FENOC
FirstEnergy Nuclear Operating Company

James H. Lash
Site Vice President

724-682-5234
Fax: 724-643-8069

August 16, 2006
L-06-095

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Subject: Beaver Valley Power Station, Unit No. 2
Docket No. 50-412, License No. NPF-73
Response to a Request for Additional Information in Support of License Amendment Request No. 183

By letter dated April 11, 2005, FirstEnergy Nuclear Operating Company (FENOC) submitted License Amendment Request (LAR) No. 183 - Revised Steam Generator Inspection Scope, for Beaver Valley Power Station Unit No. 2 (Letter L-05-061, Reference 1). Revised markups to the proposed Technical Specifications and Bases were provided on January 27, 2006 (Letter L-06-013, Reference 2). On May 10, 2006, FENOC received a draft Request for Additional Information (RAI) from the NRC pertaining to LAR No. 183. The RAI questions were discussed during a May 18, 2006 conference call with the NRC. During the call, it was agreed that FENOC would provide a response to the questions in their draft form. A minor modification to one of the questions was provided by the NRC on May 22, 2006. The draft RAI questions, as modified, and the associated FENOC responses are provided in Attachment A.

The responses to the RAI do not affect the conclusions of either the supporting safety analysis or the no significant hazard evaluation provided in Reference 1. No new regulatory commitments are contained in this submittal. If there are any questions or if additional information is required, please contact Mr. Gregory A. Dunn, Manager, FENOC Fleet Licensing, at (330) 315-7243.

I declare under penalty of perjury that the foregoing is true and correct. Executed on August 16, 2006.

Sincerely,

James H. Lash

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References:

1. Beaver Valley Unit No. 2 License Amendment Request No. 183 - Revised Steam Generator Inspection Scope, Letter L-05-061 dated April 11, 2005
2. Beaver Valley Unit No. 2 Supplement to License Amendment Request No . 183 Revised Steam Generator Inspection Scope (TAC No. MC6768), Letter L-06-013 dated January 27, 2006

Attachment: FENOC Responses to Request for Additional Information

c: Mr. T. G. Colburn, NRR Senior Project Manager
Mr. P. C. Cataldo, NRC Senior Resident Inspector
Mr. S. J. Collins, NRC Region I Administrator
Mr. D. A. Allard, Director BRP/DEP
Mr. L. E. Ryan (BRP/DEP)

FENOC RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION LICENSE AMENDMENT REQUEST FOR REVISED STEAM GENERATOR INSPECTION SCOPE (F* CRITERION) FIRSTENERGY NUCLEAR OPERATING COMPANY BEAVER VALLEY POWER STATION UNIT 2 DOCKET NO. 50-412

By letter dated April 11, 2005 (ML051040080), FirstEnergy Nuclear Operating Company (FENOC), the licensee for Beaver Valley Power Station (BVPS) Unit 2, submitted a license amendment request to revise the scope of steam generator tube inspections. The amendment defines a distance called F* (F-star), which is measured downward into the tubesheet. The portion of tubing in the tubesheet below the F* distance would be excluded from inspection. Technical justification for this change was provided in Westinghouse topical report WCAP-16385-P, Revision 1, "F* Tube Plugging Criterion for Tubes with Degradation in the Tubesheet Roll Expansion Region of the Beaver Valley Unit 2 Steam Generators," dated March 2005.

In order to complete its review the staff needs the additional information requested below.

1. **The staff was unable to determine the extent to which the leak test results in WCAP-14697 considered the effect of tubesheet bow. As a result, it is not clear to which tube locations these data would apply. In addition, although the leak rates for the test data in WCAP-14697 were low, numerous tubes could have flaws that go undetected with your proposed inspection extent. This could result in an unacceptably high amount of leakage when all tubes are considered.**

   Given the above, please provide additional justification for your methodology for assessing accident induced leakage for the region of the tube that will not be required to be inspected by the proposed technical specifications. For example, address the number of tubes that could be affected by degradation at the end of your current licensed period of operation, the axial elevation of the degradation in these tubes (if not assuming all tubes have degradation at the location where the inspections are no longer performed), and the severity of the degradation (if not assuming a 360-degree through-wall flaw). Please provide the technical basis associated with the above if you are not assuming all tubes have 360-degree through-wall flaws at the end of the inspection distance.

