Attachment 10

"Technical Evaluation to Verify the Adequacy of the Peach Bottom Atomic Power Station Spent Fuel Pool (SFP) Storage Rack Criticality Margins Dated August 16, 2010" (Non-Proprietary Version)

Technical Evaluation to Verify the Adequacy of the Peach Bottom Atomic Power Station Spent Fuel Pool (SFP) Storage Rack Criticality Margins Dated August 16, 2010

This engineering technical evaluation was performed in accordance with CC-AA-309-101, Rev. 11 to verify the adequacy of Peach Bottom Atomic Power Station Spent Fuel Pool (SFP) storage rack criticality margins. This is Revision 3 of this Technical Evaluation. Revision 1 was prepared to demonstrate margin to regulatory criticality criteria based substantially upon analyses that have been explicitly reviewed and approved by NRC. Revision 2 incorporates updated RACKLIFE projections and BADGER data, and reflects a revision to Reference 9. Revision 3 incorporates changes associated with revisions to References 16 and 17, and the issuance of References 18 and 19.

1.0 Reason for Evaluation/Scope

This technical evaluation assesses the adequacy of the Peach Bottom SFP storage racks to maintain criticality margin in excess of that required by the Peach Bottom Technical Specification 4.3.1.1.b requirement of 5 percent ($K_{eff} \leq 0.95$), accounting for projected degradation of the Boraflex neutron absorber material and fuel designs currently resident or projected for loading in the fuel pools and reactors.

2.0 Detailed Evaluation

2.1 Background

The current Peach Bottom Atomic Power Station, Units 2 and 3 high-density Spent Fuel Pool (SFP) storage racks were designed and manufactured by Westinghouse Electric Corporation and placed in-service in 1986 under plant modification # 1140. A Safety Analysis Report (SAR) in support of the upgraded racks and associated Technical Specification changes (Reference 1) was submitted to NRC as part of a License Amendment Request (LAR) in June of 1985 and supplemented in August of 1985 and December of 1985. Section 3.1 of this Safety Analysis Report addressed the criticality control capability of the racks. The LAR was subsequently reviewed and approved by NRC, as documented in license amendments 116 and 120 for Peach Bottom Atomic Power Station, Units 2 and 3, respectively. NRC issuance of these amendments is documented in the Reference 2 letter and associated Safety Evaluation, dated February 19, 1986. The underlying technical bases for the criticality analysis results presented in the Reference 1 Safety Analysis Report are documented in Section 4.4 of Westinghouse Electric Corporation report WNEP-8542, Design Basis of High Density Spent Fuel Storage Racks for Philadelphia Electric Company, Peach Bottom Atomic Power Station Units 2 & 3 (Reference 3).

The original criticality design analysis for the Westinghouse high-density storage racks (Reference 3) was performed with the AMPX system of codes for cross section generation and the KENO-IV Monte Carlo program for reactivity evaluation. The analysis assumed a bounding design basis fuel assembly of the

GE 7X7 mechanical design, uniformly enriched to 3.5% U-235 with a maximum Uranium loading of 17.3 grams per axial centimeter and no burnable poison. This lattice was demonstrated to bound later 8X8 and 8X8R mechanical designs. This analysis also assumed a minimum as-built Boron-10 density of 0.021 grams B-10 per square centimeter of the Boraflex neutron absorber material imbedded in the rack panels. The analysis concluded that the maximum K_{eff} of the racks under limiting normal and off-normal design basis conditions, accounting for appropriate manufacturing tolerances and calculational uncertainties at a 95/95 probability/confidence level, was 0.9357. In Section 2.1 of the Reference 2 Safety Evaluation Report, NRC documents the acceptability of the criticality analysis, including analytical methods, statistical treatments and overall results. The new technical specification criticality limit of 17.3 grams U-235 per axial centimeter of total active fuel height of the assembly was approved. Subsequent to NRC approval, the final version of the Westinghouse report (Rev. 2 – 7/21/86) was added as a reference into the UFSAR Section 10 discussion regarding the fuel pool.

