ will be maintained when the boron concentration is at or above 889 ppm.

The spent fuel pool storage satisfies Criterion 2 of 10 CFR 50.36 (Ref. 3).

Attachment 5

1CAN100601

Spent Fuel Pool Racks Modifications with Poison Material Inserts in ANO Unit 1

Table 4.7.26 the following conclusions may be drawn regarding the reactivity effect of the interfaces:

- In the Region 1 and Region 2 racks, a fresh fuel checkerboard and uniform spent fuel loading may be placed in the same rack. Calculations for the Region 2 racks show a slight increase in reactivity (Δk = +0.0011) compared to the reference reactivity. This increase is accommodated by the margin in the calculations (max k_{eff} for Region 2 racks with spent fuel is 0.9950). Therefore, this condition is allowed for Region 1 and Region 2 racks.
- In Region 1 and Region 2 racks, if adjacent racks contain a checkerboard of fresh fuel assemblies, the checkerboard must be maintained across the gap, i.e., fresh fuel assemblies may not face each other across a gap.
- In Region 3, uniform loading of fresh fuel at 4.35 wt% ^{235}U may be combined with 3 of 4 loading in the same rack as long as a row of fresh and spent fuel in the 3 of 4 loading pattern faces the uniform loading of all fresh fuel at 4.35 wt% ^{235}U.
- If adjacent Region 3 racks contain different loading patterns (one rack contains all fresh fuel at 4.35 wt% and the other rack contains a 3 of 4 loading pattern), both fresh and spent fuel must be in the outer row of the rack containing the 3 of 4 pattern.
- If adjacent Region 3 racks both contain 3 of 4 loading patterns, both racks may not have fresh fuel facing the other rack. Calculations with both Region 3 racks containing 3 of 4 patterns with all fresh fuel in the outer row of one rack and fresh and spent fuel in the outer row of the second rack shows a slight increase in reactivity (Δk = +0.0006) compared to the reference case. This increase is accommodated by the margin in the calculations (max k_{eff} for Region 3 racks with 3 of 4 pattern is 0.9966). Therefore, this condition is allowed.
- All interfaces between dissimilar racks (Region 1-Region 3 and Region 2-Region 3) do not result in an increase in the reactivity, and therefore, are permitted. Calculations were performed with a 3 of 4 loading pattern in the Region 3 racks, with fresh fuel (5.0 wt% ^{235}U) in the outer row facing the other rack. This is bounding for the Region 3 rack containing all fresh fuel at 4.35 wt%, because the analyzed cases have higher reactivity fuel in the outer row of the rack.

4.2 METHODOLOGY

The principal method for the criticality analysis of the high-density storage racks is the three-dimensional Monte Carlo code MCNP4a [4.3]. MCNP4a is a continuous energy three-dimensional Monte Carlo code developed at the Los Alamos National Laboratory. MCNP4a was selected because it has been used previously and verified for criticality analyses and has all of the necessary features for this analysis. MCNP4a calculations used continuous energy cross-section data based on ENDF/B-V and ENDF/B-VI. Exceptions are two lumped fission products calculated by the CASMO-4 depletion code that do not have corresponding cross sections in MCNP4a. For these isotopes, the CASMO-4 cross sections are used in MCNP4a. This approach has been validated [4.4] by showing that the cross sections result in the same reactivity effect in both CASMO-4 and MCNP4a.

Benchmark calculations, presented in Appendix 4A, indicate a bias of 0.0009 with an uncertainty of ± 0.0011 for MCNP4a, evaluated with a 95% probability at the 95% confidence level [4.1]. The calculations for this analysis utilize the same computer platform and cross-section libraries used for the benchmark calculations discussed in Appendix 4A.

The convergence of a Monte Carlo criticality problem is sensitive to the following parameters: (1) number of histories per cycle, (2) the number of cycles skipped before averaging, (3) the total number of cycles and (4) the initial source distribution. The MCNP4a criticality output contains a great deal of useful information that may be used to determine the acceptability of the problem convergence. This information has been used in parametric studies to develop appropriate values for the aforementioned criticality parameters to be used in storage rack criticality calculations. Based on these studies, a minimum of 10,000 histories were simulated per cycle, a minimum of 100 cycles were skipped before averaging, a minimum of 150 cycles were accumulated, and the initial source was specified as uniform over the fueled regions (assemblies). Further, the output was reviewed to ensure that each calculation achieved acceptable convergence. These parameters represent an acceptable compromise between calculational precision and computational time.

Fuel depletion analyses during core operation were performed with CASMO-4 (using the 70-group cross-section library), a two-dimensional multigroup transport theory code based on capture probabilities [4.7-4.9]. CASMO-4 is used to determine the isotopic composition of the spent fuel. In addition, the CASMO-4 calculations are restarted in the storage rack geometry, yielding the two-dimensional infinite multiplication factor (k_{inf}) for the storage rack to determine the reactivity effect of fuel and rack tolerances, temperature variation, depletion uncertainty, and to perform various studies. For all calculations in the spent fuel pool racks, the Xe-135 concentration in the fuel is conservatively set to zero.

The evaluation performed to establish the burnup versus enrichment curve (loading curve) for the Region 1 and Region 2 racks, consists of MCNP4a calculations performed at selected enrichments between 2.0 wt% and 5.0 wt%, and for burnup values slightly above and below the expected loading curve. Points on the proposed loading curve are then calculated by linear interpolation for each enrichment, based on an appropriate target value (max k_{eff} = 0.9950) for the reactivity. Burnup versus enrichment values are calculated for cooling times of 0, 5, 10, 15 and 20 years. For the Region 3 racks the minimum required burnup for the single spent fuel assembly was determined with MCNP4a calculations, performed at an enrichment of 5.0 wt% ^{235}U and at burnup values slightly above and below the expected required burnup. The minimum burnup was then calculated by linear interpolation, based on an appropriate target value (max k_{eff} = 0.9966) for the reactivity.

The maximum k_{eff} is determined from the MCNP4a calculated k_{eff}, the calculational bias, the temperature bias, and the applicable uncertainties and tolerances (bias uncertainty, calculational uncertainty, rack tolerances, fuel tolerances, depletion uncertainty) using the following formula:

(e.g., depletion uncertainty and axial burnup distribution penalty) are not applicable to the Region 3 loading pattern with all fresh fuel of 4.35 wt% ^{235}U. Results show that the maximum k_{eff} of the Region 3 racks is less than 1.0 at a 95% probability at a 95% confidence level with no credit for soluble boron.