Response: The applied roll torques used for the leakage specimens of WCAP-14697 were adjusted to account for reduction in contact pressure due to tubesheet bow, thus the effects of tubesheet bow are reflected in the leak test data. The final torque values were selected to provide equivalent contact pressures during normal operation and postulated main steamline break (MSLB) conditions. Appendix B of WCAP-14697 makes reference to the use of adjusted torque values.

The remainder of the response to the above question will establish that leakage potential from 100 percent through-wall indications located greater than 3 inches below the top of tubesheet is negligible or nil. Since contact pressures far exceed the maximum driving pressure for potential leakage during an MSLB, leakage from flaws that go undetected outside the proposed inspection extent would be negligible. Leakage potential of expanded tubes is influenced by tube outside diameter (OD) growth due to thermal expansion and internal pressurization, residual effects of the expansion process, and tubesheet bow effects. For the top of tubesheet elevation the combined effect of these contributors results in positive contact force between the tube and tubesheet during all plant conditions.

At 3 inches below the top of tubesheet, neglecting residual effects of the roll expansion, the tubesheet bow contact pressure reduction is slightly overcome by the thermal and pressure growth for all tube locations (see Figure 1). Thus, when the residual expansion process effects

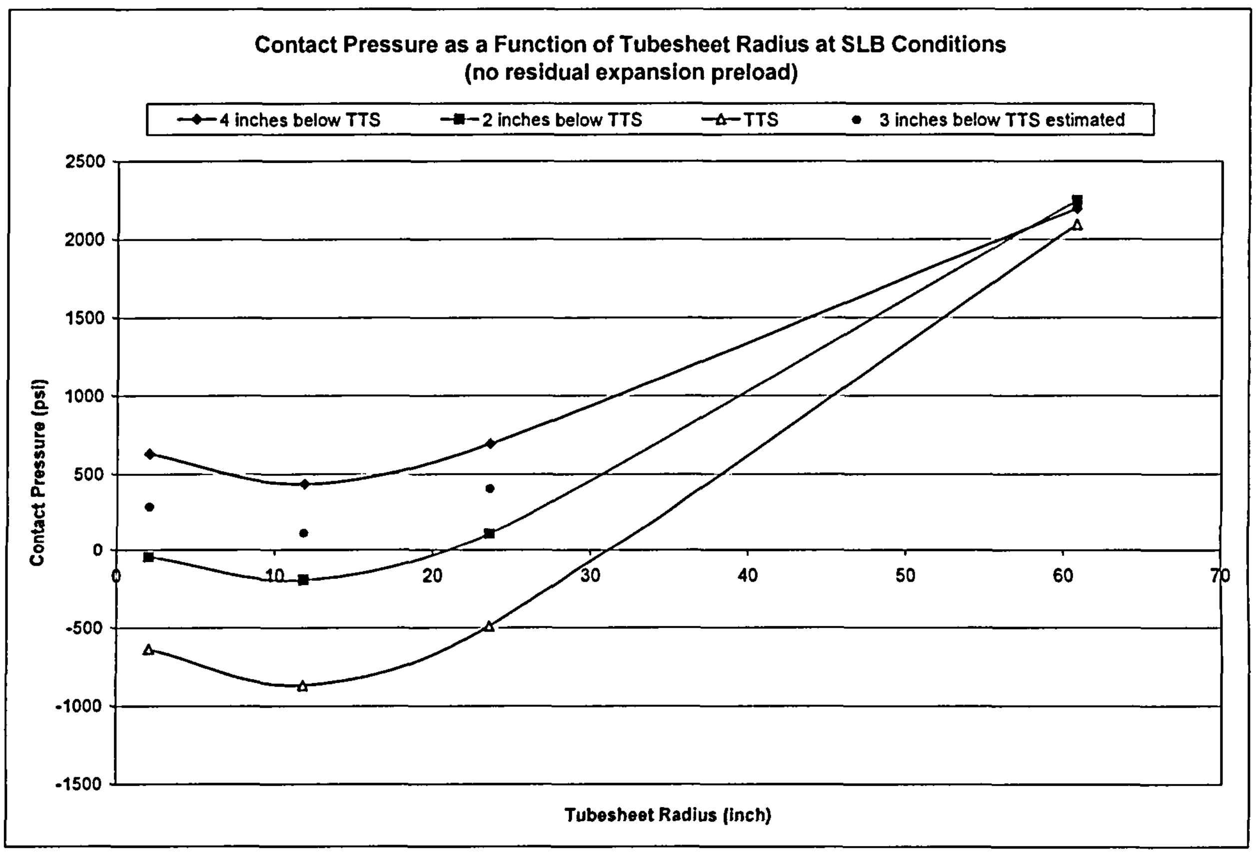

Figure 1

are considered, all tubes will retain contact pressure equal to or greater than the contact pressure associated with the expansion process, or approximately 3800 to 4000 psi. This comparison considers the limiting radial location on the tubesheet. At this contact pressure primary to secondary leakage at MSLB conditions is not anticipated; thus, there is no basis to assume postulated indications below the F* inspection distance would contribute to leakage. From Figure 1 it can be seen at the 30 inch radius location and 3 inches below the top of

tubesheet, the total tube to tubesheet contact pressure is approximately 4500 psi and far exceeds the MSLB condition maximum driving pressure of 2560 psi. About 75 percent of the tubes reside outside of the 30 inch radial location.

While all tube in tubesheet expansion processes are designed to close the tube to tubesheet gap, the post expansion condition with regard to residual contact forces and resistance to postulated leakage vary greatly depending upon the applied process. Observed conditions from leakage testing of explosive or hydraulically expanded tube in tubesheet conditions cannot be applied generally to mechanical roll expansion. The leakage potential is dependent upon the tube to tubesheet interaction forces and tubesheet hole surface conditions at specific