September 30, 2005

Mr. L. William Pearce
Vice President
FirstEnergy Nuclear Operating Company
Beaver Valley Power Station
Post Office Box 4
Shippingport, PA 15077

SUBJECT: BEAVER VALLEY POWER STATION, UNIT NOS. 1 AND 2 (BVPS-1 AND 2) - REQUEST FOR ADDITIONAL INFORMATION (RAI) - EXTENDED POWER UPRATE (EPU) (TAC NOS. MC4645 AND MC4646)

Dear Mr. Pearce:

By letter to the U.S. Nuclear Regulatory Commission (NRC) dated October 4, 2004, as supplemented by letters dated February 23, May 26, June 14, July 8, July 28, and September 6, 2005, FirstEnergy Nuclear Operating Company (the licensee), submitted a license amendment request (LAR) for BVPS-1 and 2 to change the operating licenses to increase the maximum authorized power level from 2689 megawatts thermal (MWt) to 2900 MWt, which represents an increase of approximately 8% above the current maximum authorized power level. The NRC staff has determined that the additional information requested in the enclosure to this letter is needed to complete its review. As discussed with your staff, we request your response within 30 days of receipt of this letter in order for the NRC staff to complete its scheduled review of your submittal. As the analyses used to support the EPU also may support your replacement steam generator LAR for BVPS-1, dated April 13, 2005, as supplemented August 26, 2005, these questions also apply to that LAR.

If you have any questions, please contact me at 301-415-1402.

Sincerely,

/RA/

Timothy G. Colburn, Senior Project Manager, Section 1
Project Directorate I
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-334 and 50-412

Enclosure: RAI

cc w/encl: See next page

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REQUEST FOR ADDITIONAL INFORMATION (RAI)

RELATED TO FIRSTENERGY NUCLEAR OPERATING COMPANY (FENOC)

BEAVER VALLEY POWER STATION, UNIT NOS. 1 AND 2 (BVPS-1 AND 2)

EXTENDED POWER UPRATE (EPU)

DOCKET NOS. 50-334 AND 50-412

By letter dated October 4, 2004, as supplemented by letters dated February 23, May 26, June 14, July 8, July 28, and September 6, 2005, Agencywide Documents Access and Management System (ADAMS), Accession Nos. ML042920300, ML051160426, ML051160429, ML051160431, ML051530376, ML051670270, ML051940575, ML052140310 and ML052550373, FENOC (the licensee) proposed changes to BVPS-1 and 2 operating licenses to increase the maximum authorized power level from 2689 megawatts thermal (MWt) to 2900 MWt rated thermal power (RTP) or approximately 8%. The Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's application against the guidelines in the EPU review standard, RS-001, Revision 0, "Review Standard for Extended Power Uprates," December 2003, and determined that it will need the additional information identified below to complete its review. As the analyses used to support EPU also may support the replacement steam generator (RSG) license amendment request (LAR) for BVPS-1, dated April 13, 2005, as supplemented August 26, 2005, these questions also apply to the RSG LAR. These second round RAI questions are numbered the same as those in the NRC staff's May 5, 2005, RAI for continuity.

Small-Break Loss-of-Coolant Accident (SBLOCA) and Post-LOCA Long-Term Cooling Analyses
EPU Licensing Report Section 5.2.2

E.2 Comparison of the high-head safety injection (HHSI) pump head flow curves for pre-EPU and EPU conditions for the SBLOCA analyses show the EPU head flow curve has increased by about 10%. Please explain how this was accomplished. Also, the flow into the two intact loops should be based on the two minimum-loop injection measurements from the surveillance testing. Please confirm this approach in arriving at the head flow curve for the SBLOCA analyses.

E.3 The NRC staff's RELAP5 code calculations show that the peak clad temperature (PCT) for a severed injection line is about 1750 ^{B}F. Although the accumulators do inject into the core, the increased core uncovery with the reduced injection capacity produces a rapid heat-up and high clad temperatures before termination of the event by the accumulators. Using BVPS-1 and 2-specific information, please show that the NOTRUMP code does not produce temperatures for this condition that are higher than the worst break in the bottom of the cold leg.

