March 5, 2007

Jay K. Thayer
Nuclear Energy Institute
Vice President, Nuclear Operations
1776 I Street, N.W.
Washington, DC 20006-3708

Dear Mr. Thayer,

Ultrasonic Testing inspection in mid-October 2006 of dissimilar metal welds at the Wolf Creek Generating Station identified five circumferential flaws in three pressurizer nozzle-to-piping dissimilar metal welds. The flaws found at Wolf Creek were significantly larger and more extensive than previously seen in the industry. During the Fall 2006 refueling outage, Wolf Creek completed its baseline pressurizer nozzle weld inspections and weld overlay repairs per industry guidance in MRP-139, "Primary System Piping Butt Weld Inspection and Evaluation Guidelines."

During public meetings with the industry on November 30, 2006, and December 20, 2006, the Nuclear Regulatory Commission (NRC) staff presented the results of fracture mechanics analyses it performed to assess the safety significance of the flaws found at Wolf Creek. As a result of these analyses, the staff concluded that there may be little or no time between leakage and rupture in pressurizer nozzle welds containing similar flaws to those found at Wolf Creek.

By letter dated January 22, 2007, the Electric Power Research Institute Materials Reliability Program (MRP) provided MRP 2007-003, "Implications of Wolf Creek Pressurizer Butt Weld Indications Relative to Safety Assessment and Inspection Requirements." This report contains the results of MRP's review of the flaws found at Wolf Creek and the industry's assessment of the implications of the discovery of these flaws on the pressurized water-reactor fleet and implementation of MRP-139 requirements.

By letter dated February 14, 2007, Nuclear Energy Institute (NEI) indicated that the MRP is undertaking an important task intended to refine the crack growth calculations pertaining to the Wolf Creek pressurizer dissimilar metal weld ultrasonic indications. These additional calculations are intended to extend the work documented in MRP 2007-003 and reinforce the industry conclusion that the industry inspection schedules for pressurizer nozzle welds do not need to be accelerated. It is our understanding that these studies are being conducted to address the NRC staff's concerns regarding the potential for rupture without prior evidence of leakage from circumferentially oriented primary water stress-corrosion cracking (PWSCC) in pressurizer nozzle welds. The goal of these studies is to reduce conservatisms and uncertainties in previous analyses and demonstrate that PWSCC in pressurizer butt welds will progress through wall and exhibit detectable leakage prior to causing a rupture.

The February 14, 2007, NEI letter contains a detailed project plan for this work, provides NRC staff the opportunity to provide comments on the plan, and requests NRC staff participation in meetings planned for project input and review. Your letter also requests that NRC identify a lead person to ensure efficiency in communication throughout the project.

The NRC staff have prepared a set of comments on the proposed project which are attached for your consideration. These comments provide NRC staff views on essential aspects of the industry project that will need to be addressed for the industry calculation to provide reasonable assurance to the NRC that PWSCC crack conditions will remain stable and not lead to rupture without significant time from the onset of detectable leakage. These comments relate to concerns of uncertainty and potential non-conservatism inherent in prior analyses. We would propose that these comments be discussed in detail during the meeting on this subject, scheduled to take place on March 7, 2007.

The advanced analyses being proposed by industry are a first of a kind effort with significant technical concerns that will need to be addressed in a relatively short time period. The potential success of this effort will not be clear until the approach industry uses to address NRC's concerns and the results of this work are evaluated by the NRC staff. While these advanced industry analyses may be sufficient to provide a justification for a limited extension of the inspection schedules for certain plants, such analyses would not provide a sufficient basis for regulatory activities such as license amendments or rulemaking

The NRC staff intend to be actively involved in reviewing the work being performed by industry and to offer its views on this project in a timely manner. In addition, the NRC staff is planning to develop independent finite element analysis to assist in benchmarking the industry work in your Task 1, Custom Extensions to the Finite Element Analysis Solutions.

The overall lead person for interacting on this project is Mr. Ted Sullivan, Office of Nuclear Reactor Regulation. NRC involvement with this project will include staff from the Offices of Nuclear Reactor Regulation and Nuclear Regulatory Research and a NRC contractor.
We recommend that expectations for interacting with these personnel be discussed at the meeting on March 7, 2007.

We look forward to working with industry on this project.

Sincerely,

/RA/

J. E. Dyer, Director
Office of Nuclear Reactor Regulation

Enclosure:
Comments on Industry Advanced 3-Dimensional Finite Element Analyses

cc: A. Marion, NEI
J. Riley, NEI
C. King, EPRI
C. Harrington, EPRI
D. Weakland, MRP
J. Gasser, MRP

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Comments on Industry Advanced 3-Dimensional (3-D) Finite Element Analyses (FEA)

The analyses the Nuclear Regulatory Commission (NRC) performed in late 2006 of the Wolf Creek pressurizer nozzle flaws were scoping analyses. These analyses were used to:

- provide information as to what could have happened if the flaws had been left in service,
- represent what could happen to other pressurized water-reactors if similar flaws exist in the pressurizer nozzle welds, and
- find out whether the flaws in the safety and relief nozzles could exhibit rupture prior to evidence of leakage.

These analyses were not conservative or bounding calculations, nor were they best estimate calculations.