4.7.4.6 Determination of the Minimum Burnup for a Single Spent Assembly in the 3 of 4 Loading Pattern

To establish a minimum required burnup for the loading pattern with 3 fresh fuel assemblies and one spent fuel assembly, calculations were performed with all assemblies having a maximum nominal initial enrichment of 5.0 wt% ^{235}U and the single spent fuel assembly having burnup values slightly above and below the expected burnup value. The acceptable burnup for the single spent fuel assembly is then calculated by linear interpolation, based on an appropriate target value (max k_{eff} = 0.9966) for the reactivity. All calculations were performed at 0 cooling time; no credit was taken for additional cooling time for the single spent assembly as the reduction in burnup would be minimal. The minimum burnup is shown for 3 of 4 loading in Table 4.7.9.

4.7.4.7 Soluble Boron Concentration for Maximum k_{eff} of 0.95

Calculations crediting soluble boron in the spent fuel pool to ensure that the reactivity does not exceed 0.95 are also performed. Calculations are performed at enrichments of 4.35 wt% ^{235}U and 5.0 wt% ^{235}U for uniform loading of fresh fuel and a 3 of 4 configuration, respectively, at a soluble boron level of 400 ppm and 800 ppm. The minimum soluble boron requirement is determined by linear interpolation between soluble boron levels to achieve a target maximum k_{eff} of 0.9450. In all cases, the maximum k_{eff} including all applicable biases and uncertainties is below the regulatory limit of 0.95. The results for each loading pattern in Region 3 is also listed in Table 4.7.10 and Table 4.7.12 for a 3 of 4 configuration and uniform loading of fresh fuel, respectively.

4.7.5 Abnormal and Accident Conditions for Region 1, 2 & 3 Racks

The effects on reactivity of credible abnormal and accident conditions are examined in this section. This section identifies which of the credible abnormal or accident conditions will result in exceeding the limiting reactivity ($k_{eff} \leq 0.95$). For those accidents or abnormal conditions that result in exceeding the limiting reactivity, a minimum soluble boron concentration is determined to ensure that $k_{eff} \leq 0.95$. The double contingency principal of ANS-8.1/N16.1-1975 [4.2] (and the USNRC letter of April 1978) specifies that it shall require at least two unlikely independent and concurrent events to produce a criticality accident. This principle precludes the necessity of considering the simultaneous occurrence of multiple accident conditions.

For the Region 3 racks it is assumed that no metamic panel is located between the mislocated assembly and the assemblies in the rack. For the loading pattern with 3 fresh fuel assemblies and 1 spent fuel assembly, it was assumed that all fresh fuel assemblies are facing the mislocated assembly. This configuration would bound the case of a misplaced assembly with the Region 3 rack filled with fresh fuel of maximum nominal enrichment of 4.35 wt% ^{235}U.

The MCNP4a model consists of a 5x5 array of fuel storage cells with a single fresh, unburned assembly placed adjacent to the rack and a 30cm water reflector. The other three sides of the model consist of reflecting boundary conditions. The mislocated assembly is placed as close to the rack face as possible to maximize the possible reactivity effect. Calculations are performed with 400pm, 800 ppm and 1200 ppm (if necessary) soluble boron, and the final soluble boron concentration is determined by linear interpolation.

4.7.5.5 Loss of All Metamic

An additional calculation was performed to determine the reactivity of the Region 3 rack in the unlikely event that the neutron absorber was to be completely absent. Credit was taken for 1600 ppm soluble boron (actual pool soluble boron concentration is higher) and the metamic material was replaced with water. The Region 3 racks without any neutron absorber are analyzed for both the 3 of 4 loading pattern and uniform loading of fresh fuel assemblies having a maximum enrichment of 4.35wt% ^{235}U (identified in Section 4.7.4). The results of this postulated accident condition show that the maximum k_{eff} is 0.9410 including bias and uncertainties.

4.7.6 Interfaces Within and Between Racks

4.7.6.1 Normal Conditions

In addition to the calculations performed for each individual rack detailed in the preceding sections, the possibility of an increased reactivity effect due to the rack interfaces within and between the racks was determined. Figure 4.5.7 is a layout of the entire ANO Unit 1 spent fuel pool, with the gaps between racks detailed for each interface. The gaps provided in Figure 4.5.7, denoted by a "C" at the rack corners, are measured from the centerline of the adjacent storage cells. Table 4.5.10 summarizes the potential rack interfaces and the gaps between these racks. The gap distances provided in the last column of Table 4.5.10 are determined from the centerline distances between racks from Figure 4.5.7 and the geometric characteristics of each type of rack. Figure 4.5.8 illustrates the measurement of the distances between the outside surfaces of the racks.

Table 4.7.26 provides a summary of the various interface calculations performed for the ANO Unit 1 spent fuel pool. Interfaces within the rack include spent and fresh fuel loading patterns within the same rack to determine acceptability. Interface calculations between racks include

Region 1-Region 1, Region 2-Region 2, Region 3-Region 3, Region 1-Region 3 and Region 2-Region 3. Figures 4.7.1 through 4.7.14 are referenced in Table 4.7.26 and provide a visual representation of the interface calculation performed. The figures show the loading pattern assumed in each rack and the value for the water gap between the racks. The calculated reactivity from the interface calculation is then compared to the calculated reactivity from the reference infinite array calculations.

4.7.6.2 Rack Lateral Motion – Seismic Event

A seismic event, could, in the absence of soluble boron, result in exceeding the regulatory limit (maximum k_{eff} of 0.95). This could possibly occur if the seismic event caused sufficient movement of the rack to a closer proximity. The seismic analysis identifies a maximum differential displacement between racks during a seismic event of 0.635 inches. Selected cases from the interface calculations described in the previous section were chosen to address this potential accident condition. The MCNP4a models described above were modified to reduce the gap between racks by an additional 0.635 inches. Calculations were performed with 800 ppm of soluble boron. The calculated reactivities from MCNP4a show that all calculated reactivities for this accident condition are below 0.90. Even with the addition of the applicable biases and uncertainties, the maximum k_{eff} would be below 0.95.

