March 24, 2004

Mr. J. A. Scalice
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 2 AND 3 — REQUEST FOR ADDITIONAL INFORMATION REGARDING NONDESTRUCTIVE EXAMINATION OF REACTOR PRESSURE VESSEL NOZZLE-TO-VESSEL WELDS AND NOZZLE BLEND RADII (TAC NOS. MC0167 AND MC0168)

Dear Mr. Scalice:

By letter dated July 25, 2003, Tennessee Valley Authority (TVA) submitted Relief Requests 2-ISI-22 and 3-ISI-18 for Browns Ferry Units 2 and 3 from the inservice inspection (ISI) requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, for the volumetric (UT) examination of reactor pressure vessel (RPV) nozzle-to-vessel welds and inner radius sections. Instead, TVA proposes, pursuant to 10 CFR 50.55a(a)(3)(i), to use the technical basis of the Boiling Water Reactor Vessel Internals Project (BWRVIP) report BWRVIP-108, "BWR Vessel and Internals Project Technical Basis for the Reduction of Inspection Requirements for the Boiling Water Reactor Nozzle-to-Vessel Shell Welds and Nozzle Blend Radii," to (1) reduce the inspection of these areas from 100 percent to 25 percent each 10-year interval and (2) replace UT by enhanced remote visual VT-1 for RPV nozzles inner radius section and by enhanced direct visual VT-1 for RPV head nozzles.

Based on our review of your submittal, the NRC staff finds that a response to the enclosed request for additional information is needed before we can complete the review. This request was discussed with your staff on March 3, 2004, and it was agreed that a response would be provided within 60 days of the issuance of this letter.

If you have any questions, please contact me at (301) 415-2315.

Sincerely,

/RA/

Eva A. Brown, Project Manager, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-260 and 50-296

Enclosure: Request for Additional Information

cc w/encl: See next page

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DATE	3/18/04	3/17/04	3/22/04	3/19/04	3/24/04

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BROWNS FERRY NUCLEAR PLANT, UNITS 2 AND 3 - REQUEST FOR ADDITIONAL INFORMATION REGARDING NONDESTRUCTIVE EXAMINATION OF REACTOR PRESSURE VESSEL NOZZLE-TO-VESSEL WELDS AND NOZZLE BLEND RADII (TAC NOS. MC0167 AND MC0168)

Dated: March 24, 2004

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REQUEST FOR ADDITIONAL INFORMATION ON RELIEF REQUEST 2-ISI-22 AND 3-ISI-18

REACTOR PRESSURE VESSELL (RPV) NOZZLE-TO-VESSEL SHELL WELDS AND

NOZZLE BLEND RADII

BROWNS FERRY, UNITS 2 AND 3

TENNESSEE VALLEY AUTHORITY

TAC NOS. MC0167 AND MC0168

Regarding Relief Requests 2-ISI-22 and 3-ISI-18

1-1. Estimate the dose saving for inspection of each type of nozzles associated with the relief requests.

1-2. Elaborate on the plant-specific inspection history by (a) identifying the type of nozzles (e.g., main steam nozzles or core spray nozzles) being inspected and the extent of coverage for each type, (b) providing information regarding disposition of reportable indications, especially those requiring flaw evaluations, and (c) providing the operating hours accumulated to date for each nozzle.

Regarding BWRVIP-108

2-1. It is stated in Section 3.2 that, “On BWR/6 RPVs, all nozzles except recirculation nozzles are unclad to improve the capability for inspection of the nozzle-to-shell welds by ultrasonic testing (UT).” Is cladding modeled in your finite element method (FEM) model for the RPV recirculation nozzle? Provide an assessment of the impact on the final probabilistic fracture mechanics (PFM) results if cladding is not modeled in the FEM model for the recirculation nozzle (Page 3-2).

2-2. Provide a quantitative assessment of the impact on the final PFM results by your assumption that SA-302, Grade B, modified material is equivalent to SA-533 Grade B, Class 1, for the vessel and that the modified SA-366 is equivalent to SA-508, Class 2, for the nozzles (Page 4-2).