In February of 1993, Philadelphia Electric Company submitted license amendment requests 175/178 (Reference 4) to replace the existing Peach Bottom Atomic Power Station, Units 2 and 3 spent fuel pool storage loading limit Technical Specifications (17.3 grams U-235 per axial centimeter of total active fuel height of the assembly) with a fuel assembly maximum in-core K_{inf} limit of 1.362. The intent of this Technical Specification revision was to provide a criticality criterion that could more readily account for advanced fuel design features such as burnable poisons, partial length fuel rods and shorter active fuel zones. The underlying technical basis for the new K_{inf} limit is documented in GE Nuclear Energy report GENE-512-92073, dated November 1992 (Reference 5). This GENE rack criticality analysis was performed with the MERIT 3-dimensional Monte Carlo program using ENDF/B-IV cross-sections. The analysis was premised on the (then current) GE11 (9X9) mechanical design loaded with 4.5% U-235 and limited Gadolinium, operating at peak reactivity conditions. The analysis was premised on the same Boraflex B-10 densities assumed in the original Westinghouse analysis (0.021 gram per square cm). The new design basis lattice was chosen to have an in-rack K_{eff} consistent with that of the original Westinghouse 7X7 design basis assembly, which provided substantial margin for future fuel designs. The lattice was significantly more reactive than any assembly ever operated or stored at Peach Bottom or elsewhere in the BWR fleet. The analysis also confirmed that all earlier fuel product lines were bounded by the updated analysis. NRC approved this license amendment request, as documented in the Reference 6 Safety Eevaluation, dated May 28, 1993. The NRC determined that the GNF analytical methods and calculation results were acceptable, and concluded that "fuel assemblies having a maximum in-core K_{inf} of 1.362 may be stored in the fuel storage racks and that TS 5.5, 'Fuel Storage', may be revised as proposed by the licensee in the February 5, 1993 application." The change to Technical Specification 5.5.D (renumbered 4.3.1.1.a with the implementation of Improved Technical Specifications) was approved. Specification 4.3.1.1.a now reads as follows:

"The spent fuel storage racks are designed and shall be maintained with fuel assemblies having a maximum K_{inf} of 1.362 in the normal reactor core configuration at cold conditions".

In June of 1996, NRC issued Generic Letter 96-04 to address the issue of Boraflex degradation in spent fuel pool storage racks. All licensees operating racks containing the Boraflex material were requested to provide an assessment of the physical condition of the Boraflex material and the impact on margin to criticality, as well as proposed actions to monitor ongoing Boraflex degradation. PECo Nuclear's response to the generic letter for Peach Bottom Atomic Power Station (Reference 14) confirmed minimal Boraflex degradation at that time and substantial margin to the regulatory limit of $K_{eff} \leq 0.95$ based on Peach Bottom Atomic Power Station, Unit 2 Boraflex "blackness testing", calculations performed using the EPRI-developed RACKLIFE computer program, and criticality analyses performed by AEA Technologies (Reference 7). PECo Energy also proposed an ongoing Boraflex monitoring program, to include RACKLIFE simulation of the racks and blackness testing using the BADGER B-10 areal density measurement system.

Since 1996 Peach Bottom has continued to monitor the condition of the Boraflex material in the Unit 2 and 3 racks by evaluating the B-10 density of each Boraflex panel using the RACKLIFE computer program at six-month intervals. This monitoring program is controlled by station procedure RT-R-004-990-2(3), "Boraflex surveillance using the RACKLIFE program." The RACKLIFE program has been calibrated using empirical B-10 density data derived from a sampling of Boraflex panels. This benchmarking of RACKLIFE is performed at approximately 4-year intervals using the EPRI-developed BADGER system. BADGER testing is controlled by station procedure RT-R-004-995-2(3), "Boraflex surveillance using the BADGER test device." RACKLIFE calculations performed for Peach Bottom Units 2 and 3 on March 24, 2010 indicate the following status of the Peach Bottom racks:

The Peach Bottom 2 (limiting) pool-average and peak panel Boraflex degradation trends are shown in Figures 1 and 1A, below:

[ ]

Figure 1
PB 2 RACKLIFE Pool Average Boraflex Degradation Trend

[ ]

Figure 1A
PB 2 RACKLIFE Peak Panel Boraflex Degradation Trend

In response to degrading trends in Boraflex B-10 density in the Peach Bottom Atomic Power Station racks, PECO Energy Company (now Exelon Generation Company, LLC) secured analyses from AEA Technology and Northeast Technology (NETCo) that quantify the reactivity effects associated with varying degrees of B-10 density loss in the Westinghouse racks. Most notably, AEA Technologies report AEAT/R/NS/0084, dated July 2000 (Reference 8) developed reactivity worths associated with 10% uniform thinning and 10 cm random gapping of the Boraflex material. The reactivity penalty derived from this analysis, [ ] delta-K, was subsequently transposed into Global Nuclear Fuel (GNF) SFP criticality analyses prepared to support the GE-14 and GNF2 fuel product upgrades (References 12 and 13, respectively). These GNF rack criticality analyses were subsequently incorporated into the Peach Bottom Atomic Power Station design basis via 50.59 evaluations prepared in support of the ECRs for the GE-14 and GNF2 design changes (reference ECRs 99-02682 and 04-00043, respectively). The GNF rack criticality analyses included demonstration that K_{inf} values associated with the new fuel designs were bounded by the original (Reference 5) GE K_{inf} conversion analysis used to derive the 1.362 technical specification limit. GE-14 and GNF-2 bundle K_{inf} calculations were performed with approved versions of TGBLA (Reference 11).