4.7.7 Boron Dilution Evaluation

The soluble boron in the spent fuel pool water is conservatively analyzed to contain a minimum of 1600 ppm under operating conditions. Significant loss or dilution of the soluble boron concentration is extremely unlikely, if not incredible. Nonetheless, an evaluation was performed based on the ANO spent fuel pool data.

The required minimum soluble boron concentration is 444 ppm under normal conditions. The volume of water in the pool is approximately 268,000 gallons. Large amounts of unborated water would be necessary to reduce the boron concentration from 1600 ppm to 444 ppm. Abnormal or accident conditions are discussed below for either low dilution rates (abnormal conditions) or high dilution rates (accident conditions). The general equation for boron dilution is,

$$C_t = C_o e^{-\frac{F}{V}t},$$

where

C_t the boron concentration at time t,
C_o the initial boron concentration,
V is the volume of water in the pool, and
F is the flow rate of unborated water into the pool

This equation conservatively assumes the unborated water flowing into the pool mixes instantaneously with the water in the pool.

For convenience, the above equation may be re-arranged to permit calculating the time required to dilute the soluble boron from its initial concentration to a specified minimum concentration, which is given below.

$$t = \frac{V}{F} \ln(C_o / C_t)$$

If V is expressed in gallons and F in gallons per minute (gpm), the time, t, will be in minutes.

4.7.7.1 Low Flow Rate Dilution

Small dilution flow around pump seals and valve stems or mis-aligned valves could possibly occur in the normal soluble boron control system or related systems. Such failures might not be immediately detected. These flow rates would be of the order of 2 gpm maximum and the increased frequency of makeup flow might not be observed. However, an assumed loss flow-rate of 2 gpm dilution flow rate would require some 118 days to reduce the boron concentration to the minimum required 444 ppm under normal conditions. Routine surveillance measurements of the soluble boron concentration would readily detect the reduction in soluble boron concentration with ample time for corrective action.

Administrative controls require a measurement of the soluble boron concentration in the pool water at least weekly. Thus, the longest time period that a potential boron dilution might exist without a direct measurement of the boron concentration is 7 days. In this time period, an undetected dilution flow rate of 33.7 gpm would be required to reduce the boron concentration to 444 ppm. No known dilution flow rate of this magnitude has been identified. Further, a total of more than 300,000 gallons of unborated water would be associated with the dilution event and such a large flow of unborated water would be readily evident by high-level alarms and by visual inspection on daily walk-downs of the storage pool area.

4.7.7.2 High Flow Rate Dilution

Under certain accident conditions, it is conceivable that a high flow rate of unborated water could flow onto the top of the pool. Such an accident scenario could result from rupture of a unborated water supply line or possibly the rupture of a fire protection system header, both events potentially allowing unborated water to spray onto the pool. A flow rate of up to 2500 gpm could possibly spray onto the spent fuel pool as a result of a rupture of the fire protection line. This would be the most serious condition and bounds all other accident scenarios. Conservatively assuming that all the unborated water from the break poured onto the top of the pool and further assuming instantaneous mixing of the unborated water with the pool water, it would take approximately 136 minutes to dilute the soluble boron concentration to 444 ppm, which is the minimum required concentration to maintain k_{eff} below 0.95 under normally operating conditions. In this dilution accident, some 340,000 gallons of water would spill on the auxiliary building floor and into the air-conditioning duct system. Well before the spilling of such a large volume of water, multiple alarms would have alerted the control room of the accident consequences (including the fuel pool high-level alarm, the fire protection system pump operation alarm, and the floor drain receiving tank high level alarm).

Instantaneous mixing of pool water with the water from the rupture of the unborated water supply line is an extremely conservative assumption. Water falling on to the pool surface would mix with the top layer of pool water and the portions of the mixed volumes would continuously spill out of the pool. The density difference between water at 150 °F (maximum permissible pool bulk water temperature) and at the temperature of the unborated water supply is small. This density difference will not cause the water falling on to the pool surface to instantaneously sink down into the racks overcoming the principal driving force for the flow in the pool, which is the buoyancy force generated in the spent fuel pool racks region due to the heat generation from the spent fuel in the racks. This would further enhance the mixing process between the pool water and spilled water above the racks.

For the fire protection system line break, upon the initial break, the fire protection system header pressure would drop to the auto start set point of the fire protection pumps. The start is accompanied with an alarm in the main control room. The annunciator response is to dispatch an operator to find the source of the pump start. Approximately 3 minutes into the event, a spent fuel pool high level alarm would be received in the main control room, assuming that the spent fuel pool level started at the low alarm. The annunciator response for high spent fuel pool level is to investigate the cause. The coincidence of the 2 alarms would quickly lead to the discovery of the failure of the fire protection system and sufficient time to isolate the failure.

The maximum flow rate from demineralized water supply would provide approximately 900 gpm into the spent fuel pool. Failure of the demineralized water header is not accompanied with an alarm; however, the time to dilute the spent fuel pool from 1600 to 444 ppm is greater than the bounding case described above. An alarm on high spent fuel pool level would be received approximately 9 minutes into the event in the main control room, assuming that the spent fuel pool level started at the low alarm. In this scenario, there is sufficient time to isolate the failure and to prevent the spilling of some 340,000 gallons of water.

The analysis assumes that for a double-ended break in the a fire protection system piping, the stream of water will arch through the air some 40 feet falling on top of the pool. This is virtually an incredible event. Should the stream of water fall upon the pool deck, a 3 inch high curb would channel some of the water to the pool drain and prevent all of the water from reaching the pool. Furthermore, the evaluation also assumes at least 3 independent and concurrent accidents occur simultaneously:

- ♦ Large amount of water flowing from the double-ended pipe break would remain undetected and is ignored.
- ♦ Pool water high level alarms either fail or are ignored.
- ♦ Alarms indicating large amounts of water flowing into the floor drain have failed or are ignored.

Considering all related facts, a significant dilution of the pool soluble boron concentration in a short period of time without corrective action is not considered a credible event.

It is not considered credible that multiple alarms would fail or be ignored or that the spilling of large volumes of water would not be observed. Therefore, such a major failure would be detected in sufficient time for corrective action to avoid violation of an administrative guideline and to assure that the health and safety of the public is protected.