E.5 The response to this question was not acceptable. The NRC staff's position is that the worst small break should be identified in all SBLOCA evaluation model (EM) submittals. The analysis approach of only investigating integer break sizes does not meet the requirements of

Enclosure

Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Section 50.46, paragraph (a)(1)(i) that states "ECCS cooling performance must be calculated in accordance with an acceptable evaluation model and must be calculated for a number of postulated loss-of-coolant accidents of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated loss-of-coolant accidents are calculated." The worst small break is typically that break (or one where the accumulators inject for a very short period of time) where the reactor coolant system (RCS) depressurizes to a minimum pressure that remains just above the accumulator action pressure. Please provide the results of the BVPS-1 and 2-specific analysis related to the limiting break.

Please explain and justify how the accumulator maximum water temperature is maintained at the 105 ^{B}F temperature assumed in the analysis.

Also, were failures of instrument tube penetrations in the lower reactor vessel head evaluated? If so, what was learned from the evaluations?

E.5a The same question above for E5 applies to E5a.

E.6 As shown in Figure (Fig.) E.6-7, removing the erratic behavior in the two-phase level between 1400 and 2200 sec shows elimination of the cooling between 1400 and 1800 sec. However, since the minimum level is not turned around until about 3200 sec, what caused the cooling between 2200 and 2400 sec? It appears that the PCT should be increased by the difference in temperatures at around 2200 sec. Please explain.

E.7 The modification to allow more than one loop seal to clear represents a change to the approved SBLOCA EM using the NOTRUMP code. Page 5-45 of WCAP-10054-P-A, "Westinghouse Small Break ECCS Evaluation Model Using the NOTRUMP CODE," August 1985, clearly states only the broken loop seal is allowed to clear. It reads:

> To ensure the most severe core mixture level and cladding heatup transient response during a small break LOCA in compliance with the spirit of Appendix K to 10 CFR 50.46, a modification was applied to the NOTRUMP small break LOCA PWR [pressurized-water reactor] model to assure conservative loop seal behaviors. This modification permits only one loop seal (the broken loop) to vent significant amounts of steam.

The EM further states: "Reiterating, break sizes larger than the threshold break size will realistically vent steam through more than one loop seal and in doing so will result in minimal core uncovery. The modification to assure conservative behavior is also applied to those breaks to ensure a continuum of response in terms of peak clad temperature when only the broken loop is artificially forced to vent steam."

The NRC staff requests that the analysis be repeated adhering to the approach approved in the topical report by allowing only the broken loop seal to clear.

Or alternatively, should Westinghouse choose to change the model to allow more than one loop seal to clear, then a full description of the new model, sensitivity studies, and appropriate benchmarking would be needed to allow the NRC staff to review this change. The additional benchmarking should include analyses of separate effects tests and integral tests experiments

to validate the new model, i.e., SEMISCALE tests series S-LH, S-UT, etc. Test S-07-10D shows the effect of loop seal clearing on the core two-phase level and the subsequent clad heat-up. Please also provide the comparisons of the new model with this test and show the effect of the new loop seal model on the long-term level in the core and PCT.

Since the NOTRUMP model combines both intact loops, a new nodalization model would need to be presented and justified. Please note that the RELAP5/MOD3 analysis of the BVPS-1 and 2 break spectrum shows only the broken loop clears for break sizes less than 6 inches in diameter.

The NRC staff also notes that the review schedule for the BVPS-1 and 2 EPU would need to be extended should Westinghouse choose to pursue modifications to the SBLOCA NOTRUMP EM loop seal model. See also the additional technical concerns expressed for E.19.