The premise of this technical evaluation revision is that the Boraflex degradation penalties developed by AEA Technology and subsequently, NETCo, as well as the methodologies used to develop those penalties, have not been reviewed by NRC for application at Peach Bottom Atomic Power Station. Earlier AEA Technology and NETCo analyses were incorporated into the Peach Bottom Atomic Power Station design basis under 50.59. This technical evaluation will assess the reactivity worths associated with Peach Bottom Boraflex degradation based on analyses previously reviewed by NRC and confirm that, given current and projected SFP rack loading and Boraflex conditions, the racks will maintain margin to regulatory criticality limits until a long-term repair/upgrade solution can be implemented.

2.2 <u>Current Peach Bottom Spent Fuel Pool Conditions</u>

- The maximum cold, uncontrolled, in-reactor K_{inf} at peak reactivity conditions for any fuel assembly operating or in storage at Peach Bottom Unit 2 is 1.2344 (Reference 10).
- The maximum cold, uncontrolled, in-reactor K_{inf} at peak reactivity conditions for any fuel assembly operating or in storage at Peach Bottom Unit 3 is 1.2342 (Reference 10).
- The PB 2 SFP currently contains 2844 bundles (max. pool capacity = 3819 bundles). The PB 2 SFP is operating at 74.47% of capacity.

- The PB 3 SFP currently contains 2945 bundles (max. pool capacity = 3819 bundles). The PB 3 SFP is operating at 77.11% of capacity.
- The majority of fuel in storage in the Peach Bottom fuel pools is depleted substantially beyond peak reactivity conditions.

2.3 Evaluation

The original criticality design basis for the Peach Bottom Atomic Power Station SFP racks was established by the rack supplier, Westinghouse Electric Corporation, and is documented in Section 4.4 of Westinghouse Report WNEP 8542, "Design Report of High Density Spent Fuel Storage Racks For Philadelphia Electric Company, Peach Bottom Atomic Power Station Units 2 & 3" (Reference 3). The analysis establishes that there is a 95% probability at a 95% confidence level that K_{eff} in the racks will remain below 0.95 when the racks are fully loaded with design basis fuel under bounding normal and postulated off-normal conditions. The assumed design basis assembly is a GE 7X7 lattice uniformly loaded with 3.5% enriched uranium dioxide. The Westinghouse model assumes a uniform neutron absorber loading of 0.021 grams B-10 per square centimeter of Boraflex material in the rack panels. 0.021 gr/cm^2 was determined to be the minimum B-10 areal density loaded into the Peach Bottom racks based on laboratory testing of all Boraflex batches used in the manufacturing process.

Section 4.4.6 of WNEP 8542 documents the results of a B-10 loading sensitivity analysis that was performed by Westinghouse at the request of NRC (in addition to sensitivity analyses for fuel enrichment and storage cell pitch). The results of these B-10 density sensitivity calculations are presented in WNEP 8542 Figure 4.4-8, "Sensitivity of K_{eff} to Poison Loading in the Peach Bottom Units 2 and 3 Spent Fuel Storage Racks". Data is plotted over a range of +/- 23.8% absolute B-10 density relative to the nominal 0.021gr/ cm^2 value. Plotted values include 95/95 confidence bands. This nominal data is displayed graphically in Figure 2, below.