The reason for the staff's recommendation to expedite the inspection/mitigation schedule, notwithstanding limitations on quantifying the immediacy of the issue, is the combination of the staff's analysis result that rupture can occur without prior leakage and the consequences of a failure of a pressurizer nozzle.

The Nuclear Energy Institute (NEI) letter dated January 26, 2007, refers to advanced non-linear finite element analyses that are being undertaken to reinforce the technical basis for industry conclusions that the industry inspection schedules for pressurizer nozzle welds do not need to be accelerated. The NEI letter dated February 14, 2007, indicates that the purpose of this project is to perform additional refined crack growth calculations removing the conservative assumption that the crack shape remains a semi-ellipse as it grows through the weld thickness. The letter further indicates that additional calculations using the customized software will be performed to investigate a wide range of input assumptions, including those for weld diameter, weld thickness, piping loads, welding residual stress, initial crack size, and initial crack shape.

In our view, results from the proposed improved modeling will be useful for regulatory purposes provided several areas of uncertainty and potential non-conservatism are also addressed. For these analyses to inform a regulatory decision, the work will have to provide reasonable assurance to the NRC that rupture will not occur without evidence of prior leakage and that such leakage from PWSCC is readily detectable under stable crack conditions.

The following reflects our thinking to date on areas of uncertainty and potential non-conservatism that need to be addressed by industry.

1. Benchmarking. The 3-D analyses being proposed by industry are a first of a kind, and benchmarking is an important aspect of this work. NRC realizes industry will be performing benchmarking. In addition, NRC will be conducting a benchmarking exercise with the industry to provide a check on the industry's 3-D finite element fracture mechanics (FE FM) efforts. NRC's models will be developed with similar analytical methodologies. Industry's calculations and results may be benchmarked against the parallel but separate NRC 3-D FE FM model.

2. Validation. A benchmarking exercise does not prove that the analytical model can accurately predict real-world performance because of the wide variability in the underlying model assumptions. A validation effort compares actual physical test results and operational data with the analytical model results. The industry analyses need to be validated by service history or laboratory experiments.

3. Safety Factor. The prior industry and NRC staff fracture mechanics analyses did not consider safety factors in their crack stability analyses. The American Society of Mechanical Engineers Boiler and Pressure Vessel Code requires the use of a safety factor of 3 to the applied stress intensity factor to determine crack stability under normal load conditions for a deterministic analysis. The safety factor is required even for a bounding analysis because there are uncertainties with all the input variables, and there are some things that are not accounted for in the deterministic analyses. Industry should consider the use of a safety factor to cover uncertainties in these analyses, including the estimation of leakage.

4. Weld Residual Stress. Fracture mechanics results are sensitive to the residual stress distribution assumed. The analyses performed on the Wolf Creek flaws included three residual stress distributions. The distributions used were selected to gain an understanding of the problem but were not viewed as bounding. The advanced analyses will need to demonstrate that the industry analysis results will not be significantly affected by other reasonable residual stress distributions that could be assumed. In addition, the effects of weld residual stress redistribution will have to be included since for stress fields with large gradients away from the crack plane and high stress in the ligament, this redistribution may cause crack arrest in the depth direction without a change in growth rate at the surface leading to long, deep surface cracks.

5. Multiple flaws and flaw size. The NRC staff fracture mechanics analyses assumed flaw sizes based on the information obtained during the inspections at Wolf Creek. These analyses did not account for multiple flaws as found in the pressurizer surge nozzle weld. In addition, given the length of the flaw found in the Wolf Creek relief nozzle weld, the flaw found may be the result of multiple initiation sites for PWSCC that subsequently joined. The advanced analyses proposed by industry will have to bound the types of flaws found at Wolf Creek and account for the possibility of multiple crack initiation and linkage in all nozzles analyzed. The advanced analyses should also take into account the uncertainty of the depth sizing.

6. Crack growth rates. The NRC staff fracture mechanics analyses assumed the 75 percentile crack growth rates from MRP-115. This assumption is customarily used for deterministic calculations. Since material sensitivity, electrochemical potential and loading type variability will affect the crack growth rates, the assumption of a single crack growth rate function (e.g., the 75 percentile crack growth rate) may not be appropriate for the objectives of the analyses being undertaken. Analyses using different crack growth rates, all other inputs and assumptions unchanged, could be expected to result in different crack profiles. The advanced analyses proposed by industry will have to address the effect of crack growth variability on the crack profile.

7. Predicting growth by K. There is evidence that the in-service growth of stress-corrosion cracking (SCC) does not match that from K-based predictions, even when the correct

geometry, crack growth rates and stressors are applied. For example, the in-service growth in the length direction for stress corrosion cracks is under predicted using current fracture mechanics techniques. This difference may be attributed to inaccurate welding residual stress predictions, non-idealized crack growth, or a fundamental issue with the crack driving force, i.e., something in addition to K-controlled growth is driving the cracks. These differences can lead to non-conservative or inaccurate leak and rupture predictions. The advanced analyses proposed by industry will have to address the limitations of predicting crack growth by K.

8. Non-idealized surface and through-wall crack stability. The crack stability methodologies developed to date assume either a semi-elliptical or constant depth surface flaw and an idealized through-wall flaw, which may lead to inaccurate stability predications. A methodology for calculating the stability of the non-idealized surface and through-wall cracks using limit load analysis and elastic plastic fracture conditions needs to be included in the analyses for accurate leakage and rupture predictions.