elevations within the tubesheet. At 3 inches below the top of tubesheet the minimum integrated (sum of all forces and effects) contact pressure between the tube and tubesheet is about 4000 psi. In comparison, at a contact pressure of 4000 psi in a WEXTEX tube the location within the tubesheet is approximately 15 inches below the top of tubesheet. The constrained crack leak rate data of the W* program shows that for contact pressures >2500 psi that leak rates are dramatically reduced compared to lesser contact pressure values. Note that the constrained crack leak data examined the effect of contact pressure on leakage potential for essentially zero expanded tube lengths. The additional resistance to leakage afforded by expanded tube length between the indication and the top of tubesheet was not present in these tests.

Additionally, the expansion process particulars must be considered. Explosive and hydraulic expansion processes affect the expanded length simultaneously and result in little if no additional (after contact with the tubesheet) wall thinning due to applied process forces. Springback of the tube OD surface could result in a lesser resistance to leakage. In roll expansion the large residual radial forces due to thinning of the tube wall after contact with the tubesheet greatly increases the resistance to leakage and likely will result in the tube OD surface conforming to tubesheet hole imperfections. Thus when thermal and pressure expansion are introduced the resistance to leakage is further increased as the surface forces at the tube to tubesheet interface will act in both axial and radial directions. The applied torque of roll expansion produces additional (after contact with the tubesheet) tube wall thinning of 3 to 4 percent by compression resulting in general yielding of the tube material during expansion. The forces required are large and are transferred across the tube wall. This transfer of forces will cause the tube OD surface to conform to the localized tubesheet hole surface imperfections to a much larger degree than with explosive or hydraulic expansion processes. Therefore, it may be concluded that postulated 100 percent through-wall flaws below the F* inspection distance will not contribute to leakage during a postulated MSLB event.

Any attempt to estimate the number of postulated indications below the inspection distance is conjecture. Comparison of observed flaws from BVPS-2 and other units is used to establish that this number is minimal. The BVPS Unit 2 steam generator (SG) tubes were shotpeened through the entire tubesheet thickness prior to operation. This has effectively reduced the stress corrosion cracking (SCC) potential. To date (>14 effective full power years (EFPY)) only two tubes have been reported with primary water stress corrosion cracking (PWSCC) in the tubesheet region. Both have been located in the top of tubesheet expansion transition.