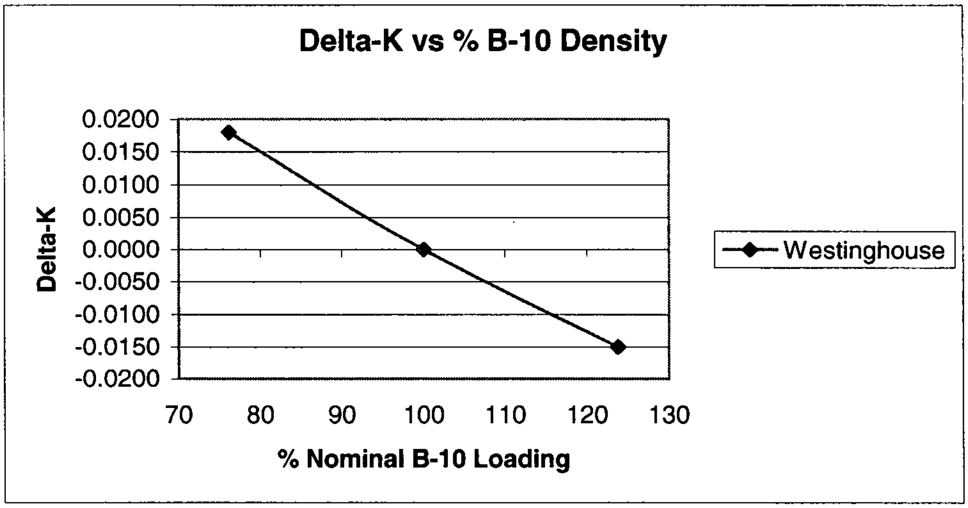

Figure 2

Sensitivity of K_{eff} to B-10 Poison Loading
From WNEP 8542

The relationship between B-10 loading and K_{eff} is observed to be approximately linear over the range of the data. The slope of the line between the nominal K_{eff} values for 0.021 grams B-10/ cm^2 and 0.016 grams B-10/ cm^2 is 0.0756% delta-k/B-10 % loss. Subsequent to NRC approval of the Westinghouse analysis (Reference 2), this linear relationship has been validated by several more recent Peach Bottom studies, including 1996 and 2000 AEA Technology analyses (References 7 and 8), and a 2009 Northeast Technology analysis (Reference 9). Results of these more recent analyses are superimposed on the results of the original Westinghouse sensitivity calculations in Figure 3, below.

[ ]

Figure 3

Sensitivity of K_{eff} to B-10 Poison Loading
Various Peach Bottom Rack Analyses

The linearity of this relationship at lower B-10 densities was further validated using Reference 7 K_{inf} sensitivity analysis results over the range of 0% to 100% poison density. This data is additionally superimposed onto the Westinghouse results in Figure 4, below.

Figure 4

Sensitivity of K_{eff} to B-10 Poison Loading
Various Peach Bottom Rack Analyses

The collective analyses performed subsequent to the original rack design analysis serve to validate the applicability of the B-10 density vs K_{eff} relationship developed by Westinghouse in the original sensitivity calculations. Further, these later analyses indicate that the correlation developed by Westinghouse will be approximately linear down to 50% B-10 density. As discussed above, using the Westinghouse nominal results for 100% and 76.2% B-10 density yields the following relationship:

0.0756% delta-K (in-rack) increase per 1% B-10 density loss

For purposes of this evaluation it will be conservatively assumed that this relationship is based on the extreme low end of the K_{eff} 95/95 uncertainty band for the 100% B-10 density point, and the extreme high end of the K_{eff} 95/95 uncertainty band for the 76.2% B-10 density point. This assumption yields the following substantially more conservative relationship:

0.1177% delta-K (in-rack) increase per 1% B-10 density loss

This more conservative relationship is shown graphically as the Westinghouse – 95/95 curve on Figure 5.

Figure 5

Sensitivity of K_{eff} to B-10 Poison Loading
Various Peach Bottom Rack Analyses

The Westinghouse design analysis documented in WNEP 8542 demonstrated that, when fully loaded with 3.5% enriched 7X7 design basis fuel, the effective multiplication constant of the as-manufactured Peach Bottom spent fuel storage racks would be 0.9357. These results accounted for applicable uncertainties at a 95% probability/95% confidence level, and met all regulatory requirements for sub-criticality. NRC-approved Peach Bottom Technical Specification amendments 175 and 178 (Units 2 and 3, respectively) demonstrated that fuel lattices with in-core K_{inf} values of 1.362 or less would be bounded by the original Westinghouse rack analysis (maintaining bundle in core $K_{inf} < 1.362$ would assure that fuel pool K_{eff} remained less than the 0.9357 value generated in the original Westinghouse analysis). A later GNF report associated with Task Scoping Document (TSD) NF-B374 (Reference 10) documents that the peak reactivity lattice ever operated or stored at Peach Bottom Atomic Power Station, Units 2 and 3 had a peak lattice K_{inf} of 1.2344. The difference between the current Technical

Specification K_{inf} limit of 1.362 and 1.2344 represents substantial margin to the 0.9357 K_{eff} value determined by Westinghouse and the regulatory limit of $K_{eff} \leq$ 0.95.

In order to express this margin to the in-core K_{inf} Technical Specification limit in terms of margin to in-rack K_{eff}, it is necessary to characterize the relationship between in-rack reactivity and uncontrolled in-core reactivity. This relationship was developed by GE and is displayed graphically in Figure 1 of the Reference 5 report GENE-512-92073. The work was originally performed to determine a reactivity bias to account for fuel enrichment of up to 4.5%. GE performed a series of calculations that evaluated both in-core and in-rack k_{inf} for a set of 4.5% enriched lattice designs of differing reactivity, where reactivity was adjusted by varying the number of gadolinium rods in the lattice. The results of this analysis are displayed in Figure 6, below.