E.9 For the 3-inch break, the top portion of the core has not been recovered and in fact the two-phase level is decreasing at 5000 sec in Fig. E.8-5. If operator action is required to cool the core for small breaks during the short term, please identify the actions and show that the core can be recovered so that the core is quenched and oxidation is no longer relevant. Identify what actions are required and show the effect on PCT and oxidation. Identify the timing for operator actions and demonstrate that the latest time for action is reflected in the emergency operating procedures (EOPs). What is the latest time allowed for the recommended operator actions? Also, since the two-phase level is below the top of the core at 5000 sec for the 3-inch break, the residual heat removal (RHR) system cannot be operated since the loops contain steam (re-establishment of single-phase natural circulation by refilling the RCS with emergency core cooling (ECC) liquid is expected to take a long time). Since RCS pressure is already low for the 3- and 4-inch breaks, depressurization with SGs and power-operated relief valves (PORVs) may not be timely nor effective. Please show the analyses that are required to show the core is quenched and oxidation is no longer increasing.

E.9a. Same concern as for E. 9 above for the 3-inch break.

E.11 For some plants, analyses of small breaks in the 0.5 ft^2 to 1.0 ft^2 range can show these breaks to be limiting since the core totally uncovers. While the duration of the uncovery is shorter for these larger small breaks, the PCT is dependent on the accumulator design to prevent temperatures from exceeding 2200 ^{B}F. Please confirm, based on BVPS-1 and 2-specific conditions, that the NOTRUMP code produces less-limiting PCTs for breaks 0.5 to 1.0 ft^2 compared to the limiting breaks controlled by HHSI (0.02 - 0.04 ft^2).

E.13 Fig. E13.1 shows the steaming rate of 50 lbs/sec at 5000 sec for the 3-inch break, yet the injection into the intact loops is only about 38 lb/sec at this time shown in Fig. 5.2.2-11A. As such, the two-phase level should decrease with time until the core uncovers to the lower steaming rate of 38 lb/sec. Please explain why the core is not uncovering more and how the two-phase level is recovered at EPU conditions for this break.

Likewise, for the 2-inch break, the steaming rate is about 60 lb/sec at 6000 sec, while the injection into the intact loop is about 33 lbs/sec. Explain why the core level does not uncover to a lower two-phase level where the steaming rate is about 33 lb/sec or that equal to the injection.

Please also provide the core inlet mass flow rate and inlet temperature vs. time for all breaks.

E.15 No hot assembly is shown in Fig. E.15-1. Please explain how the sink temperature is computed in the hot channel for PCT determinations. How is the core bypass modeled? Also, with one cell in the uphill side of the pump suction leg, explain how loop seal clearing occurs as predicted by the NOTRUMP code.

E.16 Please explain why there is condensation in the broken loop. It is the NRC staff's understanding that no ECC water can accumulate in the broken loop since the critical flow rate for these breaks is far greater than the injection rate. If the break is on the bottom of the discharge leg below the injection point, all of the injection will pass immediately out the break. Condensation by the flow stream is expected to be small since highly superheated steam should be entering the break through the broken loop. Please explain how the condensation is calculated in the intact and broken loops.

E.19 Please explain the meaning of the statement: "The EPU analysis was performed with the latest version of NOTRUMP EM and, thus, all 10 CFR 50.46 changes that were to be implemented on a forward-fit basis are included in the analyses." Were additional changes, beyond those described in the response to this question, made to the approved method included in the analyses? If so, please describe them and provide an analysis to justify the changes.

Please explain how the new ECC system delivery curves were generated. Are these curves based on surveillance test data and do they take into account the two minimum-measured injection delivery rates adjusted for instrument error? Was an analysis of net positive suction head (NPSH) performed to show adequate margins at the higher injection flow rates? Please explain.

Please explain why a reduced hot assembly average power peaking factor is conservative. Use of the appropriate/higher hot assembly power should increase the hot bundle steam temperatures during uncovery, which should increase the hot rod/hot channel sink temperatures and the PCT. Please justify the use of the lower peaking factor.

