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A Duke Energy Company

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Subject: Duke Energy Corporation
Oconee Nuclear Station, Units 1, 2 and 3
Docket Numbers 50-269, 50-270 and 50-287
Response to Request for Additional Information -
Proposed Technical Specification Amendment
Generic Letter 96-04 - Spent Fuel Storage Racks
(TSCR 2000-01)

By letter dated December 28, 2000, as supplemented by letter dated February 15, 2001, Duke Energy Corporation (Duke) submitted a License Amendment Request (LAR) to revise the Oconee Nuclear Station, Units 1, 2, and 3, Technical Specifications related to controls used to ensure acceptable margins of subcriticality in the Spent Fuel Pools (SFP) to account for Boraflex degradation. Duke has previously provided responses to requests for information by letters dated April 26, 2001, and June 26, 2001.

Attachment A to this letter provides Duke's response to NRC information requests provided by emails from D. E. LaBarge to R. C. Douglas on June 29, 2001 and August 6, 2001. The attachments to this letter provide replacement pages and sections to revise the LAR as follows:

This Letter's Attachment	LAR Attachment	Description	Discussion
B	1	Markup TS Pages	Add and replace selected pages
C	2	Proposed TS Pages	Add and replace selected pages
D	3	Description and Technical Justification	Replace Attachment
E	6	Criticality Analysis	Replace Attachment
F	7	Dilution Analysis	Replace Attachment

Duke's December 28, 2000 letter requested NRC approval of the TS change by September 15, 2001. However, due to delays in the start of the upcoming Oconee Unit 3 refueling outage, Duke requests NRC approval of the proposed TS amendments by December 28, 2001, with a subsequent 60-day implementation period ending February 26, 2002. The current administrative minimum burnup limits for fuel storage in the Oconee SFPs are valid through December 18, 2001, and would need to be revised to allow continued storage during the delayed implementation period. Projections of Boraflex degradation in the Oconee SFPs

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Rec'd at NRC/DCD 12/06/01

indicate that, for extended operation of the SFPs through at least June 2002, minimum fuel burnup requirements would increase by less than 0.50 GWD/MTU. This minor increase would not affect the status of the fuel that is currently stored in the Oconee SFPs, since all fuel assemblies that have experienced at least one cycle of reactor irradiation will still qualify for storage without restriction in the SFPs.

The above described revisions do not change the conclusion provided in the No Significant Hazards Consideration evaluation or the Environmental Impact Assessment provided with the December 28, 2000 submittal.

Please contact R. C. Douglas at 864-885-3073 for additional information or questions concerning these submittals.

Very Truly Yours,

W. R. McCollum, Jr.
Site Vice President
Oconee Nuclear Station

Enclosure a/s

cc: L. A. Reyes
M. C. Shannon
D. E. LaBarge
V. R. Autry

AFFIDAVIT

W. R. McCollum, Jr., states that he is Site Vice President of Duke Energy Corporation; that he is authorized on the part of said corporation to sign and file with the Nuclear Regulatory Commission this supplemental information for an amendment to the Oconee Nuclear Station Facility Operating License Nos. DPR-38, DPR-47, and DPR-55 and Technical Specifications; and that all statements and matters set forth therein are true and correct to the best of his knowledge.

W. R. McCollum, Jr., Site Vice President

Subscribed and sworn to me: 10-31-01
Date

Conice M Breazeale, Notary Public

My Commission Expires: 2-12-2003
Date

SEAL

Duke Energy Corporation
Response to NRC Request for Additional Information

A. Attachment 3, Description of Proposed Changes and Technical Justification

1. NRC Question

Page four and five of attachment three states that the proposed change to the surveillance requirement (SR) 3.7.12.1 frequency for verifying the Spent Fuel Pool boron concentration is changed from 31 days to seven days; and that this change conforms to the SR frequency to the STS frequency. The STS frequency of NUREG-1430 for verifying pool boron concentration is every 7 hours, however, the frequency identified in NRC staff acceptance for referencing topical report WCAP-14416-P, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, is every seven days. Please clarify which document is being relied upon to justify taking credit for boron in spent fuel pool criticality analysis.

Response:

As noted above, the Surveillance Requirement (SR) 3.7.12.1 frequency for verifying the Spent Fuel Pool (SFP) boron concentration is changed from 31 days to seven days. This change is in conformance with the surveillance frequency of seven days provided in NUREG-1430, Revision 1, "Standard Technical Specifications – Babcock and Wilcox Plants," dated April 1995, in addition to WCAP-14416-P, as noted above.

Also, the seven-day surveillance frequency for determining the boron concentration in the Borated Water Storage Tank (SR 3.5.4.3) is specified in NUREG-1430, Revision 1. The current SR 3.5.4.3 boron concentration surveillance interval remains unchanged at seven days.

2. NRC Question

Page five of attachment three states that upon approval of this LAR, UFSAR Section 9.1.2.5, Boraflex, will be deleted since the Boraflex remaining in the spent fuel racks would no longer be credited with maintaining fuel subcritical. Upon approval of the LAR will the Boraflex panels remain in the spent fuel pool or will they be removed?

Response

As noted above, UFSAR Section 9.1.2.5, Boraflex, will be deleted since the Boraflex remaining in the spent fuel racks would no longer be credited with maintaining fuel subcritical. There are no plans to remove the spent fuel racks containing the Boraflex panels. Although the boron remaining in the Boraflex panels is slowly being dissolved into the SFP as the Boraflex degrades, no deliberate action is being contemplated to either remove the boron from the Boraflex panels or to remove the Boraflex panels from the spent fuel racks.

3. NRC Question

Page five of attachment three, Technical Justification, states that the spent fuel pool boron concentration limit currently specified in the COLR is well above the minimum required boron credit of 430 ppm for non-accident conditions. When taking credit for boron in the spent fuel pool following the NRC accepted WCAP-14416-NP-A the intent is to analyze dilution events resulting from various accidents. Therefore, referencing a minimum concentration of 430 ppm for non-accidents is found to be non-conservative. What is the minimum boron concentration needed to maintain $k_{eff} \leq 0.95$ under accident conditions? Page six of attachment three indicates that your analysis of various dilution events should have been evaluated using a minimum soluble boron concentration of 826 ppm for Units 1 and 2 spent fuel pool and 1001 ppm soluble boron for Unit 3 spent fuel pool–do you agree?– and if not provide bases for a non-conservative assumption of 400 ppm and 430 ppm respectively under non-accident conditions?

Response

In performing the supporting analyses for its December 28, 2000 LAR submittal, Duke followed the methodologies outlined in the SER for WCAP-14416-NP-A, and in the NRC memo from L. Kopp dated August 19, 1998. As noted in Attachments 3 and 6 of the LAR submittal, and in the response to Question 4 in the April 26, 2001 RAI, these methodologies specify three (3) criteria that must be met in order to take partial credit for soluble boron in the spent fuel pools, for storage under **normal conditions** (undamaged racks, no misloaded fuel assemblies, and spent fuel pool water temperature below 150 degrees F):

> *Criterion N1*: With the spent fuel storage racks loaded with fuel of the maximum permissible reactivity and flooded with full-density unborated water, the maximum k_{eff} shall be less than 1.0, including mechanical and calculational uncertainties.
>
> *Criterion N2*: With the spent fuel storage racks loaded with fuel of the maximum permissible reactivity and flooded with full-density water borated to **X** ppm, the maximum k_{eff} shall be no greater than 0.95, including mechanical and calculational uncertainties.
>
> *Criterion N3*: The amount of soluble boron credit **X** (from *Criterion N2*) must be less than the boron remaining following a worst-case credible boron dilution event in the spent fuel pool.

In the above criteria N2 and N3, the variable X for normal storage conditions was determined to be 400 ppm for the Unit 1 and 2 SFP and 430 ppm for the Unit 3 SFP. These values are documented and compared with the worst case boron dilution event concentrations in the table at the end of this response.

In addition, the following criterion must be satisfied for spent fuel pool storage under **accident conditions**:

> *Criterion A1*: The maximum k_{eff} shall be no greater than 0.95, including mechanical and calculational uncertainties, with the spent fuel pool flooded with full-density water borated to at least **Y** ppm.

For the Oconee spent fuel pools, the accident conditions that were considered include an assembly misload event, heatup of the spent fuel pool water above 150 degrees F, and a heavy load drop onto the storage racks.

In the above *Criterion A1*, the variable **Y** is 2220 ppm boron, which is the current minimum required in the Oconee spent fuel pools per the COLR. Per the double contingency principle, it is not required to assume that a boron dilution event is occurring in conjunction with any of the accidents mentioned in the above paragraph. However, note that, due to the nature of the various boron dilution scenarios, there is a significant probability that a dilution event could occur with the average spent fuel pool water temperature above 150 degrees F. Therefore, the dilution event should be considered the limiting boron concentration for comparison with the subcriticality boron requirements of the spent fuel pool heatup accident event.

In the markup and proposed TS changes provided in Attachments B and C to this response letter, the 2220 ppm value is imposed as an actual minimum boron concentration – in addition to the requirement that the boron concentration be within the bounds specified in the COLR – for the spent fuel pool and the BWST.

The table below summarizes the results of the bounding criticality and dilution analyses for fuel storage under normal and accident conditions, in accordance with the subcriticality criteria outlined above. Note that the heavy load drop accident requires approximately 2220 ppm in order to achieve a k_{eff} below 0.95. The supporting analysis for this accident included the following biases and uncertainties:

- Benchmark Method Bias
- Grid Effect Bias
- BP-Pull Bias
- Calculational Burnup Bias
- Axial Burnup / 3D Bias
- Benchmark Method Uncertainty
- Monte Carlo Computational Uncertainty
- Enrichment Manufacturing Uncertainty
- Fuel Density Manufacturing Uncertainty
- Cladding Diameter Manufacturing Uncertainty
- Storage Rack Cell Wall Thickness Manufacturing Uncertainty
- **Boron Measurement Uncertainty**
- Burnup Measurement Uncertainty
- Burnup Computational Uncertainty

The limiting boron dilution event for the Unit 3 SFP has been changed due to the need to consider a second SFP drawdown event involving use of the SFP to maintain Unit 3 reactor coolant inventory via the HPI pumps following certain tornado damage events to Unit 3. This "HPI Suction Alignment" dilution event is further described in Attachment F to this response letter, and results in a final boron concentration of 957 ppm in the Unit 3 SFP.

The following table summarizes the results of the above described analyses (this table is also provided in LAR Attachment 3).

Bounding Spent Fuel Pool Events

SFP	Event [a]	Initial Boron Concentration	Final Boron Concentration (compared to required boron concentration)	Maximum k_{eff} at the Final Boron Conc	Acceptance Criteria (k_{eff})	Boron Concentration Required for Acceptance Criteria	Submittal Discussion Reference(s)
1&2	Normal Storage Conditions -- No Boron	N/A	0	<1.0	< 1.0	0	Att.6, § 3.1 (page 6) Att. 6, Table 10 (page 28)
3	Normal Storage Conditions -- No Boron	N/A	0	<1.0	< 1.0	0	Att.6, § 3.1 (page 6) Att. 6, Table 10 (page 28)
1&2	Normal Storage Conditions – partial credit for soluble boron [b]	2220	825	<< 0.95	≤ 0.95	400	Att. 6, Table 10 (page 28) Att. 7, §6.2 (page 27)
3	Normal Storage Conditions – partial credit for soluble boron [b]	2220	957	<< 0.95	≤ 0.95	430	Att. 6, Table 10 (page 28) Att. 7, §6.3 (page 29)
1&2	Cask Drop Accident	2220	2220	0.9491	≤ 0.95	2220	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
3	Cask Drop Accident	2220	2220	0.9392	≤ 0.95	2220	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
1&2	Fuel Assembly Misload Accident	2220	2220	<<0.95	≤ 0.95	1110	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
3	Fuel Assembly Misload Accident	2220	2220	<<0.95	≤ 0.95	1210	Att.6, § 4.0 (page 16) Att. 6, Table 10 (page 28)
1&2	SFP Heatup Accident Condition [b]	2220	825	<<0.95	≤ 0.95	470	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
3	SFP Heatup Accident Condition [b]	2220	957	<<0.95	≤ 0.95	500	Att.6, § 4.0 (page 16) Att. 6, Table 10 (page 28)

(a) Each event is evaluated with the limiting fuel enrichment, burnup and storage configuration.
(b) With limiting dilution event, the SSF drawdown of the SFP and subsequent emergency makeup (for the Unit 1&2 SFP), or HPI Suction Alignment with makeup (Unit 3 SFP).

4. NRC Question

Page 11 of attachment 3, Conclusion, states that the minimum boron concentration would be ensured by the Oconee TS 3.7.12, however, the TS proposed indicates that the minimum boron concentration would be as stated within the COLR. Placing the requirement for soluble boron in the COLR is consistent with the Standard Technical Specification NUREG-1430. Please clarify whether you followed the NRC acceptance for referencing WCAP-14416-NP-A, which requires the minimum soluble boron concentration to be stated within the TS, or the STS, which specifies the COLR as the controlling document for the minimum boron concentration.

Response

The minimum boron concentration required to bound the subcriticality requirements for all accident conditions in the Oconee SFPs (2220 ppm) may, for some fuel cycles, be different from the minimum boron concentrations required to meet other operational or safety parameters for related systems. Accordingly, TS 3.7.12 is revised to establish a minimum boron concentration of either $\geq$ 2220 ppm or the limit specified in the COLR, whichever is greater. This same limit is also applied to TS 3.5.4, Borated Water Storage Tank (BWST). The Bases of these TSs are also revised to reflect these changes. Markup and replacement TS and TS Bases pages are provided in Attachments B and C to this letter, respectively, for insertion into the December 28, 2000 submittal.

B. Attachment 7

1. NRC Question

The approach identified in the attachment states that WCAP-14416-NP-A was followed to complete dilution analysis. However, staff verification of dilution times based on beginning and end point soluble boron concentrations, dilution times, and volumes indicate that the results within the submittal are non-conservative. Please clarify that the analysis follows the NRC acceptance criteria for referencing WCAP-14416-NP-A.

Response

In the SER for the WCAP-14416 methodology, the NRC referenced WCAP-14181 as providing additional guidance for dilution analysis. The equations derived in WCAP-14181 assume that overflow begins as soon as unborated water is added to the SFP and does not consider the significant volume of water that must be added to finish filling up the pool. In its initial submittal, Duke considered Section 3.2 of WCAP-14181 to represent a sample problem rather than a rigorous, prescriptive calculational method, and that the simplifying assumption does not preclude consideration of the "filling up" process in the analysis. The simplified WCAP-14181 equations produce a more conservative estimate of the boron concentration.

The enclosed Attachment 7 revision documents the Oconee dilution analyses using the simplified approach presented in WCAP-14181 where applicable. This approach applies to all scenarios except those that do not involve overflow of the SFP. In those scenarios, boron dilution occurs when some of the initial SFP water volume is intentionally removed and later replaced with unborated water. The methodology used in the analysis of these scenarios is presented in the revised Attachment 7.

2. NRC Question

Page 16 of attachment seven indicates that the operations support staff does not recall the FW Booster Pump(s) ever being used. Therefore, a pipe break in the FW line is not considered to be a credible boron dilution accident. Is the line under pressure or is it isolated and unable to provide inventory to the spent fuel pool under any condition that could potentially result in a FW line break?

Response

In its normal system configuration, the line from the main FW header up to the SFP area is not isolated and provides a flow path all the way back to the Filtered Water Storage Tanks located on the roof of the Oconee Service Building. These horizontal tanks are 12 feet in diameter with the bottom of the tanks at approximately elevation 845'. Since the FW Booster Pumps are normally not running, the pressure in the line is determined by the level in the FW Storage Tanks and the line losses between the tanks and the postulated break location. For a break located at the top of the SFP (elevation 844'), the maximum static head is 13 feet based on the top of the tank being at approximately elevation 857'. This corresponds to a maximum pressure of less than 6 psig. In addition, there are considerable line losses between the tanks and the SFP location (from one end of the plant to the other). When the Filter Pumps are running to refill the tanks, there is expected to be a small rise in system pressure until the tanks are full. However, for any reasonable postulated crack size in this "low energy" piping, neither the tanks nor the Filter Pumps would be able supply any appreciable flow rate to a break location in the Unit 3 SFP area. Thus, this scenario was not considered to be a credible dilution source based on its limited flow capacity. Furthermore, this scenario is bounded by the DW line break (300 gpm) involving a system at a much higher normal pressure and higher flow capacity into the pool.

3. NRC Question

Page 28 of the attachment states based on the analysis presented above, it is concluded that there are no credible events that would result in the dilution of the spent fuel pool boron concentration to less that the boron credit limit for each pool. What systems will notify the operator to take action to mitigate a spent fuel pool dilution event? What procedures are used to identify potential spent fuel pool dilution events?

Response

The primary means of detecting a dilution event is the SFP level instrument and its associated indication and alarms in the main control room. Alarm Response Procedure SA-9/A-5, "Spent Fuel Pool Level High/Low," directs operators to check proper valve alignments, check for Demin Water flow to the SFP, and to sample SFP water for proper boron concentration. Other means to detect a dilution event include surveillance during normal operator rounds and detection of flooding in the auxiliary building. Security personnel also conduct routine surveillance of security doors in the Spent Fuel Pool area. Normal operator rounds are conducted once per shift in the SFP area, and control room level indication is also checked once per shift.

The expectation is that a dilution event would result in the overflow of the pool into the lower areas of the Auxiliary Building and into the Fuel Loading Bay (truck bay). The flow that spills over into the Auxiliary Building will flow into the 6th floor corridor and into various adjacent rooms. From these locations, some water will enter various floor drains while a significant portion is expected to drain into the rooms and corridors in the lower elevations and into the stairway and elevator shaft. Through a combination of these pathways, all of this flow eventually ends up in the Low Activity Waste Tank (LAWT) in the HPI pump room in the Auxiliary Building basement. If the overflow rate is greater than both LAWT transfer pumps (approximately 100 gpm), then the LAWT will fill up to its high-level alarm setpoint which is annunciated in the control room. At lower flow rates, there is a great deal of additional time available for plant personnel to observe and report flooding in the various corridors and stairs.

During an event in 1990, plant personnel mistakenly initiated transfer of Fuel Transfer Canal water to the SFP instead of the BWST at 900 gpm. At the time, the SFP water level was already high (about 2 feet below overflow) being above the high-level alarm setpoint and the upper range of the SFP level instrumentation. Therefore, there was no alarm or indication of the increasing SFP level in the control room while the 900 gpm flow to the SFP continued. The pool began to overflow after approximately 30 minutes and a report of water in the basement was received (T=30). A small amount of water was reported coming down the wall of the kitchen adjacent to the control room (T=35). Operators dispatched to locate the source of the water reported 10 minutes later (T=45) the SFP was overflowing. Operators recognized immediately the misalignment problem and terminated the transfer of coolant. An estimated 10,000 gallons of water was released into the Auxiliary Building. After an additional six minutes (T=51), a Unit 2 Penetration Room humidity alarm was received, and the Unit 1 Penetration Room humidity alarm was received 10 minutes after that (T=61). This event illustrates the effectiveness of plant personnel to detect pool overflow events even when the normal level indications and alarms are not available.

4. NRC Question

The licensee stated that a substantial amount of water is required to significantly dilute the spent fuel pool. If calculations were completed following the NRC acceptance criteria for referencing WCAP-14416-NP-A and minimum pool soluble boron concentrations of 826 ppm and 1001 ppm what amount of water is required and specifically what systems are capable of providing the necessary amount of water to dilute the spent fuel pools boron concentration?

Response

The amount of soluble boron credited in the criticality analysis for normal storage conditions, as reported in Attachment 6, is 430 ppm for the Unit 1 & 2 SFP and 400 ppm for the Unit 3 SFP. Table 2 and Table 3 of Attachment 7 provide a tabulation of the dilution times to reach the boron credit limit. The maximum postulated dilution flow rate is a 300 gpm pipe break or system misalignment originating from the Demineralized Water (DW) System. The analysis results show that at this flow rate it would take at least 49.1 hours (883,800 gallons) to dilute the Unit 1 & 2 SFP down to its boron credit limit of 400 ppm and 32.7 hours (588,600 gallons) to dilute the Unit 3 SFP down to its boron credit limit of 430 ppm.

The results in Attachment 7 also show that the more important scenarios are not the overflow dilution events, but rather those scenarios in which borated water is intentionally removed (pumped) from the pool and later replaced with unborated water. The methodology used in the analysis of these scenarios is presented in the revised Attachment 7.

5. NRC Question

The licensee stated that since such large volumes of water is required to dilute the pool that a dilution event would be detected by plant personnel, ..., or by normal operator rounds through the spent fuel pool area. How often are operator rounds completed and what procedures are followed by the operator within the spent fuel pool area to detect a dilution event? What corrective actions are taken to mitigate a dilution event following detection?

Response

The detection of dilution events is discussed in detail in the response to Question 3 above.

Following the detection of a dilution event, response procedures direct operators to locate and isolate the dilution source and enter Spent Fuel Cooling (SF) System operating procedures to restore the SFP back to normal conditions.

SF System operating procedures provide guidance to operators for how to return the SFP back to normal level (drain to coolant storage system or radwaste system), and then how to restore the SFP boron concentration by transferring concentrated boric acid from the Concentrated Boric Acid Storage Tank (CBAST). These procedures would also be used following an SSF event or HPI drawdown of the Spent Fuel Pool when a fire truck is used to refill the SFP. However, additional TSC guidance may be required to cope with the potential loss of power to the transfer pumps or other equipment.

6. NRC Question

The licensee stated that for the SSF scenario, the addition of makeup water to the spent fuel pool is expected prior to 36 hours. The addition of makeup water earlier during SSF event reduces the rate of boron removal from the pool by the RCMUP. Use of SSF letdown would also add some boron back to the spent fuel pool and partially reduce the dilution effects of makeup water. The drawing provided to the staff indicates that letdown to the SFP is not the normal line-up. What actions are taken (automatic or manual) to line-up the SFP letdown valves to allow the SFP to receive the letdown flow? What is the rate of letdown flow versus the boil-off rate that the SFP will see do to the increase heat load experienced by the SFP in the SSF mode?

Response

The SSF Letdown is used as a means of pressurizer level control (to prevent water solid conditions) without using the SSF RC Makeup Bypass Line or the RV head vents. The SSF Letdown alignment is accomplished by opening valve HP-428 and then opening and throttling HP-426 as needed to maintain appropriate pressurizer level. These valves are controlled remotely from the SSF.

The time when letdown is needed depends largely on RCS and RC pump seal leakage rates. The time for this is also dependent on decay heat levels and how long it takes operators to activate the SSF. These factors impact how much primary inventory is boiled off through the pressurizer safety relief valves. Use of SSF letdown is expected to occur at around 24 hours but could occur earlier or later based on the factors discussed above.

The high temperature letdown flow to the SFP will consist of a 2-phase mixture due to the pressure drop from the RCS back to the SFP. The SSF Letdown capacity is slightly higher than the RCMUP flow rate but the system is operated intermittently to maintain a relatively constant RCS inventory. The SFP bulk coolant temperature at this point is also at or approaching saturation temperature. Thus, the additional letdown flow adds a small amount of saturated liquid to the SFP volume, and the rest becomes saturated steam that exits the pool with effectively no net increase in heat load to the SFP. The amount of soluble boron in the letdown coolant can vary greatly depending on the point at which the unit is in its operating cycle, however, this level of boron will gradually increase as the RCMUP continues to inject to the RCS.

For the dilution analysis, the additional boron from the SSF Letdown flow is conservatively neglected. The additional liquid volume added to the SFP is also neglected. This treatment is consistent with the assumption that all makeup water is added after the drawdown by the RCMUP is complete.

Note that the primary consideration regarding SSF Letdown is not whether there is an increase in the SFP boiloff rate, but rather whether it increases the rate of boron removal by the RCMUP. In this regard, the use of the SSF Letdown actually adds some additional boron while marginally increasing SFP coolant inventory prior to completion of the drawdown.

7. NRC Question

Address the potential for boron precipitation in a SSF drawdown event (before refilling from Lake Keowee). (Question from July 30, 2001 conference call).

Response

In the SSF scenario described in Attachment 7, the boron concentration in the SFP will increase gradually as the pool boils away inventory (prior to initiating makeup). The dilution analysis presented in the revised Attachment 7 demonstrates that the maximum possible boron concentration is 3180 ppm in the Unit 3 SFP. This concentration is well below the boron saturation limit, which is estimated to be in excess of 41,000 ppm.

8. NRC Question

Describe how the fire truck makeup line connects to the SF Cooling System? (Question from July 30, 2001 conference call).

<u>Response</u>

There is no direct connection between the fire truck makeup line and the Spent Fuel Cooling System piping. The fire truck makeup line consists of a fire truck connection at plant grade-level at the SFP truck bay roll-up door and piping that goes directly up to the operating level of the SFP (Elevation 844'). At this point, the piping has an open end that discharges directly into the SFP.

Attachment B

Duke Energy Corporation
Response to Request for Additional Information

Changes To Markup
TS And TS Bases Pages
Of LAR Attachment 1

Retain the LAR Attachment 1 cover page.

TS Pages

Add TS 3.5.4, pages 1 and 2.
Replace existing TS 3.7.12, pages 1 and 2 (including inserts) with the following TS 3.7.12, pages 1 and 2.
Retain TS 3.7.13 provided with the LAR.
Replace existing TS 4.0, page 2 with the following TS 4.0, page 2.

TS Bases Pages

Add TS B 3.5.4, pages 1 thru 6.
Replace existing TS B 3.7.12, pages 1 and 2 (including inserts) with the following TS B 3.7.12, pages 1 thru 5.
Replace the entire existing TS B 3.7.13 pages (including inserts) with the following TS B 3.7.13, pages 1 thru 6.

NOTE

~~Strike out~~ on the above revised markup pages indicates deleted information.
Italic text on the above revised markup pages indicates added information

FOR INFORMATION ONLY

3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

3.5.4 Borated Water Storage Tank (BWST)

LCO 3.5.4 The BWST shall be OPERABLE.

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. BWST boron concentration not within limits. OR BWST water temperature not within limits.	A.1 Restore BWST to OPERABLE status.	8 hours
B. BWST inoperable for reasons other than Condition A.	B.1 Restore BWST to OPERABLE status.	1 hour
C. Required Action and associated Completion Time not met.	C.1 Be in MODE 3. AND C.2 Be in MODE 5.	12 hours 36 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.5.4.1	-------------------------NOTE------------------------- Only required to be performed when ambient air temperature is < 45°F or > 115°F. -- Verify BWST borated water temperature is ≥ 45°F and ≤ 115°F.	24 hours
SR 3.5.4.2	Verify BWST borated water volume is ≥ 350,000 gallons.	7 days
SR 3.5.4.3	Verify BWST boron concentration is*:* *a. Within limits specified in the COLR;* *AND* *b. ≥ 2220 ppm.* ~~within the limit specified in the COLR.~~	7 days

3.7 PLANT SYSTEMS

3.7.12 Spent Fuel Pool Boron Concentration

LCO 3.7.12 The spent fuel pool boron concentration limit shall be within ~~the~~ limits ~~specified in the COLR.~~.