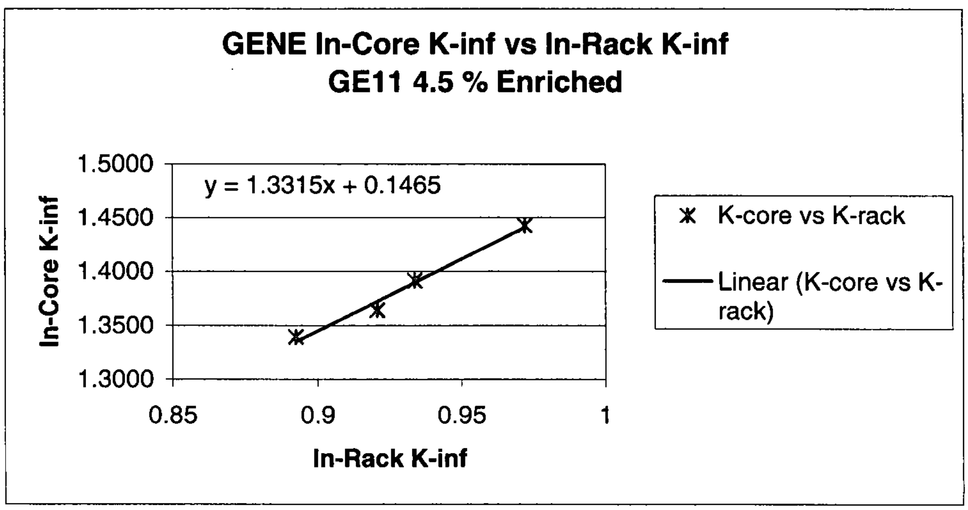

Figure 6

Relationship Between Storage Rack K_{inf} and In-Core K_{inf}

A least square fit through the data yields the equation:

In-Core K_{inf} = 1.3315 * In-Rack K_{inf} + 0.1465

Applying this equation, the current in-core k_{inf} Tech Spec limit of 1.362 is equivalent to an in-rack k_{inf} of 0.9129, and the current peak Peach Bottom Atomic Power Station reactivity lattice in-core k_{inf} (1.2344) is equivalent to an in-rack k_{inf}

of 0.8171. The difference between these values (0.9129-0.8171= 0.0958) represents 9.58% delta-k margin to the original Westinghouse in-rack k_{eff} value of 0.9357, and 11.01% margin to the regulatory limit of 0.95.

The current average uniform B-10 loss from all Boraflex panels in the Peach Bottom Atomic Power Station racks is [ ]% (bounding Unit 2 value). Applying the more conservative B-10 density/reactivity correlation developed above (0.1177% delta-K increase per 1% B-10 density loss) yields the following Boraflex degradation penalty:

(0.1177% delta-K/% B-10 density loss) X [ ]% B-10 density loss = [ ]% delta-K

A projection of future reactivity margin is also considered. Assuming 45% uniform B-10 loss from all Boraflex panels in the Peach Bottom racks (remaining within the range in which the boron loss reactivity effect characteristic is linear, as illustrated in Figure 4), and applying the more conservative B-10 density/reactivity correlation developed above (0.1177% delta-K (in-rack) increase per 1% B-10 density loss) yields the following Boraflex degradation penalty:

(0.1177% delta-K (in-rack)/% B-10 density loss) X 45% B-10 density loss = 5.30% delta-K (in-rack)

It is recognized that fuel design changes may be required in the future to support extended power uprate or other changes in operation strategy. Accordingly, it is assumed that at some future time the maximum lattice in-core K_{inf} will be raised to 1.26 (2.56% in-core delta-K increase relative to the currently limiting assembly in storage in the Peach Bottom Unit 2 racks). Using the approach described above this translates to a 1.92% in-rack delta-k to address more reactive fuel designs that may be stored in the pools in the future. Exelon currently does not expect to implement a power uprate or significant change in cycle operating strategy over the next 2 years. It should be noted that 10X10 fuel designs currently being loaded at Peach Bottom Atomic Power Station are more than .5% (in-core) less reactive than the most limiting 9X9 designs loaded prior to the introduction of GE-14 mechanical design.