Please refer to the concerns with the loop seal model as described in E.7 above

E.20 The current SBLOCA analyses for BVPS-1 and 2 fail to justify identification of the worst small-break case. Since the integer break spectrum is too coarse, analysis of break sizes between the integer sizes could produce PCTs much higher than those reported in the recent analysis. Please demonstrate that the worst SBLOCA has been identified in the current pre-EPU analyses. Please also note that for any changes made to the SBLOCA analyses that result in PCT increases of more than 50 ^{B}F, a re-analysis of the break spectrum and/or limiting break must be reported to the staff for review.

E.21 Same concern as for E.20

E.24 Please show that the boric acid concentration does not exceed 30 weight percent (wt%) for all small breaks where boiling occurs for extended periods of time. Also, steam exiting the two-phase surface in the core contains boric acid which can plate out on the spacer grids and the fuel alignment plate or any structures in the upper plenum, thus increasing the resistance to steam exiting the core. Please justify that boric acid plate-out does not increase the steam resistance in the loop and depress the two-phase level into the core. During condensation of

the primary steam, can plate-out of boric acid block the SG tubes or increase the tube resistance? What happens to the boric acid after the steam condenses on the tube walls or any other structures in the loop? Please explain.

E. 25 Can a failure in the ability to cool the refueling water storage tank (RWST) affect the SBLOCA or large-break LOCA (LBLOCA) analyses? What is the worst single failure associated with the RWST cooling system? Please explain.

E.27 Plant short-term analyses (in the first 3 hrs) show that with a break placed on the top of the discharge leg, the initial core uncovery can be increased as the steam pressure builds in the upper plenum forcing vapor into the suction leg. With the deep loop seals, and the break on the top of the pipe, the loop seals do not clear of liquid and during the first 2 hrs the clad temperatures can become very high and then remain above 1500 EF. Preliminary NRC staff's calculations show that the PCT exceeds 2200 EF during the initial loop seal blowout for the 0.04 ft^2 current licensing basis (CLB) and remains above 1500 EF until about 3 hrs into the event. Please show that breaks on the top of the pipe are not more limiting than those on the bottom of the pipe using the NRC-approved version of NOTRUMP for the SBLOCA EM.

Plant-specific analyses show that small breaks can uncover during the long term (2-3 hrs) due to loop seal refilling. If plant cooldowns are initiated no later than 1 hr post-LOCA, the effects of loop seal refilling for small breaks may be averted. Please describe the EOP instructions and timing for initiating a plant cooldown following an SBLOCA. What is the latest time post-LOCA the operators are instructed to initiate a cooldown to shutdown cooling?

For large breaks, plants with deep loop seals can uncover during the long term. While temperatures are not expected to exceed 10 CFR 50.46 limits, oxidation limits can become excessive with a slowly increasing core two-phase level with time. Since large breaks on the top of the discharge leg (large enough so that the ECC cannot refill the RCS and re-establish single phase natural circulation) can produce a long-term uncovery of the top of the core, operator actions such as those mentioned to cool down the RCS will be ineffective for large breaks since the system is already depressurized. Please explain how the post-LOCA recovery guidance addresses large breaks with long-term uncovery. Also, how do the uncertainties related to break type in best-estimate LOCA (BELOCA) analyses, as mentioned in the response, cover loop seal refilling and the attendant thermal hydraulic effects? Please explain.

E.30 See and address the comments for E.20

F.1 Does the calculated mixture volume include the effect of the loop resistance? The loop resistance will depress the mixture volume in the inner vessel, especially in the first 1-2 hrs when the decay heat steaming rate is high. Please show the effect of the loop resistance on the mixing volume and boric acid concentration vs. time. SG heat addition will superheat the steam in the cold legs. Was this included in the loop resistance? Please explain. What is the effect of liquid in the loop seals on mixing volume and boric acid content? Does the analysis consider injection from the boric acid storage tank and how were they included in the analysis?

F.2 Please show the effect of the loop resistance on the mixing volume vs. time and the effect of loop seal refilling. The loop seal is not expected to remain clear for the 7-8 hr time period prior to the switch to simultaneous injection. Downcomer boiling will also reduce the size of the

mixing volume. Please provide an analysis of the effect of downcomer boiling on the mixing volume vs. time.