APPLICABILITY: When fuel assemblies are stored in the spent fuel pool.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Spent fuel pool boron concentration not within limit.	------------------NOTE----------------- LCO 3.0.3 is not applicable. --	
	A.1 Suspend movement of fuel assemblies in the spent fuel pool.	Immediately
	AND	
	A.2 Initiate action to restore spent fuel pool boron concentration to within limit.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.7.12.1	Verify the spent fuel pool boron concentration is ~~within limit.~~ *:* *a. Within limits specified in the COLR;* *AND* *b. $\geq$ 2220 ppm.*	~~31~~ *7* days ~~AND~~ ~~After each makeup to the spent fuel pool~~

4.0 DESIGN FEATURES

4.3 Fuel Storage (continued)

b. k_{eff} ~~≤ 0.95~~< *1.0* if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

c. *$k_{eff} \leq 0.95$ if fully flooded with water borated to 430 ppm, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR. Maintaining the normal spent fuel pool boron concentration within the TS limits assures $k_{eff} \leq 0.95$ for any accident condition*;

~~c~~*d.* A nominal 10.65 inch center to center distance between fuel assemblies placed in spent fuel storage racks serving Units 1 and 2;

~~d~~*e.* A nominal 10.60 inch center to center distance between fuel assemblies placed in spent fuel storage racks serving Unit 3;

f~~e~~. A nominal 25.75 inch center to center spacing between fuel assemblies placed in the fuel transfer canal.

4.3.2 Capacity

The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1312 fuel assemblies in the spent fuel storage racks serving Units 1 and 2 and 825 fuel assemblies in the spent fuel storage racks serving Unit 3. In addition, up to 4 assemblies and/or 1 failed fuel container may be stored in each fuel transfer canal when the canal is at refueling level. Spent fuel may also be stored in the Oconee Nuclear Station Independent Spent Fuel Storage Installation.

B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

B 3.5.4 Borated Water Storage Tank (BWST)

BASES

BACKGROUND

The BWST supports the ECCS and the Reactor Building Spray System by providing a source of borated water for ECCS and reactor building spray pump operation. In addition, the BWST supplies borated water to the refueling canal for refueling operations.

A normally open, motor operated isolation valve is provided in each LPI line to allow the operator to isolate the BWST from the LPI System after the LPI pump suction has been transferred to the reactor building sump following depletion of the BWST during a loss of coolant accident (LOCA). Use of a single BWST to supply both ECCS trains is acceptable because the BWST is a passive component, and passive failures are not assumed to occur coincidentally with a LOCA.

This LCO ensures that:

a. The BWST contains sufficient borated water to support the ECCS during the injection phase;

b. Sufficient water volume exists in the reactor building sump to support continued operation of the ECCS and reactor building spray pumps at the time of transfer to the recirculation mode of cooling; and

c. The reactor remains subcritical following a LOCA and returns subcritical following a MSLB once borated water from the ECCS reaches the core.

Insufficient water inventory in the BWST could result in insufficient cooling capacity by the ECCS when the transfer to the recirculation mode occurs.

Improper boron concentrations could result in a reduction of SDM or excessive boric acid precipitation in the core following a LOCA, as well as excessive caustic stress corrosion of mechanical components and systems inside containment.

The minimum boron concentration limit assures that when water from the BWST is added to the SFP or the refueling cavity with the refueling cavity and the SFP connected by the open fuel transfer tube, the minimum boron concentration limit of the SFP is met.

APPLICABLE SAFETY ANALYSES

During accident conditions, the BWST provides a source of borated water to the high pressure injection (HPI), low pressure injection (LPI), and reactor building spray pumps. As such, it provides reactor building cooling and depressurization, core cooling, and replacement inventory and is a source of negative reactivity for reactor shutdown. The design basis transients and applicable safety analyses concerning each of these systems are discussed in the Applicable Safety Analyses section of Bases B 3.5.2, "High Pressure Injection (HPI)," B 3.5.3, "Low Pressure Injection (LPI)," and B 3.6.5, "Reactor Building Spray and Cooling Systems." These analyses are used to assess changes to the BWST in order to evaluate their effects in relation to the acceptance limits.

The limit on volume of ≥ 350,000 gallons (46.0 ft) is based on several factors. Sufficient deliverable volume must be available to provide at least 20 minutes of full flow of all LPI pumps prior to the transfer to the reactor building sump for recirculation. Twenty minutes gives the operator adequate time to prepare for switchover to reactor building sump recirculation.

A second factor that affects the minimum required BWST volume is the ability to support continued LPI pump operation after the manual transfer to recirculation occurs. When LPI pump suction is transferred to the sump, there must be sufficient water in the sump to ensure adequate net positive suction head (NPSH) for the LPI and reactor building spray pumps. The amount of water that enters the sump from the BWST and other sources is one of the input assumptions of the NPSH calculation. Since the BWST is the main source that contributes to the amount of water in the sump following a LOCA, the calculation does not take credit for more than the minimum volume of usable water from the BWST.

The maximum volume of water in the BWST is limited by design and ensures the solution in the sump following a LOCA is within a specified pH range that will minimize the evolution of iodine and the effect of chloride and caustic stress corrosion cracking on the mechanical systems and components.

The volume range ensures that refueling requirements are met and that the capacity of the BWST is not exceeded. Note that the volume limits refer to total, rather than usable, volume required to be in the BWST; a certain amount of water is unusable because of tank discharge line location and other physical characteristics.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The limit for minimum boron concentration of the COLR was established to ensure that, following a LOCA, with a minimum BWST level, the reactor will remain subcritical in the cold condition following mixing of the BWST and Reactor Coolant System (RCS) water volumes. Large break LOCAs assume that all CONTROL RODS remain withdrawn from the core until reflood. At this time, the analysis assumes one half of the CONTROL ROD worth is available.

The minimum and maximum concentration limits both ensure that the long term solution in the sump following a LOCA is within a specified pH range that will minimize the evolution of iodine and the effect of chloride and caustic stress corrosion cracking on the mechanical systems and components.

The maximum limit for boron concentration in the BWST of the COLR is also based on the potential for boron precipitation in the core during the long term cooling period following a LOCA. For a cold leg break, the core dissipates heat by pool boiling. Because of this boiling phenomenon in the core, the boric acid concentration will increase in this region. If allowed to proceed in this manner, a point may be reached where boron precipitation will occur in the core. Post LOCA emergency procedures direct the operator to establish dilution flow paths in the LPI System to prevent this condition by establishing a forced flow path through the core regardless of break location. These procedures are based on the minimum time in which precipitation could occur, assuming that maximum boron concentrations exist in the borated water sources used for injection following a LOCA.

Boron concentrations in the BWST in excess of the limit could result in precipitation earlier than assumed in the analysis.

The 45°F lower limit on the temperature of the solution in the BWST was established to ensure that the solution will not freeze. This temperature also helps prevent boron precipitation and ensures that water injection in the reactor vessel will not be colder than the lowest temperature assumed in reactor vessel stress analysis. The 115°F upper limit on the temperature of the BWST contents is consistent with the maximum injection water temperature assumed in the accident analysis.

The numerical values of the *volume and temperature* parameters stated in the SRs are actual values and do not include allowance for instrument errors.

BASES

Applicable Safety Analyses (continued)

The numerical value of the SR 3.5.4.3 minimum boron concentration limit (≥ 2220 ppm) includes allowances for analytical, mechanical and instrument measurement uncertainties.

The BWST satisfies Criterion 3 of 10 CFR 50.36 (Ref. 1).

LCO

The BWST exists to ensure that an adequate supply of borated water is available to cool and depressurize the reactor building in the event of an accident; to cool and cover the core in the event of a LOCA, thereby ensuring the reactor remains subcritical following an accident; and to ensure an adequate level exists in the reactor building sump to support ECCS and reactor building spray pump operation in the recirculation MODE. To be considered OPERABLE, the BWST must meet the limits for water volume, boron concentration, and temperature established in the SRs.

APPLICABILITY

In MODES 1, 2, 3, and 4, the BWST OPERABILITY requirements are dictated by the ECCS and Reactor Building Spray System OPERABILITY requirements. Since all or portions of the ECCS and Reactor Building Spray System must be OPERABLE in MODES 1, 2, 3, and 4, the BWST must be OPERABLE to support their operation.

Core cooling requirements in MODE 5 are addressed by LCO 3.4.7, "RCS Loops – MODE 5, Loops Filled," and LCO 3.4.8, "RCS Loops – MODE 5, Loops Not Filled," respectively. MODE 6 core cooling requirements are addressed by LCO 3.9.4, "DHR and Coolant Circulation – High Water Level," and LCO 3.9.5, "DHR and Coolant Circulation – Low Water Level."

ACTIONS

A.1

With either the BWST boron concentration or borated water temperature not within limits, the condition must be corrected within 8 hours. In this condition, the ECCS cannot perform its design functions. Therefore, prompt action must be taken to restore the tank to OPERABLE status or to place the unit in a MODE in which these systems are not required. The 8 hour limit to restore the temperature or boron concentration to within limits was developed considering the time required to change boron concentration or temperature and assuming that the contents of the tank are still available for injection.

BASES

ACTIONS (continued)

B.1

With the BWST inoperable for reasons other than Condition A (e.g., water volume), the BWST must be restored to OPERABLE status within 1 hour. In this condition, neither the ECCS nor the Reactor Building Spray System can perform its design functions. Therefore, prompt action must be taken to restore the BWST to OPERABLE status or to place the unit in a MODE in which the BWST is not required. The allowed Completion Time of 1 hour to restore the BWST to OPERABLE status is based on this condition simultaneously affecting multiple redundant trains.

C.1 and C.2

If the Required Action and associated Completion Time are not met, the unit must be brought to a MODE in which the LCO does not apply. To achieve this status, the unit must be brought to at least MODE 3 within 12 hours and to MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required unit conditions from full power conditions in an orderly manner and without challenging unit systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.4.1

Verification every 24 hours that the BWST water temperature is within the specified temperature band ensures that the fluid will not freeze and that the fluid temperature entering the reactor vessel will not be colder than assumed in the reactor vessel stress analysis; and the fluid temperature entering the reactor vessel will not be hotter than assumed in the LOCA analysis. The 24 hour Frequency is sufficient to identify a temperature change that would approach either temperature limit and has been shown to be acceptable through operating experience.

The SR is modified by a Note that requires the Surveillance to be performed only when ambient air temperatures are outside the operating temperature limits of the BWST. With ambient temperature within this band, the BWST temperature should not exceed the limits.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.5.4.2

Verification every 7 days that the BWST contained volume is ≥ 350,000 gallons (46.0 ft.) ensures that a sufficient initial supply is available for injection and to support continued ECCS pump operation on recirculation. Since the BWST volume is normally stable, a 7 day Frequency has been shown to be appropriate through operating experience.

SR 3.5.4.3

Verification every 7 days that the boron concentration of the BWST fluid is within the required band ensures that the reactor will remain subcritical following a LOCA. Since the BWST volume is normally stable, a 7 day sampling Frequency is appropriate and has been shown to be acceptable through operating experience. *The COLR revision process assures that the minimum boron concentration specified in the COLR bounds the limit specified by this SR.*

REFERENCES

1. 10 CFR 50.36.

B 3.7 PLANT SYSTEMS

B 3.7.12 Spent Fuel Pool Boron Concentration

BASES

BACKGROUND

The Oconee spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B_4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B_4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, the Oconee spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 1. The methodology ensures that the spent fuel rack multiplication factor, k_{eff}, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 2) and NRC guidance (Ref. 3). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 5.00 weight percent (wt %) Uranium-235 while maintaining $k_{eff} \leq 0.95$, including uncertainties, tolerances, biases, and credit for soluble boron. Note that the criticality analysis accounts for a maximum as-built enrichment tolerance of 0.05 wt % U-235. For example, for a specified maximum design enrichment of 5.00 wt % U-235, an as-built enrichment up to 5.05 weight percent is acceptable. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff} \leq 0.95$. The soluble boron concentration required to maintain $k_{eff} \leq 0.95$ under normal conditions is 430 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis without the presence of the soluble boron in the pool (excluding certain burnup-related uncertainties described in the criticality analysis). The criticality analysis performed shows that the acceptance criteria for criticality are met for the

BASES (continued)

storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, no credit for the Boraflex neutron absorber panels, and storage configurations and enrichment limits specified by LCO 3.7.13.

~~As described in the following LCO 3.7.13, "Spent Fuel Assembly Storage," fuel assemblies are stored in the spent fuel pool racks in accordance with criteria based on initial enrichment and discharge burnup. Although the water in the spent fuel pool is normally borated to ≥ limits specified in the COLR, the criteria that limit the storage of a fuel assembly to specific rack locations are conservatively developed without taking credit for boron.~~

APPLICABLE SAFETY ANALYSES

~~The requirements for spent fuel pool boron concentration specified ensure that a minimum boron concentration is maintained in the pool. The requirements for spent fuel assembly storage specified ensure that the fuel stored in the pool remains subcritical. 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 (Ref. 2) based upon the accident condition in which all soluble poison is assumed to have been lost, specify that the limiting~~ $\cancel{k_{eff}}$ ~~of 0.95 be evaluated in the absence of soluble boron. Hence, the design of the spent fuel storage racks is based on the use of unborated water, which maintains the spent fuel pool in a subcritical condition during normal operation with the pool fully loaded. The double contingency principle discussed in ANSI N-16.1-1975, (Ref. 1) and the NRC guidelines (Ref. 2) allows credit for soluble boron under abnormal or accident conditions, since only a single accident need be considered at one time. For example, the most severe accident scenario is associated with the accidental misloading of a fuel assembly. This could increase the reactivity of the spent fuel pool. To mitigate this postulated criticality related accident, boron is dissolved in the pool water.~~

~~The concentration of dissolved boron in the spent fuel pool satisfies Criterion 2 and 3 of 10 CFR 50.36 (Ref. 3).~~

Most accident conditions do not result in an increase in reactivity in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, four accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a loss of normal

BASES (continued)

cooling to the spent fuel pool water which causes an increase in the pool water temperature. The third is the misloading of a fuel assembly into a location in which the restrictions on location, enrichment and burnup are not satisfied. The fourth is a drop of a heavy load onto the spent fuel racks.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 430 ppm required to maintain $k_{eff} \leq$ to 0.95 under normal storage conditions) can be assumed as a realistic initial condition, since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by these postulated accidents, to maintain $k_{eff} \leq 0.95$. It was found that a spent fuel pool boron concentration of 2220 ppm was sufficient to maintain $k_{eff} \leq 0.95$ for the worst-case postulated criticality-related accident (the heavy load drop event). Specification 3.7.12 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

The minimum boron concentration limit ensures the SFP boron concentration is adequate to meet the sub-criticality requirements of fuel stored in the SFP for the most limiting accident in the SFP: A cask drop onto fuel in the SFP.

Note that it is plausible that the "loss of normal cooling" accident could occur in conjuction with a spent fuel pool boron dilution event. Criticality calculations show that the soluble boron needed to maintain $k_{eff} \leq$ 0.95 for the "loss of normal cooling" accident (500 ppm) is still less than the boron concentration following the worst-case credible dilution event (825 ppm).

Therefore, maintaining the spent fuel pool boron concentration within the limits assures $k_{eff} \leq 0.95$ for any accident condition. For normal storage conditions, Specification 4.3.1 c. requires that the spent fuel rack k_{eff} be $\leq$ 0.95 when flooded with water borated to 430 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 k_{eff} design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which

BASES (continued)

could result in the dilution of the spent fuel pool boron concentration to 430 ppm is not a credible event.

The numerical value of the SR 3.7.12.1 minimum boron concentration limit (≥ 2220 ppm) includes allowance for analytical mechanical and instrument measurement uncertainties.

The concentration of dissolved boron in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 5).

LCO

The ~~concentration of~~ dissolved boron *concentration limits for* ~~in~~ the spent fuel pool ~~specified in the COLR~~ preserves the assumption used in the analyses of the potential accident scenarios described above. This concentration of dissolved boron is the minimum required concentration for fuel assembly storage and movement within the fuel storage pool.

APPLICABILITY

This LCO applies whenever fuel assemblies are stored in the spent fuel pool.

ACTIONS

A.1 and A.2

The Required Actions are modified by a Note indicating that LCO 3.0.3 does not apply.

If moving irradiated fuel assemblies while in MODE 5 or 6, LCO 3.0.3 would not specify any action. If moving irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the fuel movement is independent of reactor operation. Therefore, inability to suspend movement of fuel assemblies is not a sufficient reason to require a reactor shutdown.

When the concentration of boron in the fuel storage pool is less than required, immediate action must be taken to preclude the occurrence of an accident or to mitigate the consequences of an accident in progress. This is achieved by immediately suspending the movement of the fuel assemblies. This does not preclude movement of a fuel assembly to a safe position. Immediate action is also required to initiate action to restore the SFP boron concentration to within limits.

SURVEILLANCE

SR 3.7.12.1

BASES (continued)

REQUIREMENTS

This SR verifies that the concentration of boron in the fuel storage pool is within the required limit. As long as this SR is met, the analyzed incidents are fully addressed. The ~~31~~ *7* day Frequency is appropriate because no major replenishment of pool water is expected to take place over a short period of time ~~and verification is required after each makeup to the SFP. The verification after each makeup should be completed within 12 hours after a 24 hour recirculation period to allow for mixing. This Completion Time is appropriate since no major replenishment of pool water is expected to take place over this period.~~. *The COLR revision process assures that the minimum boron concentration specified in the COLR bounds the limit specified by this SR.*

REFERENCES

~~1. ANSI N-16.1-1975.~~

~~2. Letter from B.K. Grimes (USNRC) to Power Reactor Licensees dated April 14, 1978.~~

1. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.

2. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.

3. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.

4. Double contingency principle of ANSI N16.1-1975, as specified in the April 14, 1978 NRC letter (Section 1.2) and implied in the proposed revision to Regulatory Guide 1.13 (Section 1.4, Appendix A).

~~3~~*5*. 10 CFR 50.36.

B 3.7 PLANT SYSTEMS

B 3.7.13 Fuel Assembly Storage

BASES

BACKGROUND

The spent fuel pool is designed to store either new (nonirradiated) nuclear fuel assemblies, or burned (irradiated) fuel assemblies in a vertical configuration underwater. The shared spent fuel pool between Unit 2 spent fuel storage cells are installed in parallel rows with center to center spacing of 10.65 inches. The Unit 3 storage pool is sized to store 825 fuel assemblies. The Unit 3 spent fuel storage cells are installed in parallel rows with center to center spacing of 10.60 inches.

The Oconee spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B_4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B_4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, the Oconee spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 1. The methodology ensures that the spent fuel rack multiplication factor, k_{eff}, is ≤ 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 2) and NRC guidance (Ref. 3). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 5.00 weight percent (wt %) Uranium-235 while maintaining $k_{eff} \leq 0.95$, including uncertainties, tolerances, biases, and credit for soluble boron. Note that the criticality analysis accounts for a maximum as-built enrichment tolerance of 0.05 wt % U-235. For example, for a specified maximum design enrichment of 5.00 wt % U-235, an as-built

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BACKGROUND (continued)

enrichment up to 5.05 weight percent is acceptable. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool k_{eff} is maintained $\leq$ 0.95. The soluble boron concentration required to maintain $k_{eff} \leq 0.95$ under normal conditions is 430 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis, without the presence of the soluble boron in the pool (excluding certain burnup-related uncertainties described in the criticality analysis). The criticality analysis performed shows that the acceptance criteria for criticality are met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, no credit for the Boraflex neutron absorber panels and storage configurations and enrichment limits Specified by LCO 3.7.13.

Three storage configurations are defined for each region; Unrestricted, Restricted and Checkerboard storage. The storage conditions for each region are described below.

- *Unrestricted storage allows storage in all cells without restriction on the storage configuration.*
- *Restricted storage allows storage of higher reactivity, slightly burned fuel when restricted to a certain storage configuration with lower reactivity fuel. Restricted Fuel regions must be bounded by either i) one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool.*
- *Checkerboard storage allows storage of the highest reactivity fuel when checkerboarded with empty storage cells. Checkerboard Fuel regions must be bounded by either i) one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool. In addition, at least three of the four faces of each Checkerboard fuel assembly must be adjacent to an empty cell at all boundaries between storage regions.*

~~The spent fuel pool is designed to store either new (nonirradiated) nuclear fuel assemblies, or burned (irradiated) fuel assemblies in a vertical configuration underwater. The shared spent fuel pool between Unit 1 and Unit 2 is sized to store 1312 fuel assemblies. The Unit 1 and Unit 2 spent fuel storage cells are installed in parallel rows with center to center spacing of 10.65 inches. The Unit 3 storage pool is sized to store 822 fuel assemblies. The spent fuel storage cells are installed in parallel rows with center to center spacing of 10.60 inches. This spacing and construction, whereby the fuel assemblies are inserted into stainless steel~~

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~~cans with neutron absorbing Boraflex attached, is sufficient to maintain a k_{eff} of $\leq$ 0.95 for spent fuel of a maximum nominal initial enrichment of up to 5.0 wt % which have accumulated burnups $\geq$ the minimum qualifying burnups of Figure 3.7.13-1 for the spent fuel pool shared by Units 1 and 2 or Figure 3.7.13-2 for the Unit 3 spent fuel pool. Fuel which has not accumulated the minimum qualifying burnups is required to be stored in the specified pattern for restricted fuel.~~

APPLICABLE SAFETY ANALYSES

~~The spent fuel pool is designed for noncriticality by use of adequate spacing, and "flux trap" construction whereby the fuel assemblies are inserted into stainless steel cans with neutron absorbing Boraflex attached.~~

~~The fuel assembly storage satisfies Criterion 2 of 10 CFR 50.36 (Ref. 1).~~

Most accident conditions do not result in an increase in reactivity of the racks in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, four accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature. The third is the misloading of a fuel assembly into a location in which the restrictions on location, enrichment and burnup are not satisfied. The fourth is a drop of a heavy load onto the spent fuel racks.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) can be applied. This double contingency principle does not require assuming two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 430 ppm required to maintain $k_{eff} \leq 0.95$ under normal storage conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by these postulated accidents, to maintain $k_{eff} \leq 0.95$. It was found that a spent fuel pool boron concentration of 2220 ppm was sufficient to maintain $k_{eff} \leq$ 0.95 for the worst-case postulated criticality-related accident (the heavy

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load drop event). Specification 3.7.12 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Note that it is plausible that the "loss of normal cooling" accident could occur in conjuction with a spent fuel pool boron dilution event. Criticality calculations show that the soluble boron needed to maintain $k_{eff} \leq .95$ for the "loss of normal cooling" accident (500 ppm) is still less than the boron concentration following the worst-case credible dilution event (825 ppm).

Therefore, maintaining the spent fuel pool boron concentration within the limits specified in the COLR assures k_{eff} is $\leq .95$ for any accident condition.

For normal storage conditions, Specification 4.3.1 c. requires that the spent fuel rack k_{eff} be ≤ 0.95 when flooded with water borated to 430 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 k_{eff} design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to 430 ppm is not a credible event.

The fuel assembly storage and concentration of dissolved boron in the spent fuel pool satisfy Criterion 2 of 10 CFR 50.36 (Ref. 5).

LCO

~~The restrictions on the placement of fuel assemblies within the fuel pool, according to the Figures in the accompanying LCO, ensure that the k_{eff} of the spent fuel pool will always remain ≤ 0.95 assuming the pool to be flooded with unborated water. The restrictions are consistent with the criticality safety analysis performed for the spent fuel pool.~~

a. *Units 1 and 2*

The restrictions on the placement of fuel assemblies within the spent fuel pool serving Units 1 and 2, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.13-1 in the accompanying LCO, ensures the k_{eff} of the spent fuel pool will always remain ≤ 0.95, assuming the pool to be flooded with water borated to 430 ppm. Fuel assemblies not meeting the criteria of Table 3.7.13-1 shall be stored in accordance with either Figure 3.7.13-1 and Tables 3.7.13-2 and 3.7.13-3 for Restricted/Filler storage, or Figure 3.7.13-2 for Checkerboard storage.

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b. *Unit 3*

The restrictions on the placement of fuel assemblies within the spent fuel pool serving Unit 3, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.13-4 in the accompanying LCO, ensures the k_{eff} of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to 430 ppm. Fuel assemblies not meeting the criteria of Table 3.7.13-4 shall be stored in accordance with either Figure 3.7.13-3 and Tables 3.7.13-5 and 3.7.13-6 for Restricted/Filler storage, or Figure 3.7.13-4 for Checkerboard storage.

APPLICABILITY

This LCO applies whenever any fuel assembly is stored in the spent fuel pool.

ACTIONS

A.1

Required Action A.1 is modified by a Note indicating that LCO 3.0.3 does not apply.

If moving fuel assemblies while in MODE 5 or 6, LCO 3.0.3 would not specify any action. If moving fuel assemblies while in MODE 1, 2, 3, or 4, the fuel movement is independent of reactor operation. Therefore, in either case, inability to move fuel assemblies is not sufficient reason to require a reactor shutdown.

When the configuration of fuel assemblies stored in the spent fuel pool is not in accordance with the LCO, immediate action must be taken to make the necessary fuel assembly movement(s) to bring the configuration into compliance with the LCO.

SURVEILLANCE REQUIREMENTS

SR 3.7.13.1

This SR verifies by administrative means that the initial enrichment and burnup of the fuel assembly is in accordance with the appropriate Figure in the accompanying LCO.

BASES

REFERENCES

1. *WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.*

2. *American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.*

3. *Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.*

4. *Double contingency principle of ANSI N16.1-1975, as specified in the April 14, 1978 NRC letter (Section 1.2) and implied in the proposed revision to Regulatory Guide 1.13 (Section 1.4, Appendix A).*

5. *10 CFR 50.36*

~~1. 10 CFR 50.36~~

Attachment C

Duke Energy Corporation
Response to Request for Additional Information

Revise LAR Attachment 2 by Changing Replacement TS and TS Bases Pages As Indicated Below:

Remove	Insert	Unchanged
Att. 2 Cover Sheet	Att. 2 Cover Sheet	-----
-----	3.5.4-2	-----
-----	3.7.12-1	-----
3.7.12-2	3.7.12-2	-----
-----	-----	3.7.13-1
-----	-----	3.7.13-2
-----	-----	3.7.13-3
-----	-----	3.7.13-4
-----	-----	3.7.13-5
-----	-----	3.7.13-6
-----	-----	3.7.13-7
-----	-----	3.7.13-8
-----	-----	3.7.13-9
-----	-----	3.7.13-10
-----	-----	3.7.13-11
-----	-----	3.7.13-12
4.0-2	4.0-2	-----
-----	B 3.5.4-1	-----
-----	B 3.5.4-3	-----
-----	B 3.5.4-4	-----
-----	B 3.5.4-5	-----
-----	B 3.5.4-6	-----
B 3.7.12-1	B 3.7.12-1	-----
B 3.7.12-2	B 3.7.12-2	-----
B 3.7.12-3	B 3.7.12-3	-----
B 3.7.12-4	B 3.7.12-4	-----
-----	B 3.7.12-5	
-----	-----	B 3.7.13-1
-----	-----	B 3.7.13-2
B 3.7.13-3	B 3.7.13-3	-----
----	----	B 3.7.13-4
----	----	B 3.7.13-5

US Nuclear Regulatory Commission
October 31, 2001

Attachment 2

OCONEE NUCLEAR STATION

Replacement TS and Bases Pages

Remove	Insert
3.5.4-2	3.5.4-2
3.7.12-1	3.7.12-1
3.7.12-2	3.7.12-2
3.7.13-1	3.7.13-1
3.7.13-2	3.7.13-2
3.7.13-3	3.7.13-3
3.7.13-4	3.7.13-4
3.7.13-5	3.7.13-5
3.7.13-6	3.7.13-6
3.7.13-7	3.7.13-7
3.7.13-8	3.7.13-8
----	3.7.13-9
----	3.7.13-10
----	3.7.13-11
----	3.7.13-12
4.0-2	4.0-2
B 3.5.4-1	B 3.5.4-1
B 3.5.4-3	B 3.5.4-3
B 3.5.4-4	B 3.5.4-4
B 3.5.4-5	B 3.5.4-5
B 3.5.4-6	B 3.5.4-6
B 3.7.12-1	B 3.7.12-1
B 3.7.12-2	B 3.7.12-2
----	B 3.7.12-3
----	B 3.7.12-4
----	B 3.7.12-5
B 3.7.13-1	B 3.7.13-1
B 3.7.13-2	B 3.7.13-2
----	B 3.7.13-3
----	B 3.7.13-4
----	B 3.7.13-5

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.5.4.1	------------------------NOTE------------------------ Only required to be performed when ambient air temperature is < 45°F or > 115°F. --- Verify BWST borated water temperature is ≥ 45°F and ≤ 115°F.	24 hours
SR 3.5.4.2	Verify BWST borated water volume is ≥ 350,000 gallons.	7 days
SR 3.5.4.3	Verify BWST boron concentration is: a. Within limits specified in the COLR; AND b. ≥ 2220 ppm.	7 days

3.7 PLANT SYSTEMS

3.7.12 Spent Fuel Pool Boron Concentration

LCO 3.7.12 The spent fuel pool boron concentration limit shall be within limits.