As discussed in the Reference 9 NETCo report, the 1-sigma B-10 density uncertainty inherent in the BADGER methodology, as benchmarked to Peach Bottom Atomic Power Station, is [ ]%. Conservatively treating this BADGER uncertainty as a non-conservative bias and applying the aforementioned reactivity correlation yields a [ ]% delta-K (in-rack) penalty associated with the BADGER methodology.

The Reference 19 NETCo report, BADGER Test Campaign at Peach Bottom Atomic Power Station Unit 3, documents gapping observed in Peach Bottom 3 Boraflex panels during the 2009 BADGER test. Measurements during this test campaign were skewed towards high duty panels. The average cumulative gap axial dimension observed over the [ ] inch length of the panels tested was [ ] inches, with the largest cumulative gap observed being [ ] inches (in only [ ]% of the panels tested). Gapping was characterized as randomly distributed both axially and radially across the racks. While gapping results from densification of the Boraflex material and does not result in an actual loss of material from the racks, for purposes of this evaluation it will be conservatively assumed that cumulative [ ] inch gaps representative of lost material are randomly distributed across all Boraflex panels in the pools. This constitutes an additional [ ]% effective B-10 density loss in the racks. Applying the aforementioned B-10 density correlation yields a [ ]% delta-k (in-rack) bias associated with uniformly distributed Boraflex gapping.

It is also appropriate to apply a [ ]% delta-K (in-rack) bias to account for undetected Boraflex cracking, as described in the Reference 9 NETCo report. The BADGER system is unable to detect axial cracks smaller than 1/3 inch in length in Boraflex panels. This bias accounts for an assumed uniform distribution of these small axial cracks.

During six BADGER testing campaigns (264 measurements) at Peach Bottom the RACKLIFE program has been demonstrated to generate conservative ([ ]% B-10 density) assessments of Boraflex panel degradation relative to BADGER empirical data. The one sigma uncertainty for deviations between RACKLIFE and BADGER measurements for the 6 BADGER testing campaigns performed at Peach Bottom was [ ]%. Conservatively treating the uncertainty as a non-conservative bias and applying the aforementioned reactivity correlation yields a [ ]% delta-K (in-rack) penalty associated with the RACKLIFE methodology.

2.4 <u>Evaluation Summary</u>

As discussed above, the original Westinghouse analysis yielded an in-rack K_{eff} of 0.9357, demonstrating 1.43% delta-K margin to the regulatory limit. The Reference 5 GE analysis determined that the in-core K_{inf} for the design basis assembly evaluated by Westinghouse was 1.362. The currently limiting assembly resident at Peach Bottom has a peak K_{inf} of 1.2344. The difference between the design basis in-core K_{inf} and the actual limiting bundle in-core K_{inf} (1.3620-1.2344) represents an additional 9.58% delta-K margin to the in-rack regulatory limit of 0.95. Combining this 9.58% delta-K margin with the 1.43% delta-K margin in the original Westinghouse analysis results in 11.01% delta-K overall margin in the original design analysis, assuming as-built Boraflex conditions.

Subtracting the conservatively derived [ ]% delta-K reactivity penalty associated with the current [ ]% uniform depletion of B-10 from all Boraflex panels in the racks results in a remaining [ ]% delta-K margin to the regulatory limit of $K_{eff} \leq 0.95$. Applying the conservatively derived BADGER system bias ([ ]% delta-K), undetected cracking bias ([ ]% delta-K), random gapping bias ([ ]% delta-K), and RACKLIFE bias ([ ]% delta-K) results in an overall [ ]% delta-K margin to 0.95 K_{eff}. This represents substantial current margin to regulatory limits for criticality on a pool average basis.

The projection of future reactivity margin is also evaluated. Subtracting the conservatively derived 5.30% delta-K reactivity penalty associated with 45% uniform depletion of B-10 from all Boraflex panels in the racks and allowing for up to 2.56% delta-K more reactive fuel (in-core), as may be required to meet future operational needs, results in a remaining [ ]% delta-K margin to the regulatory limit of $K_{eff} \leq 0.95$. Applying a conservatively derived BADGER system bias ([ ]% delta-K), undetected cracking bias ([ ]% delta-K), random gapping bias ([ ]% delta-K) and RACKLIFE bias ([ ]% delta-K) results in a remaining [ ]% delta-K margin to 0.95 K_{eff}. The reactivity margin balance is summarized below.