4.8 New Fuel Storage Racks Criticality Analysis

The New Fuel Storage Vault is intended for the receipt and storage of fresh fuel under normally dry conditions where the reactivity is very low. To assure the criticality safety under accident conditions and to conform to the requirements of General Design Criterion 62, "Prevention of Criticality in Fuel Storage and Handling," two separate criteria must be satisfied as defined in NUREG-0800, Standard Review Plan 9.1.1, "New Fuel Storage." These criteria are as follows:

- When fully loaded with fuel of the highest anticipated reactivity and flooded with clean, unborated water, the maximum reactivity, including uncertainties, shall not exceed a k_{eff} of 0.95.
- With fuel of the highest anticipated reactivity in place and assuming optimum hypothetical low density moderation (i.e., fog or foam), the maximum reactivity shall not exceed a k_{eff} of 0.98.

The New Fuel Storage Vault provides two 4 x 9 storage rack modules with cell array storage location arranged on a 21 inch lattice spacing. Calculations were made with 238-group NITAWL/KENO5a code package (SCALE 4.3), a three-dimensional Monte Carlo analytical technique, with fresh fuel assemblies with 4.95 wt% nominal intitial enrichment. These calculations were made for various moderator densities and the results are shown in Figure 4.8.1; the peak reactivity (optimum moderation) occurs at 9% moderator density. The calculations for the configuration illustrated in Figure 4.8.2 confirms that five locations in each of the storage racks are required to remain empty in order to meet the regulatory limits. Results of the criticality safety analysis are summarized in Table 4.8.1 for the two accident conditions for fuel assemblies of 4.95 ± 0.05 wt% initial enrichment. The maximum reactivity at 9% moderator density is 0.9726, including uncertainties, which is within the regulatory limit of 0.98, thus confirming the acceptability of the New Fuel Vault for 4.95 ± 0.05 wt% fuel.

Additional calculations at 9% moderator density, performed for the storage pattern depicted in Figure 4.8.3, show that this storage configuration is acceptable for storage of fresh fuel assemblies of up to 4.20 wt% enrichment with four locations in each rack array required to remain empty.

For the fully flooded accident condition, calculations are performed as infinite array calculations (i.e., no blocked cells). Under these conditions and with fuel of 4.95 ± 0.05 wt% enrichment, the maximum reactivity, including all uncertainties is less than the regulatory limit of 0.95 for k_{eff}, thus confirming the acceptability of the NFV for 4.95 wt% fuel in the fully flooded accident condition. At 4.2 wt% enrichment in the flooded condition, the reactivity will be substantially lower than that for 4.95 ± 0.05 wt% enrichment and would therefore be acceptable for storage.

4.9 Fuel Handling Equipment

Criticality safety evaluations were also performed for handling of fresh fuel assemblies during transfer from the new fuel vault to the reactor core, including the new-fuel elevator, the upender and fuel carriage, and the temporary storage rack within the transfer canal. The new fuel elevator is located on the south wall of the pool facing the Region 1 spent fuel storage racks. This device can position a fresh fuel assembly 16 inches (assembly center line) from the wall. The distance from the wall to the edge of the rack is 24.5 inches. A distance of 7.845 inches exists between the centerline of the assembly in the elevator and the edge of the closest fuel storage cell in the rack. The maximum reactivity with fuel in the new fuel elevator (with Region 1 containing a checkerboard of fresh fuel) is 0.9359 with credit for 100 ppm soluble boron. Additional calculations were performed to evaluate the effect of accidentally dropping or misplacing an assembly adjacent to the new fuel elevator while it is loaded. A most reactive location for the dropped assembly was determined. A credit of 700 ppm boron will ensure k-effective remains below 0.95 should such an event occur. The new fuel elevator therefore meets the criticality acceptance criteria defined in 10 CFR 50.68. The upender/fuel carriage device handles a single assembly. The maximum reactivity of a single fresh assembly containing 4.95 w/o ± 0.05 enriched fuel in water is bounded by the fresh fuel, fully moderated case in Table 4.8.1, which has a maximum k_{eff} of 0.9431. Furthermore for a postulated accident in which a second fresh assembly was positioned near the upender/fuel carriage, the presence of soluble boron (1600 ppm minimum) excludes the possibility of any criticality concern.

The transfer canal incorporates a 7-cell temporary storage rack on a linear array at a 21-1/8 inch spacing (6 locations for fuel assemblies and 1 location for damaged fuel). The maximum k-effective for normal operation of this rack was determined to be 0.9412. Evaluations of a potential mis-placement of a fresh fuel assembly at a position of closest approach to another assembly in the spent fuel rack, separated only by the structure of the temporary rack, shows that the maximum k_{eff} (in the absence of any soluble boron) would be 0.9702. The presence of 200 ppm soluble boron would be sufficient to maintain the maximum k-effective below 0.95. However, the transfer canal, during refueling operations, would always contain the minimum Technical Specification boron concentration (> 2000 ppm), significantly reducing reactivity and further eliminating any criticality concern.

Table 4.7.1
Summary of the Criticality Safety Analyses for Region 1 without Soluble Boron at 0 Years Cooling Time

Design Basis Burnup at 5.0 wt% ^{235}U		39.0 GWD/MTU
Soluble Boron		0 ppm
Uncertainties		
Bias Uncertainty (95%/95%)	± 0.0011	
Calculational Statistics (95%/95%, 2.0×σ)	± 0.0010	
Fuel Eccentricity	+ 0.0142	
Rack Tolerances	± 0.0066	
Fuel Tolerances	± 0.0074	
Depletion Uncertainty	± 0.0127	
Statistical Combination of Uncertainties[9]	± 0.0215	
Reference k_{eff} (MCNP4a)		0.9638
Total Uncertainty (above)		0.0215
Temperature Bias		0.0085
Calculational Bias (see Appendix 4A)		0.0009
Maximum k_{eff}		**0.9947**
Regulatory Limiting k_{eff}		**1.0000**

[9] Square root of the sum of the squares.