EPRI SGDD data from plants with full depth roll expanded tubes that were not shotpeened prior to operation shows many PWSCC indications per plant for similar accumulated EFPY. Prior to replacement 1359 PWSCC indications were reported at Farley 2; 2671 PWSCC indications were reported at McGuire 1. In both cases the degradation was predominantly axially oriented. Previous data submitted to the NRC as part of W* license amendments has shown the PWSCC initiation potential is decreased with increasing depth below the top of tubesheet. As BVPS Unit 2 has not reported PWSCC below the expansion transition, and the potential for initiation is reduced with increasing depth below top of tubesheet, there is essentially no potential for flaw development below the F* inspection distance.

As a precautionary measure, bulge and overexpansion signals below the F* distance were inspected with a +Pt coil at the 2R11 outage. No degradation was reported. Thus, there is no basis to assume that a large number of tubes will contain degradation below the F* inspection distance. Further evidence as to the effectiveness of shotpeening prior to operation is found in inspection data from a plant with Model D4 SGs. These SGs use full depth roll expansion and were shotpeened prior to operation. This plant has similar accumulated EFPY as BVPS Unit 2 but has a hot leg operating temperature of 620°F. The difference in hot leg operating temperature suggests a PWSCC initiation potential 1.6 times that of BVPS Unit 2. To date, about 10 tubes have been reported with PWSCC in the F* distance. This plant also contains approximately 1900 tubes that are expanded using the WEXTEX explosive expansion process. At the last outage all WEXTEX tubes were inspected with the +Pt coil full depth through the tubesheet. No PWSCC degradation was reported in these tubes. Other plants with Model 51 SGs that have applied or requested application of the W* alternate repair criterion have reported PWSCC in up to 3% of the total tube population. Without shotpeening, this would equate to approximately 57 postulated PWSCC indications in the D4 plant. As no PWSCC has been reported in WEXTEX tubes with hot leg operating temperatures 9 to 20°F greater than Model 51 SGs, the D4 plant experience supports the conclusion that shotpeening prior to operation has and will continue to effectively limit PWSCC potential at BVPS Unit 2. This evidence that through-wall degradation is unlikely to develop, in addition to the discussion of contact pressures presented in the first part of the RAI response which concludes no leakage from postulated 100% through-wall indications below F*, provides further assurance that leakage need not be assumed.

With regard to long term application, shotpeening is a stress modification to the inside diameter (ID) surface of the tube. The impact of the shot on the ID surface produces a compressive stress, and compressive stresses are generally not associated with SCC initiation. Normal plant operating temperatures within the SG are not sufficient to result in a relaxation of this stress; therefore, there is no basis to postulate that continued operation would result in a relaxation of the compressive stresses on the tube ID.

Additionally, approximately 25% of the tubesheet region +Pt tests for SGA from the 2R11 inspection were re-examined to determine the lowest test extent. For these tubes the average inspection depth below the top of tubesheet was 3.80 inch with a maximum depth of inspection of 6.41 inch. Only one PWSCC indication was reported at the 2R11 for all SGs; this indication

was reported at the top of tubesheet expansion transition. As no degradation was reported at depths other than the top of tubesheet expansion transition, and actual test extents exceeded 3 inches below top of tubesheet, the BVPS-2 data is consistent with other plant experiences which indicate a reduced PWSCC potential for deeper depths below the top of tubesheet.

Note that prior F* applications at numerous other units have assumed no leakage from postulated indications below the F* inspection distance.

With respect to the values of hole diameter and contact pressure cited in the December 2, 2005 response to RAI 6, were these developed with the finite element model or perforated plate model? If the perforated plate model, please discuss at what radial location at the top of the tubesheet the effect of bow is neutral (e.g., at a tubesheet radius of 33-inches).

Response: For purposes of leakage assessment the finite element analysis results were applied.

2. **In response to request for additional information #6 dated December 2, 2005, a summary of leak test data was provided. Please verify the number of specimens and the leak rates for these specimens, since the staff's review of WCAP-14697 would result in different leak rates and number of specimens than those quoted in the December 2, 2005 letter.**

Response: The information is based on a total of five specimens of 1 and 2 inch roll expansion lengths, tested at a pressure differential of 2650 psi. Samples L3, L7, and L18 used a 1 inch roll expansion length. Samples L4 and L8 used a 2 inch roll expansion length. (Refer to Table 2-2 of WCAP-14697.)