Current Margin Summary

Description	Reactivity
Margin to Westinghouse $K_{eff} < 0.9357$	9.58%
Additional Margin to $K_{eff} < 0.95$	1.43%
Total Margin	11.01%

[ ]

Future Margin Summary

Description	Reactivity
Margin to Westinghouse $K_{eff} < 0.9357$	9.58%
Additional Margin to $K_{eff} < 0.95$	1.43%
Total Margin	11.01%

45% Uniform B-10 Density Loss	-5.30%
2.56% K_{inf} Increase in Future Fuel Designs	-1.92%

As previously discussed, the range over which the boron loss reactivity effect characteristic remains linear is illustrated in Figure 4. The linear characteristic remains in effect down to approximately [ ]% B-10 depletion. Beyond this level of depletion, the reactivity effect becomes non-linear. Since this non-linear effect has not been included in this evaluation, the evaluation approach is considered valid only up to the time at which Boraflex panels reaches [ ]% B-10 depletion. This evaluation specifically supports 45% B-10 loss.

RACKLIFE calculations currently project that the leading Boraflex panel in the Peach Bottom 2 fuel pool will exceed 45% B-10 depletion (as indicated by RACKLIFE) in 2014, as shown in figure 7, below.

Figure 7

Peach Bottom 2 RACKLIFE Peak Panel
% B-10 Density Loss Projection

The above evaluations are based on the original Westinghouse criticality analysis assumptions and methodology and supported by more recent studies. Additional safety margins to the 0.95 K_{eff} limit are discussed below. These margins have not been explicitly accounted for in the evaluation and, therefore, constitute additional 'margin to safety'.

The Peach Bottom rack criticality analysis is based on the 'minimum certified' Boraflex B-10 areal density (0.021 gm/cm^2). The actual average, as fabricated B-10 areal density of all panels manufactured for the PB2 and 3 racks was 0.0235 gm/cm^2, 11.9% higher than the density assumed in the original analysis. The reactivity worth of an additional 11.9% B-10 density is approximately 1.4% delta-K.

The existing Peach Bottom licensing basis rack criticality analysis is based on a bundle with an in-core K_{inf} of 1.362. The evaluation above identifies the margin associated with the actual, as-loaded peak bundle reactivity (in-core K_{inf} of 1.2344). A large majority of assemblies in the Peach Bottom pools have been depleted well beyond peak reactivity conditions, with in-core, cold, uncontrolled K_{inf} values less than 1.0, providing significant unaccounted margin.

3.0 Conclusion

An assessment of margin to criticality limits has been performed for the Peach Bottom Atomic Power Station spent fuel pool storage racks. The evaluation accounts for actual fuel in storage as well as fuel projected to be stored in the future, and relies principally upon criticality analyses previously reviewed and approved by NRC. Historical analysis results have been validated using more current methods and applied in a conservative manner. The condition of the Boraflex panels in the racks has been and will continue to be determined using the industry standard EPRI RACKLIFE methodology, which will continue to be regularly benchmarked to Boraflex blackness measurements obtained using the EPRI-developed BADGER system. The underlying Westinghouse and GNF analyses apply NRC approved methods and account for appropriate modeling biases and uncertainties. This evaluation concludes that Technical Specification 4.3.1.1.b (K_{eff} less than or equal to 0.95) is currently met for all storage cells in both Peach Bottom Atomic Power Station fuel pools, and will continue to be met at least until such time as individual Boraflex panels exceed 45% Boron-10 density loss relative to the minimum density assumed in the original Westinghouse design analysis. This evaluation is based on a conservative assessment of reactivity as a function of B-10 areal density in the racks. The most significantly degraded panel in either Peach Bottom fuel pool, as evaluated by the RACKLIFE methodology, is currently operating with [ ]% density loss relative to the average as-manufactured panel density of 0.0235 gm/cm^2. The evaluation is premised on all fuel loaded in the racks having an in-reactor, cold, uncontrolled infinite lattice multiplication factor (K_{inf}) of less than 1.26 at peak reactivity conditions, as evaluated using GNF's NRC approved TGBLA06A lattice physics methodology. The most reactive assembly currently stored in either fuel pool or currently in operation (including the incoming P2R18 reload of GNF2 fuel) has a peak K_{inf} of 1.2344. A significant majority of assemblies stored in the Peach Bottom pools have been depleted well beyond peak reactivity conditions.

Peach Bottom Atomic Power Station, Unit 2 reload 18 fuel is of the GNF2 mechanical design, and will be loading in reload quantities for the first time during P2R18. The in-core k-infinity of the maximum reactivity P2R18 lattice at peak reactivity conditions is 1.2087, 2.57% less reactive than limiting 9X9 designs currently in storage in the Peach Bottom pools. As is the case with GE-13 and GE-14 GNF fuel operated at Peach Bottom subsequent to the issuance of Reference 6, P2R18 GNF2 reload fuel in-core criticality characteristics have been explicitly evaluated by GNF using the same NRC-approved (Reference 11) lattice physics program (TGLBA06A) used in the analyses described in this technical evaluation. GNF2 fuel, including that to be loaded during P2R18, may be evaluated for fuel storage criticality using the methods specified in this technical evaluation, subject to the same limitations as all earlier GNF mechanical designs.