APPLICABILITY: When fuel assemblies are stored in the spent fuel pool.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Spent fuel pool boron concentration not within limit.	-----------------NOTE---------------- LCO 3.0.3 is not applicable. ---	
	A.1 Suspend movement of fuel assemblies in the spent fuel pool.	Immediately
	<u>AND</u>	
	A.2 Initiate action to restore spent fuel pool boron concentration to within limit.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.7.12.1	Verify the spent fuel pool boron concentration is: a. Within limits specified in the COLR; AND b. $\geq$ 2220 ppm.	7 days

4.0 DESIGN FEATURES

4.3 Fuel Storage (continued)

b. $k_{eff} < 1.0$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

c. $k_{eff} \leq 0.95$ if fully flooded with water borated to 430 ppm, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR. Maintaining the normal spent fuel pool boron concentration within the TS limits assures $k_{eff} \leq 0.95$ for any accident condition;

d. A nominal 10.65 inch center to center distance between fuel assemblies placed in spent fuel storage racks serving Units 1 and 2;

e. A nominal 10.60 inch center to center distance between fuel assemblies placed in spent fuel storage racks serving Unit 3;

f. A nominal 25.75 inch center to center spacing between fuel assemblies placed in the fuel transfer canal.

4.3.2 Capacity

The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1312 fuel assemblies in the spent fuel storage racks serving Units 1 and 2 and 825 fuel assemblies in the spent fuel storage racks serving Unit 3. In addition, up to 4 assemblies and/or 1 failed fuel container may be stored in each fuel transfer canal when the canal is at refueling level. Spent fuel may also be stored in the Oconee Nuclear Station Independent Spent Fuel Storage Installation.

B 3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

B 3.5.4 Borated Water Storage Tank (BWST)

BASES

BACKGROUND

The BWST supports the ECCS and the Reactor Building Spray System by providing a source of borated water for ECCS and reactor building spray pump operation. In addition, the BWST supplies borated water to the refueling canal for refueling operations.

A normally open, motor operated isolation valve is provided in each LPI line to allow the operator to isolate the BWST from the LPI System after the LPI pump suction has been transferred to the reactor building sump following depletion of the BWST during a loss of coolant accident (LOCA). Use of a single BWST to supply both ECCS trains is acceptable because the BWST is a passive component, and passive failures are not assumed to occur coincidentally with a LOCA.

This LCO ensures that:

a. The BWST contains sufficient borated water to support the ECCS during the injection phase;

b. Sufficient water volume exists in the reactor building sump to support continued operation of the ECCS and reactor building spray pumps at the time of transfer to the recirculation mode of cooling; and

c. The reactor remains subcritical following a LOCA and returns subcritical following a MSLB once borated water from the ECCS reaches the core.

Insufficient water inventory in the BWST could result in insufficient cooling capacity by the ECCS when the transfer to the recirculation mode occurs.

Improper boron concentrations could result in a reduction of SDM or excessive boric acid precipitation in the core following a LOCA, as well as excessive caustic stress corrosion of mechanical components and systems inside containment.

The minimum boron concentration limit assures that when water from the BWST is added to the SFP or the refueling cavity with the refueling cavity and the SFP connected by the open fuel transfer tube, the minimum boron concentration limit of the SFP is met.

BASES (continued)

APPLICABLE SAFETY ANALYSES

During accident conditions, the BWST provides a source of borated water to the high pressure injection (HPI), low pressure injection (LPI), and reactor building spray pumps. As such, it provides reactor building cooling and depressurization, core cooling, and replacement inventory and is a source of negative reactivity for reactor shutdown. The design basis transients and applicable safety analyses concerning each of these systems are discussed in the Applicable Safety Analyses section of Bases B 3.5.2, "High Pressure Injection (HPI)," B 3.5.3, "Low Pressure Injection (LPI)," and B 3.6.5, "Reactor Building Spray and Cooling Systems." These analyses are used to assess changes to the BWST in order to evaluate their effects in relation to the acceptance limits.

The limit on volume of ≥ 350,000 gallons (46.0 ft) is based on several factors. Sufficient deliverable volume must be available to provide at least 20 minutes of full flow of all LPI pumps prior to the transfer to the reactor building sump for recirculation. Twenty minutes gives the operator adequate time to prepare for switchover to reactor building sump recirculation.

A second factor that affects the minimum required BWST volume is the ability to support continued LPI pump operation after the manual transfer to recirculation occurs. When LPI pump suction is transferred to the sump, there must be sufficient water in the sump to ensure adequate net positive suction head (NPSH) for the LPI and reactor building spray pumps. The amount of water that enters the sump from the BWST and other sources is one of the input assumptions of the NPSH calculation. Since the BWST is the main source that contributes to the amount of water in the sump following a LOCA, the calculation does not take credit for more than the minimum volume of usable water from the BWST.

The maximum volume of water in the BWST is limited by design and ensures the solution in the sump following a LOCA is within a specified pH range that will minimize the evolution of iodine and the effect of chloride and caustic stress corrosion cracking on the mechanical systems and components.

The volume range ensures that refueling requirements are met and that the capacity of the BWST is not exceeded. Note that the volume limits refer to total, rather than usable, volume required to be in the BWST; a certain amount of water is unusable because of tank discharge line location and other physical characteristics.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The limit for minimum boron concentration of the COLR was established to ensure that, following a LOCA, with a minimum BWST level, the reactor will remain subcritical in the cold condition following mixing of the BWST and Reactor Coolant System (RCS) water volumes. Large break LOCAs assume that all CONTROL RODS remain withdrawn from the core until reflood. At this time, the analysis assumes one half of the CONTROL ROD worth is available.

The minimum and maximum concentration limits both ensure that the long term solution in the sump following a LOCA is within a specified pH range that will minimize the evolution of iodine and the effect of chloride and caustic stress corrosion cracking on the mechanical systems and components.

The maximum limit for boron concentration in the BWST of the COLR is also based on the potential for boron precipitation in the core during the long term cooling period following a LOCA. For a cold leg break, the core dissipates heat by pool boiling. Because of this boiling phenomenon in the core, the boric acid concentration will increase in this region. If allowed to proceed in this manner, a point may be reached where boron precipitation will occur in the core. Post LOCA emergency procedures direct the operator to establish dilution flow paths in the LPI System to prevent this condition by establishing a forced flow path through the core regardless of break location. These procedures are based on the minimum time in which precipitation could occur, assuming that maximum boron concentrations exist in the borated water sources used for injection following a LOCA.

Boron concentrations in the BWST in excess of the limit could result in precipitation earlier than assumed in the analysis.

The 45°F lower limit on the temperature of the solution in the BWST was established to ensure that the solution will not freeze. This temperature also helps prevent boron precipitation and ensures that water injection in the reactor vessel will not be colder than the lowest temperature assumed in reactor vessel stress analysis. The 115°F upper limit on the temperature of the BWST contents is consistent with the maximum injection water temperature assumed in the accident analysis.

The numerical values of the volume and temperature parameters stated in the SRs are actual values and do not include allowance for instrument errors.

BASES

Applicable Safety Analyses (continued)

The numerical value of the SR 3.5.4.3 minimum boron concentration limit ($\geq$ 2220 ppm) includes allowances for analytical, mechanical and instrument measurement uncertainties.

The BWST satisfies Criterion 3 of 10 CFR 50.36 (Ref. 1).

LCO

The BWST exists to ensure that an adequate supply of borated water is available to cool and depressurize the reactor building in the event of an accident; to cool and cover the core in the event of a LOCA, thereby ensuring the reactor remains subcritical following an accident; and to ensure an adequate level exists in the reactor building sump to support ECCS and reactor building spray pump operation in the recirculation MODE. To be considered OPERABLE, the BWST must meet the limits for water volume, boron concentration, and temperature established in the SRs.

APPLICABILITY

In MODES 1, 2, 3, and 4, the BWST OPERABILITY requirements are dictated by the ECCS and Reactor Building Spray System OPERABILITY requirements. Since all or portions of the ECCS and Reactor Building Spray System must be OPERABLE in MODES 1, 2, 3, and 4, the BWST must be OPERABLE to support their operation.

Core cooling requirements in MODE 5 are addressed by LCO 3.4.7, "RCS Loops – MODE 5, Loops Filled," and LCO 3.4.8, "RCS Loops – MODE 5, Loops Not Filled," respectively. MODE 6 core cooling requirements are addressed by LCO 3.9.4, "DHR and Coolant Circulation – High Water Level," and LCO 3.9.5, "DHR and Coolant Circulation – Low Water Level."

ACTIONS

A.1

With either the BWST boron concentration or borated water temperature not within limits, the condition must be corrected within 8 hours. In this condition, the ECCS cannot perform its design functions. Therefore, prompt action must be taken to restore the tank to OPERABLE status or to place the unit in a MODE in which these systems are not required. The 8 hour limit to restore the temperature or boron concentration to within limits was developed considering the time required to change boron concentration or temperature and assuming that the contents of the tank are still available for injection.

BASES

ACTIONS (continued)

B.1

With the BWST inoperable for reasons other than Condition A (e.g., water volume), the BWST must be restored to OPERABLE status within 1 hour. In this condition, neither the ECCS nor the Reactor Building Spray System can perform its design functions. Therefore, prompt action must be taken to restore the BWST to OPERABLE status or to place the unit in a MODE in which the BWST is not required. The allowed Completion Time of 1 hour to restore the BWST to OPERABLE status is based on this condition simultaneously affecting multiple redundant trains.

C.1 and C.2

If the Required Action and associated Completion Time are not met, the unit must be brought to a MODE in which the LCO does not apply. To achieve this status, the unit must be brought to at least MODE 3 within 12 hours and to MODE 5 within 36 hours. The allowed Completion Times are reasonable, based on operating experience, to reach the required unit conditions from full power conditions in an orderly manner and without challenging unit systems.

SURVEILLANCE REQUIREMENTS

SR 3.5.4.1

Verification every 24 hours that the BWST water temperature is within the specified temperature band ensures that the fluid will not freeze and that the fluid temperature entering the reactor vessel will not be colder than assumed in the reactor vessel stress analysis; and the fluid temperature entering the reactor vessel will not be hotter than assumed in the LOCA analysis. The 24 hour Frequency is sufficient to identify a temperature change that would approach either temperature limit and has been shown to be acceptable through operating experience.

The SR is modified by a Note that requires the Surveillance to be performed only when ambient air temperatures are outside the operating temperature limits of the BWST. With ambient temperature within this band, the BWST temperature should not exceed the limits.

BASES

SURVEILLANCE REQUIREMENTS (continued)	<u>SR 3.5.4.2</u> Verification every 7 days that the BWST contained volume is ≥ 350,000 gallons (46.0 ft.) ensures that a sufficient initial supply is available for injection and to support continued ECCS pump operation on recirculation. Since the BWST volume is normally stable, a 7 day Frequency has been shown to be appropriate through operating experience. <u>SR 3.5.4.3</u> Verification every 7 days that the boron concentration of the BWST fluid is within the required band ensures that the reactor will remain subcritical following a LOCA. Since the BWST volume is normally stable, a 7 day sampling Frequency is appropriate and has been shown to be acceptable through operating experience. The COLR revision process assures that the minimum boron concentration specified in the COLR bounds the limit specified by this SR.
REFERENCES	1. 10 CFR 50.36.

B 3.7 PLANT SYSTEMS

B 3.7.12 Spent Fuel Pool Boron Concentration

BASES

BACKGROUND

The Oconee spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B_4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B_4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, the Oconee spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 1. The methodology ensures that the spent fuel rack multiplication factor, k_{eff}, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 2) and NRC guidance (Ref. 3). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 5.00 weight percent (wt %) Uranium-235 while maintaining $k_{eff} \leq 0.95$, including uncertainties, tolerances, biases, and credit for soluble boron. Note that the criticality analysis accounts for a maximum as-built enrichment tolerance of 0.05 wt % U-235. For example, for a specified maximum design enrichment of 5.00 wt % U-235, an as-built enrichment up to 5.05 weight percent is acceptable. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff} \leq 0.95$. The soluble boron concentration required to maintain $k_{eff} \leq 0.95$ under normal conditions is 430 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis without the presence of the soluble boron in the pool (excluding certain burnup-related uncertainties described in the criticality analysis). The criticality

BASES

BACKGRUND (continued)

analysis performed shows that the acceptance criteria for criticality are met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, no credit for the Boraflex neutron absorber panels, and storage configurations and enrichment limits specified by LCO 3.7.13.

APPLICABLE SAFETY ANALYSES

Most accident conditions do not result in an increase in reactivity in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, four accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature. The third is the misloading of a fuel assembly into a location in which the restrictions on location, enrichment and burnup are not satisfied. The fourth is a drop of a heavy load onto the spent fuel racks.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 430 ppm required to maintain $k_{eff} \leq$ to 0.95 under normal storage conditions) can be assumed as a realistic initial condition, since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by these postulated accidents, to maintain $k_{eff} \leq 0.95$. It was found that a spent fuel pool boron concentration of 2220 ppm was sufficient to maintain $k_{eff} \leq 0.95$ for the worst-case postulated criticality-related accident (the heavy load drop event). Specification 3.7.12 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

The minimum boron concentration limit ensures the SFP boron concentration is adequate to meet the sub-criticality requirements of fuel stored in the SFP for the most limiting accident in the SFP: A cask drop onto fuel in the SFP.

BASES

APPLICABLE SAFETY ANALYSES (continued)

Note that it is plausible that the "loss of normal cooling" accident could occur in conjuction with a spent fuel pool boron dilution event. Criticality calculations show that the soluble boron needed to maintain $k_{eff} \leq 0.95$ for the "loss of normal cooling" accident (500 ppm) is still less than the boron concentration following the worst-case credible dilution event (825 ppm).

Therefore, maintaining the spent fuel pool boron concentration within the limits assures $k_{eff} \leq 0.95$ for any accident condition. For normal storage conditions, Specification 4.3.1 c. requires that the spent fuel rack k_{eff} be $\leq$ 0.95 when flooded with water borated to 430 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 k_{eff} design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to 430 ppm is not a credible event.

The numerical value of the SR 3.7.12.1 minimum boron concentration limit ($\geq$ 2220 ppm) includes allowance for analytical mechanical and instrument measurement uncertainties.

The concentration of dissolved boron in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 5).

LCO

The dissolved boron concentration limits for in spent fuel pool preserves the assumption used in the analyses of the potential accident scenarios described above. This concentration of dissolved boron is the minimum required concentration for fuel assembly storage and movement within the fuel storage pool.

APPLICABILITY

This LCO applies whenever fuel assemblies are stored in the spent fuel pool.

ACTIONS

A.1 and A.2

The Required Actions are modified by a Note indicating that LCO 3.0.3 does not apply.

BASES

ACTIONS

A.1 and A.2 (continued)

If moving irradiated fuel assemblies while in MODE 5 or 6, LCO 3.0.3 would not specify any action. If moving irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the fuel movement is independent of reactor operation. Therefore, inability to suspend movement of fuel assemblies is not a sufficient reason to require a reactor shutdown.

When the concentration of boron in the fuel storage pool is less than required, immediate action must be taken to preclude the occurrence of an accident or to mitigate the consequences of an accident in progress. This is achieved by immediately suspending the movement of the fuel assemblies. This does not preclude movement of a fuel assembly to a safe position. Immediate action is also required to initiate action to restore the SFP boron concentration to within limits.

SURVEILLANCE REQUIREMENTS

SR 3.7.12.1

This SR verifies that the concentration of boron in the fuel storage pool is within the required limit. As long as this SR is met, the analyzed incidents are fully addressed. The 7 day Frequency is appropriate because no major replenishment of pool water is expected to take place over a short period of time. The COLR revision process assures that the minimum boron concentration specified in the COLR bounds the limit specified by this SR.

REFERENCES

1. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.

2. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.

3. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.

BASES

REFERENCES (continued)	4.	Double contingency principle of ANSI N16.1-1975, as specified in the April 14, 1978 NRC letter (Section 1.2) and implied in the proposed revision to Regulatory Guide 1.13 (Section 1.4, Appendix A).
	5.	10 CFR 50.36.

BASES (continued)

APPLICABLE SAFETY ANALYSES (continued)

loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature. The third is the misloading of a fuel assembly into a location in which the restrictions on location, enrichment and burnup are not satisfied. The fourth is a drop of a heavy load onto the spent fuel racks.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) can be applied. This double contingency principle does not require assuming two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 430 ppm required to maintain $k_{eff} \leq 0.95$ under normal storage conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by these postulated accidents, to maintain $k_{eff} \leq 0.95$. It was found that a spent fuel pool boron concentration of 2220 ppm was sufficient to maintain $k_{eff} \leq 0.95$ for the worst-case postulated criticality-related accident (the heavy load drop event). Specification 3.7.12 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Note that it is plausible that the "loss of normal cooling" accident could occur in conjuction with a spent fuel pool boron dilution event. Criticality calculations show that the soluble boron needed to maintain $k_{eff} \leq .95$ for the "loss of normal cooling" accident (500 ppm) is still less than the boron concentration following the worst-case credible dilution event (825 ppm).

Therefore, maintaining the spent fuel pool boron concentration within the limits specified in the COLR assures k_{eff} is $\leq .95$ for any accident condition.

For normal storage conditions, Specification 4.3.1 c. requires that the spent fuel rack k_{eff} be ≤ 0.95 when flooded with water borated to 430 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 k_{eff} design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to 430 ppm is not a credible event.

The fuel assembly storage and concentration of dissolved boron in the spent fuel pool satisfy Criterion 2 of 10 CFR 50.36 (Ref. 5).

Attachment D

Duke Energy Corporation
Response to Request for Additional Information

Replacement
License Amendment Request Attachment 3, Description of Proposed Changes and Technical Justification

Note:

Changes from the original request, as supplemented, are indicated by change bars.

Description of Proposed Changes and Technical Justification

Introduction

The proposed amendment provides revised spent fuel pool storage configurations, revised spent fuel pool storage criteria, and revised fuel enrichment and burnup requirements which take credit for soluble boron in maintaining acceptable margins of subcriticality in the spent fuel storage pools. Also, the proposed amendment provides additional criteria for ensuring acceptable levels of subcriticality in the spent fuel storage pools.

As described below, the proposed change to Oconee Technical Specification (TS) 3.7.12, Spent Fuel Pool Boron Concentration, credits soluble boron in maintaining acceptable margins of subcriticality in the spent fuel storage pools and provides appropriate surveillance requirements. This aspect of the change does not take credit for boron remaining in the fuel storage rack Boraflex panels. Proposed changes to TS 3.7.13, Fuel Assembly Storage, provide spent fuel pool storage criteria, fuel enrichment and burnup requirements. The criteria of TS 4.3 are revised to describe acceptable levels of subcriticality in the Oconee spent fuel storage pools.

Also, changes are proposed to TS 3.5.4, Borated Water Storage Tank, that establish an appropriate minimum boron concentration. These changes provide added assurance the spent fuel pool minimum boron concentration limits are maintained.

Credit for soluble boron, along with revised fuel storage configurations to maintain acceptable levels of spent fuel subcriticality, has already been approved for a number of other nuclear plants. These include Byron and Braidwood (Safety Evaluation (SE) dated December 4, 1997), Farley (SE dated January 23, 1998), Vogtle (SE dated February 20, 1998), and South Texas Project (SE dated March 3, 1999). These plants used the methodology described in WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" (Reference 1) to perform their criticality analyses. The methodology used as the basis for this amendment application is also based on the Reference 1 methodology, although different computer codes were used for some elements of the analyses. These codes were qualified through benchmarking to relevant critical experiments. The analysis methodology and computer codes used in support of this application were deemed acceptable for use at Duke's

McGuire Nuclear Station (SE dated November 27, 2000). The major difference between the Oconee and McGuire analyses is that Oconee does not credit boron remaining in the Boraflex panels as did the McGuire analyses.

The following Technical Justification and the supporting attachments describe the methodology, computer codes and their usage in the development of analyses that form the basis for this amendment application.

Approval of this proposed amendment is requested by December 28, 2001. Implementation of the approved amendment would be completed by February 26, 2002. Projections of Boraflex degradation in the Oconee SFPs indicate that, for extended operation of the SFPs through at least June 2002, the current administratively-controlled minimum fuel burnup requirements would increase by less than 0.50 GWD/MTU. This minor increase would not affect the status of the fuel that is currently stored in the Oconee SFPs, since all fuel assemblies that have experienced at least one cycle of reactor irradiation will still qualify for storage without restriction in the SFPs.

<u>Current Licensing Basis</u>

The elements of the Current Licensing Basis (CLB) relevant to this amendment application are:

1. The spent fuel storage racks are designed in accordance with the "NRC Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14, 1978 and revised January 18, 1979.

2. The racks are designed to meet the nuclear requirements of ANSI N210-1976. The effective multiplication factor, k_{eff}, in the spent fuel pool is less than or equal to 0.95, including all uncertainties.

3. Soluble boron is credited for maintaining the most reactive fuel with $k_{eff} \leq 0.95$ under accident conditions.

4. The racks are designed to allow coolant flow such that boiling in the water channels between fuel assemblies does not occur.

5. The racks are designed to preclude the insertion of a fuel assembly in other than design locations.

6. The Boraflex Monitoring Program assures the required 5% criticality margin is maintained. This program has been

determined to effectively manage the Boraflex during the extended Oconee license life.

Description of Proposed Changes

Technical Specification (TS) and TS Bases

The existing design basis for preventing criticality in the Oconee spent fuel storage pools is that, including uncertainties, there is a 95% probability at a 95% confidence level that k_{eff} of the fuel storage assembly array will be less than or equal to 0.95 with full density moderation under both accident and non-accident conditions. A design basis standard condition states that the spent fuel pool water is assumed to be unborated. This License Amendment Request (LAR) proposes an exception to this standard condition and a revision to the existing Oconee TSs and spent fuel storage pool design bases. The proposed changes are described below and are based upon no Boraflex remaining in the pools, as described in the revised Oconee Spent Fuel Pool Criticality Analysis (Attachment 6):

1. TS 4.3 is revised to provide new acceptable levels of subcriticality for spent fuel storage. Upon incorporation of the proposed changes to TS 3.7.13, these acceptable levels of subcriticality are for <u>normal</u> storage conditions: |

   a. An effective neutron multiplication factor (k_{eff}) less than 1.0 if fully flooded with unborated water, including an allowance for uncertainties as described in Oconee UFSAR Section 9.1; and,

   b. $k_{eff} \leq 0.95$ if fully flooded with water borated to 430 ppm, including an allowance for uncertainties as described in UFSAR Section 9.1.

2. TS 3.7.13, Fuel Assembly Storage, is revised to provide revised spent fuel pool storage configurations, revised spent fuel pool storage criteria, and revised fuel enrichment and burnup requirements. With the applicable minimum concentration of soluble boron present in the spent fuel storage pool and no credit for the Boraflex neutron absorber panels, these changes ensure that the pool storage rack k_{eff} is ≤ 0.95 under non-accident conditions (including the unlikely occurrence of a worst-case spent fuel storage pool dilution event with thorough mixing) and accident conditions. The applicable minimum concentration of soluble boron is ensured by existing Oconee TS 3.7.12. Note that credit for soluble boron is currently used at

Oconee for Mode 6 reactivity control in the reactor vessel, to compensate for a misloaded fuel assembly in the spent fuel storage pools, and for control of reactivity during the loading of spent fuel storage casks. The TS 3.7.13 Bases are also revised to address these changes.

3. TS 3.7.12, Spent Fuel Pool Boron Concentration, is revised to include a minimum boron concentration requirement of 2220 ppm and to increase the frequency of surveillance requirements from 31 days to 7 days. With credit being taken for soluble boron in the spent fuel pool, the increased surveillance frequency ensures the appropriate minimum concentration of soluble boron is maintained in the spent fuel storage pool for both normal and accident conditions. Note that credit for soluble boron is currently used at Oconee for Mode 6 reactivity control in the reactor vessel, to compensate for a misloaded fuel assembly in the spent fuel storage pools, and for control of reactivity during the loading of spent fuel storage casks. The TS 3.7.12 Bases are also revised to address this change.

4. TS 3.5.4, Borated Water Storage Tank (BWST), is revised to provide a minimum boron concentration of 2220 ppm. This minimum boron concentration limit ensures that any water transferred from the BWST to the spent fuel pool satisfies the minimum boron concentration requirements of TS 3.7.12. The TS 3.5.4 Bases are also revised to address this change.

The existing TS 3.7.13 specifies the requirements for spent fuel pool storage configurations, fuel pool storage criteria, fuel enrichment, and fuel burnup. Consequently, plant operating procedures already include controls to ensure these existing requirements are satisfied. These procedural controls will be revised and maintained as needed to reflect the revised TS 3.7.13 described in item 2 above. Finally, current controls on spent fuel pool boron concentration and water inventory will be evaluated and procedures will be upgraded as necessary to ensure that the spent fuel pool boron concentration and water inventory are controlled during both normal and accident situations. The existing Oconee spent fuel pool storage systems, supporting systems, and instrumentation are not modified as a result of this proposed LAR.

In the unlikely event of a worst-case spent fuel storage pool dilution event without thorough mixing, the proposed changes ensure that the pool storage rack k_{eff} is < 1.0 under non-accident conditions with no credit for soluble boron (including all biases and uncertainties, with the exception of certain burnup-related uncertainties described in the criticality analysis), and no credit for the Boraflex neutron absorber panels.

The above described TS changes are consistent with the requirements of NUREG-1430, Standard TSs (STS) for Babcock and Wilcox Plants, Revision 1. The proposed change to the Surveillance Requirement (SR) 3.7.12.1 frequency for verifying the Spent Fuel Pool Boron concentration is changed from 31 days to 7 days. This change conforms the SR frequency to the STS frequency.

Licensing Bases (LB)

On approval of this application Boraflex will not be relied upon to maintain the required criticality margin. Therefore, the above described LB item No. 6 concerning the Boraflex Monitoring Program would be deleted.

Other proposed changes to the above described LB items include the following:

LB Item No. 1 - Add a reference to "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants", dated August 19, 1998. This memo superseded portions of the 1978 NRC position and the subsequent 1979 revision.