Table 4.7.2
Summary of the Criticality Safety Analyses for Region 1 with Soluble Boron at 0 Years Cooling Time

Design Basis Burnup at 5.0 wt% ^{235}U		39.0 GWD/MTU
Soluble Boron		248 ppm
Uncertainties		
Bias Uncertainty (95%/95%)	± 0.0011	
Calculational Statistics (95%/95%, 2.0×σ)	± 0.0011	
Fuel Eccentricity	+ 0.0142	
Rack Tolerances	± 0.0066	
Fuel Tolerances	± 0.0074	
Depletion Uncertainty	± 0.0127	
Statistical Combination of Uncertainties[10]	± 0.0215	
Reference k_{eff} (MCNP4a)		0.9141
Total Uncertainty (above)		0.0215
Temperature Bias		0.0085
Calculational Bias (see Appendix 4A)		0.0009
Maximum k_{eff}		**0.9450**
Regulatory Limiting k_{eff}		**0.9500**

[10] Square root of the sum of the squares.

Table 4.7.5
Summary of the Criticality Safety Analyses for Region 2 without Soluble Boron at 0 Years Cooling Time

Design Basis Burnup at 5.0 wt% ^{235}U		42.8 GWD/MTU
Soluble Boron		0 ppm
Uncertainties		
Bias Uncertainty (95%/95%)	± 0.0011	
Calculational Statistics (95%/95%, $2.0\times\sigma$)	± 0.0011	
Fuel Eccentricity	+ 0.0168	
Rack Tolerances	± 0.0039	
Fuel Tolerances	± 0.0073	
Depletion Uncertainty	± 0.0139	
Statistical Combination of Uncertainties[13]	± 0.0234	
Reference k_{eff} (MCNP4a)		0.9613
Total Uncertainty (above)		0.0234
Temperature Bias		0.0093
Calculational Bias (see Appendix 4A)		0.0009
Maximum k_{eff}		**0.9949**
Regulatory Limiting k_{eff}		**1.0000**

[13] Square root of the sum of the squares.

Table 4.7.6
Summary of the Criticality Safety Analyses for Region 2 with Soluble Boron at 0 Years Cooling Time

Design Basis Burnup at 5.0 wt% ^{235}U		42.8 GWD/MTU
Soluble Boron		236 ppm[14]
Uncertainties		
Bias Uncertainty (95%/95%)	± 0.0011	
Calculational Statistics (95%/95%, 2.0×σ)	± 0.0012	
Fuel Eccentricity	+ 0.0168	
Rack Tolerances	± 0.0039	
Fuel Tolerances	± 0.0073	
Depletion Uncertainty	± 0.0139	
Statistical Combination of Uncertainties[15]	± 0.0234	
Reference k_{eff} (MCNP4a)		0.9114
Total Uncertainty (above)		0.0234
Temperature Bias		0.0093
Calculational Bias (see Appendix 4A)		0.0009
Maximum k_{eff}		**0.9450**
Regulatory Limiting k_{eff}		**0.9500**

[14] Calculations performed for 5.0 wt% fuel with a burnup of 36.4 GWD/MTU at 20 years cooling time, resulted in a slightly higher soluble boron requirement of 237ppm
[15] Square root of the sum of the squares.

Table 4.7.9
Summary of the Criticality Safety Analyses for Region 3 without Soluble Boron for a 2x2 Checkerboard of 3 Fresh Fuel Assemblies and 1 Spent Fuel Assembly at 0 Years Cooling Time

Design Basis Burnup for Single (5.0 wt%) Spent Assembly	20.1 GWD/MTU
Soluble Boron	0 ppm
Uncertainties	
Bias Uncertainty (95%/95%)	± 0.0011
Calculational Statistics (95%/95%, 2.0×σ)	± 0.0014
Fuel Eccentricity	Negative
Rack Tolerances	± 0.0060
Fuel Tolerances	± 0.0053
Depletion Uncertainty	± 0.0012
Statistical Combination of Uncertainties[18]	± 0.0082
Reference k_{eff} (MCNP4a)	0.9858
Total Uncertainty (above)	0.0082
Temperature Bias	0.0017
Calculational Bias (see Appendix 4A)	0.0009
Maximum k_{eff}	**0.9966**
Regulatory Limiting k_{eff}	**1.0000**

[18] Square root of the sum of the squares.

Table 4.7.10
Summary of the Criticality Safety Analyses for Region 3 with Soluble Boron for a 2x2 Checkerboard of 3 Fresh Fuel Assemblies and 1 Spent Fuel Assembly at 0 Years Cooling Time

Design Basis Burnup for Single (5.0 wt%) Spent Assembly	20.1 GWD/MTU
Soluble Boron	444 ppm
Uncertainties	
Bias Uncertainty (95%/95%)	± 0.0011
Calculational Statistics (95%/95%, 2.0×σ)	± 0.0012
Fuel Eccentricity	Negative
Rack Tolerances	± 0.0060
Fuel Tolerances	± 0.0053
Depletion Uncertainty	± 0.0012
Statistical Combination of Uncertainties[19]	± 0.0082
Reference k_{eff} (MCNP4a)	0.9342
Total Uncertainty (above)	0.0082
Temperature Bias	0.0017
Calculational Bias (see Appendix 4A)	0.0009
Maximum k_{eff}	**0.9450**
Regulatory Limiting k_{eff}	**0.9500**

[19] Square root of the sum of the squares.

Table 4.7.14[22]
Minimum Burnup versus Enrichment Values for Region 1 Racks with Spent Fuel

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time	Minimum Burnup (GWD/MTU)						
0	2.3	9.2	15.5	22.1	27.7	33.0	39.0
5	2.2	8.7	14.8	21.1	26.7	31.1	37.1
10	2.1	8.3	14.0	20.0	25.6	29.8	35.3
15	2.0	8.1	13.6	19.4	25.3	29.1	34.0
20	2.0	8.0	13.5	19.0	24.6	28.6	33.3

[22] Linear interpolation between burnups for a given cooling time is allowed. However, linear interpolation between cooling times is not allowed, therefore the cooling time of a given assembly must be rounded down to the nearest cooling time.

Table 4.7.15[23]
Minimum Burnup versus Enrichment Values for Region 2 Racks with Spent Fuel

Enrichment	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Cooling Time	Minimum Burnup (GWD/MTU)						
0	4.5	11.7	18.7	25.7	30.6	36.9	42.8
5	4.2	11.0	17.6	24.2	29.1	34.4	40.7
10	4.0	10.6	16.7	23.0	28.1	33.0	38.6
15	4.0	10.1	15.9	22.4	27.4	31.8	37.4
20	4.0	9.8	15.7	21.8	26.8	31.2	36.4

[23] Linear interpolation between burnups for a given cooling time is allowed. However, linear interpolation between cooling times is not allowed, therefore the cooling time of a given assembly must be rounded down to the nearest cooling time.