2-3. The summation sign Σ in Equation (4-3) suggests that force F is a discrete function. Provide the theta value for each discrete F value and demonstrate that the summation of all moments generated by discrete forces is M_{RES} (Page 4-3).

2-4. Provide the applied forces and bending moments for all four types of nozzles and justify the exclusion of the twisting moment (moment about the x-axis in Figure 4.10) from your analysis. Compare your applied forces and bending moments with design loads for boiling-water reactor (BWR) plants and demonstrate that your selection is bounding (Page 4-3).

Enclosure

2-5. Justify your selection of the thermal loads for the four types of nozzles. Compare your idealized thermal loads shown in Figure 4-12 to Figure 4-20 with those from operating history of BWR plants and demonstrate that your selection is bounding (Page 4-4).

2-6. The boundary conditions for your FEM model are shown graphically in Figure 4-21. Clarify them by using three translational degrees of freedom, for example, specify the boundary conditions at the bottom nodes as: r(free), θ(free), and z(fixed). Also, point out the degrees of freedom that you specified in the FEM model to prevent the rigid body motion (Page 4-5).

2-7. Figures 4-30 through 4-37 show the stresses for the blend radius and the nozzle-to-vessel shell weld for the four types of nozzles. Explain (1) why the pressure-induced hoop stress varies so much azimuthally, considering that the nozzle hole in the vessel will have similar effect on all azimuthal positions, especially when the typical angular distance between the nozzle and the edge of the FEM model is about eight times the diameter of the nozzle and (2) why the hoop stresses at nozzle blend radius are significantly worse than those at the nozzle-to-shell weld. This serves as a check of your FEM modeling accuracy (Page 4-5).

2-8. The assumed cracks are described in the statement, “The fracture mechanics evaluation presented in Sections 5 and 6 considers flaws either parallel or perpendicular to the nozzle-to-shell weld location. The evaluation considers an axial flaw at the nozzle blend radii.” Provide schematics of these three types of flaw (location and orientation) in Figure 4-1 (Page 4-6). Also, provide test and service data supporting the assumed aspect ratio of 2 to 1 for all flaws before and during the crack growth (Page 5-6).

2-9. To be consistent with the staff position made on a variety of issues related to the BWRVIP-05 review, please provide the following:

a. The role that RPV copper and nickel contents play in the PFM analysis under the assumed negligible fluence condition.
b. A figure showing all test data (additional data plus the original five pertinent to BWRVIP-05) with the fitted curve representing the stress corrosion initiation equation of Table 5-1.
c. Justification for assuming that the initial RT_{ndt} for the weld and forging is -20°F.
d. Justification for using a fatigue crack growth rate based on limited data as shown in Figure 5-1.
e. The basis for the assumed flaw density, flaw distribution, flaw number due to stress corrosion initiation, and probability of detection curves for the nozzle/shell weld and nozzle blend radius.
f. Justification for using any test data, methodology, or conclusions of BWRVIP-05 for reactor vessel shells and welds data in this application.

2-10. Perform a worst-case study using the following revisions:

a. A conservative stress corrosion crack (SCC) initiation curve for sensitized 304 stainless steels.
b. A more conservative number of flaws per nozzle for nozzle blend radius, say 0.1 instead of 0.001.

c. A standard deviation of 15% of the mean for fracture toughness.
d. A standard deviation of 15% of the mean for upper-shelf fracture toughness.
e. The Argonne National Laboratory SCC growth rate (approximately 10 times of your rate; also, the typo “σ” in your SCC equation in Table 5-1 should be corrected).
f. A threshold stress intensity factor of 10 ksi√in, considering recent progress in understanding other types of SCC.
g. The current ASME Section XI reference bilinear fatigue crack growth law (R>0.65) for carbon and low alloy steels in water environment for both nozzle-to-vessel welds and nozzle blend radii.
h. Flaw density, flaw distribution, and probability of detection much more conservative than those used in the BWRVIP-05 review. (Since it is difficult to get consensus on these parameters, a sensitivity study on their influence on PFM results is useful.)