LB Item No. 2 - Replace the reference to ANSI N210-1976 with its superseding standard, ANSI/ANS-57.2-1983. Replace the last sentence with: "Per 10 CFR 50.68(b)(4), the effective multiplication factor, k_{eff}, in the spent fuel pool is less than or equal to 0.95, including all uncertainties, with partial credit for soluble boron. The k_{eff} remains below 1.0 (subcritical) if the spent fuel pool is flooded with unborated water."

Updated Final Safety Analysis Report (UFSAR)

On approval of this LAR, UFSAR Section 9.1.2.5, Boraflex, will be deleted since the Boraflex remaining in the spent fuel racks would no longer be credited with maintaining fuel subcritical. UFSAR 9.1.2.5 describes the design of the Boraflex panels in the spent fuel racks and Boraflex's role in maintaining fuel subcritical. UFSAR 9.1.2.5 also describes the Boraflex Monitoring Program credited for license renewal during the period of extended operation.

Although Boraflex remaining in the spent fuel storage rack Boraflex panels will no longer be credited for maintaining fuel subcritical, Duke does not plan to physically remove the Boraflex panels.

Other UFSAR changes related to removal of Boraflex from the licensing basis will be implemented per 10 CFR 50.71(e).

Technical Justification

The Oconee spent fuel storage racks were analyzed taking credit for soluble boron as allowed in the NRC approved "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" described in WCAP-14416-NP-A (Reference 1), where appropriate. The WCAP-14416-NP-A methodology, as well as the dilution methodology it references (WCAP-14181, "Westinghouse Owners Group Evaluation of the Potential For Diluting PWR Spent Fuel Pool"), does not address all criticality-related events applicable to the Oconee spent fuel pools. For these events, other analytical methodologies are used as described herein and in Attachments 6 and 7. These events include: 1) The Oconee SSF drawdown dilution event; 2) The Oconee HPI Suction Alignment dilution event; and 3) A heavy load (dry storage transfer cask) drop onto the fuel storage racks in the spent fuel pool.

Normal Conditions:

Utilizing the spent fuel pool storage configurations, spent fuel pool storage criteria, and the fuel enrichment and burnup requirements described in the revised Oconee Spent Fuel Pool Criticality Analysis, this analysis demonstrates that under non-accident conditions (undamaged storage racks, no misloaded fuel assemblies, and spent fuel pool water temperatures less than 150 degrees F) a spent fuel storage pool boron concentration of 430 ppm is adequate to maintain the spent fuel storage rack $k_{eff} \leq 0.95$ with no credit for the Boraflex neutron absorber panels. Existing Oconee TS 3.7.12 states that the spent fuel pool storage boron concentrations shall be maintained within the limits specified in the Oconee Core Operating Limits Report (COLR). This LAR proposes an additional minimum boron concentration limit of 2220 ppm in TS 3.7.12 (Spent Fuel Pool Boron Concentration), and TS 3.5.4 (Borated Water Storage Tank). The pertinent areas governed by TS 3.5.4 can affect the spent fuel pool boron concentration when connected directly.

It is possible that the boron concentration in the spent fuel storage pool could be lowered below the proposed minimum boron concentration limit of 2220 ppm by a pool dilution event.

Consequently, an analysis of dilution event spent fuel storage pool boron concentrations is necessary to ensure that acceptable levels of subcriticality are maintained during and following the event (Attachment 7). Based upon the double contingency principle, this dilution event is assumed to occur under non-accident conditions, with the exception of the "significant spent fuel pool water temperature change" event described in the Accident Conditions discussion in this section. As part of this spent fuel storage pool dilution event analysis, calculations were performed to define the dilution time and volumes for the spent fuel pool. The dilution sources available at Oconee were compiled and evaluated against the calculated dilution volume to identify the bounding dilution event.

The Oconee dilution analysis (see Attachment 7) concluded that the bounding credible dilution event for the Unit 1 / 2 spent fuel pool was due to removal of borated water from the SFP for up to 72 hours by the Standby Shutdown Facility (SSF). This scenario assumes no other source of borated water is available to the SFP and requires manually aligning fire trucks to pump water directly from the Lake Keowee to refill the SFP. The bounding credible dilution event for the Unit 3 spent fuel pool is the HPI Suction Alignment event, which involves removal of borated water from the SFP in order to supply HPI suction flow in the event the BWST is damaged and unavailable. As with the SSF event described above, the refill source for the HPI Suction Alignment event is unborated water from Lake Keowee.

In the unlikely event either of the above dilution events occurred, the dilution analyses indicate that the boron concentration of the spent fuel pool serving Units 1 and 2 would be reduced to approximately 825 ppm, and the Unit 3 spent fuel pool boron concentration would be reduced to approximately 957 ppm. The dilution analyses assume a conservative initial boron concentration of 2220 ppm and thorough mixing of the non-borated water added to a pool. This post-dilution boron concentration is well above the minimum required boron credit of 430 ppm for non-accident conditions.

The above post-dilution event boron concentrations are based upon the assumption that all of the non-borated water added to a spent fuel pool is thoroughly mixed with the water in the pool. It is likely that thorough mixing would occur. However, if mixing were not adequate, it is possible that a localized pocket of non-borated water could form somewhere in the spent fuel pool. This possibility is addressed by the calculation described in Attachment 6 that shows that the spent fuel storage pool k_{eff} will still be less than 1.0 (subcritical) on a 95/95 basis - excluding certain burnup-related uncertainties - with the spent fuel pool filled with non-borated water.

Thus, in the unlikely event that the worst-case dilution event occurred and then a pocket of non-borated water formed in the spent fuel pool due to inadequate mixing, acceptable subcritical conditions, as defined in Reference 1 and 10 CFR 50.68(b)(4), would still be maintained in the Oconee spent fuel storage pools.

Accident Conditions:

Many of the postulated spent fuel pool accidents at Oconee will not result in an increase in k_{eff} of the spent fuel racks. Such accidents include the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules, and the drop of a fuel assembly between rack modules and the pool wall. At Oconee, the spent fuel assembly rack configuration precludes the insertion of a fuel assembly between rack modules. The placement of an assembly between the rack and the pool wall would result in a lower k_{eff} relative to the criticality analysis due to the increased neutron leakage at the spent fuel pool wall, because the criticality analysis assumes an infinite array of fuel assemblies. In the case where a fuel assembly in its most reactive condition is dropped onto the spent fuel racks, analysis shows that the rack structure pertinent for criticality is not excessively deformed. For this event, previous accident analysis with unborated water showed that a dropped fuel assembly resting horizontally on top of the spent fuel rack has sufficient water separating it from the active fuel height of stored fuel assemblies to preclude neutronic interaction.

However, four accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. If a fuel assembly were to be dropped or placed into the cask loading area of a pool, any reactivity increase would be bounded by the fuel assembly misload accident described below.

Two other postulated accidents that need to be addressed in accordance with Reference 4 are a significant change in the spent fuel pool water temperature and the misloading of a fuel assembly. A fuel assembly misload accident relates to the use of restricted storage locations based on fuel assembly type, initial maximum enrichment, and burnup. The misloading of a fuel assembly constitutes not meeting the enrichment and burnup requirements of that restricted location. The result of the misloading is to add positive reactivity to the storage configuration. The placement of assemblies into these restricted locations is controlled by procedures. Reference 4 requires that only a single fuel assembly misload be analyzed unless there are circumstances that make multiple loading errors credible. Redundant checks and procedural verifications of each fuel assembly movement within the Oconee spent fuel pools preclude the occurrence of multiple fuel assembly loading errors in any storage region.

A significant change in the spent fuel pool water temperature (outside the "normal" range of 68 °F to 150 °F) can be the result of either the loss of normal cooling to the spent fuel pool water, which causes an increase in the temperature of the water passing through the stored fuel assemblies, or a large makeup to the pool with cold water, which could happen in the SSF scenario described above. The loss of spent fuel pool cooling causes a decrease in water density, which raises system reactivity for racks with no Boraflex present. A decrease in pool temperature causes an increase in water density, which reduces the reactivity for racks being analyzed with the assumption that no Boraflex is present. These reactivity effects are attributable to the fact that the "flux trap" design of the Oconee spent fuel pool storage racks is heavily overmoderated, even in unborated water conditions, when Boraflex is not present in the storage racks. The boron requirement for the water temperature accident is compared against the most limiting boron concentration from the dilution events described earlier (825 ppm), since a dilution event can occur in conjunction with abnormal water temperature changes in the spent fuel pool. The revised analysis for the spent fuel pool water change accident shows that a maximum of 500 ppm boron is needed to maintain $k_{eff} \leq 0.95$, which is still well below the worst-case dilution event boron concentration of 825 ppm.

In addition to the accidents described above, the criticality consequences of a postulated heavy load drop onto the spent fuel racks have been reanalyzed to consider the proposed fuel storage configurations and without credit for Boraflex in the spent fuel pool racks. The heavy load drop analysis, performed in accordance with NUREG-0612, shows that the minimum spent fuel pool boron concentration of 2220 ppm specified in TS 3.7.12 is sufficient to maintain the maximum k_{eff} below 0.95. The heavy load drop evaluation accounts for analytical, mechanical, and boron measurement uncertainties.

For each storage configuration proposed in the proposed TS 3.7.13, a spent fuel rack criticality analysis was performed as described in the revised Oconee Spent Fuel Pool Criticality Analysis (Attachment 6). This analysis evaluated the amount of soluble boron necessary to ensure that the spent fuel rack k_{eff} will be maintained less than or equal to 0.95 following a significant change in spent fuel pool temperature or the misloading/drop of a fuel assembly. This evaluation determined that for the fuel assembly drop or misload accidents, a minimum boron concentration of 1110 ppm in the Units 1 and 2 pool, and 1210 ppm in the Unit 3 pool, is required to maintain k_{eff} less than or equal to 0.95. For the heavy load drop accident, a boron concentration of 2220 ppm is sufficient to maintain k_{eff} less than or equal to 0.95. Therefore, a boron concentration of 2220 ppm is bounding for all accidents. TS 3.7.12 requires the spent fuel pool storage boron concentrations be maintained $\geq$ 2220 ppm, AND within the limits specified in the Oconee Core Operating Limits Report (COLR).

Consequently, under the applicable accident conditions (except the water temperature change accident concurrent with the dilution event described above), maintaining spent fuel pool boron concentrations at or above the TS 3.7.12 minimum of 2220 ppm will assure that the spent fuel storage rack k_{eff} is $\leq$ 0.95 when fuel is stored in accordance with the revised spent fuel pool storage configurations, revised spent fuel pool storage criteria, and revised fuel enrichment and burnup requirements specified in the proposed change to TS 3.7.13. Based on the double contingency principle, the analyses for the fuel assembly drop, fuel assembly misload, and heavy load drop accidents do not have to account for these accidents occurring simultaneously or in conjunction with a spent fuel pool dilution event.

<u>Summary</u>

The analyses performed in support of this request have been performed in accordance with NRC-approved methodology, where applicable to the Oconee spent fuel pool design. In those cases where the WCAP-14416-NP-A and WCAP-14181 methodologies do not address a spent fuel pool event applicable to Oconee, an alternate methodology is employed. These alternate methodologies and results from their applications are documented in Attachments 6 and 7.

The results of the criticality analysis for the Oconee spent fuel storage racks indicate that the acceptance criteria for criticality, per 10 CFR 50.68 (b)(4), are met; that is, $k_{eff} \leq$ 0.95, including all uncertainties, for normal and accident conditions (with partial or full credit for soluble boron), and $k_{eff} < 1.0$ for the postulated condition of no boron in the spent fuel pool. The criticality analyses take credit for soluble boron (where allowed) and credit for burnup, but do not take credit for any Boraflex remaining in the storage racks. Each spent fuel pool has three proposed storage configurations: Unrestricted, Restricted and Checkerboard storage.

The total boron credit requirements for these configurations in the Unit 1 & 2 pool are 400 ppm for normal conditions, 470 ppm for the SFP heatup event (pool temperature above 150 °F), and 2220 ppm to bound all other accident conditions. The total boron credit requirements for these configurations in the Unit 3 pool are 430 ppm for normal conditions, 500 ppm for the Spent Fuel Pool heatup event, and 2220 ppm to bound all other accident conditions.

The results of these analyses, whether using NRC-approved or alternate methodologies, demonstrate the proposed credit for soluble boron meets the requirements of 10 CFR 50.68 (b)(4).

The following table summarizes the results of the above-described analyses.

Bounding Spent Fuel Pool Events

SFP	Event [(a)]	Initial Boron Concen-tration	Final Boron Concentration (compared to required boron concentration)	Maximum k_{eff} at the Final Boron Conc	Acceptance Criteria (k_{eff})	Boron Concentration Required for Acceptance Criteria	Submittal Discussion Reference(s)
1&2	Normal Storage Conditions -- No Boron	N/A	0	<1.0	<1.0	0	Att.6, § 3.1 (page 6) Att. 6, Table 10 (page 28)
3	Normal Storage Conditions -- No Boron	N/A	0	<1.0	<1.0	0	Att.6, § 3.1 (page 6) Att. 6, Table 10 (page 28)
1&2	Normal Storage Conditions – partial credit for soluble boron [(b)]	2220	825	<< 0.95	$\leq$ 0.95	400	Att. 6, Table 10 (page 28) Att. 7, §6.2 (page 27)
3	Normal Storage Conditions – partial credit for soluble boron [(b)]	2220	957	<< 0.95	$\leq$ 0.95	430	Att. 6, Table 10 (page 28) Att. 7, §6.3 (pages 29)
1&2	Cask Drop Accident	2220	2220	0.9491	$\leq$ 0.95	2220	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
3	Cask Drop Accident	2220	2220	0.9392	$\leq$ 0.95	2220	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
1&2	Fuel Assembly Misload Accident	2220	2220	<<0.95	$\leq$ 0.95	1110	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
3	Fuel Assembly Misload Accident	2220	2220	<<0.95	$\leq$ 0.95	1210	Att.6, § 4.0 (page 15) Att. 6, Table 10 (page 28)
1&2	SFP Heatup Accident Condition [(b)]	2220	825	<<0.95	$\leq$ 0.95	470	Att.6, § 4.0 (page 16) Att. 6, Table 10 (page 28)
3	SFP Heatup Accident Condition [(b)]	2220	957	<<0.95	$\leq$ 0.95	500	Att.6, § 4.0 (page 16) Att. 6, Table 10 (page 28)

(a) Each event is evaluated with the limiting fuel enrichment, burnup and storage configuration.
(b) With limiting dilution event, the SSF drawdown of the SFP and subsequent emergency makeup (for the Unit 1&2 SFP), or HPI Suction Alignment (Unit 3 SFP).

Conclusion

Revision of the Oconee TSs and design bases as proposed in this LAR provide a level of safety comparable to the conservative criticality analysis methodology required by References 1 through 4 of this attachment. Consequently, the health and safety of the public will not be adversely affected by the proposed Technical Specification changes.

References

1. WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology", Revision 1, November 1996.

2. USNRC Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, NUREG-0800, June 1987.

3. USNRC Spent Fuel Storage Facility Design Bases (for Comment) Proposed Revision 2, 1981, Regulatory Guide 1.13.

4. Letter from Laurence Kopp (NRC) to T. Collins (NRC), "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants", August 19, 1998.

Attachment E

Duke Energy Corporation
Response to Request for Additional Information

Replacement
License Amendment Request Attachment 6,
"Oconee Spent Fuel Pool
Criticality Analysis"

Note:

Changes from the original request, as supplemented, are indicated by change bars.

OCONEE SPENT FUEL POOL CRITICALITY ANALYSIS

Table of Contents

1.0 INTRODUCTION

This attachment describes the criticality analysis of the Oconee Nuclear Station spent fuel storage racks. This analysis takes credit for soluble boron in the spent fuel pool water as allowed in Reference 8.1 of this attachment and 10 CFR 50.68(b).

It should be noted that the Westinghouse methodology in Reference 8.1 was used as the basis for the methodology used in this analysis. However, since this analysis was performed by Duke Energy, some minor differences in the application of the methodology exist. For example, this analysis used a different set of computer codes to perform the calculations (as described in Section 2.0) instead of those described in Reference 8.1. So, while the process and criteria defined in the "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" were followed, the methodology used for this submittal, which is based on the Westinghouse methodology, is described in this attachment.

The Oconee Nuclear Station has two spent fuel pools; one pool serves Units 1 and 2 and the other pool serves Unit 3. The storage rack design for each Oconee spent fuel pool utilizes the poison material Boraflex. Due to the degradation of the Boraflex poison material, no credit is taken for the negative reactivity of the Boraflex in the criticality analysis.

The criticality analysis takes credit for burnup and storage configuration restrictions to achieve acceptable spent fuel storage limits. Three storage configurations are defined for each spent fuel pool: Unrestricted, Restricted, and Checkerboard storage. Unrestricted storage allows storage in all cells without restriction on the storage configuration. Restricted storage allows storage of higher reactivity fuel when restricted to a certain storage configuration with lower reactivity fuel. Checkerboard storage allows storage of the highest reactivity fuel in each region when checkerboarded with empty storage cells.

The main design criteria for the Oconee spent fuel storage rack criticality analysis are that $k_{eff} < 1.0$ with no boron (including tolerances and fresh fuel uncertainties) and $k_{eff} \leq 0.95$ with credit for soluble boron. The bounding soluble boron credit required for the storage configurations in both pools is 430 ppm for normal conditions and 2220 ppm for accident conditions.

1.1. Spent Fuel Storage Rack Design

Oconee has two independent spent fuel pools; one pool serves Units 1 and 2 and the other pool serves Unit 3. The spent fuel storage rack in each pool consists of a standard flux trap design.

The storage rack design for the spent fuel pool serving Units 1 and 2 consists of stainless steel cells that are spaced at 10.65 inches and were constructed with a minimum 0.02 gm/cm^2 loading of B_{10} neutron absorbing material attached to the exterior cell wall wrapper plate. This spent fuel pool has a nominal capacity of 1312 locations.

The basic spent fuel storage pool rack arrangement for the Units 1 and 2 spent fuel pool is shown in Figure 1 and a schematic of the cell configuration is also provided.

The storage rack design for the spent fuel pool serving Unit 3 consists of stainless steel cells that are spaced at 10.60 inches and were constructed with a minimum 0.03 gm/cm^2 loading of B_{10} neutron absorbing material attached to the exterior cell wall wrapper plate. This spent fuel pool has a nominal capacity of 825 locations.

The basic spent fuel storage pool rack arrangement for the Unit 3 spent fuel pool is shown in Figure 2 and a schematic of the cell configuration is also provided.

2.0 COMPUTER CODES AND METHODOLOGY

The methodology employed in this analysis is based on the "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" (Reference 8.1). While the process and criteria defined in the Westinghouse methodology were followed, the actual methodology employed in this submittal is described in this attachment.

The methodology employed in this analysis uses both the CASMO-3/TABLES-3/SIMULATE-3 and SCALE systems of codes for criticality analysis. CASMO-3/TABLES-3/SIMULATE-3 is used primarily and SCALE with KENO-Va is used for limited applications. These code systems were validated through benchmarking to relevant critical experiments as described later in this section.

The burnup credit approach to fuel rack criticality analysis requires calculation and comparison of reactivity values over a range of burnup and initial enrichment conditions. In order to accurately model characteristics of irradiated fuel which impact reactivity, a criticality analysis method capable of evaluating arrays of these irradiated assemblies is needed. An advanced nodal methodology combining CASMO-3/TABLES-3/SIMULATE-3 is suitable for this purpose, and is used in this analysis. CASMO-3 is an integral transport theory code, SIMULATE-3 is a nodal diffusion theory code, and TABLES-3 is a linking code that reformats CASMO-3 data for use in SIMULATE-3. This methodology permits direct coupling of incore depletion calculations and resulting fuel isotopics with out-of-core storage array criticality analyses. The CASMO-3/TABLES-3/SIMULATE-3 methodology has been previously approved for use in criticality analysis of the Oconee spent fuel storage racks (Reference 8.2).

The CASMO-3/TABLES-3/SIMULATE-3 methodology is validated by comparison to measured results of fuel storage critical experiments. The criticality experiments used to benchmark the methodology were the Babcock and Wilcox close proximity storage critical experiments performed at the CX-10 facility (Reference 8.3). The B&W critical experiments used are specifically designed for benchmarking reactivity calculation techniques. The criticality experiments examined have similar nuclear characteristics to spent fuel storage and are applicable to conditions encountered during the handling of LWR fuel outside reactors.

The results of the CASMO-3/TABLES-3/SIMULATE-3 benchmark calculations are shown in Table 1. There are no significant trends in the results with respect to moderator soluble boron concentration, array spacing, or boron level in the isolation sheets.

The SCALE/KENO-Va system of computer codes is used for limited applications not modeled by CASMO-3. These include problems with large water gaps, such as the checkerboard storage configuration. SCALE/KENO-Va is also used for problems that standard CASMO geometry cannot model, such as the determination of an uncertainty to be applied for an assembly not located in the center of the storage location. This methodology utilizes three-dimensional Monte Carlo theory. Specifically, this analysis method employs the CSAS25 sequence contained in Criticality Analysis Sequence No. 4 (CSAS4). CSAS4 is a control module contained in the SCALE-4.2 system of codes. The CSAS25 sequence utilizes two cross-section processing codes

(NITAWL and BONAMI) and the Monte Carlo code (KENO-Va) for calculating the effective multiplication factor for the system. The 27 Group NDF4 cross section library was used exclusively in the SCALE/KENO-Va analysis.

The KENO-Va methodology is also benchmarked to measured results of fuel storage critical experiments. The criticality experiments used to benchmark the KENO-Va methodology were from the PNL reports PNL-3314 (Reference 8.4), PNL-2438 (Reference 8.5) and PNL-6205 (Reference 8.6). The criticality experiments examined have similar nuclear characteristics to spent fuel storage and are applicable to conditions encountered during the handling of LWR fuel outside reactors.

The results of the KENO-Va benchmark calculations are shown in Table 2. There are no significant trends in the results with respect to fuel pin spacing, array spacing, poison loading and material or fuel enrichment.

For additional verification that the models used in the Oconee criticality analysis are accurate, calculated k_{eff}s from CASMO-3, SIMULATE-3 and KENO-Va, for an array of fresh 2.0 wt % U-235 Mark B11 fuel, are compared in Table 3. The results listed in Table 3 show very good agreement between the diffusion theory and Monte Carlo codes, with CASMO-3 and SIMULATE-3 being slightly conservative compared to KENO-Va.

3.0 CRITICALITY ANALYSIS

This section describes the criticality analysis performed to determine the spent fuel storage limits for the Oconee spent fuel storage racks.

The Oconee criticality analysis comprises the following general steps. First, design information is obtained for the different fuel assemblies in use at Oconee (e.g., Mark-B10, Mark-B11, etc.), as well as for the fuel storage racks in the Oconee spent fuel pools. With this information the analyst builds computer models of the fuel assemblies and performs several fuel depletions at different enrichments, mimicking in-reactor irradiation conditions. From these depletion cases, low-temperature, no-boron branch cases are performed in which the fuel assembly is put into the spent fuel racks with various fuel storage configurations (unrestricted, restricted/filler, and checkerboard/empty). These branch case computer calculations yield k_{eff} (effective multiplication factor) results for several enrichment/burnup combinations. To each

k_{eff} result various reactivity penalties are added to account for mechanical uncertainties and code methodology biases/uncertainties, which gives the no-boron 95/95 k_{eff} for that enrichment/burnup/storage configuration combination.

Using these 95/95 k_{eff} results, for each evaluated enrichment the lowest burnup is determined for which the no-boron 95/95 k_{eff} is less than 1.00. In this manner the minimum burnup limits are developed for a given enrichment, fuel pool, and storage configuration (as in Tables 7, 8, and 9 of this Attachment).

Next, the analyst ascertains a bounding amount of soluble boron credit that reduces the previously determined no-boron 95/95 k_{eff}s from less than 1.00 to less than or equal to 0.95, and accounts for burnup-related biases and uncertainties as well. This amount of soluble boron credit required is verified to ensure it does not exceed the amount remaining following a worst-case credible boron dilution event.

Several potential spent fuel pool accident scenarios are also evaluated, including an assembly misloading event, accidents that increase or decrease the fuel pool water temperature, and a heavy load drop event. The amount of soluble boron needed to keep the 95/95 k_{eff} at or below 0.95 is determined for each of these accidents, and the maximum amount required is verified to ensure it does not exceed the minimum spent fuel pool boron concentration for normal operations.

The following assumptions are used in the spent fuel pool criticality analysis:

1. All fuel designs used, or planned for use, at Oconee are analyzed. This includes the following Framatome 15 x 15 fuel designs: Mark-B8 and earlier, Mark-B9, Mark-B10, Mark-B10G and Mark-B11. All fuel designs are analyzed for all cases and only the most reactive fuel design is used to set the storage requirements.

2. All evaluations for normal SFP conditions are modeled at both 68 and 150 ^{o}F. Only the most reactive temperature is used to set the storage requirements. For abnormal SFP temperature conditions, the criticality calculations are performed at 32 and 212 ^{o}F.

3. All calculations are performed in 2-D; i.e. no axial effects are modeled. A reactivity bias is included in the

overall k_{eff} calculations, to account for differences between 2-D and 3-D modeling.

4. "No xenon" conditions are assumed in the storage racks.

5. No credit is taken for the spacer grid material.

6. The storage racks in both spent fuel pools contain no Boraflex.

3.1. No Boron 95/95 k_{eff}

This section describes the methodology used to determine the limits for the k_{eff} calculation with no boron, including biases and uncertainties (95/95 k_{eff}).

Per Reference 8.1, the 95/95 k_{eff} must be less than 1.0 with no boron. The calculation of the 95/95 k_{eff} must consider various biases and uncertainties related to the materials and construction of the racks. Specifically, the biases and uncertainties accounted for in the Oconee spent fuel pool criticality analysis are the bias and uncertainty associated with the benchmarking of the methodology, a bias to account for 3-dimensional effects not captured by the 2-dimensional model, and the uncertainty due to mechanical tolerances from the manufacturing process. The mechanical tolerance uncertainty comprises the following components: cell ID, CTC spacing, cell thickness, plenum thickness, enrichment, fuel pellet dish volume, fuel pellet theoretical density, fuel pellet OD, clad OD and assembly position within the storage cell. For the no boron 95/95 k_{eff}, these biases and uncertainties are generated at no boron conditions. Additional uncertainties related to burned fuel are discussed with the burnup credit methodology. Table 4 lists the biases and uncertainties for each region.

A no boron 95/95 maximum design k_{eff} is defined to be 1.0 less the combination of all the biases and uncertainties. For the final k_{eff} to remain less than 1.0, the calculated k_{eff} must remain less than the no boron maximum design k_{eff}. Since the combined biases and uncertainties are dependent on the fuel storage rack, two no boron 95/95 maximum design k_{eff}s are defined, one for each spent fuel pool. These maximum design k_{eff}s are listed in Table 4.

To determine the maximum enrichment for Unrestricted storage, CASMO-3 is used to iterate on enrichment until the calculated k_{eff} from CASMO-3 meets the no boron 95/95 maximum design k_{eff}. Since CASMO-3 is a lattice code, its calculations are for single assemblies in an infinite array, which is representative of the Unrestricted 100% storage option. The results of the fresh fuel limits for Unrestricted storage are summarized in Table 6.

Assemblies which do not qualify for Unrestricted storage must be stored in a restricted storage configuration. Two restricted storage configurations are employed; Restricted storage with low reactivity 'Filler' assemblies in a specified storage pattern, and Checkerboard storage with empty cells in a specified storage pattern.