Leak rates (in terms of drops per minute) are described in Table 2-2 of WCAP-14697. As discussed during a May 18, 2006 conference call, the difference in leak rates (in terms of gallons rather than drops) calculated by the NRC staff resulted from application of a differing drops per gallon conversion factor. The leakage allowance proposed for degradation permitted to remain in service via application of F* was developed using a factor of 72,000 drops per gallon.

3. **In the incorporation of the F* criteria into your plugging or repair limit section of your technical specifications, it does not appear that you have specified a plugging limit for the portion of the parent tubing within the tubesheet associated with a sleeve joint. Please discuss your plans for modifying your TS to clarify that tubes with degradation in the parent tube associated with the sleeve joint will be plugged upon the detection of any flaws.**

Response: The supplement to LARs 324 and 196 (Steam Generator Tube Integrity) dated August 3, 2006 included proposed TS 6.19.c, "Provisions For SG Tube Repair Criteria." Proposed TS 6.19.c.3 would require plugging of tubes with a flaw in a tube to sleeve joint that occurs in the sleeve or in the original tube wall. The license amendment regarding SG tube integrity is expected to be approved prior to the F* amendment.

4. **In your April 14, 2006 letter, you indicated that tubes required by TS 4.4.5.4.a.6.a to be plugged or repaired would have no leakage assessed. The basis for such an approach is not clear, especially if a 100% through-wall flaw was detected. Please clarify your approach for assessing leakage within the F* distance. For example, do you plan on reviewing the inspection results to confirm that no tubes are through-wall (or near through-wall) and, therefore, will not leak? In addition, if you do find a flaw that could leak do you plan on assessing the leakage from this flaw? If not, discuss why not. The staff recognizes the current approach of plugging flaws on detection in this region should provide very high confidence that no potential leaking flaws are identified in this region; however, such an approach can not ensure it with certainty.**

Response: All observed degradation within the F* distance will be evaluated for leakage potential and if it is judged that the indication depth is 100% through-wall, any postulated leakage at MSLB conditions will be considered in the condition monitoring report. All degradation observed within the F* distance will be plugged upon detection. If observed flaw occurrence rate data suggest a potential for new occurrences of 100% through-wall degradation within the F* distance by the end of the next operating cycle, any postulated leakage will be addressed in the operational assessment.

5. **In your April 14, 2006 letter, you discuss tubesheet hole dilation near the neutral plane of the tubesheet (refer to the response to RAI 3).**

   Please confirm that the topical reports that authorized sleeving at Beaver Valley prohibit the installation of sleeves below the mid-plane region of the tubesheet. If they do not, please address the original question for all locations where sleeve joints can be installed (i.e., are the hole dilations in the peripheral region of the bundle near the primary face of the tubesheet (for the most limiting tube) less than the hole dilations at the secondary face of the tubesheet in the central region of the tube bundle (for the most limiting tube)).

Response: The design of TIG welded sleeves described in topical report CEN-629-P locates the lower (hardroll) joint of non-full length sleeves in the mid-plane region of the tubesheet. The sleeve installation tooling includes a hard stop which controls sleeve elevation within the tubesheet. This stop places the tube to sleeve hardroll joint at the approximate mid-plane elevation, where tubesheet bow effects are essentially neutral. The design of full length sleeves described in CEN-629-P locates the lower end of the sleeve at the bottom of the

tubesheet. In tubes sleeved in the tubesheet region, F* can only be applied to the original tube wall below the sleeve. Therefore, F* cannot be applied to tubes with full length TIG welded sleeves because the original tube does not extend below the lower end of the sleeve.

Laser welded sleeves described in topical report WCAP-13483 are flared at the lower end, ensuring that the end of the sleeve is always at the bottom of the tubesheet. For the same reason as full length TIG welded sleeves, F* cannot be applied to tubes with laser welded sleeves. While laser welded sleeving is permitted by TS, none are installed at BVPS-2 and Westinghouse no longer supports this product.