2-11 Is it unclear how the licensee plans to implement BWRVIP-108 at BFN-2 and -3. Several issues exist concerning nozzle selection and distribution, scheduling, prioritization and historical examinations. For each plant, BFN-2 and -3, develop a matrix, or table, that lists all nozzles on the reactor pressure vessel, and for each nozzle, include the following information:

a. Date of last inspection, for both volumetric and/or enhanced VT-1.
b. Highlight specific nozzles chosen to be among the proposed 25% sample.
c. Explain how nozzles in each type (as listed in the licensee's request) were selected for the proposed 25% sample (e.g., stress, operating conditions, fabrication or historical factors, randomly, etc.).
d. Identify nozzles remaining to be examined during the current interval, with and without approval of the proposed alternative.
e. Planned examination date(s) for nozzles in the proposed alternative.
f. Include above information for nozzles outside the scope of the proposed alternative (e.g., feedwater).

2-12 In the licensee's proposed alternative, it is unclear whether the nozzles initially selected for examination during the current period/interval will be re-inspected during successive periods/intervals. In addition, the distribution and completion percentages required during each period require clarification. Please confirm that, except for the total number of examinations, all other applicable requirements of ASME Section XI will be met.

2-13 In addition to the reduced volumetric examinations described in the proposed alternative, previous requests for relief concerning enhanced VT-1 visual examinations of nozzle inner radius sections have either been approved by the NRC staff, or are pending approval. The licensee states:

“TVA is requesting that the reduction from 100 percent to 25 percent of the nozzles each 10-year inspection interval in this [2-ISI-22 and 3-ISI-18] request for relief apply to the aforementioned requests for relief, for the enhanced remote or direct visual (VT-1) examination, capable of a 1-mil wire resolution, in accordance with ASME Section XI, VT-1 requirements.”

Clarify whether enhanced VT-1 visual examinations will continue to be performed on all RPV nozzles (excluding feedwater), or only on a reduced population of nozzles selected by the BWRVIP-108 proposed alternative. If the latter, confirm that enhanced VT-1 visual examinations will be performed on the same nozzles selected under this proposed alternative.

2-14 On page 2-2 of BWRVIP-108, it is stated that results from failed candidates with more than two missed detections or false calls are excluded from the data being analyzed. Further discuss the failed candidate data in terms of what is being included versus excluded from the analysis, and state the percentage of total candidate data that is represented by failed candidate data that is being excluded.

2-15 On page 2-2 of the BWRVIP-108, it is stated:

"The term ε_i, is assumed to be normally distributed with a variance of σ^2_ε."

The standard estimates used for logistic regression are maximum likelihood estimates that assume the data is binomially distributed. Confirm that the Electric Power Research Institute is using the standard estimation method for logistic regression, and if so, the description should be altered to reflect this method.

2-16 On page 2-3 of the BWRVIP-108, statements regarding the relative merits of using "passed" verses "passed plus failed" candidates to estimate probability of detection (POD). It is stated:

"The inclusion of candidates that failed in their first attempt is provided for information. Inclusion of passed candidates only may be overly optimistic, as the large majority of candidates were required to detect 100% of the flaws in order to pass."

It is important to emphasize that POD curves calculated from passed candidates will *always* produce an overly-optimistic estimate of these candidates' true POD. This type of testing bias is so well known in statistics that it has a special term of *regression to the mean*.

The term *regression to the mean* refers to the propensity of a random variable that is extreme on its first measurement to tend to be closer to the center of the distribution on a later measurement. This means that if one selects candidates with "high" POD scores (i.e. the passed candidates), they would tend to exhibit lower scores if tested again. A second test on the passed candidates would produce an unbiased estimate of their true POD, and exhibit a bias with respect to the first set of scores. It would be difficult to calculate the magnitude of this bias; not only would one need to know the statistical variability in the test (which is available), but one would also need to know the variability in the candidates capability. However, this variability would generally affect the bias in POD in the following manner.

- Test variability low and candidate variability high implies the bias in POD will be low.
- Test variability high and candidate variability low implies the bias in POD will be high.