For Restricted storage to be effective, the storage requirements must be carefully selected to optimize the use of the spent fuel storage cells for the current and expected inventory of fuel for each region. A Restricted storage pattern is defined for the Oconee spent fuel pools which allows assemblies not qualified for Unrestricted storage to be stored in 2 out of every 4 locations, with the other two locations being qualified low reactivity 'Filler' assemblies. This storage pattern is shown in Figure 3. By storing the more reactive assemblies not qualified for Unrestricted storage with less reactive fuel, the overall reactivity of the array remains less than the no boron 95/95 maximum design k_{eff}. The Restricted storage pattern is intended for temporary storage of partially burned fuel offloaded from the reactor during refueling outages.

Prior to performing any reactivity calculations, the requirements of either the Filler or Restricted assemblies must be selected. In this analysis, the requirements for the Restricted assemblies were selected first and the Filler requirements were then calculated for the Restricted assembly requirements chosen. The fresh fuel limits defined for Restricted storage are summarized in Table 6.

The maximum enrichment for the Filler fuel in the Restricted storage configurations is calculated using SIMULATE-3. To evaluate the Restricted storage patterns, the model must have the ability to analyze different assemblies in the same problem. This required the nodal code. SIMULATE-3 was executed to calculate k_{eff} of the Restricted storage array containing dissimilar fuel. The maximum enrichment for the Filler fuel was determined by iterating on enrichment until the calculated k_{eff} from SIMULATE-3 met the no boron 95/95 maximum design k_{eff}. The results of the fresh fuel limits for Filler fuel in the Restricted storage configuration are summarized in Table 6.

Assemblies which do not qualify for Unrestricted or Restricted storage must be stored in a Checkerboard storage pattern with empty storage locations. Checkerboard storage allows storage of the most reactive fuel allowed at the Oconee Nuclear Station, specifically fresh fuel up to 5.00 wt % U-235.

The goal of Checkerboard storage is to be able to store the most reactive fuel assemblies allowed in the spent fuel pools. This is accomplished by storing the most reactive assemblies with empty storage locations to keep the overall reactivity of the array beneath the required reactivity limit. To determine the storage pattern for Checkerboard storage, the calculated k_{eff} is changed by varying the number of empty cells until the calculated k_{eff} is less than or equal to the maximum design k_{eff}. The calculated k_{eff}s are taken from KENO-Va. The Checkerboard storage pattern is shown in Figure 4.

The Unrestricted, Restricted and Checkerboard storage patterns for each region allows optimum usage of all the storage cells in the Oconee racks for a wide range of fuel assemblies.

3.1.1 No Boron 95/95 k_{eff} - Burnup Credit

In order to store fuel with enrichments higher than the maximum enrichment limits for fresh fuel, the concept of reactivity equivalencing is employed. Reactivity equivalencing determines an equivalent reactivity by introducing a reactivity effect that was not previously considered. In this case, the negative reactivity from fuel burnup is used to offset the positive reactivity from higher enrichments until the reactivity is equivalent to that of the fresh fuel maximum enrichment case (i.e. the no boron 95/95 maximum design k_{eff}).

To use burnup credit, additional uncertainties related to depleted fuel must also be accounted for. The only burnup-related uncertainty included in the no boron 95/95 maximum design k_{eff} calculation is the reactivity increase associated with the removal of Burnable Poison assemblies (BP-pull). All other burnup-related uncertainties, namely the uncertainty in the calculated reactivity versus burnup, the uncertainty in the measured burnup, and the axial burnup bias, will be accounted for with boron credit as discussed in Section 3.2.

A bias is applied in the burnup credit calculations to account for a reactivity increase due to the shadowing effect of a BP. For burnup credit calculations, the standard criticality assumption is made that no removable poisons are in the assembly. However, an assembly which has a BP removed after its first cycle of operation is more reactive than an assembly that never contained a BP. A BP-pull bias is applied to account for this effect. A study of a database of BP-pull data for Oconee determined a maximum BP-pull reactivity increase of 0.008 Δk at 20 GWD/MTU. The bias is assumed to be linear from 0 GWD/MTU to the maximum bias at 20 GWD/MTU and is constant beyond 20 GWD/MTU. This is conservative because the reactivity of the BP-pulled assembly tends to approach the reactivity of the non-BP'd assembly by EOL. For burnup credit calculations, the bias only needs to be applied for assemblies with burnup. CASMO-3 is used for Unrestricted storage burnup credit calculations, hence the entire bias is applied since every assembly has burnup. For the SIMULATE-3 model used for the Restricted storage calculations, only the Filler fuel has burnup. The Restricted fuel is modeled as fresh fuel with the maximum enrichments from Table 6. Therefore, an appropriate ratio of the BP-pull bias is applied for the Restricted storage array since only part of the array has burnup.

Summarizing, the BP-pull bias for each region is as follows.

$$\text{Unrestricted Storage BP-pull bias} = \frac{0.008 \times \text{BU}}{20}$$

$$\text{Restricted Storage BP-pull bias} = \frac{0.004 \times \text{BU}}{20}$$

Where: BU = Assembly burnup in GWD/MTU up to a maximum of 20

To model fuel burnup, CASMO-3 was used to deplete the fuel under hot full power reactor conditions. CASMO-3 restarts were then performed to model the depleted assemblies in the storage racks. This ensures the reactivity of the depleted assembly is explicitly determined in the storage rack conditions. CASMO-3 restarts are performed at 5 GWD/MTU intervals from 0 to 60 GWD/MTU and at 0.5 w/o enrichment intervals from 2.0 to 5.0 w/o. A TABLES-3 library was also created from the CASMO-3 storage rack restart data to allow modeling the burned fuel in SIMULATE-3.

The burnup credit calculations are performed similar to the calculations that determined the maximum fresh fuel enrichments except that instead of varying the enrichment, the burnup is varied. As with the maximum fresh fuel enrichment calculations, for Unrestricted storage the calculated k_{eff}s come from CASMO-3, specifically the storage rack cases with burned fuel. For Restricted storage, the calculated k_{eff}s come from

SIMULATE-3. The calculated k_{eff}s are used to determine minimum burnup limits for each enrichment to ensure that the 95/95 storage rack k_{eff} is < 1.0. The burnup limit is the burnup where the calculated k_{eff} equals the no boron maximum design k_{eff} from Table 4 minus the appropriate BP-pull bias discussed above. The minimum burnup requirements for each enrichment are determined by linearly interpolating between the calculated burnups. This linear interpolation assumes that the calculated k_{eff} vs. burnup curve is linear. This is a very good assumption over small ranges of burnup.

The minimum burnup requirements for each enrichment are then plotted versus burnup and enrichment to yield a storage curve. A separate storage curve is generated for each type of storage and each region. A fuel assembly qualifies for a specific storage configuration if its burnup and enrichment fall above the storage curve.

The results of the burnup credit calculations are summarized in Tables 7 through 9. The allowable storage curves for each storage configuration are shown in Figures 5 and 6.

3.2 Boron Credit 95/95 k_{eff}

This section describes the methodology used to determine the amount of soluble boron required to maintain the 95/95 $k_{eff} \leq$ 0.95. The soluble boron required consists of two components; the boron required to reduce the no boron 95/95 k_{eff} from 1.0 to 0.95, and the boron required to account for uncertainties in the reactivity equivalencing methods. The boron needed to simultaneously account for these two components represents the total amount of soluble boron credit needed. This required boron concentration must be less than the amount of boron available for normal conditions. The amount of boron available for normal conditions is determined from an appropriate boron dilution analysis. Additional boron requirements are needed to compensate for reactivity increases as a result of postulated accidents. These are discussed in the Section 4.

Just as with the no boron 95/95 k_{eff} calculation, the calculation of the soluble boron credit 95/95 k_{eff} must consider various biases and uncertainties related to the materials and construction of the racks. Two types of biases and uncertainties are developed for the two components of the boron credit calculations. The biases and uncertainties for the **base** calculation (with fresh fuel) must consider the same biases and uncertainties used in determining the no boron 95/95 k_{eff}. The biases and uncertainties for the **final** calculation must include the biases and uncertainties associated with the base calculation, as well as those related to reactivity equivalencing. The calculations of all the uncertainties for the soluble boron credit 95/95 k_{eff} are then performed with the boron concentration required to maintain k_{eff} less than 0.95. Table 5 lists the boron credit biases and uncertainties for each region.

Note that all the calculations that determined boron credit requirements including those involving burnup-related uncertainties, as discussed in Section 3.2.1, and those for various SFP accident scenarios, as discussed in Section 4.0 were performed at the highest enrichment (5.00 wt % U-235)/burnup combinations on the proposed fuel storage reactivity equivalence curves for the Oconee SFPs. The computations were carried out in this manner in order to avoid potential non-conservatisms recently identified in NUREG contract report CR-6683, titled "A Critical Review of the Practice of Equating the Reactivity of Spent Fuel to Fresh Fuel in Burnup Credit Criticality Safety analyses for PWR Spent Fuel Pool Storage." The main finding in this report is that if a reactivity equivalence (burnup credit) curve is developed assuming pure, unborated water in the SFP, it may be non-conservative to apply that curve to situations in which boron is present in the SFP water. As Table 5 in CR-6683 shows, the degree of the non-conservatism increases with increasing burnup and/or boron concentration. Therefore, if the highest enrichment/burnup location on the reactivity equivalence curve is used for calculations in a borated water environment, the validity and conservatism of the results is assured.

The soluble boron credit 95/95 maximum design k_{eff} is then 0.95 less the combined biases and uncertainties described above. For the total k_{eff} to remain less than 0.95, the calculated k_{eff} must remain less than the boron credit maximum design k_{eff}. Since the combined biases and uncertainties are dependent on the fuel storage rack and fuel storage configuration, boron credit 95/95 maximum design k_{eff}s are defined for **base** and **final** calculations, for unrestricted and restricted fuel, and for each Oconee spent fuel pool. These maximum design k_{eff}s are listed in Table 5.

To determine the boron concentration required for $k_{eff} \leq 0.95$, SIMULATE-3 is used to iterate on the boron concentration using the appropriate fresh fuel enrichment for each region until the calculated k_{eff} from SIMULATE-3 is less than the soluble boron credit 95/95 maximum design k_{eff}. Two sets of cases are run for each fuel pool for Unrestricted and Restricted storage.

For the **base** calculations, the appropriate fresh fuel enrichments for each case are the maximum fresh fuel enrichments for Unrestricted and Restricted storage in each region, as shown in Table 6. The **base** calculations determine the total soluble boron credit required (without accidents), not including reactivity equivalencing.

For the **final** calculations, which include the boron credit for reactivity equivalencing, the highest burnup limit for each pool is used. Two sets of cases are run for each pool for Unrestricted and Restricted storage configurations. The burnups for Unrestricted storage are the burnup limits for 5.00 wt % U-235 unrestricted fuel. The burnups for Restricted storage are the burnup limits for 5.00 wt % U-235 Restricted fuel with the pertinent 5.00 wt % U-235 Filler assemblies at their corresponding burnup limits.

The **final** calculations, therefore, establish the total soluble boron credit required (without accidents), including reactivity equivalencing.

Note that no **base** or **final** boron credit calculations are performed for Checkerboard fuel storage. The boron concentrations required to maintain k_{eff} less than 0.95 for the Unrestricted and Restricted storage patterns will bound the required boron for Checkerboard storage. The Checkerboard configuration is inherently less reactive than the Restricted or Unrestricted storage configurations. In addition, the greater quantity of borated water in the Checkerboard/empty cell configuration means that a lower boron concentration is needed to produce a reactivity effect equivalent to that for the Unrestricted and Restricted storage patterns.

3.2.1 Boron Credit 95/95 k_{eff} - Reactivity Equivalencing Uncertainties

In addition to the boron credit required to maintain $k_{eff} \leq 0.95$, boron credit is also used to compensate for uncertainties associated with the reactivity equivalencing (i.e., burnup-related) methods. Only the burnup credit reactivity equivalencing method is used in this analysis.

For burnup credit, the uncertainties associated with this reactivity equivalencing method are as follows:

Burnup Credit Uncertainties

BP-pull Bias
Calculated reactivity and depletion versus burnup
Measured Burnup
Axial Burnup Distribution

Previous analysis for Oconee fuel determined an exposure reactivity bias of 0.0048 Δk at 50 GWD/MTU to be applied linearly versus burnup. However, a more conservative value will be used which is consistent with other boron credit analyses (Reference 8.1). A value of 0.01 Δk at 30 GWD/MTU applied linearly versus burnup will be used for the calculated reactivity uncertainty.

To determine the amount of boron credit required to compensate for the uncertainty in the calculation of burnup, the burnup credit reactivity bias is determined for the highest burnup requirement from the fuel storage curves for each pool. The calculated burnup uncertainty is then included in the determination of the soluble boron credit 95/95 maximum design k_{eff}.

The uncertainty on measured burnup is assumed to be 4%. To assume a burnup uncertainty of 4% is to assume the measured power distribution was low by 4% for its entire depletion history, when in reality it is low at times and high at other times. The value of 4% chosen for the Measured Burnup Uncertainty appears to be quite conservative, especially in light of the recent EPRI report TR-112054 ("Determination of the Accuracy of Utility Spent Fuel Burnup Records" - July 1999), which concludes that Measured Burnup Uncertainties on the order of 2% are justifiable.

To determine the amount of boron credit required for the measurement uncertainty on burnup, the highest burnup requirement from the fuel storage curves for each region is determined. The highest burnup requirement is then reduced by 4%. SIMULATE-3 is then run at the actual burnup limit, with the burnup reduced 4%. The increase in reactivity for the 4% reduced burnup is then included in the determination of the soluble boron credit 95/95 maximum design k_{eff}.

Since the criticality analyses used to define the spent fuel storage limits are performed in two dimensions, non-conservative axial burnup distribution reactivity effects must be accounted for as a separate bias. In a supporting calculation for this request, a conservative set of biases was developed that accounts for the reactivity difference between a fuel assembly with an explicit axial (3-D) burnup profile and one with a uniform (2-D) profile at the same average burnup. A realistic bounding axial burnup profile was determined by sampling several burnup shapes from recent Oconee reactor operation core-follow calculations. Explicit 3-D calculations with these burnup profiles were then performed (including top and bottom reflectors), and the resulting k_{eff}s were compared with those of their uniform-profile 2-D counterparts. The biases were computed and tabulated as a function of both burnup and initial enrichment. Trends are consistent with those published in the Westinghouse Spent Fuel Rack Criticality Analysis (WCAP-14416-NP-A), although the biases calculated by Duke are generally higher than the biases reported by Westinghouse.

In the total k_{eff} equations for boron credit calculations in the spent fuel pool criticality analysis, the conservative axial bias corresponding to the highest enrichment / burnup storage limit was employed, since, among all enrichment / burnup combinations on the reactivity equivalence curve, the highest yields the largest positive axial bias. For Unrestricted storage, this is the burnup limit for Unrestricted 5.00 wt % U-235 fuel. For Restricted storage, these are the burnup requirements for Restricted and Filler fuel at 5.00 wt % U-235. The axial burnup reactivity biases are then included in the determination of the soluble boron credit 95/95 maximum design k_{eff}. The boron credit requirements are summarized in Table 10.

4.0 <u>ACCIDENT CONDITIONS</u>

As part of the criticality analysis for the Oconee spent fuel pools, abnormal and accident conditions are considered to verify that acceptable criticality margin is maintained for all conditions. Most accident conditions will not result in an increase in k_{eff} of the rack. However, accidents can be postulated which would increase the reactivity of the spent fuel pool. These accidents must be analyzed to verify acceptable criticality safety margin exists. Since boron is used to compensate for reactivity increases as a result of postulated accidents, acceptable criticality safety margin exists if the total boron requirements are less than the normal concentration in the storage pool water. The exception to this is a fuel pool water temperature change event (described later in this section) that may occur concurrently with a spent fuel pool boron dilution event. The boron requirement for such a temperature change accident must be compared against the minimum credible boron concentration following a worst-case dilution event.

The most severe accident in terms of criticality is the drop of a heavy load onto the spent fuel pool racks. In accordance with NUREG-0612, the criticality consequences of a postulated heavy load drop onto the Oconee spent fuel racks are re-analyzed to account for the loss of Boraflex and the changed fuel storage configurations associated with this TS amendment. This evaluation considers a scenario in which a heavy load (e.g., dry storage transfer cask and/or crane equipment) falls onto the spent fuel storage racks, crushing them together in an optimum-reactivity arrangement. The revised heavy load drop analysis shows that the minimum required spent fuel pool boron concentration (currently 2220 ppm) is sufficient to maintain the maximum k_{eff}, including all biases and uncertainties, below 0.95, thereby meeting the subcriticality acceptance criterion of NUREG-0612. The evaluation for the heavy load drop considered all pertinent mechanical, calculational, and boron measurement biases and uncertainties in determining its bounding k_{eff}s. The most reactive crushed-rack scenario yielded a 95/95 k_{eff} of 0.9491 with 2220 ppm of boron in the spent fuel pool water. To maintain k_{eff} below 0.95 for the worst-case heavy load drop event, then, it is necessary to have the minimum boron concentration (2220 ppm) available.
Another accident that can increase rack k_{eff} is the misloading of an assembly; in particular, misloading the highest reactive assembly allowed in the pool in place of the lowest reactive assembly. The scenario for such an accident is the substitution of a fresh 5.00 wt % U-235 fuel assembly for a required Filler assembly.

Since the SIMULATE-3 models for the Oconee storage racks consist of a 2x2 array reflected with periodic boundary conditions, the substitution of a fresh 5.00 wt % U-235 fuel assembly for a required Filler assembly is extremely conservative since this accident condition is infinitely reflected. A more realistic representation of this accident is to model a larger array, and misloading a single assembly near the center of this array. However, since substantial criticality margin exists, the overly conservative 2x2 array is sufficient. Note that Reference 8.7 requires that only a single fuel assembly misload be analyzed unless there are circumstances that make multiple loading errors credible. Redundant checks and procedural verifications of each fuel assembly movement within the Oconee spent fuel pools preclude the occurrence of multiple fuel assembly loading errors in any storage region.

Other accidents which could have an impact on reactivity in the spent fuel pool are those that affect the water temperature of the spent fuel pool. Accidents can be postulated which either increase or decrease the temperature of the spent fuel pool. Therefore, to bound the conceivable range of temperatures of the spent fuel pool water, the accident analysis considers water temperatures of 32 and 212 ^{o}F. The results of this temperature change evaluation show that a maximum of 500 ppm boron is required to maintain k_{eff} below 0.95 at the most reactive temperature, 212 ^{o}F. Since it is plausible that such temperature change accidents can occur in conjunction with a spent fuel pool boron dilution event, it is necessary to compare the 500 ppm required to the worst-case credible dilution event boron concentration in either Oconee spent fuel pool. This dilution event boron concentration, as detailed in Attachment 7 for the SSF drawdown/refill event in the Unit 1&2 SFP, is 825 ppm. Therefore, adequate subcriticality margin exists for situations in which a spent fuel pool heatup or cooldown occurs concurrently with a boron dilution event.

With the exception of the heavy load drop event, which is evaluated at 2220 ppm boron, the above accident conditions are analyzed and the boron concentration is iterated upon until the calculated k_{eff} is less than the no boron 95/95 maximum design k_{eff}. This boron concentration, combined with the boron concentration for boron credit 95/95 k_{eff} from Section 3.2 represents the total credit for boron that is required for accident conditions. This total boron requirement must be less than the normal spent fuel pool boron concentration ($\geq$ 2220 ppm) or, for the case of the fuel pool water temperature change accidents, less than the worst-case credible dilution event boron concentration.

Note that by combining the boron required for accidents with the boron required to maintain $k_{eff} \leq 0.95$ (i.e. the boron credit 95/95 maximum design k_{eff}), the accident conditions are imposed on top of the dilution accident for the total boron requirements. However, accident conditions are not assumed with no boron conditions. This is consistent with previous criticality analysis methodology where the double contingency principle is applied for accidents. The double contingency principle allows credit for soluble boron under other abnormal or accident conditions since only a single accident need be considered at one time. To not assume the presence of some boron would be a second unlikely event. The difference with the boron credit methodology is that, for added assurance that sufficient criticality safety margin exists, the dilution of the pool with perfect mixing to 825 ppm in the Unit 1 & 2 pool and 957 in the Unit 3 pool is assumed to be a credible event.

The additional boron credit requirements for accident conditions are summarized in Table 10.

5.0 BORON CREDIT SUMMARY

This analysis takes partial credit for soluble boron in the spent fuel pool for both normal and accident conditions. Boron credit is used to compensate for uncertainties related to reactivity equivalencing and accident conditions. The total boron credit requirements for each pool are shown in Table 10 and summarized below.

Oconee Unit 1 & 2 Pool Summary of Boron Requirements		
	Boron Credit Required	Boron Available
Normal Conditions	400	825[1]
SFP Heatup (above 150 °F) Accident Condition, concurrent with worst-case dilution event	470	825[1]
All other Accident Conditions	2220	2220[2]

Oconee Unit 3 Pool Summary of Boron Requirements		
	Boron Credit Required	Boron Available
Normal Conditions	430	957[1]
SFP Heatup (above 150 °F) Accident Condition, concurrent with worst-case dilution event	500	957[1]
All other Accident Conditions	2220	2220[2]

[1] - From dilution analysis (see Attachment 7)
[2] - Current limit specified in the Core Operating Limits Report. The 2220 ppm boron concentration is imposed as an additional numeric lower limit in the proposed changes to the surveillance requirements for TS 3.7.12 (SFP Boron Concentration), and TS 3.5.4 (BWST).

6.0 REGION INTERFACE RESTRICTIONS

Fuel will be stored in each spent fuel pool according to three different loading configurations. The boundary conditions between these configurations are analyzed to assure that the storage configurations at a boundary do not cause an increase in the nominal k_{eff} above the design criteria limit on k_{eff} for the pool. The design criterion is that k_{eff} remain less than 1.0 with no boron (excluding certain burnup-related uncertainties described in Section 3.2.1). This is the most limiting criterion since there is a large margin between the boron required and the boron available to the $k_{eff} \leq 0.95$ limit with boron as shown in Section 5.0. This analysis is performed to determine if there is a need for revised administrative restrictions at the boundaries. The results of this evaluation indicate that the region interface restrictions listed below are necessary.

Region Interface Restrictions Units 1 and 2 Spent Fuel Pool

Unrestricted Storage	No restrictions
Restricted Storage	Storage Regions of Restricted Fuel shall not be bounded by Checkerboard Fuel regions. Therefore, Restricted Fuel regions must be bounded by either i) at least one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool.
Checkerboard Storage	Storage Regions of Checkerboard Fuel shall not be bounded by Restricted Fuel regions. Therefore, Checkerboard Fuel regions must be bounded by either i) at least one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool. In addition, at least three of the four faces of each Checkerboard Fuel assembly must be adjacent to an empty cell, at all boundaries between storage regions.

Region Interface Restrictions Unit 3 Spent Fuel Pool

Unrestricted Storage	No restrictions
Restricted Storage	Storage Regions of Restricted Fuel shall not be bounded by Checkerboard Fuel regions. Therefore, Restricted Fuel regions must be bounded by either i) at least one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool.
Checkerboard Storage	Storage Regions of Checkerboard Fuel shall not be bounded by Restricted Fuel regions. Therefore, Checkerboard Fuel regions must be bounded by either i) at least one row of fuel qualifying as Unrestricted Fuel (including empty cells as necessary), ii) one row of empty cells, or iii) a wall of the spent fuel pool. In addition, at least three of the four faces of each Checkerboard Fuel assembly must be adjacent to an empty cell, at all boundaries between storage regions.

7.0 SUMMARY OF RESULTS

The results of the criticality analysis for the Oconee spent fuel storage racks indicate that the acceptance criteria for criticality are met; that is, $k_{eff} \leq 0.95$ including all uncertainties. This analysis takes credit for soluble boron, credit for burnup, and no credit for Boraflex. Each spent fuel pool has three storage configurations: Unrestricted, Restricted and Checkerboard storage.

The spent fuel storage limits are summarized in Tables 7 through 9 and Figures 5 and 6. Note that the "design maximum" enrichment indicated in Tables 7 through 9 is the nominal maximum enrichment of any fuel pin in the assembly being considered. The maximum allowed enrichment tolerance is 0.05 wt % U-235.

The total boron credit requirements for these configurations in the Unit 1 & 2 pool are 400 ppm for normal conditions, 470 ppm for the SFP heatup event (pool temperature above 150 °F), and 2220 ppm to bound all other accident conditions. The total boron credit requirements for these configurations in the Unit 3 pool are 430 ppm for normal conditions, 500 ppm for the SFP heatup event, and 2220 ppm to bound all other accident conditions.

8.0 REFERENCES

8.1 Westinghouse Spent Fuel Rack Criticality Analysis Methodology," WCAP-14416-NP-A, Westinghouse Commercial Nuclear Fuel Division, Revision 1, November, 1996.

8.2 "Issuance of Amendments - Oconee Nuclear Station, Units 1, 2 and 3," Amendment Nos. 209, 209 and 206 to Facility Operating Licenses DPR-38, DPR-47 and DPR-55, U.S. Nuclear Regulatory Commission, May 3, 1995.

8.3 Baldwin, Hoovler, Eng, and Welfare, "Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel", B&W-1484-7, July, 1979.

8.4 Beirman, S.R., Clayton, E.D., "Criticality Experiments with Subcritical Clusters of 2.35 and 4.31 wt% 235U Enriched UO2 Rods in Water at a Water to Fuel Volume Ratio of 1.6" PNL-3314, July 1980.

8.5 Beirman, S.R., et al, "Critical Separation Between Subcritical Clusters of 2.35 wt% 235U Enriched UO2 Rods in Water with Fixed Neutron Poisons" PNL-2438, October 1977.

8.6 Beirman, S.R., "Criticality Experiments to Provide Benchmark Data on Neutron Flux Traps" PNL-6205, June 1988.

8.7 Letter from L. Kopp (NRC) to T. Collins (NRC), "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants", August 19, 1998.