Table 4.7.23
Region 1 Accident Conditions

Abnormal/Accident Condition	Soluble Boron Requirement
Abnormal Temperature – Spent Fuel	326 ppm
Abnormal Temperature – Fresh Fuel	209 ppm
Dropped Assembly – Horizontal	Negligible
Dropped Assembly – Vertical	Negligible
Misloaded Assembly – Spent Fuel	521 ppm
Misloaded Assembly – Fresh Fuel	804 ppm
Mislocated Assembly – Spent Fuel	493 ppm
Mislocated Assembly – Fresh Fuel	889 ppm
Maximum	**889 ppm**

Table 4.7.24
Region 2 Accident Conditions

Abnormal/Accident Condition	**Soluble Boron Requirement**
Abnormal Temperature – Spent Fuel	332 ppm
Abnormal Temperature – Fresh Fuel	278 ppm
Dropped Assembly – Horizontal	Negligible
Dropped Assembly – Vertical	Negligible
Misloaded Assembly – Spent Fuel	551 ppm
Misloaded Assembly – Fresh Fuel	867 ppm
Mislocated Assembly – Spent Fuel	480 ppm
Mislocated Assembly – Fresh Fuel	875 ppm
Maximum	**875 ppm**

Table 4.7.25
Region 3 Accident Conditions

Abnormal/Accident Condition	Soluble Boron Requirement
Abnormal Temperature	Negative
Dropped Assembly – Horizontal	Negligible
Dropped Assembly – Vertical	Negligible
Misloaded Assembly – 3 of 4 Pattern	672 ppm
Mislocated Assembly – 3 of 4 Pattern	843 ppm
Maximum	**843 ppm**

Table 4.7.26 Interface Calculations

Interface Calculation	Figure #	Reactivity (k_{calc})	Reference Reactivity (k_{calc})	Delta k	Acceptable?
Region 1 to Region 1 with fresh fuel checkerboard in each rack. Fresh fuel assemblies facing in adjacent racks.	4.7.1	0.9352	0.9329	+0.0023	N
Region 1 – Checkerboard and Spent Fuel in same rack.	4.7.2	0.9596	0.9638	-0.0042	Y
Region 2 to Region 2 with fresh fuel checkerboard in each rack. Fresh fuel assemblies facing in adjacent racks.	4.7.3	0.9454	0.9431	+0.0023	N
Region 2 – Checkerboard and Spent Fuel in same rack.	4.7.4	0.9673	0.9662	+0.0011	Y
Region 3 to Region 3 with no Metamic Panel in the gap. 3 of 4 pattern with fresh fuel at 5.0 wt% ^{235}U facing each other in both racks.	4.7.5	0.9908	0.9858	+0.0050	N
Region 3 to Region 3 with no Metamic Panel in the gap. 3 of 4 pattern with fresh fuel at 5.0 wt% ^{235}U in one rack facing fresh and spent fuel in other rack across gap.	4.7.6	0.9864	0.9858	+0.0006	Y
Region 3 to Region 3 with no Metamic Panel in the gap. All fresh fuel at 4.35 wt% ^{235}U in one rack, 3 of 4 pattern with fresh fuel facing gap in other rack.	4.7.7	0.9890	0.9860	+0.0030	N
Region 3 to Region 3 with no Metamic Panel in the gap. All fresh fuel at 4.35 wt% ^{235}U in one rack, 3 of 4 pattern with fresh and spent fuel facing gap in other rack.	4.7.8	0.9838	0.9860	-0.0022	Y
Region 1 to Region 3, Fresh Fuel Checkerboard in Region 1 rack, 3 of 4 pattern in Region 3 rack.	4.7.9	0.9825	0.9858	-0.0033	Y
Region 1 to Region 3, Spent Fuel in Region 1 rack, 3 of 4 pattern in Region 3 rack.	4.7.10	0.9822	0.9858	-0.0036	Y
Region 2 to Region 3, Fresh Fuel Checkerboard in Region 2 rack, 3 of 4 pattern in Region 3 rack.	4.7.11	0.9832	0.9858	-0.0026	Y
Region 2 to Region 3, Spent Fuel in Region 2 rack, 3 of 4 pattern in Region 3 rack.	4.7.12	0.9834	0.9858	-0.0024	Y
Region 3 – 3 of 4 and Fresh Fuel 4.35 wt% ^{235}U in same rack. All fresh 5.0 wt% facing all fresh 4.35 wt%	4.7.13	0.9881	0.9860	+0.0021	N
Region 3 – 3 of 4 and Fresh Fuel 4.35 wt% ^{235}U in same rack. Fresh and spent 5.0 wt% facing all fresh 4.35 wt%	4.7.14	0.9835	0.9860	-0.0025	Y

Attachment 6

1CAN100601

Structural/Seismic Considerations for Addition of Metamic Panels to the Flux Traps of Two Spent Fuel Racks at ANO-1

Friction at the support to pool floor interface is modeled by the linear friction springs with stiffness K_f up to the limiting lateral load μN, where N is the current compression load at the interface between support and liner. At every time-step during time history analysis, the current value of N (either zero, if the pedestal has lifted off the floor, or a restraining force) is computed.

The modeling of the effective compression stiffness with the gap element of stiffness K_s includes the pedestal stiffness and local stiffness of the underlying pool slab.

4.8 Poison Insert Modeling

The metamic poison inserts consist of two nominal 7" wide x 155" long by 0.1" thick metamic panels per flux trap. Each metamic panel is enclosed in a formed 26 gage sheet metal channel. The channels are nominally 7.12" deep with .43" flanges x 155" long. The metamic panels are held in the channels by a 4" long x 26 gage sheet metal channel-shaped band at the top and bottom, and four 6" long x 26 gage sheet metal channel-shaped bands between the 4" bands, spaced at about 30" to 32" center to center. These bands are spot welded to the outside channel "flanges" with two spot welds on each side. The inserts are detailed on References 14 and 15.