An important conclusion is that the true POD curve (for passed candidates) is somewhere between the “passed'' and “passed plus failed” curves. Both curves are important in evaluating inspection performance. Of course, a reviewer would feel most comfortable with “passed” and “passed plus failed” curves that were close together. In selecting one of these two curves to represent inspection performance, the “passed plus failed” curve should be used because it is more conservative.

From the comments on page 2-5, it appears that the sizing model developed in 2.1.2 has been developed from “passed” data. The discussion above concerning biases that are associated with “passed” data when estimating POD curves are also relevant to sizing. Please estimate the flaw sizing model using “passed plus failed” data, and discuss the magnitude of the potential bias and how this affects the overall analyses for detection and sizing performance.

2-17 On page 2-7 of BWRVIP-108, it is stated that only passed candidates are included in the analysis of sizing error. Later on page 2-11, the report states “For the purpose of calculating structural reliability the “ALL” curve of Figure 2-9 is most appropriate for examinations performed since 1995 as well as future examinations.” In the earlier work of Section 2, the passed plus failed data is used for detection but in this section dealing with PCR, only the passed candidates are being used. Explain the basis for only using the “passed” candidates.

Section 2 provides a quantitative description of inspection capability (i.e, in the form of probability of reporting or rejecting the flow as unacceptable (PCR)). However, it cannot be determined whether or not the capability is “poor” or “excellent” unless a benchmark has been established for comparison of the results. For example, if the proposed 25 percent reduction in examinations would be acceptable whenever the PCR curve was above 90 percent for flaws larger than 0.3-inches, one might conclude that the current inspection capability is “acceptable.” Provide definitions for acceptable and unacceptable PCR curve results.

2-18 The results presented in Fig 2-10 are quite dramatic. One would like to conclude that the reduction in sizing error sigma could be completely ascribed to improvements in inspection capability. However, the reduction may be due to a number of factors such as differences in the flaws (or materials) between Program for the Inspection of Steel Components (PISC) and Performance Demonstration Initiative (PDI). The report contains no discussion as to the reasons for this significant reduction in sizing error. Please discuss this dramatic change, and provide the technical details of the similarities and differences in these data.

2-19 In BWRVIP-108, Section 5.6, it is stated that “POD pass plus fail” curves were used in the probabilistic fracture mechanics (PFM) calculation. From the analysis in Section 2.0, it would seem that the proper curve to use would be the PCR curve, which also includes the effects of sizing error. Explain why the PCR curve results were not used for the PFM calculations.

2-20 Tables 5-3 to 5-5 show little information concerning the efficacy of inspections. Provide a ratio of failure probabilities which would be much more informative.

cc:

Mr. Karl W. Singer, Senior Vice President
Nuclear Operations
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. James E. Maddox, Vice President
Engineering & Technical Services
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Ashok S. Bhatnagar, Site Vice President
Browns Ferry Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Decatur, AL 35609

General Counsel
Tennessee Valley Authority
ET 11A
400 West Summit Hill Drive
Knoxville, TN 37902

Mr. T. J. Niessen, Acting General Manager
Nuclear Assurance
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Michael D. Skaggs, Plant Manager
Browns Ferry Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Decatur, AL 35609

Mr. Jon R. Rupert, Vice President
Browns Ferry Unit 1 Restart
Browns Ferry Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Decatur, AL 35609

Mr. Robert G. Jones
Browns Ferry Unit 1 Plant Restart Manager
Browns Ferry Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Decatur, AL 35609

Mr. Mark J. Burzynski, Manager
Nuclear Licensing
Tennessee Valley Authority
4X Blue Ridge
1101 Market Street
Chattanooga, TN 37402-2801

Mr. Timothy E. Abney, Manager
Licensing and Industry Affairs
Browns Ferry Nuclear Plant
Tennessee Valley Authority
P.O. Box 2000
Decatur, AL 35609

Senior Resident Inspector
U.S. Nuclear Regulatory Commission
Browns Ferry Nuclear Plant
10833 Shaw Road
Athens, AL 35611

State Health Officer
Alabama Dept. of Public Health
RSA Tower - Administration
Suite 1552
P.O. Box 303017
Montgomery, AL 36130-3017

Chairman
Limestone County Commission
310 West Washington Street
Athens, AL 35611