F.3 The use of saturation temperature at the core inlet is not justified. Since the ECC pumped injection contains 65 ^{B}F water, please show that the temperature of the water entering the core during the injection phase does not produce precipitation prior to the switch to hot-side injection. At 6.5 hrs, the switch to hot-side injection will flush high concentrate boric acid into the sump. Please show that there is no local precipitation when this switch occurs.

F.4 The simple calculation ignores diffusion. With a subcooled region in the lower portion of the core, boric acid will diffuse into the colder region as shown by the test data once the density difference across the core increases sufficiently. Thus, at the switch time to simultaneous injection, please show that the boric acid concentration is below the precipitation limit at the minimum injection temperature or minimum temperature of the subcooled region in the bottom portion of the core.

F.5. It is understood that the hot leg switchover time is not related to the switch to recirculation. The timing for switch to recirculation affects the injection temperature, the fluid balance in the vessel and the potential for boric acid precipitation at the bottom of the core. Fig. F.1-4 shows that the boron concentration at 6.5 hrs is about 28 wt%. This concentration requires the temperature in the bottom of the core to remain above approximately 212 ^{B}F. Please provide the analysis to show that the temperature at the core inlet up to 6.5 hrs does not exceed 212 ^{B}F.

F.6 This response provides insufficient information to address the question (for an example of the type of information needed by the NRC staff, please see the Westinghouse-CE Topical Report, CENPD-254). What specific operator actions are required to assure the boric acid is controlled or dispersed before a late/rapid depressurization using PORVs, for example? What is the minimum RCS pressure following opening of both PORVs between 2 and 7 hrs and what is the RCS concentration and temperature of the subcooled water in the core bottom? What is the longest duration boiling time and maximum boric acid concentration calculated for SBLOCAs that would be allowed by the guidance and directions given to the operators in the EOPs? Could the concentration be high enough that a late depressurization with sprays or PORVs would cause precipitation?

F.8 What is the maximum containment pressure at 6.5 and 6 hrs? Is there sufficient flow in excess of the core boil-off rate to flush the core? Please show the boron concentration vs. time for a minimum flushing flow of 5 gpm initiated at 6.5 hrs?

F.9 How much debris can accumulate in BVPS-1 and 2 during the 6.5-hr time period leading up to the switch to simultaneous injection? What is the effect of debris particles on the precipitation characteristics? Please provide the results of studies specific to BVPS-1 and 2 and show the impact on the boron concentration vs. time.

General Question

Does BVPS-1 and 2 have bottom-mounted instrument tubes (penetrating the RV lower head)? What is the tube diameter?

Generic concerns

The NRC staff understands that the licensee is pursuing resolution of the 2 below listed questions with Westinghouse on a schedule to be determined. Please provide the schedule for the response to these issues.

E.12 Since the NOTRUMP code models the core as four cells, any subcooled water entering the core will be heated in the first large cell. As such, the tendency will be to over-swell the two-phase level. Four cells is insufficient to accurately predict the void distribution in a heated core, especially with a skewed power shape. Please show the sensitivity of the 3-inch break to 12 and 24 core nodes. RELAP5/MOD3 with 24 core nodes shows the PCT for the 3-inch break of about 2100 EF and a PCT greater than 2200 ^{B}F for the 0.04 ft^2 break. This may be due, in part, to the more detailed core nodalization and the fact that only the broken cold leg loop seal clears in the RELAP5 analysis. All other pertinent RELAP5 assumptions are consistent with the EPU conditions, i.e., top-peaked axial power distribution, HHSI injection curve, 1.2 x American Nuclear Society 1971 decay heat standard, etc.

F.9 More specific information and justification for the model and analysis is required. Some of the finer debris particles will permeate the core region and possibly adhere to the boric acid. Rising steam bubbles will mix the finer debris particles in the core and could cause them to concentrate.

cc:

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