The design of the metamic inserts has evolved over time to the present configuration where the sheet metal channels with the metamic panels are now held (front to front) at a nominal 1.20" apart, measured out to out between the backs of the channel sections. They are held by ten to fourteen pairs of 0.075" thick x 0.95" wide x 4" long plates, spaced 7" to 20" welded to the channel flanges along the length, plus a pair of 0.90" wide x 4" long plates (0.02" thick at the bottom and 0.075" thick at the top) welded to the channel flanges at the top and bottom.

There are four 22 Gage sheet metal formed bands described as horizontal supports, between the two insert halves along with four pairs of corresponding 22 Gage sheet metal formed bands described as vertical supports. The original purpose of these "supports" was to hold the opposing channel/panel sections together during shipping and insertion into the flux traps. Now that the design is such that the panel/channel sections are fixed by the plates on the flanges, these "supports" no longer have any function. They are classified as non-safety related and provide no structural support, and assumed no interference. The total mass/weight of these supports is very small (≈0.1 lb each). In the rack models, the inserts are modeled with more than double their actual weight. Hence, the horizontal and vertical supports are not considered explicitly.

There are also three sets of wedge blocks made from ½" plate, with one set at the top, one at the bottom, and the other located about $^2/_5$ the distance from the top, between the other two. These wedge blocks were originally designed to hold the insert halves apart and against the inside walls of the flux traps after insertion into the flux traps. Since the panels with their wrapper channels are now fixed by the added plates at a nominal 1.20" outside width and the opposing panel assemblies are now offset vertically $1^{13}/_{16}$", the wedge blocks likely are not in contact with each other, and hence cannot be counted on to provide any structural support. They are included for mass/weight effects only in the insert model, with mass distribution varied proportionately to account for their locations in the rack models.

To determine equivalent structural properties for the metamic insert panels for inclusion in the rack models, a model of a typical metamic panel was developed using shell elements.

and subscripts x and y reflect the particular bending plane.

Combined flexure and compression (or tension) on a net section:

$$\frac{f_a}{0.6S_y}+\frac{f_{bx}}{F_{bx}}+\frac{f_{by}}{F_{by}}<1.0$$

The above requirements are to be met for both direct tension and compression.

7.2.6 Bearing Allowable Stress - OBE

Allowable Bearing Stress from Section NF-3226.1 of the ASME Code [16]:

$$F_b = S_y = 27{,}500 \text{ psi}$$

7.2.7 Weld Allowable Stress or Force (By Analysis and Test) - OBE

Allowable maximum shear stress on the net section of a weld is given by:

$F_w = 0.3\ S_u$ (on the weld material) or

$F_w = 0.4\ S_y$ (on the base metal material in shear)

$F_w = 0.6\ S_y$ (on the base metal material in tension)

where S_u is the weld material ultimate strength at temperature and S_y is the base metal yield strength at temperature. Per Ref. [9] the weld material used is an E80 electrode with an S_u = 80 ksi. For fillet weld legs in contact with base metal, the shear stress on the gross section is limited to $0.4S_y$, where S_y is the base material yield strength at temperature.

Therefore the allowable weld stress is:

$F_w = 0.3\ S_u$ = .3 * 80 ksi = 24 ksi (on the weld material)

$F_w = 0.4\ S_y$ = 0.4 * 27,500 psi = 11,000 psi (on the base metal material in shear)

$F_w = 0.6\ S_y$ = 0.6 * 27,500 psi = 16,500 psi (on the base metal material in tension)

The spot weld and fillet weld allowables were determined by test, with the spot weld capacity found to be lower than that for the fillet welds. Capacity for both welds was then taken as:

$$F_w = T.L. * (S / S_u)$$

Where: *T.L.* is the mean ultimate capacity test results. From Ref. [19] the mean of the 15 test samples for the spot weld = 680 lb (rounded to the nearest 10 lb)

S = ASME Code Allowable Stress S = 17.2 ksi from Ref. [18] (Note that failure of the test was a base metal failure, therefore, *S*, is the base metal allowable stress.)

7.3.5 Combined Bending and Tension or Compression Allowable Stress - DBE

Combined bending and compression on a net section satisfies:

$$\frac{f_a}{0.667 * F_e} + \frac{C_{mx} f_{bx}}{D_x F_{bx}} + \frac{C_{my} f_{by}}{D_y F_{by}} < 1$$

Where all of the terms have been defined in Subsections 7.2.5 and 7.3.2.

Combined flexure and compression (or tension) on a net section:

$$\frac{f_a}{0.667 * F_e} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} < 1.0$$

Where $0.667 * F_e$ is limited to the tension allowable of 28,500 psi. The above requirements are to be met for both direct tension and compression.

7.3.6 Bearing Allowable Stress - DBE

Per Section F-1334.10 [16], Bearing Stress need not be evaluated for loads when Limit D Service Limits are specified.

7.3.7 Weld Allowable Stress and Force (By Test) - DBE

For welds, the allowable maximum weld stress is not specified in Appendix F of the ASME Code. An appropriate limit for weld throat stress is conservatively set here as:

$F_w = 0.3\ S_u$ x factor (on the weld material)

$F_w = 0.4\ S_y$ x factor (on the base metal in shear)

$F_w = 0.6\ S_y$ x factor (on the base metal in tension)

where: factor = (Level D shear stress limit) / (Level A shear stress limit) = 17,100/11,000 = 1.55

and S_u and S_y were defined in Section 7.2.7

Therefore the allowable weld stress is:

$F_w = 0.3\ S_u$ x factor = 1.55*0.3 * 80 ksi = 37.2 ksi (weld material)

$F_w = 0.4\ S_y$ x factor = 1.55 * 0.4 * 23,750 psi = 14,725 psi (base metal in shear)

$F_w = 0.6\ S_y$ x factor = 1.55 *0.6 * 23,750 psi = 22,088 psi (base metal in tension)

The spot weld and fillet weld allowable loads were determined by test from F-1332.7 of Appendix F [16] and were taken (using the lower OBE allowable load for the spot welds) as:

$$F_w = 0.7 * T.L. * (S_u / S_u^*)$$

10.0 Conclusions

The overall design objectives of the spent fuel storage pool at ANO Unit 1 have been shown to meet the various Regulatory Guides, the Standard Review Plan, and industry standards. The structural adequacy of the SFP maximum density spent fuel racks at ANO Unit 1 with the new poison inserts have been evaluated using the appropriate regulatory and design standards. Postulated loadings for normal, seismic, and accident conditions at the ANO Unit 1 site were considered in this analysis and evaluation. The design adequacy of the racks and the poison inserts has been confirmed with analyses that were performed in compliance with the USNRC Standard Review Plan [1], the USNRC Office of Technology Position Paper [2], Lawrence Livermore Report UCRL52342 [3] and ANO Specification APL-C-502 [4]. All applicable displacement and stress acceptance criteria have been met for the racks and the new poison inserts, as summarized for the OBE and DBE in Tables 10.1, 10.2 and 10.3 below. Results for the Pool Structure Analysis are summarized in Table 9.1 above.