Table 1 - CASMO-3/TABLES-3/SIMULATE-3, Benchmarking Results

Core	Soluble Boron	Moderator Temp	Separation Spacing (cm)	Poison Sheet (%B)	k_{eff} calc	k_{eff} meas	Bias
2	1037	18.5	0	n/a	1.00271	1.0001	-0.00261
3	764	18	1.636	n/a	1.00319	1.0000	-0.00319
9	0	17.5	6.544	n/a	.99908	1.0030	0.00392
10	143	24.5	4.908	n/a	.99795	1.0001	0.00215
11	514	26	1.636	SS	1.00493	1.0000	-0.00493
13	15	20	1.636	1.614	1.00914	1.0000	-0.00914
14	92	18	1.636	1.257	1.00451	1.0001	-0.00441
15	395	18	1.636	0.401	.99608	0.9988	0.00272
17	487	17.5	1.636	0.242	.99889	1.0000	0.00111
19	634	17.5	1.636	0.1	1.00003	1.0002	0.00017
				avg k_{eff}calc	1.00165	st.dev calc	0.00412
				avg k_{eff} meas	1.00023	avg bias	-0.00142

CASMO-3/TABLES-3/SIMULATE-3 Methodology Bias = -0.00142

CASMO-3/TABLES-3/SIMULATE-3 Methodology Uncertainty = 0.01199

Table 2 - KENO-Va, Benchmarking Results

Report	Exp. Number	Calculated k_{eff}	std dev	Report	Exp. Number	Calculated k_{eff}	std dev
PNL-3314	043	0.99991	0.00295	PNL-3314	085	0.98979	0.00354
PNL-3314	045	0.9984	0.00335	PNL-3314	094	0.99568	0.00383
PNL-3314	046	0.9999	0.0033	PNL-3314	095	0.99914	0.004
PNL-3314	047	1.00532	0.00346	PNL-3314	096	0.99908	0.00349
PNL-3314	048	1.00083	0.00326	PNL-3314	097	0.99731	0.00342
PNL-3314	04c	0.99727	0.00317	PNL-3314	098	0.99494	0.00353
PNL-3314	051	1.00114	0.00392	PNL-3314	100	0.99621	0.00378
PNL-3314	053	0.99105	0.0035	PNL-3314	101	0.99799	0.00391
PNL-3314	055	0.99502	0.00409	PNL-3314	105	0.99911	0.00339
PNL-3314	056	0.99249	0.0038	PNL-3314	106	0.99323	0.00353
PNL-3314	057	0.99603	0.00317	PNL-3314	107	0.99812	0.00302
PNL-3314	058	0.99613	0.00321	PNL-3314	131	0.99708	0.00379
PNL-3314	059	0.99233	0.00377	PNL-3314	996	1.0115	0.00304
PNL-3314	060	0.99657	0.00362	PNL-3314	997	1.00775	0.00305
PNL-3314	061	0.99331	0.00371	PNL-2438	005	0.9923	0.00348
PNL-3314	062	0.9954	0.00418	PNL-2438	014	0.99212	0.00321
PNL-3314	064	0.98736	0.00351	PNL-2438	015	0.99207	0.00301
PNL-3314	065	0.99728	0.00392	PNL-2438	021	0.99119	0.00302
PNL-3314	066	0.9942	0.00374	PNL-2438	026	0.99218	0.00314
PNL-3314	067	0.99153	0.00374	PNL-2438	027	0.99396	0.00312
PNL-3314	068	0.99169	0.00333	PNL-2438	028	0.99092	0.00322
PNL-3314	069	0.99684	0.00396	PNL-2438	029	0.99366	0.00319
PNL-3314	06d	1.00645	0.004	PNL-2438	034	0.99596	0.00323
PNL-3314	070	0.98921	0.00369	PNL-2438	035	0.98911	0.00317
PNL-3314	071	0.99405	0.00342	PNL-6205	214	0.99117	0.00353
PNL-3314	072	0.98865	0.00356	PNL-6205	223	0.99726	0.0038
PNL-3314	073	0.98801	0.00343	PNL-6205	224	0.99329	0.00388
PNL-3314	083	0.99043	0.00341	PNL-6205	229	1.00119	0.00355
PNL-3314	084	0.99366	0.00364	PNL-6205	230	1.00031	0.00406

Average k_{eff} = 0.99559

KENO-Va Methodology Bias = 0.00441

KENO-Va Methodology Uncertainty = 0.00739

Table 3 - CASMO-3 / SIMULATE-3 / KENO Va, Comparisons

Rack Region	Fuel Enrichment	Fuel Type	CASMO k_{eff}	Simulate k_{eff}	KENO k_{eff}
ONS Unit 1 & 2 Pool	2.0	Mark B11	.98034	.980247	.97368
ONS Unit 3 Pool	2.0	Mark B11	.99478	.994680	.98404

Table 4 - No Boron Biases and Uncertainties

Bias or Uncertainty	Unit 1 & 2 Pool	Unit 3 Pool
Methodology Bias*	-0.00142	-0.00142
3-Dimensional Bias*	-0.00309	-0.00312
95/95 Methodology Uncertainty	0.01199	0.01199
Mechanical Uncertainty	0.019770	0.021014
Combined Bias and Uncertainty	0.023122	0.024194
No Boron 95/95 Maximum Design k_{eff}	0.976878	0.975806

Combined Bias and Uncertainty:

$$\Delta k = \Delta k_{MethBias} + \Delta k_{3\text{-Dimensional}} + \sqrt{\Delta k^2_{MethUnc} + \Delta k^2_{MechUnc}}$$

* Negative bias conservatively ignored

Table 5 - Boron Credit Biases and Uncertainties

Unrestricted Storage Bias or Uncertainty	**Unit 1 & 2 Pool**	**Unit 3 Pool**
Methodology Bias*	-0.00142	-0.00142
3-Dimensional Bias*	-0.00309	-0.00312
BP-Pull Bias	0.008	0.008
Calculational Burnup Uncert	0.011356	0.012099
Measurement Burnup Uncert	0.008366	0.008883
Axial Burnup Bias	0.009003	0.012594
95/95 Methodology Uncertainty	0.01199	0.01199
Mechanical Uncertainty	0.020700	0.022521
Base Combined Bias and Uncert	0.023921	0.025514
Final Combined Bias and Uncert	0.060647	0.067090

Restricted Storage Bias or Uncertainty	**Unit 1 & 2 Pool**	**Unit 3 Pool**
Methodology Bias*	-0.00142	-0.00142
3-Dimensional Bias*	-0.00309	-0.00312
BP-Pull Bias	0.008	0.008
Calculational Burnup Uncert	0.011769	0.012588
Measurement Burnup Uncert	0.008142	0.008532
Axial Burnup Bias	0.009849	0.015165
95/95 Methodology Uncertainty	0.01199	0.01199
Mechanical Uncertainty	0.020700	0.022521
Base Combined Bias and Uncertainty	0.023921	0.025514
Final Combined Bias and Uncertainty	0.061682	0.069799

Boron Credit 95/95 Maximum Design k_{eff} (**Base** Calc - Fresh Fuel, All Storage)	0.926079	0.924486

Table 5 - Boron Credit Biases and Uncertainties (continued)

Unrestricted Storage -- Boron Credit 95/95 Maximum Design k_{eff} (**Final** Calc - including Reactivity Equivalencing)	0.889353	0.882910
Restricted Fuel -- Boron Credit 95/95 Maximum Design k_{eff} (**Final** Calc - including Reactivity Equivalencing)	0.888318	0.880201

Base Combined Bias and Uncertainty:

$$\Delta k = \Delta k_{\text{MethBias}} + \Delta k_{\text{3-Dim}} + \sqrt{\Delta k^2_{\text{MethUnc}} + \Delta k^2_{\text{MechUnc}}}$$

Final Combined Bias and Uncertainty:

$$\Delta k = \Delta k_{\text{MethBias}} + \Delta k_{\text{3-Dim}} + \Delta k_{\text{BP-pull}} + \Delta k_{\text{CalcBUUnc}} + \Delta k_{\text{MeasBUUnc}} + \Delta k_{\text{AxialBUBias}} + \sqrt{\Delta k^2_{\text{MethUnc}} + \Delta k^2_{\text{MechUnc}}}$$

* Negative bias conservatively ignored

Table 6 - Summary of Maximum Fresh Fuel Enrichment Limits (w/o U-235)

Type of Storage	Unit 1 & 2 Pool	Unit 3 Pool
Unrestricted	1.91	1.81
Restricted	2.56	2.48
Filler	1.41	1.31
Checkerboard	5.00	5.00

Table 7 - Minimum Qualifying Burnup versus Initial Design Maximum Enrichment For Unrestricted Storage

Oconee 1/2 Pool		Oconee 3 Pool	
Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)	Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)
1.91	0.00	1.81	0.00
2.00	1.43	2.00	3.16
2.50	8.08	2.50	9.79
3.00	13.85	3.00	15.72
3.50	19.30	3.50	21.30
4.00	24.47	4.00	26.54
4.50	29.35	4.50	31.50
5.00	34.07	5.00	36.30

Table 8 - Minimum Qualifying Burnup versus Initial Design Maximum Enrichment For Restricted Storage

Oconee 1/2 Pool		Oconee 3 Pool	
Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)	Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)
2.56	0.00	2.48	0.00
3.00	4.19	3.00	5.00
3.50	8.68	3.50	9.59
4.00	13.02	4.00	14.01
4.50	17.31	4.50	18.38
5.00	21.53	5.00	22.60

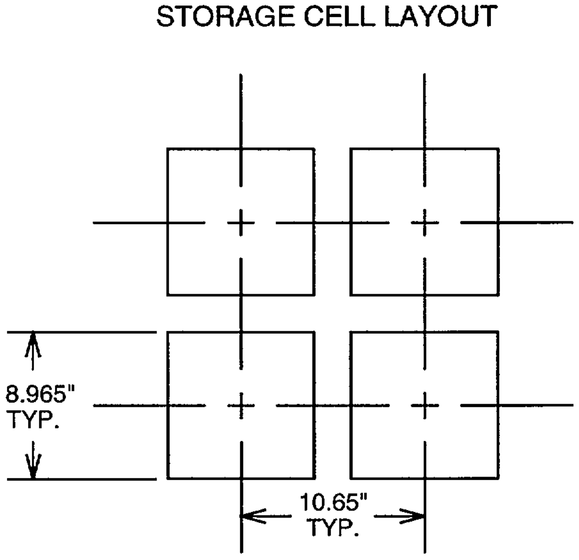
Table 9 - Minimum Qualifying Burnup versus Initial Design Maximum Enrichment For Filler Assemblies

Oconee 1/2 Pool		Oconee 3 Pool	
Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)	Initial Design Maximum Enrichment (wt % U-235)	Minimum Burnup (GWD/MTU)
1.41	0.00	1.31	0.00
2.00	12.28	2.00	15.40
2.50	19.68	2.50	22.96
3.00	26.28	3.00	29.59
3.50	32.39	3.50	35.82
4.00	38.18	4.00	41.76
4.50	43.73	4.50	47.45
5.00	49.09	5.00	52.93

Table 10 - Summary of Boron Credit Requirements

	Unrestricted		Restricted w/ Filler	
	o12	ou3	o12	ou3
k-eff $\leq$ 0.95				
Boron required for k-eff $\leq$ 0.95	170	170	170	170
Reactivity Equivalencing				
Additional boron required for burnup credit uncertainties	230	260	230	260
Accident conditions				
Boron required for misload	1110	1210	1110	1210
Boron required for abnormal heat load	470	500	470	500
Boron required for emergency makeup	400	430	400	430
Boron required for heavy load drop	2220	2220	2220	2220
Boron required for single assy in water	270	270	270	270
Total Boron Credit Required w/o Accidents	400	430	400	430
Total Boron Credit Required with Accidents	2220	2220	2220	2220

Figure 1 - Oconee Unit 1 and 2 Fuel Pool Layout



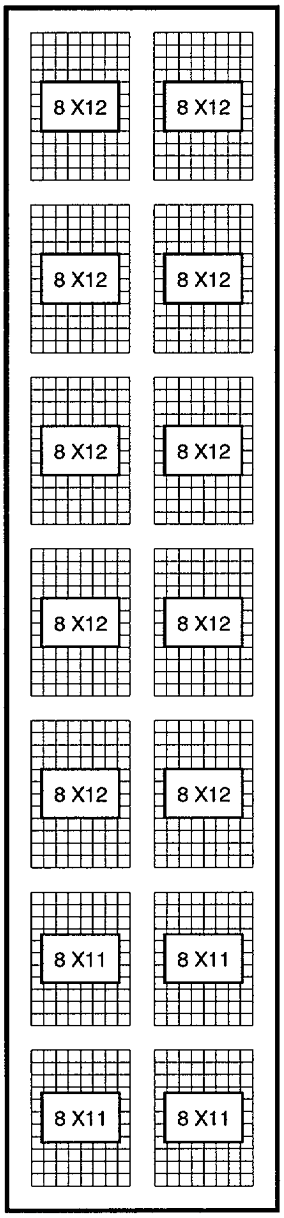
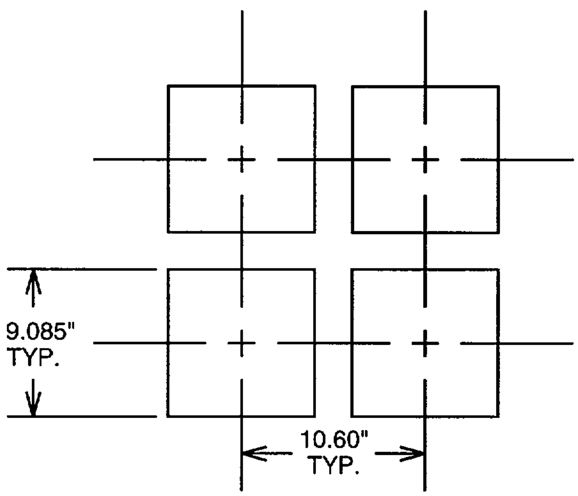


Figure 2 - Oconee Unit 3 Fuel Pool Layout

STORAGE CELL LAYOUT



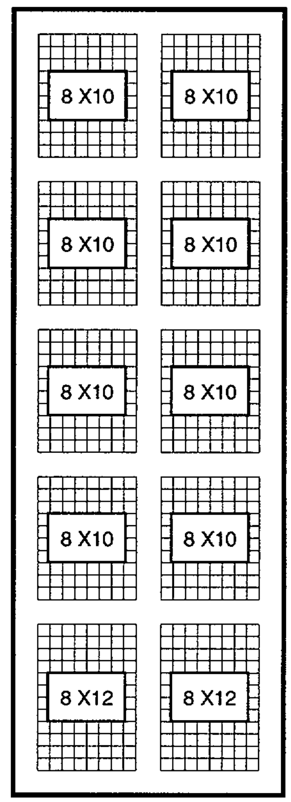


Figure 3 - 2 out of 4 Restricted Storage Pattern

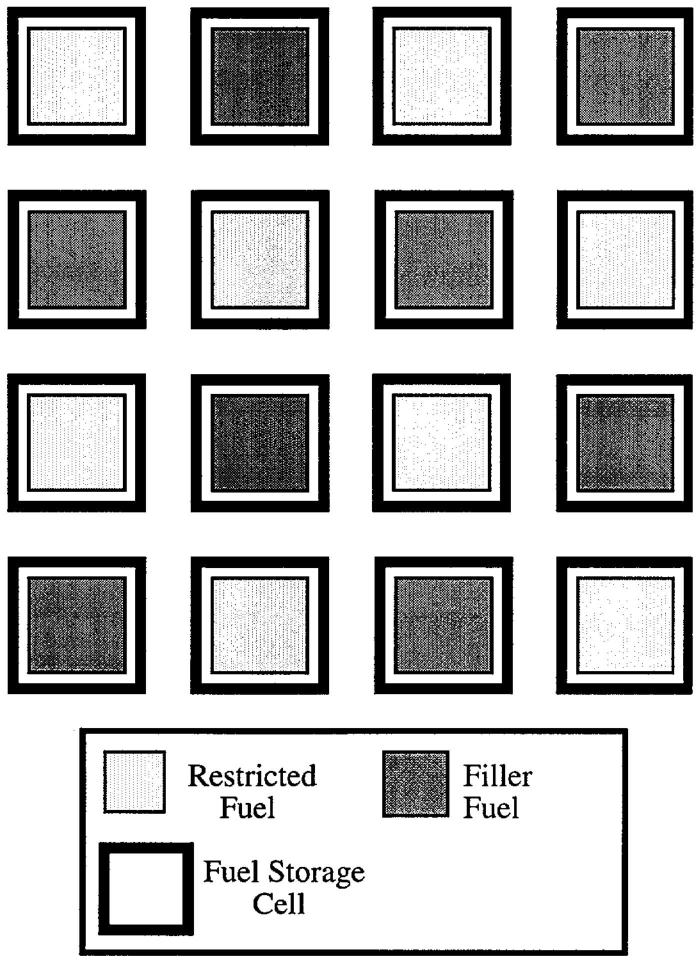


Figure 4 - 2 out of 4 Checkerboard Storage Pattern

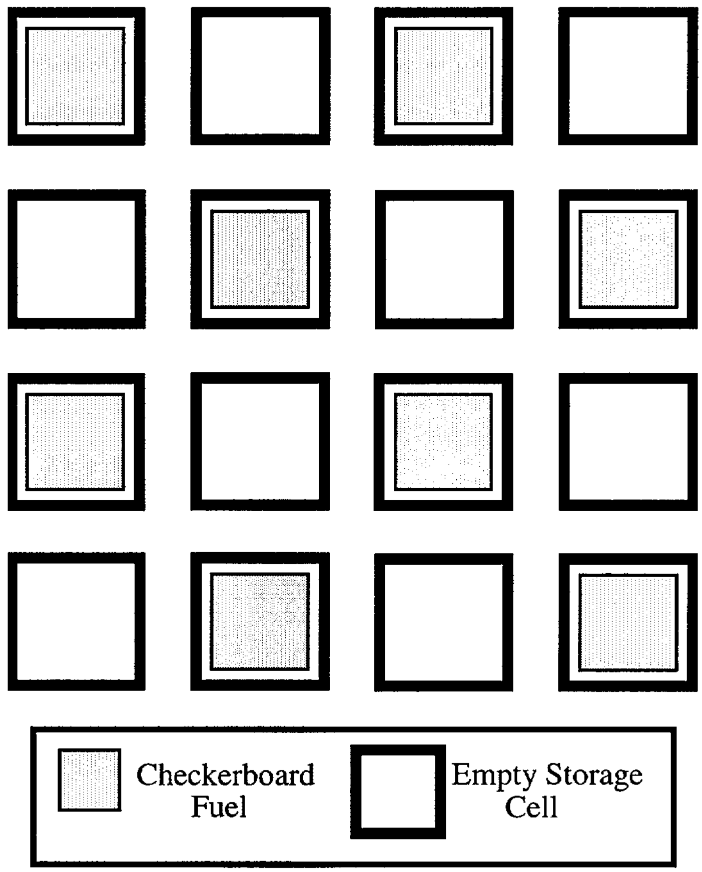
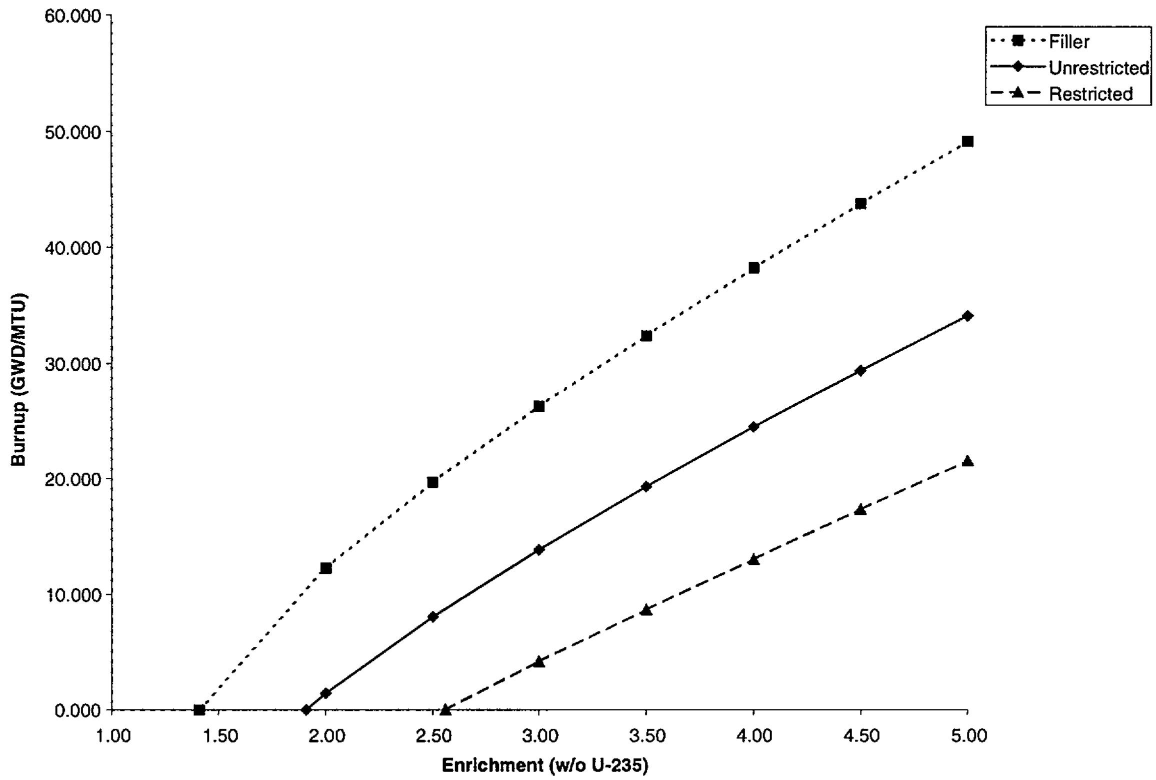
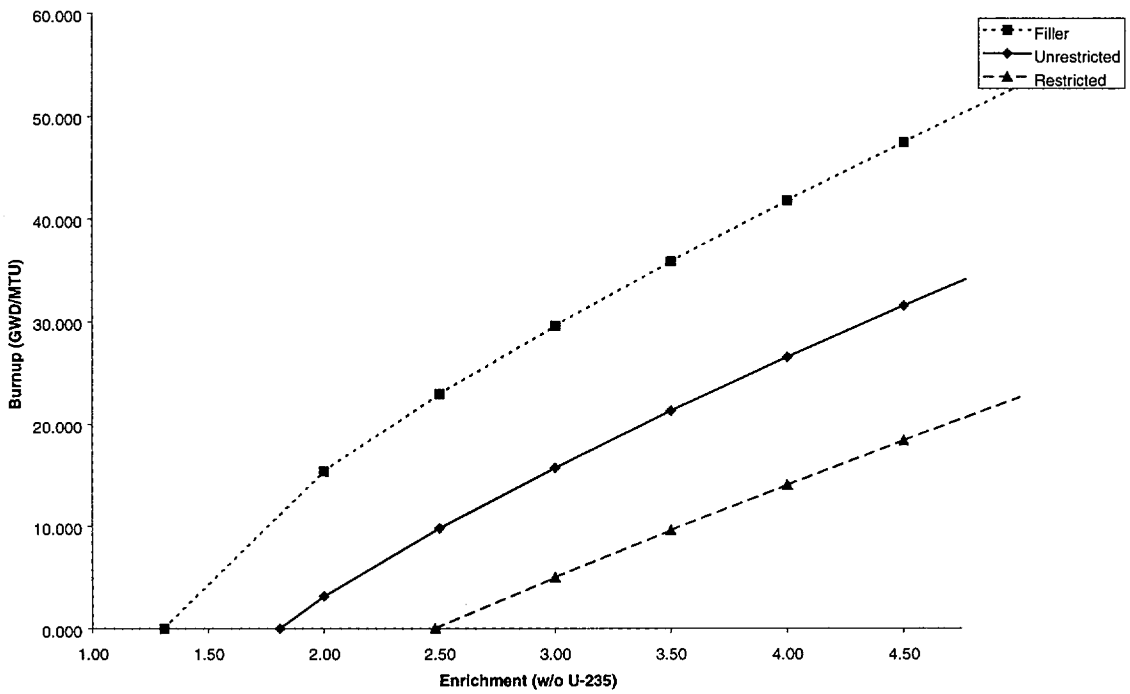


Figure 5 - Oconee Units 1 and 2 Pool, Burnup Versus Enrichment Limits



Note: Plotted from data provided on Tables 7, 8 and 9.

Figure 6 - Oconee Unit 3 Pool, Burnup versus Enrichment Limits



Note: Plotted from data provided on Tables 7, 8 and 9.

Attachment F

Duke Energy Corporation
Response to Request for Additional Information

Replacement
License Amendment Request Attachment 7,
"Evaluation of Potential Boron Dilution Accidents for the Oconee Spent Fuel Pools"

Note:

Changes from the original request, as supplemented, are indicated by change bars.

Evaluation Of Potential Boron Dilution Accidents For The Oconee Spent Fuel Pools

Table of Contents

1.0 INTRODUCTION/BACKGROUND

The current criticality analysis for the Oconee Spent Fuel Pools takes credit for a solid boron material in the fuel racks known as Boraflex. This material has unexpectedly degraded over time and has lead to a loss of boron in the material. As this degradation has continued, it has become necessary to reduce or eliminate credit for the solid boron in the racks in the criticality analysis. In order to continue meeting criticality design criteria, it is necessary to take credit for soluble boron contained in the spent fuel pool water. Potential accidents that could add significant amounts of unborated water to the spent fuel pools causing dilution of the pool boron concentration are identified and evaluated. This evaluation will determine the minimum possible boron concentration that could result from a credible boron dilution accident event. The results will also provide timing estimates of boron concentrations resulting from these accidents.

The overall governing methodology for crediting soluble boron is described in WCAP-14416-NP-A (Reference 1). This approach requires that a boron dilution analysis be performed to ensure that sufficient time is available to detect and mitigate the dilution before the 0.95 k_{eff} criticality design basis criterion is exceeded. This approach further states that the dilution analysis should include an evaluation of the following plant-specific features:

1. Spent Fuel Pool and Related System Features
   a) Dilution Sources
   b) Dilution Flow Rates
   c) Boration sources
   d) Instrumentation
   e) Administrative Procedures
   f) Piping
   g) Loss of Off-Site Power Impact
2. Boron Dilution Initiating Events (including operator error)
3. Boron Dilution times and Volumes.

The staff has concluded that the new methodology in WCAP-14416 can be used in licensing actions. All licensees proposing to use the new method for soluble boron credit should identify potential events which could dilute the spent fuel pool boron to the concentration required to maintain the criticality safety limit and should quantify the time span of these dilution events to show that sufficient time is available to enable adequate detection and suppression of any dilution event. The effects of incomplete boron mixing should be considered.

The methodology employed uses four basic steps:

1. Develop Preliminary List of Potential Events
2. Screen Events that are not Credible or are Irrelevant
3. Evaluate Events for Dilution Times and Volumes
4. Summarize Results and Conclusions

A preliminary list of events for review was developed through the review of several industry studies and review of the design of the Oconee Spent Fuel Pool and related systems. A plant walkdown was conducted to examine spent fuel pool structural features and the spatial relationships between the spent fuel pool and related plant systems. A review of industry spent fuel pool operating experience did not identify any new failure modes that were not considered. Many types of postulated events were screened because they lead to consequences different than deboration, and others were screened because they are not credible with the Oconee pool design.

Events which were not initially screened were evaluated further to determine the potential impact of those events on pool boron concentration. In some cases, the accident source of unborated water comes from a finite source that is relatively small compared to the volume of the pool. These events were evaluated to show the resulting boron concentration if the entire source were added to the pool and the length of time required to do so. The review of plant systems and structural design and a plant walkdown also examined whether any sources of unborated water could come from continuously flowing systems originating at Lake Keowee. These so-called "infinite" water sources were evaluated for the highest flow rate as the bounding case, and evaluated to determine the available time for operator action to show that sufficient time is available to terminate the flow into the pool.

Note that the NRC's acceptance of the WCAP-14416 methodology includes a reference to WCAP-14181 which provides additional guidance for evaluating boron dilution events (Reference 4). WCAP-14181 provides an example problem and set of equations to evaluate the rate of boron dilution at various flow rates. The equations derived in WCAP-14181 assume that the pool begins to overflow as soon as unborated water is added to the SFP (i.e., it maintains a constant mixing volume). This assumption is conservative in that no consideration is given to the significant volume of water that must be added to finish filling up the pool to the top.

Most of the dilution events considered are evaluated using this standard methodology. However, there are two scenarios which do not involve overflow of the SFP and can not be evaluated using the standard methodology. Both in the SSF and the HPI Suction Alignment scenarios, some of the initial SFP water volume is intentionally removed and later replaced with unborated water.