This evaluation demonstrates [ ]% delta-K reactivity margin to the regulatory limit of $K_{eff} \leq 0.95$ for current conditions based on current pool-average B-10 density losses and [ ]% delta-K reactivity margin for future operation based on a maximum pool average B-10 density loss of 45%. For conservatism, future operation will be monitored based on a peak panel B-10 density reduction of 45%. Given these margins, continued operation of the Peach Bottom spent fuel pool storage racks is acceptable within the constraints designated below:

1. Less than 45% B-10 density loss from individual Boraflex panels relative to the minimum certified B-10 loading.
2. Maximum K_{inf} of stored fuel ≤ 1.260

4.0 References

1. Peach Bottom Atomic Power Station Units 2 & 3, Spent Fuel Storage Capacity Modification Safety Analysis Report, Revision 2, Philadelphia Electric Company, December 1985.
2. Safety Evaluation By the Office of Nuclear Reactor Regulation Supporting Amendments Nos. 116 and 120 to Facility Operating Licenses Nos. DPR-44 and DPR-56, dated February 19, 1986.
3. G. Knock, et al, Design Report of High Density Spent Fuel Storage Racks For Philadelphia Electric Company, Peach Bottom Atomic Power Station Units 2 & 3, WNEP 8542, Revision 1, dated June 18, 1985.
4. Peach Bottom Atomic Power Station Units 2 & 3, Technical Specification Change Request 92-21, Fuel Storage Criticality, dated February 5, 1993.
5. Peach Bottom Atomic Power Station Spent Fuel Storage K_{inf} Conversion Analysis, GENE-512-92073, November 1992.
6. Safety Evaluation By the Office of Nuclear Reactor Regulation Related to Amendment Nos. 175 and 178 to Facility Operating Licenses Nos. DPR-44 and DPR-56, dated May 28, 1993.
7. J. Gulliford, et al, An Assessment of the Possible Effects of Boraflex Degradation on K_{eff} for the Peach Bottom Storage Pools, AEAT-0791, AEA Technology Engineering Services, dated November 7, 1996.
8. D. Sweet, et al, Criticality Assessment of the Peach Bottom Spent Fuel Ponds with Degraded Boraflex Panels, AEAT/R/NS/0084, Issue 1, AEA Technology Engineering Services, July, 2000.
9. M. Harris, et al, Criticality Analysis of the Peach Bottom Spent Fuel Racks for GNF 2 Fuel with Maximum Boraflex Panel Degradation, NET-264-02-P, Revision 4, Northeast Technology Corporation, dated December 17, 2009.
10. Letter from N. Pinchuk (Global Nuclear Fuels) to J. Tusar (Exelon Nuclear), Peach Bottom 2 and 3 Maximum Cold Uncontrolled K-Infinities (TSD NF-B374), dated May 8, 2009.
11. General Electric Standard Application for Reactor Fuel, NEDE-24011-P-A-16 (or Latest Approved Revision).
12. GE14 Spent Fuel Storage Rack Analysis for Peach Bottom Atomic Power Station, J11-03761-00-SFP, Global Nuclear Fuel, July, 2000.
13. GNF2 Spent Fuel Storage Rack Criticality Analysis for Peach Bottom Atomic Power Station Units 2 & 3, 0000-0035-7327-SFP, Revision 2, Global Nuclear Fuel, June, 2008.
14. Letter from G.A. Hunger (Philadelphia Electric Co) to U.S. Nuclear Regulatory Commission, "Response to Generic Letter 96-04, Boraflex Degradation In Spent Fuel Pool Storage Racks," dated October 25, 1996.
15. IR 864431, "Potential Non-Compliance with 10CFR50.59".
16. BADGER Test Campaign at Peach Bottom Unit 2, NET-264-01, Revision 03, Northeast Technology Corporation, dated July 8, 2010.

17. BADGER Test Campaign at Peach Bottom Atomic Power Station Unit 3 NET-247-01, Revision 01, Northeast Technology Corporation, dated July 8, 2010.
18. 2010 BADGER Test Campaign at Peach Bottom Unit 2, NET-350-01, Revision 00, NETCo Products and Services Division of Scientech, dated July 8, 2010.
19. BADGER Test Campaign at Peach Bottom Atomic Power Station Unit 3, NET-311-01, Revision 00, NETCo Products and Services Division of Scientech, July 8, 2010.