Table 10.1 – Summary of Stress Results for OBE Load Case

Component	Stress Type	D + L + E		
		Applied Stress (psi)	Allowable Stress (psi)	Stress Interaction
Cell	Axial+Bending Buckling	10209.4 5485.4	16500 7612	0.619 0.721
Wrapper Welds	Shear	8847	11000	0.804
Cell Seam Welds	Shear	18786	24000	0.783
Cell to Cell Welds at Top at Bottom	 Shear Shear	 12259 19681	 24000 24000	 0.511 0.820
Cell to Base Plate Welds	Tension	12790	16500	0.775
Support Pad	Axial Shear Bearing	9322.9 2115.9 8274.2	16500 11000 27500	0.565 0.192 0.301
Threads	Shear	8128.5	11000	0.739
Support Plate	Axial Shear	330.1 2543.9	16500 11000	0.020 0.231
Metamic Insert Enclosure Channel Buckling Spot Welds	 Axial + Bending Axial Compression Shear Force	 44.3 94.2 lb --	 151/16500 360 lb 170 lb	 0.261 0.262 --

Note: 1) Shear force on the spot welds are insignificant from seismic loading.

11.0 References

[1] USNRC NUREG-0800, Standard Review Plan, June 1987.

[2] (USNRC Office of Technology) "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14,1978, and January 18, 1979 amendment thereto.

[3] UCRL52342, "Effective Mass and Damping of Submerged Structures," Lawrence Livermore National Laboratory, April 1, 1978.

[4] ANO Technical Specification APL-C-502, "Technical Specifications for Earthquake Resistance Design of Structures and/or Components Located in the Auxiliary Building for the Arkansas Nuclear One Unit 1 Power Plant," Rev. 2, 4-22-87.

[5] Stevenson & Associates Calculation ANO-ER-02-051, "Seismic Re-qualification of the Arkansas Nuclear One Unit 1 Spent Fuel Racks," Rev. 1, June 28, 2006.

[6] SOLVIA, Finite Element System, Version 99, Solvia Engineering, AB, Sweden, 1987-2001.

[7] SOLVIA, Finite Element System, Version 03, Solvia Engineering, AB, Sweden, 1987-2006.

[8] Westinghouse Drawing 1-W62A-017(1)-0

[9] Calculation 91E-0079-01, Revision 1, "Design Report for Spent Fuel Storage Racks for AP&L Co.," 9-20-96 (analysis performed in 1982).

[10] Levy, S. and Wilkinson, J.P.D., "The Component Element Method in Dynamics with Application to Earthquake and Vehicle Engineering," McGraw Hill, 1976.

[11] ASCE Standard 4-98, "Seismic Analysis of Safety Related Nuclear Structures and Commentary," American Society of Civil Engineers, Copyright 2000.

[12] Stevenson & Associates Report, "Independent Evaluation of Seismic Response of Spent Fuel Storage Racks Currently Being Procured for Salem Nuclear Power Plant," Dec. 1, 1993.

[13] NUREG/CR-5912, BNL-NUREG-52335, "Review of the Technical Basis and Verification of Current Analysis Methods Used to Predict Seismic Response of Spent Fuel Storage Racks," Brookhaven National Laboratory, October 1992.

[14] Holtec International Drawing 4127, "Fabrication Drawing of Metamic Inserts for ANO-1 Spent Fuel Racks," Revision 13, 9/28/06.

[15] Holtec International Drawing 3917, "Metamic Inserts and Fuel Leadins for Spent Fuel Racks," Revision 11, 9/28/06.

[16] ASME Boiler & Pressure Vessel Code, Section III, Subsection NF, 1980, through Winter 1981 Addendum.

[17] Stevenson and Associates, Program THSPEC – Verification and User's Manual for Computer Code THSPEC.

[18] ASME Boiler & Pressure Vessel Code, Section III, Appendices, 1980, through Winter 1981 Addendum.

[19] Stork Herron Testing Labs, Specimen Load Tests, Dec. 18, 2003.

[20] Chun, R., Witte, M. and Schwartz, M., "Dynamic Impact Effects on Spent Fuel Assemblies," UCID-21246, Lawrence Livermore National Laboratory, October 1987.

[21] ACI 349-85, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute, Detroit, Michigan, 1985.

[22] ACI 318-95, Building Code Requirements for Structural Concrete, American Concrete Institute, Detroit, Michigan, 1995.

[23] Entergy letter to the NRC dated April 2, 2003. "License Amendment Request to Modify the Fuel Assembly Enrichment, the Spent Fuel Pool (SFP) Boron Concentration Technical Specification (TS) 3.7.14, the Loading Restrictions in the SFP in TS 3.7.15, and to Modify the Fuel Storage Design Features in TS 4.3."

[24] Entergy letter to Stevenson & Associates – ANO-2003-00144, dated Dec. 8, 2003, Subject: "Spent fuel Pool Inputs Required for the Unit 1 Rack Seismic Analysis."

[25] ANO-1 SFP Rack Design Inputs, Design Input Record, Document Number ANO-2005-00252, 11/16/2005.

[26] Stevenson & Associates Calculation ANO-ER-02-010, "Review of Structural Analysis of the Arkansas Nuclear One Unit 1 Spent Fuel Pool For Revised Fuel Rack Loads," Rev. 0, June 28, 2006.

[27] Chajes, A., "Principles of Structural Stability Theory," Prentice-Hall, New Jersey, 1974.

[28] ANO-1 SFP Rack Design Inputs, Design Input Record, Document Number ANO-2005-00252, 11/16/2005.

[29] ANO-1 SFP Rack Design Inputs, Design Input Record, Document Number Holtec Drawing 3917 and 4127, 9/29/2006, Rev. 1.