To evaluate these scenarios, the standard methodology was modified to adapt a new set of assumptions using the general approach of WCAP-14416. A new set of dilution equations were developed to replace those previously provided by WCAP-14181 in order to reflect the conditions involved in this alternative dilution process. A complete description of the alternate methodology is provided in Section 6.0.

2.0 ASSUMPTIONS

A number of important assumptions were made to perform this analysis. Most of the major assumptions are discussed below. Other assumptions are discussed in the analysis as they arise.

2.1 Design Criteria

The spent fuel pool is the source of borated water for the Standby Shutdown Facility (SSF). As such, it is required to supply the required flow for 72 hours. The spent fuel pool must supply the SSF intake with a maximum of 29 gpm per unit.

Technical Specification 3.7.11 (Spent Fuel Pool Water Level) requires that spent fuel pool water level shall be ≥ 21.34 feet above the top of irradiated fuel assemblies. This level corresponds to elevation 837.84'. Therefore, allowing for instrument uncertainty, the lowest spent fuel pool water level permitted during operation is 2 feet (indicated) below the normal level 840'. A total level instrument uncertainty of 0.16 feet is estimated based on 0.11 feet of instrument string uncertainty plus an addition 0.05 feet due to parallax error reading the gauge.

An assumption used in the thermal hydraulic analysis for the current spent fuel pool rack design requires that the minimum water level in the Units 1 and 2 spent fuel pool shall never drop below one (1) foot above the top of the fuel assemblies.

2.2 Similarities and Differences Between Unit 1 and 2 Spent Fuel Pool (SFP) and Unit 3 SFP

Figure 1 provides a diagram of the elevations of the Unit 1 and 2 spent fuel pool. The layout and arrangement of the Unit 3 Spent Fuel Pool is similar to the Unit 1 and 2 Spent Fuel Pool except it only has one set of Fuel Transfer Tubes and is shorter in length. This difference in length is the primary difference between the pools that affects the boron dilution analysis and results in a small volume of water. No significant differences were found in design parameters between the interfacing systems for each spent fuel pool except that a filtered water system line runs through the Unit 3 spent fuel pool area. Although there were some differences in piping layout around the pool areas and in the spent fuel pool cooling systems, no other differences were found that would have any obvious effect on the rate or magnitude of dilution in either pool. As a result of the difference in volume, separate calculations are made for each Spent Fuel Pool.

2.3 Boron Concentration

The initial pool boron concentration is conservatively assumed to be 2220 ppm. This corresponds to the COLR limit currently in use for all three units at Oconee. Normal pool boron concentration is 2500 ppm. Based on the double contingency principle, it is not necessary to postulate that the pool boron concentration is below its TS minimum concentration concurrently with a second (unlikely) event that puts a large volume of unborated water into the pool (Reference 1).

2.4 Spent Fuel Pool Water Level

The initial pool water level is assumed to be at the normal level at elevation 840'. The TS minimum level is 21.34 feet above the fuel, which corresponds to an elevation of 837' + 10". However, due to the double contingency principle, it is not necessary to postulate that the spent fuel pool level is below its normal level concurrently with a second (unlikely) event that puts a large volume of unborated water into the pool.

Therefore, the initial volume of water (V_0) will credit water up to normal elevation 840'. The outline dimensions of each pool are shown in Figure 1. The volume of water in the pool is also dependent upon the number of fuel assemblies in the spent fuel pool at a given time. It is assumed for all accidents except the SSF and HPI Suction Alignment scenarios that the maximum number of fuel assemblies (FA) in the spent fuel pool are 1312 FA for U1/U2 and 825 FA for U3. In the SSF and HPI Suction Alignment scenarios, the maximum number assemblies in the pool depends on the number of units generating power (or in startup). If Units 1 and 2 are both generating power, there can only be a maximum of 1195 FA in the U1/U2 spent fuel pool. If Unit 3 is generating power, there can only be a maximum of 708 FA in the U3 spent fuel pool. The volume of water in each pool at normal elevation are 515,740 gallons in the Units 1 and 2 spent fuel pool and 358,460 gallons in the Unit 3 spent fuel pool.

This analysis is only addressing dilution events where there is the potential to add large amounts of unborated water to the spent fuel pool. Events involving a large loss of spent fuel pool coolant inventory are not evaluated for boron dilution from emergency makeup used to restore spent fuel pool level. Certain catastrophic failures of the pool could result in a large loss of spent fuel pool inventory that could cause a zircaloy cladding fire. However, it is assumed that plant procedures will address boron addition as a part of the emergency makeup response. In addition, the revised spent fuel pool criticality analysis examines a case where there is no soluble boron in the spent fuel pool. Emergency makeup without boration could lead to a loss of all boron and thus a loss of criticality safety margin; however, the "no boron" case shows that k_{eff} will remain less than 1.0, including reactivity biases and uncertainties, with the exception of certain burnup-related uncertainties described in Attachment 6.

2.5 Mixing Factors

It is conservatively assumed that any unborated water that enters the pool will mix completely with the existing water in the pool. Complete mixing generally maximizes the rate of boron dilution. This assumption is consistent with the approach used in Reference 2 and in similar licensing submittals made by other licensees.

Good mixing is expected for the dilution events of interest. Operation of the Spent Fuel Cooling (SF) System in conjunction with thermal mixing of warmer water rising from the fuel help ensure good mixing in the pool. Specifically, the SF pumps continuously recirculate water from the North end of the pool to the South end. Normally only 1 or 2 SF Pumps are in service with a capacity of approximately 900 gpm each. During refueling outages, all three SF Pumps are usually in service.

Partial mixing may occur in cases where a pipe breaks in the pool area and causes the pool to overflow. In this case, the water entering the pool may not fully mix with the rest of the pool inventory before exiting the pool. Partial mixing in this case would serve only to slow-down the dilution of the rest of the pool. However, it is unnecessary and impractical to attempt to quantify mixing effectiveness. The potential for "pockets" of lower boron concentration or other mixing problems are bounded by the "no boron" criticality case and do not need to be considered further. The availability and capacity of the SF pumps to induce mixing also does not need to be considered.

In the SSF and HPI Suction Alignment scenarios, it is assumed that makeup to the spent fuel pool does not begin until the end of the event after all of the SSF or HPI coolant volume has been removed. Under this assumption, the degree of mixing does not affect the results.

2.6 Piping Break Sizes

It is assumed that any piping system in the spent fuel pool areas could break and discharge into the pool. For the low pressure systems identified in the spent fuel pool areas, there is no specified licensing criteria for piping break size. In such cases, the break size (or break flow rate) selected should be chosen commensurate with the size of the piping involved, the system pressure, and system flow capacity. These specific considerations are discussed on a case-by-case basis for each postulated line break in Section 5.1.

2.7 Refueling Operations

During refueling outages, the Fuel Transfer Canal (inside the Reactor Building (RB)) is filled with borated water and connected to the Spent Fuel Pool to perform refueling operations. In this configuration, the SF Cooling System suction is typically aligned to draw a portion of its flow from the Fuel Transfer Canal or from the LPI Decay Heat Line coming off of the RCS. This flow goes into the spent fuel pool and is returned to the Fuel Transfer Canal via the Fuel Transfer Tubes (via valves SF-1 and SF-2 shown in Figure 1). In this alignment, a dilution event occurring in the Fuel Transfer Canal could also impact the boron concentration in the spent fuel pool.

For this analysis, it is assumed that dilution events originating in the Fuel Transfer Canal during refueling operations with SF-1 or SF-2 open are bounded by dilution events originating in the spent fuel pool and do not need to be considered separately. This assumption is supported by the following arguments.

- The Fuel Transfer Canal contains a significant amount of water (approx. 39,198 ft^3 not including the deep end (69.5' x 24' x 23.5')). The Reactor Vessel and RCS piping would also be connected to the Fuel Transfer Canal adding another approximately 12,000 ft^3 to the mixing volume. Combined, these volumes provide an additional 51,198 ft^3 of water (approximately 383,000 gallons) not including the Fuel Transfer Canal "Deep End" or the SF system piping volume. This is more than the initial volume in the Unit 3 spent fuel pool and 74% of the initial volume of the Unit 1 and 2 spent fuel pool. This significant amount of additional borated water substantially reduces the amount of potential dilution.

- The dilution sources for the Fuel Transfer Canal are essentially the same for the Fuel Transfer Canal as for the spent fuel pool. The primary sources would be from the Demineralized Water (DW) system and from the BHUTs with the same flow rates and volumes as considered for the Spent Fuel Pools. There is also Filtered Water (FW) System piping in the Fuel Transfer Canal area, however, this system is not in operation and does not need to be considered (See Section 5.2.3).

- The only other piping systems in the RB at an elevation equal to or higher than the operating floor of the Fuel Transfer Canal (Elev. 841'+6") are Component Cooling (CC) and Low Pressure Service Water (LPSW.) The CC System is used to cool the control rod drive stator coolers during power operations, but CC is not in operation during refueling operations and does not need to be considered. The LPSW lines supply cooling water to the RB Auxiliary Coolers (Elev. 844'+6" and 861'+6") and to two fire hose stations on elevation 861'+6". The Aux. Coolers are each supplied by a 4" line and the hose stations are supplied by 2.5" lines. These components and the supply headers are located on the opposite sides of the "D-rings" away from the Fuel Transfer Canal.

- It would be very difficult for water from a break in one of these LPSW supply lines to migrate to the Fuel Transfer Canal because each of the four RB Auxiliary Coolers is located on top of or immediately next to floor grating above the RB Intermediate Floor. There are also 4" floor drains for all of the concrete floor sections on the 844'+6" elevation. Thus, the vast majority of water from such a break would drain directly to the lower elevations of the RB and be detected almost immediately in the RB Normal Sump, well before any high level alarms are indicated by the spent fuel pool level instrumentation. In any case, it is reasonable to assume that the maximum amount of LPSW flow reaching the Fuel Transfer Canal would be less than the 300 gpm flow rate assumed for a DW line break in Section 5.1.

- It is important to note that the top of the Fuel Transfer Canal is at elevation 841'+6" which is 2.5 feet lower than the top of the spent fuel pool (elevation 844'). Thus, if a significant addition of water occurred, the Fuel Transfer Canal would overflow instead of the spent fuel pool. This would lead to a rapid increase in RB Normal Sump level and level indication alarms.

Therefore, considering these factors, it is a reasonable assumption that the consequences of dilution events originating in the Fuel Transfer Canal during refueling operation with SF-1 or SF-2 open are bounded by the consequences of dilution events occurring in the spent fuel pool and do not need to be considered separately.

3.0 IDENTIFICATION AND SCREENING OF DILUTION INITIATING EVENTS

A preliminary list of events for review was developed through the review of several industry studies (References 2 and 3) and review of the Oconee Spent Fuel Pools and related systems. Table 1 provides a listing of the types of events considered and how these events were dispositioned. Many types of postulated events were screened because they lead to consequences different than boron dilution, and others were screened because they are not credible with the Oconee pool designs.

4.0 EVALUATION OF BORON DILUTION TIMES AND VOLUMES

In order to determine the boron concentration for various flow rates and volumes it is necessary to examine the dimensions and configuration of the spent fuel pool. The Oconee pools consist of a single compartment in which fuel is stored and other fuel handling activities are conducted (including cask loading). There are no other connecting compartments as is the case at some nuclear facilities. As a result of this design, there are no alternate configurations or alignments used in the spent fuel pool that need to be considered in this analysis.

The NRC accepted methodology refers to WCAP-14181 (Reference 3) for the dilution equations needed to estimate the boron concentration. Those equations are derived using the assumption that overflow begins as soon as unborated water is added to the SFP and do not consider the significant volume of water that must be added to finish filling up the pool. This simplifying assumption results in a reasonable but more conservative estimate of the boron concentration.

The volume of water in the Unit 1 and 2 Spent Fuel Pool at normal level is 72,710 cubic feet minus the volume of the fuel assemblies (2.87 ft^3/FA). During a refueling outage the maximum number of FA in the U1/U2 spent fuel pool is 1312. This results in an initial spent fuel pool water volume of 68,944.56 ft^3 (i.e., 72,710 - (2.87 × 1312)). This volume corresponds to 515,740 gallons. When both units are not in refueling, the maximum number of fuel assemblies is only 1195. Thus, the initial spent fuel pool water volume would be 69,280.35 ft^3 (i.e., 72,710 - (2.87 × 1195)). This volume corresponds to 518,252 gallons.

The volume of water in the Unit 3 Spent Fuel Pool at normal level is 50,287 cubic feet minus the volume of the fuel assemblies (2.87 ft^3/FA). During a refueling outage the maximum number of FA in the U3 spent fuel pool is 825. This results in an initial spent fuel pool water volume of 47,919.25 ft^3 (i.e., 50,287 - (2.87 × 825)). This volume corresponds to 358,460 gallons. When the unit is not in refueling, the maximum number of fuel assemblies is only 708. Thus, the initial spent fuel pool water volume would be 48,255.04 ft^3 (i.e., 50,287 - (2.87 × 708)). This volume corresponds to 360,972 gallons.

Using the simplified approach the boron concentration can be conservatively estimated using the following equation.

$$C = C_o\, e^{(-Q/V_o)(t\times 60)} \qquad \text{(Equation 1)}$$

where C_o = Initial Pool Boron Concentration (2220 ppm),
Q = Flow rate into Pool (gpm),
V_o = Initial Pool Water Volume (gallons), and
t = Length of time after initiation of dilution flow (hours), and
60 = Conversion factor for converting hours to minutes.

Equation 1 is based on WCAP-14181 Section 3.2. Using this equation, the pool boron concentration was estimated for a range of flow rates for various times from 1 to 72 hours with the results presented in Table 2 for the U1/U2 SFP and in Table 3 for the U3 SFP.

However, in some of the events to be evaluated, the source of dilution flow is defined by a fixed volume instead of a continuous dilution flow. If the entire dilution volume is added to the pool then the pool boron concentration is found using a equation below:

$$C = C_o e^{-\left(\frac{V}{V_o}\right)} \qquad \text{(Equation 2)}$$

where C_o = Initial Pool Boron Concentration (2220 ppm),
V_o = Initial Pool Water Volume (gallons), and
V = Water Volume added to pool (gallons).

Equation 1 can also be rearranged and solved for time t, in order to find how much time it takes at a given flow rate to dilute the SFP down to a specific boron concentration. This will be used to calculate the amount of time required to dilute the SFP down to the minimum boron limit (C_M) credited in the SFP criticality analysis.

$$t = \left(\frac{V_o}{Q \times 60}\right) \cdot \ln\left(\frac{C_o}{C_M}\right) \qquad \text{(Equation 3)}$$

where C_M = 400 ppm (Unit 1/2 SFP)
C_M = 430 ppm (Unit 3 SFP)

5.0 EVALUATION OF SPENT FUEL POOL DILUTION EVENTS

5.1 Pipe Breaks

Both Oconee Spent Fuel Pools are located at an elevation above all adjacent buildings. Pipe breaks in adjacent buildings or areas can not flow into the pool and are excluded from consideration.
Through the review of plant drawings and a plant walkdown, piping

for the following systems was identified in the spent fuel pool area that, if broken, could flow into the spent fuel pool:

Pipe Break Dilution Sources

Area / System	Pipe Size
U1/U2 SFP - Demin Water Supply (DW)	1.5 inch
U3 SFP - Demin Water Supply (DW)	1.5 inch
U3 SFP - Filtered Water Supply (FW)	1.5 inch

All three of these lines were installed for use by plant personal for decontamination of equipment or other miscellaneous purposes. The filtered water line in the Unit 3 spent fuel pool area is part of an inactive branch of the Filtered Water (FW) System that is fed by the Filtered Water Booster Pumps. At the time that Oconee was under construction, the purpose of this part of the FW System was to provide a means for decontamination of Spent Fuel Shipping Casks and decontamination of the Fuel Transfer Canal. However, in practice, other systems such as demineralized water (DW) are used for these purposes, and the operations support staff does not recall the FW Booster Pump(s) ever being used. Therefore, a pipe break in the FW line is not considered to be a credible boron dilution accident.

The DW line does present a credible pipe break accident even though the probability of such a break is very small and the expected break flow area would also be very small. The Demineralized Water (DW) System creates demineralized water on demand as demineralized water is taken out of the supply header. This is accomplished by drawing water from the Filtered Water Storage Tank and sending the water through a series of filters and demineralizer and into the supply header. The FW Pressure Filter Pumps automatically start to replenish the Filtered Water Storage Tank inventory from the FW Reaction Tank. The FW Reaction Tank is automatically replenished from LPSW. In its normal operating mode ("dual pass alignment"), the DW System has a maximum capacity of approximately 145 gpm. During plant startup, the DW System is often placed into an alternate alignment referred to as "single pass", that increases the system's maximum capacity to approximately 300 gpm. Because of the DW System's ability to continuously and automatically get water from LPSW (i.e., Lake Keowee), the DW System will be conservatively assumed to be an "infinite" source of water.

For the sake of simplicity, it will also be assumed that break size produces a 300 gpm flow rate equaling the DW System's maximum capacity. This assumption is very conservative considering that the lines in the pool areas are relatively small and that the break location would be a considerable distance from the source of DW pumps located in the Service Building. It is doubtful that even a complete guillotine break could produce this flow rate due to friction losses over such a long distance in such a small diameter pipe.

Table 2 and Table 3 provide a tabulation for each SFP of the resulting boron concentration over time from a 300 gpm dilution flow rate. The amount of time required (at 300 gpm) to dilute the SFPs down to the boron credit limit is calculated using equation 3.

Unit 1/2 SFP - (boron credit limit = 400 ppm)

$$t = \left(\frac{515{,}740}{300 \times 60}\right) \cdot \ln\left(\frac{2220}{400}\right) = 49.1\,\text{hrs}$$

Unit 3 SFP - (boron credit limit = 430 ppm)

$$t = \left(\frac{358{,}460}{300 \times 60}\right) \cdot \ln\left(\frac{2220}{430}\right) = 32.7\,\text{hrs}$$

5.2 Misalignment of Systems Interfacing with SF System

The potential exists for systems that interface (directly or indirectly) with the SF System to become misaligned due to operator errors or component malfunction or failure causing unborated water to be added to the Spent Fuel Pool. These interfacing systems are the Coolant Treatment (CS) System , Demineralized Water (DW) System, Filtered Water (FW) System, and Recirculated Cooling Water (RCW) System. The potential impact of these systems and the Spent Fuel Pool Demineralizers is evaluated below.

Note: The SSF Reactor Coolant Makeup Pump for each unit also connects to the its respective spent fuel pool through the Fuel Transfer Tube. While this system is not capable of initiating a dilution event, use of the pump in an SSF event can result in a significant reduction in SFP inventory that may require makeup to the SFP from unborated sources. Impact of SSF operation is discussed further in in Section 5.3 and in Section 6.0.

There is also a SF System interface with the Low Pressure Injection (LPI) System and the Borated Water Storage Tank (BWST), however, this connection is a fully borated system and not included as a dilution source. This connection can be used to align the HPI suction to the SFP to mitigate certain tornado events. The impact of this alignment is discussed separately in Sections 5.3 and 6.0.

5.2.1 Dilution From Coolant Storage (CS) System

The Coolant Storage (CS) System is a large system of tanks, pumps, piping, and valves used to process and store primary system coolant and provide makeup coolant to the Spent Fuel Pools and BWST. The key components of interest in the system are below:

Component	Number	Capacity	Boron Level
RC Bleed Holdup Tank (BHUT)	2 per Unit	11,000 ft^3 each (82,300 gal.)	"A" BHUT is borated water, "B" BHUT is demin water
Concentrated Boric Acid Storage Tank (CBAST)	1 per Unit	3,000 ft^3 each (22,400 gal.)	Very High Boron Concentration
Boric Acid Mix Tank	1 Tank for U1/U2 and 1 Tank for U3	500 ft^3 each (3,700 gal.)	Very High Boron Concentration

There is a corresponding transfer pump for each of the tanks listed above. The system can be cross-connected to transfer coolant to other units. The suction lines to both Bleed Holdup Transfer Pumps can be cross-connected to each other but not to another unit's BHUT. The "A" BHUTs are normally maintained at 60% of tank capacity with a relatively high boron concentration. This boron concentration is only required to be maintained above the primary system boron concentration that is gradually reduced over the operating cycle. The "B" BHUTs are normally maintained at 20% of tank capacity of pure demineralized water. Each transfer pump has a capacity of approximately 130 gpm to deliver flow to the SFP under optimum conditions.

It will be conservatively assumed that at the beginning of an accident both BHUTs for one unit are completely filled with unborated demineralized water. The worse case postulated accident would result from an error occurred that inadvertently cross-connected the suction of the RC Bleed Transfer Pumps on this unit and aligned the discharge to the SF Cooling System. It is not considered credible to have more than one unit's CS system misaligned at the same time. In this alignment, the entire volume of unborated water in the two BHUTs (82,300 + 82,300) is assumed to be pumped into the spent fuel pool.

The first case involves dilution of the SFPs from a fixed volume (164,600 gallons maximum) from the RC Bleed Holdup Tanks (BHUTs). The new results for this scenario are shown below:

Unit 1 & 2 SFP $$C = (2220) \cdot e^{-\left(\frac{164600}{515740}\right)} = 1613 \text{ ppm}$$

Unit 3 SFP $$C = (2220) \cdot e^{-\left(\frac{164600}{358460}\right)} = 1403 \text{ ppm}$$

At an assumed maximum flow rate of 260 gpm (2 pumps at a flow rate of 130 gpm each), it will require 10.6 hrs to pump 164,600 gallons into the SFP.

$$t = \frac{164{,}600 \text{ gallons}}{(260 \text{ gpm} \times 60 \text{ min/hr})} = 10.6 \text{ hours}$$

5.2.2 Dilution From Demineralized Water (DW) System

There are two direct paths in which to add unborated water to the pool from the Demineralized Water (DW) System. First, there is a connection between DW and the SF Cooling System (valve DW-112). Second, there a hose station beside the pool that could be used to add demineralized water directly into the spent fuel pool. In both of these cases, the dilution of the spent fuel pool is bounded by the DW pipe break case analyzed in Section 5.1 and is not estimated separately.

There is also an indirect path to add DW water to the spent fuel pool through the Coolant Storage System (BHUTs). However, the dilution impact of this case is bounded both by the case analyzed for the CS System in Section 5.2.1 and also by the DW pipe break case analyzed in Section 5.1.

5.2.3 Dilution From Filtered Water System

As discussed in Section 2.6, the FW System is not actively used. The expected impact of this system would also be bound by the DW System case (i.e., FW Booster Pump capacity is less than DW System capacity).

5.2.4 Recirculated Cooling Water (RCW) System (SF Heat Exchanger Leak)

The Recirculated Cooling Water (RCW) System provides cooling water to the SF heat exchangers for decay heat removal. There is no direct connection between the RCW System and SF System. However, a connection could occur if a leak were to develop in a SF heat exchanger that is in service. In case of a leak, RCW water would be expected to flow into the SF System since RCW is at a slightly higher pressure. It is expected that the flow rate from such leakage would be very small due to the very small difference in system operating pressures seen at the heat exchanger.

Even if a significant flow rate resulted from a leak, the impact on the spent fuel pool boron concentration would be very small due to the limited volume of water available in the RCW System to flow into the SF Cooling System. Approximately 25,000 gallons would normally be available in the Unit 1 and 2 RCW Surge Tank and 7,500 gallons would be normally available in the Unit 3 RCW Surge Tank. Normally, the Unit 1 and 2 RCW is operated separately from the Unit 3, however, a cross-connected configuration is possible. Thus, the total dilution volume is conservatively assumed to include both tanks, which equals 32,500 gallons. Note that the level alarms from the RCW surge tank in addition to the spent fuel pool high level alarm would also alert control room operators of the lost inventory and the source of the leak. A maximum leak rate of 10 gpm is conservatively assumed for a bounding time estimate.

The boron concentration resulting from a dilution volume of 32,500 gallons is calculated using Equation 2. The boron concentration for the Unit 1 and 2 spent fuel pool is 2084 ppm and for the Unit 3 spent fuel pool is 2028 ppm. At an assumed maximum leak rate of 10 gpm, 54.2 hrs are required to put 32,500 gallons into the SFP.

Because of the limited amount of water available in the RCW System and the mechanisms available to operators to identify such leakage, a SF heat exchanger leak can not result in any significant dilution of the spent fuel pool.

5.2.5 Boron Removal By Spent Fuel Pool Demineralizer

When the spent fuel pool demineralizer is first placed in service after being recharged with fresh resin it can initially remove boron from the water passing through it. The demineralizer normally utilizes a mixed bed of anion and cation resin which would remove only a small amount of boron before saturating. Because of the small amount of boron removed by the demineralizer, it is not considered a limiting dilution event for the purposes of this evaluation.

5.3 Loss of Off-Site Power

None of the interfacing systems considered as potential dilution sources are automatically supplied with backup emergency power in case of a Loss of Off-Site Power (LOOP) event, and thus are not capable of putting unborated water into the spent fuel pool following a LOOP event. Electrical power to these systems (SF, DW, RCW, and CS) must be manually restored and the systems manually restarted. Several hours are available to restore spent fuel cooling.

However, if a loss of off-site power leads to a station blackout, there are two potential scenarios that are possible in which operators may intentionally remove borated water from the SFP. Specifically, these scenarios are activation of the SSF (use of RCMUP) and HPI Suction Alignment to SF Cooling (tornado damage mitigation). If power is not restored in a timely manner, unborated water is added back to the SFP using a fire truck.

As discussed in Section 1.0, the SSF and HPI Suction Alignment scenarios do not involve overflow of the SFP and can not be evaluated using the standard dilution methodology. These events are therefore evaluated using an alternative approach discussed in Section 6.0.

5.4 Evaluation of Infrequent Spent Fuel Pool Configurations

There are no other connecting compartments as is the case at some nuclear facilities. As a result of this design, there are no alternate configurations or alignments used in the spent fuel pool that need to be considered in this analysis.

6.0 Evaluation of SSF and HPI Suction Alignment Scenarios

Because the SSF and the HPI Suction Alignment scenarios do not involve overflow of the SFP, they can not be evaluated using the methodology described in References 1 and 3. The same general assumptions discussed in Section 2.0 regarding initial pool conditions also apply to these scenarios. The primary differences are that the SFP volume changes during the scenarios and different equations must be used to determine the boron concentration.

The general sequence of events is that a significant volume of borated water is removed (pumped) from the SFP to mitigate an accident related to the reactor core. Normal SFP cooling is also lost in this event. In the SSF scenario, some additional volume of water is lost due to boiling in the SFP. At a later time, unborated water is added back to the SFP to restore coolant level and inventory. The mechanism of boron removal is pumping instead of coolant overflow, however, boron dilution does not occur until makeup is initiated.

Under condition where the water volume added to the pool does not overflow the pool, the pool boron concentration is described by the following general equation:

$$C = \frac{C_o * V_o}{V'} \qquad \text{Equation 4}$$

where C_o = Initial Pool Boron Concentration (ppm),
V_o = Initial Pool Water Volume (gallons), and
V' = New SFP Volume (after water is added or subtracted)
Typically, $V' = V_o + \Delta V$.

When the pool is in a boiling condition, the resulting boron concentration is estimated using the same equation except that the variable ΔV is a negative value. This equation is valid in this circumstance because boiling removes the water without removing the boron.

6.1 Assumptions for Makeup Water for SSF and HPI Drawdown Events

The same general assumptions discussed in Section 2.0 regarding initial pool conditions also apply to these scenarios (e.g., normal pool level, SFP volume, boron concentration). The following additional assumptions are used in the dilution analysis.

1. Makeup water to the spent fuel pool for these scenarios is assumed to be unborated, corresponding to the worst case condition in which power is not available to pump borated water from the BHUT or CBAST. No credit is taken for the addition of solid boron during the event.

2. Although emergency procedures call for makeup to the spent fuel pool during the "drawdown" of spent fuel pool level, it is conservatively assumed that makeup to the spent fuel pool does not begin until the drawdown is complete. (This maximizes the amount of boron removed from the pool).

3. When the water is replaced, it is assumed that the spent fuel pool is refilled up to elevation 844' (pool overflow level), at which point makeup flow is either temporarily stopped or throttled to match the pool boiloff rate. This assumption is made because of potential difficulties associated with a station blackout (e.g., loss of normal instrumentation, restricted access to the spent fuel pool area).

6.2 SSF Scenario

The Standby Shutdown Facility (SSF) includes an independent diesel generator AC power source and the Reactor Coolant Makeup Pump (RCMUP) which takes suction from the spent fuel pool to provide seal injection flow for the Reactor Coolant Pumps. The SSF is designed to respond to security events, Appendix R fire events, flooding events, or tornado events, but is also credited for responding to station blackout scenarios if emergency power fails.

There are four phenomena taking place simultaneously that determine the boron concentration in the spent fuel pool.

1. Removal of Coolant by the RCMUPs
2. Boiloff of Spent Fuel Pool Coolant
3. Coolant Makeup
4. SSF Letdown Flow

Operation of the SSF is postulated for up to 72 hours. During this 72 hours, the RCMUP can draw a maximum of 29 gpm of flow from the pool to deliver to the RCP seals. The maximum volume of borated water taken from the pool (per unit) is estimated to be (29 gpm x 60 min/hr x 72 hr) 125,280 gallons (V_{SSF}). Since the Unit 1 and 2 spent fuel pool serves both units' RCMUPs, the volume removed from it is doubled or 250,560 gallons. The removal of coolant from the spent fuel pool does not directly affect pool boron concentration at that specific time, but rather determines the amount of makeup water required at a later time.

The SSF drawdown is assumed complete when spent fuel pool level reaches the design limit of 1 foot above the top of the fuel. This design requirement incorporates the worse case SFP heat loads including core off-load conditions. The SSF drawdown includes both coolant removed by the RCMUP and water lost to boiloff.

Note that the Unit 1 and 2 spent fuel pool has higher spent fuel pool level requirements during refueling operations to maintain SSF operability for the other unit. These higher level requirements ensure that under the highest potential heat loads that at least 1 foot of level is maintained above the fuel after 72 hours of SSF operations without spent fuel pool makeup. Thus, it is concluded that the assumption of normal pool level is acceptable.

While this drawdown is taking place the pool will heat up to the saturation temperature and begin boiling. The point in time at which boiling begins is determined by the heat load in the spent fuel pool which is in turn a function of the number of fuel assemblies and the time after the last core off-load. Boiling in the spent fuel pool has the effect of increasing boron concentration as water leaves the pool but the boron is left behind. Without makeup flow, boiling causes the boron concentration of the coolant injected into the RCS to gradually rise.

On the other hand, plant procedures have provisions to provide makeup to the pool during SSF operation. Although normal makeup sources to the spent fuel pool are assumed to be unavailable, guidance is provided to align fire trucks to pump water directly from Lake Keowee into the pools. Makeup to the pool is expected to begin prior to 36 hours after the initiation of the SSF event. However, the design basis for the SSF does not require makeup for a full 72 hours at which point spent fuel pool can be no lower than 1 foot above the top of the fuel assemblies. In order to maximize the removal of boron from the pool, it is conservatively assumed that makeup begins at 72 hours.

SSF Letdown to the spent fuel pool can be used during an SSF event to control RCS inventory (pressurizer level). The extent to which SSF Letdown is used is dependent on many different factors including decay heat rate in the core, RCS leakage rates, and the time at which SSF systems are initiated. These factors can vary to the extent that SSF Letdown may be needed during nearly the entire event or it may not be needed at all. The SSF Letdown capacity is greater than the RCMUP flow rate but would be operated intermittently to maintain a relatively constant RCS inventory. Thus, over time, the average SSF Letdown flow rate is expected to be less than the RCMUP flow rate.

The letdown coolant will also contain at least some soluble boron but varies greatly depending on what point the unit is at in its operating cycle. A significant portion of the SSF Letdown coolant is also expected to boiloff because its temperature will be significantly above the saturation temperature in the pool. However, the net effect to the SFP is a small increase in SFP inventory and a small increase in total boron. In this way, the SSF letdown acts to reduce the amount of makeup required to refill the spent fuel pool, and return a small fraction of boron back to the SFP. For purposes of the dilution analysis, however, the effects of the SSF Letdown are conservatively neglected.

Realistically, pool boron concentration changes dynamically because the four factors affecting pool boron concentration can occur simultaneously and because they can be initiated at different times. For example, the onset of boiling can vary from as little as 8.6 hours to over 24 hours depending on the heat load in the pool and the initial pool temperature. The time at which makeup is initiated also dramatically affects the boron concentration. Therefore, it is desirable to establish a set of simplifying assumptions that will maximize the dilution of the pool and envelope all of the dynamic effects that could occur.

The first simplifying assumption is that during the SSF event the pool will be drawn down to 1 foot above the rack (elevation 817.5'). Of the volume of water above elevation 817.5', a fixed volume is removed from the pool by the RCMUP and the rest is assumed to boil off. This assumption is consistent with the SFF design basis and maximum decay heat. The assumption also eliminates the need to perform time to boil calculations.

The second simplifying assumption is to estimate the boron concentration in the pool as if this boiloff occurs prior to and independently of the operation of the RCMUP. This assumption maximizes the rate of boron removal by the RCMUP. The boron concentration calculated at the end of this boiloff stage (C_B)would then be the same as the boron concentration when the pool reaches 1 foot above the fuel racks (elevation 817.5 feet).

For Unit 1 & 2 Spent Fuel Pool:

<u>Water Volume in U1 & U2 SFP Below Elevation 817.5'</u>

$V_B = V_o - \Delta V$

where V_o with both units at power is 518,252 gallons, thus,

V_B = (518,252 gal)-[7.4805 gal/ft^3 x (84.25 x 24 x (840-817.5))]

V_B = 177,927 gallons

<u>U1 & U2 SFP Boiloff Boron Concentration</u>

$$C_B = \frac{C_o * V_o}{V_B + V_{SSF}} = \frac{2220*(518252)}{(177927)+(250560)} = 2685 \text{ ppm}$$

Where V_{SSF} (250,560) is the volume removed by both SSF RCMUPs.

At a level of 1 foot above the fuel racks and a boron concentration of 2685 ppm, makeup water is added back to the SFP to refill the pool to a maximum level at elevation 844' where makeup flow is throttled to match boiloff or normal SFP cooling is restored. This addition of unborated water will dilute the SFP down to the minimum possible concentration as calculated below.

SSF Scenario - U1 & U2 SFP Final Boron Concentration

$$C = \frac{C_B * V_B}{V_o + V_T} = \frac{2685 * (177927)}{(518252) + (60502)} = 825 \text{ ppm}$$

where 60,502 equals the volume of water to raise the SFP level from normal level to the overflow elevation (844). For example, V_T = (84.25') x (24') x (4') = 8088 ft^3, or 60,502 gallons.

For Unit 3 Spent Fuel Pool:

Water Volume in U3 SFP Below Elevation 817.5'

$V_B = V_o - \Delta V$

where V_o with the unit at power is 360,972 gallons, thus,

V_B = (360,972 gal)-[7.4805 gal/ft3 x (58 x 24 x(840-817.5))]

V_B = 126,683 gallons

U3 SFP Boiloff Boron Concentration

$$C_B = \frac{C_o * V_o}{V_B + V_{SSF}} = \frac{2220 * (360972)}{(126683) + (125280)} = 3180 \text{ ppm}$$

Where V_{SSF} (250,560) is the volume removed by both SSF RCMUPs.

At a level of 1 foot above the fuel racks and a boron concentration of 3180 ppm, makeup water is added back to the SFP to refill the pool to a maximum level at elevation 844' where makeup flow is throttled to match boiloff or normal SFP cooling is restored. This addition of unborated water will dilute the SFP down to the minimum possible concentration as calculated below.

SSF Scenario - U3 SFP Final Boron Concentration

$$C = \frac{C_B * V_B}{V_o + V_T} = \frac{3180 * (126683)}{(360972) + (41651)} = 1001 \text{ ppm}$$

where 41,651 equals the volume of water to raise the SFP level from normal level to the overflow elevation (844). For example,

V_T = (58') x (24') x (4') = 5568 ft^3, or 41,651 gallons.

Below is a summary of the Stages of an SSF Event

Stage of an SSF Event	Unit 1 & 2 SFP	Unit 3 SFP
Boiloff	89,765 gallons assumed boiled away from SFP	109,009 gallons assumed boiled away from SFP
Boiloff Concentration	2685 ppm	3180 ppm
RCS Makeup by RCMUP	250,560 gallons removed from SFP	125,280 gallons removed from SFP
SFP Makeup To Overflow Level	400,827 gallons added back to SFP	275,940 gallons added back to SFP
Final Boron Concentration	825 ppm	1001 ppm

6.3 HPI Suction Alignment Scenario

In the HPI Suction scenario, one High Pressure Injection (HPI) pump is aligned to take suction from the Spent Fuel Pool. The purpose of this alignment is to mitigate tornado events in which the BWST is damaged and can not supply HPI suction requirements. This scenario is also associated with a station blackout caused by the tornado, which renders the SF Cooling System unavailable.

Due to flow restrictions, only one HPI pump can take suction from the SFP at a time. Therefore, either Unit 1 HPI or Unit 2 HPI can take suction from the Unit 1 & 2 SFP but not both at the same time.

This alignment uses the SF Cooling System discharge line through valve SF-50. Although this line extends down into the pool to elevation 809', there is a ½" drilled hole in the pipe at elevation 822' as a siphon breaker. During periods of high heat load in the SFP, HPI may not be able to draw the pool down to elevation 822' feet due to flashing in the line. Flashing in the line would cause a loss of the siphon necessary to maintain HPI flow from the SFP. Because of this siphon limitation, it is not possible for HPI to remove water from the SFP once it heats up to near the saturation temperature. For this calculation, it is conservatively assumed that HPI can draw the SFP all the way down to elevation 822' (18 feet below normal water level).

Therefore, the volume of water removed from the SFPs by HPI can be estimated as follows:

Calculation of Volume $V_{removed}$

Unit 1 & 2 SFP

$V_{removed}$ = L x W x ΔH
$V_{removed}$ = (84.25') x (24') x (18') = 36,396 ft^3
$V_{removed}$ = 272,260 gallons

Unit 3 SFP

$V_{removed}$ = L x W x ΔH
$V_{removed}$ = (58') x (24') x (18') = 25,056 ft^3
$V_{removed}$ = 187,431 gallons

It is assumed that either Unit 1 or Unit 2 is shutdown for refueling, which provides the limiting case for its initial pool volume (515,740 gallons). Unit 3 would have been at power in order to initiate this alignment. At the end of the event, it is assumed that the SFP is refilled up to the overflow level (elevation 844') with unborated water. The dilution volume required to refill the SFP is equal to $V_{removed}$+ V_T or 332,762 gallons for U1/U2 SFP and 229,082 gallons for U3 SFP. The variable V_T represents the volume required to fill the SFP from normal level up to the overflow elevation of 844' and is calculated in Section 6.2. The final boron concentration is calculated using Equation 5 below.

$$C = \frac{C_o * (V_o - V_{removed})}{V_o + V_T} \qquad \text{(Equation 5)}$$

Thus,

U1 & U2 SFP
$$C = \frac{2220_{ppm} * (515740 - 272260)}{515740 + 60502} = 938 \text{ ppm}$$

U3 SFP
$$C = \frac{2220_{ppm} * (360972 - 187431)}{360972 + 41651} = 957 \text{ ppm}$$

7.0 RESULTS

A summary of dilution event results is provided in the following tables for each spent fuel pool.

Unit 1 and 2 Spent Fuel Pool Results

Event Scenario	Dilution Volume & Dilution Flow Rate	Final Boron Conc.(ppm) & Dilution Time	Time to Reach 400 ppm
Pipe Break (1.5" DW Header)	"infinite source" at 300 gpm (assumed)	Time Dependent (See Tables 2 & 3)	49.1 hrs
Dilution From 2 RC Bleed Holdup Tanks (BHUTs)	164,600 gallons at 260 gpm	1613 ppm at 10.6 hrs	-
Dilution From Recirculated Cooling (RCW) Water	32,500 gallons at 10 gpm (assumed)	2084 ppm at 54.2 hrs	-
Dilution From DW System	"infinite source" at 300 gpm (assumed)	Time Dependent (See Tables 2 & 3)	49.1 hrs
SSF Operation (Refill to Overflow)	Drawdown to 817.5'; Refill to 844'	825 ppm at >72 hrs	-
HPI Suction From SFP (Refill to Overflow)	272,260 gallons removed and 332,762 added back	938 ppm	-

Unit 3 Spent Fuel Pool Results

Event Scenario	Dilution Volume & Dilution Flow Rate	Final Boron Conc.(ppm) & Dilution Time	Time to Reach 430 ppm
Pipe Break (1.5" DW Header)	"infinite source" at 300 gpm (assumed)	Time Dependent (See Tables 2 & 3)	32.7 hrs
Dilution From 2 RC Bleed Holdup Tanks (BHUTs)	164,600 gallons at 260 gpm	1403 ppm at 10.6 hrs	-
Dilution From Recirculated Cooling (RCW) Water	32,500 gallons at 10 gpm (assumed)	2028 ppm at 54.2 hrs	-
Dilution From DW System	"infinite source" at 300 gpm (assumed)	Time Dependent (See Tables 2 & 3)	32.7 hrs
SSF Operation (Refill to Overflow)	Drawdown to 817.5'; Refill to 844'	1001 ppm at >72 hrs	-
HPI Suction From SFP (Refill to Overflow)	187,431 gallons removed and 229,082 added back	957 ppm	-

Table 2 and Table 3 also provide an estimate of the length of time required for various flow rates to fill the pools to the high level alarm setpoint and to reach the pool overflow level. Note that these tables should not be used to characterize the SSF or HPI Suction Alignment scenarios.

8.0 CONCLUSIONS

Potential deboration accident scenarios in the spent fuel pool have been evaluated over a range of possible conditions. These postulated events involve combinations of multiple human errors, piping breaks, and system malfunctions that make a significant loss of boron in the spent fuel pool very unlikely. The impact of these accidents result in a range of values of boron concentration depending on dilution flow rates and coolant volumes. The results also show that the dilution process requires many hours to significantly reduce pool boron concentration even under the most limiting conditions and provides sufficient time for operator actions to terminate the accident. Based on the analysis presented above, it is concluded that there are no credible events that would result in the dilution of the spent fuel pool boron concentration to less than the boron credit limit for each pool.

This conclusion is supported by the following:

1. A substantial amount of water is required to significantly dilute the spent fuel pool. At a maximum postulated pipe break flow of 300 gpm, it takes approximately 32.7 hours to pump the volume of water necessary to dilute the Unit 3 SFP down to the minimum boron credit limit of 430 ppm. At 300 gpm, it takes approximately 49.1 hours to dilute the Unit 1 and 2 SFP down to its minimum boron credit limit of 400 ppm. No single tank or combination of two tanks in the plant contains this volume of unborated water and would, therefore, require multiple errors to align additional sources to the spent fuel pool. Conservative assumptions were also made that both bleed holdup tanks were completely full of unborated water, which is considered to be a very unlikely condition.

2. Since such a large volume of water is required, a spent fuel pool dilution event would be readily detected by plant personnel by level alarms, by flooding in the auxiliary building, or by normal operator rounds through the spent fuel pool area.

3. For all scenarios except the SSF scenario, the SF Cooling System is assumed to be available and operating. The volume of coolant contained in the SF Cooling piping has been conservatively neglected in the initial pool volume estimate.

4. Sensitivity analysis indicates that even if substantially higher flow rates of unborated water into the spent fuel pool are assumed, there is still sufficient time available to detect and respond to such an event. Furthermore, the assumption of a 300 gpm flow rate is conservative. Normally the DW system is used in a "dual pass alignment" which has a maximum flow capacity of approximately 145 gpm. It is generally only during plant startup that the DW System is placed into "single pass" mode which increases the system's maximum capacity to approximately 300 gpm. This 300 gpm assumption also ignores the impact of line losses and pipe break size. Thus, the expected flow rate from a DW pipe break would be much less than 300 gpm during the limited time that the system is aligned in the "single pass" mode.

5. For the SSF scenario, the addition of makeup water to the spent fuel pool is expected prior to 36 hours. The addition of makeup water earlier during the SSF event reduces the rate of boron removal from the pool by the RCMUP. Use of SSF letdown would also add some boron back to the spent fuel pool and partially reduce the dilution effects of makeup water.

6. In the the SSF scenario (limiting case for Unit 1 & 2 SFP), the boiloff of water down to 1 foot above the fuel racks is conservatively based on the maximum possible heat loads expected in the SFP immediately following a core discharge to the pool. With the decreasing heat loads following a typical refueling outage, the actual onset of pool boiling is expected to occur at a later time and result in less boron from being removed from the SFP.

7. The analysis conservatively assumes that the initial pool boron concentration is 2220 ppm corresponding to the COLR limit currently in use for all three units at Oconee. Normally, pool boron concentration is maintained at around 2500 ppm.

9.0 REFERENCES

1. WCAP-14416-NP-A, Revision 1, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Westinghouse Electric Corporation, November 1996.

2. NUREG-1353, "Beyond Design Basis Accidents in Spent Fuel Pools", U.S. Nuclear Regulatory Commission, April 1989.

3. WCAP-14181, "Westinghouse Owners Group Evaluation of the Potential For Diluting PWR Spent Fuel Pools," Westinghouse Electric Corporation, July, 1995.

4. Collins, T. (NRC), letter to T. Greene (WOG), "Acceptance For Referencing of Licensing Topical Report WCAP-14416-P, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology", October 25, 1996.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Structural Failure - Missiles	Screened	Postulated missiles causing damage to the pool structure could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event.
Structural Failure - Aircraft Crashes	Screened	Postulated damage to the pool structure from an aircraft crash could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event. (See also below - "Piping Damage caused by Airplane Crashes")
Structural Failure - Heavy Load Drops	Screened	Postulated heavy load drop events causing damage to the pool structure could lead to a loss of inventory and zircaloy cladding fire but can not cause a dilution event.
Seismic Structural Failure	Screened	Seismic structural failure is postulated to cause an unrecoverable loss of water in the SFP, and leads to a zircaloy cladding fire and cannot cause a dilution event.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Reactor Cavity Seal Failure and/or Nozzle Dam Failure	Screened	The design of the Oconee Reactor Cavity Seals makes a catastrophic failure of the seals extremely unlikely. Such failures would be quickly isolated by procedure by closing valves SF-1 and SF-2 (Fuel Transfer Tube Isolation Valves). In addition, a catastrophic failure would result in a loss of SFP inventory that could cause a zircaloy cladding fire and is not a boron dilution initiating event. The same conclusion applies to other failures of the reactor coolant system piping during refueling operation (including nozzle dams).
Loss of Cooling/Makeup	Screened	Loss of cooling/normal makeup is not considered a deboration event since the loss of inventory through evaporation and/or boil off does not remove boron from the pool.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Inadvertent Drainage/Loss of Inventory	Screened	Most loss of inventory events are expected to be small. Design features of the SF system (e.g., siphon breaks) purposely limit the amount of water that could be removed from the pool due to SF system pipe breaks, system malfunctions, or operator errors. A boron dilution event could occur if unborated water is used to refill the pool. However, these events are not generally expected to remove enough water to deborate the pool significantly. Plant procedures will address the addition of boron to the pool in response to a significant loss of inventory which requires emergency makeup water.
Fires (at or near the pool)	Screened	Typically, combustible loadings around the pool area are relatively small. If the fire hose stations in the Aux Bldg were used to extinguish a fire, the volume of water required to extinguish a local fire is not expected to be of sufficient magnitude to cause a significant change in pool boron concentration.
External Floods	Screened	The location of the spent fuel pool is high enough to preclude floodwater from entering the pool due to flooding of the site.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Internal Floods	Evaluated under Loss of Power Events	The location of the spent fuel pool is high enough to preclude floodwater from entering the pool due to flooding in adjacent plant buildings. However, a large internal flood could lead to activation of the SSF to mitigate the flood. From an SFP perspective, the impact of SSF activation is no different for floods than for Blackout Events because in either case SFP cooling is lost and the volume of coolant removed from the pool is same. Therefore, the impact of flooding events will be covered by the loss of power scenarios analyzed in Section 5.3.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Storms Causing Runoff into the Spent Fuel Pool	Screened	The location of the spent fuel pool is high enough to preclude storm water from entering the pool due to flooding of the site. However, the roof drains for the Spent Fuel Pool Building are located directly above the pool. This piping is located inside the building and thus is unlikely to be damaged by wind or missile damage due to a tornado strike event on the plant site and is not considered further. The likelihood of a random piping break in a gravity-fed line such as this is very remote. Even with a significant crack in the piping, most of the water flow would go down the drain (path of least resistance). To have any significant dilution, the break would have to be very large and concurrent with a probable maximum precipitation (PMP) event (26.6" rain in 48 hours). **This is not considered a credible event and is screened.** Note: The area on the roofs are roughly 5650 sq. ft. on U1/U2 SFP and 4300 sq. ft. on the U3 SFP. A PMP would only generate 93,700 gallons on U1/U2 SFP and gallons on the U3 SFP. Thus even a PMP event draining straight into the pools could not produce a dilution event greater than other postulated events.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Pipe Breaks caused by seismic events, or tornadoes	Evaluate	Some piping in the SFP area (DW and FW) is not seismically qualified and is not specifically protected from tornadoes. Realistically the probabilities of these failure events is lower than from random pipe breaks. In particular, the probability of tornado wind or missile damage is judged to be extremely low and should not need to be considered further. However, the identified piping is also susceptible to a random failure and will be evaluated in Section 5. The outcome is basically the same regardless of the cause of the piping failure.
Random Pipe Breaks	Evaluate	Piping in the vicinity of the pool will be evaluated for dilution accidents.
Other Damage caused by Airplane Crashes	Screened	The likelihood of an aircraft crash on either of the Oconee Spent Fuel Pools is extremely remote and is not evaluated as a credible boron dilution initiating event
Tank Ruptures near the SFP	Screened	Review of plant drawings and a plant walkdown determined that no tanks in or around the plant could flow into the SFP if the tank ruptured.
Dilution Events Initiated in the Reactor Coolant System	Screened	No credible pathways could be identified for this type of event.
Misalignment of Systems Interfacing with SF system	Evaluate	There are several interfacing systems that will be evaluated.
Loss of Off-site Power	Evaluate	The impact of loss of ac power events will be reviewed and evaluated including possible SSF and HPI Suction Alignment scenarios.

Table 1 - Preliminary List of Dilution Initiating Events

Initiating Event	Disposition	Screening Notes
Loss of Boron Due To Demineralizers or other Purification Equipment	Evaluate	The potential impact of the purification system will be evaluated.
Infrequent SFP Configurations	Screened	No alternative configurations exist for the Oconee SFPs.

Table 2 - Unit 1 and 2 Spent Fuel Pool Deboration Accident Analysis

SFP Boron Concentration (ppm)

Initial Pool Boron Conc. =	C_o	2220	ppm
Initial Pool Level =	L_o	840.000	feet
Initial Spent Fuel Pool Volume =	V_o	515,740	gallons
Volume to fill SFP from Normal Level to Overflow =	V_T	60,502	gallons

			Flow Rate Into SFP (gpm)							
			50	*100*	*150*	*300*	*400*	*500*	*750*	*1000*
Fill To Pool Overflow Level	T_T (hrs)		*20.2*	*10.1*	*6.7*	*3.4*	*2.5*	*2.0*	*1.3*	*1.0*
High Level Alarm (Elev. 840'+8.4")	Detection Time (hrs)		3.53	1.76	1.18	0.59	0.44	0.35	0.24	0.18
	Flowrate (gpm) -->		*50*	*100*	*150*	*300*	*400*	*500*	*750*	*1000*
Pool Concentration (ppm) versus Time and Flowrate	Time (hours)	0	2220	2220	2220	2220	2220	2220	2220	2220
		0.5	2214	2207	2201	2182	2169	2156	2125	2095
		1	2207	2194	2182	2144	2119	2095	2035	1976
		2	2194	2169	2144	2070	2023	1976	1865	1759
		4	2169	2119	2070	1931	1843	1759	1566	1394
		6	2144	2070	1999	1801	1679	1566	1315	1105
		8	2119	2023	1931	1679	1530	1394	1105	875
		10	2095	1976	1865	1566	1394	1241	928	694
		12	2070	1931	1801	1460	1270	1105	779	550
		16	2023	1843	1679	1270	1054	875	550	345
		24	1931	1679	1460	961	727	550	273	136
		36	1801	1460	1184	632	416	273	96	34
		48	1679	1270	961	416	238	136	34	8
		60	1566	1105	779	273	136	68	12	2
		72	1460	961	632	180	78	34	4	1
Time (hrs) Required To Dilute Down To 400 ppm --->			295	147	98	49.1	36.8	29.5	19.6	14.7

Table 3 - Unit 3 Spent Fuel Pool Deboration Accident Analysis

SFP Boron Concentration (ppm)

Initial Pool Boron Conc. =	C_o	2220	ppm
Initial Pool Level =	L_o	840.000	feet
Initial Spent Fuel Pool Volume =	V_o	358,460	gallons
Volume to fill SFP from Normal Level to Overflow =	V_T	41,651	gallons

			Flow Rate Into SFP (gpm)							
			50	*100*	*150*	*300*	*400*	*500*	*750*	*1000*
Fill To Pool Overflow Level	T_T (hrs)		*13.9*	*6.9*	*4.6*	*2.3*	*1.7*	*1.4*	*0.9*	*0.7*
High Level Alarm (Elev. 840'+8.4")	Detection Time (hrs)		2.43	1.21	0.81	0.40	0.30	0.24	0.16	0.12
	Flowrate (gpm) -->		*50*	*100*	*150*	*300*	*400*	*500*	*750*	*1000*
Pool Concentration (ppm) versus Time and Flowrate	Time (hours)	0	2220	2220	2220	2220	2220	2220	2220	2220
		0.5	2211	2201	2192	2165	2147	2129	2085	2042
		1	2201	2183	2165	2111	2076	2042	1958	1878
		2	2183	2147	2111	2008	1942	1878	1727	1588
		4	2147	2076	2008	1816	1698	1588	1344	1137
		6	2111	2008	1910	1642	1486	1344	1045	813
		8	2076	1942	1816	1486	1299	1137	813	582
		10	2042	1878	1727	1344	1137	961	633	416
		12	2008	1816	1642	1215	994	813	492	298
		16	1942	1698	1486	994	761	582	298	152
		24	1816	1486	1215	665	445	298	109	40
		36	1642	1215	899	364	199	109	24	5
		48	1486	994	665	199	89	40	5	1
		60	1344	813	492	109	40	15	1	0
		72	1215	665	364	60	18	5	0	0
Time (hrs) Required To Dilute Down To 430 ppm --->			196	98	65.4	32.7	24.5	19.6	13.1	9.8

Figure 1 - Oconee Spent Fuel Pool Elevations and Volumes