From: Leonard Olshan
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Date: 5/29/01 9:27AM
Subject: Fwd: REVISED Questions for the MRP on CRDM Cracking Interim Report

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From: Allen Hiser
To: Leonard Olshan
Date: 5/29/01 9:23AM
Subject: REVISED Questions for the MRP on CRDM Cracking Interim Report

Attached are revised questions for the MRP on the CRDM cracking interim report. The revisions, highlighted in bold in the attachment, are provided for Question (2) of Section 4 and a new "Additional Question" on loose parts assessment.

CC: Bill Bateman; Brian Sheron; C. E. (Gene) Carpenter; Edwin Hackett; Gary Holahan; Jack Strosnider; James Medoff; Jin Chung; John Zwolinski; Keith Wichman; Matthew Mitchell; Michael Mayfield; Nilesh Chokshi; Peter Wen; William Koo

The staff has reviewed TP-1001491, Part 2, "PWR Materials Reliability Program Interim Alloy 600 Safety Assessments for US PWR Plants (MRP-44), Part 2: Reactor Vessel Top Head Penetrations," and has developed the following comments.

Section 3.0

(1) The staff agrees that due consideration of the interference fit incorporated into the initial fabrication of VHPs is important in evaluating the ability to rely on leakage detection (boric acid walkdowns) to identify through-wall degradation of these locations. Although the recent events at ANO-1 and Oconee indicate that it is possible to detect PWSCC through-wall flaws based on boric acid walkdowns, the information provided in Section 3.0 does not support the conclusion that these events were "bounding" (i.e., that for an equivalently sized through-wall flaw at another facility, an equivalent or greater amount of leakage would be expected).

(2) In order to better understand the leakage potential of PWSCC at VHP locations, provide information as to what the precise interference fits were (as opposed to a range of values) for the VHPs which leaked at ANO-1 and Oconee. This information is vital in understanding how comparisons can be made to the leakage potential for VHPs at other facilities.

(3) Provide additional information to clarify your statement that, "analyses show that the initial fit tends to open up at operating temperature and pressure." The staff would note that based on information in ASME Code Section II, Part D, the coefficient of thermal expansion for Alloy 600 is slightly greater than that for low alloy vessel steels throughout the temperature range of interest (70 °F to 600 °F). This would lead to the conclusion that the magnitude of the interference fit would grow as the vessel was heated up from room temperature to operating temperature. Further, internal pressurization of the VHP nozzle may be expected to further expand the nozzle into the vessel head penetration. Other potential effects related to RPV head distortion at pressure, flange rotation, and/or vessel head penetration ovalization are not discussed in Section 3.0. Address how these factors may affect central and peripheral VHPs differently.

(4) Provide information on any predictive modeling of this leakage scenario (i.e., leakage through a PWSCC flaw into the annular region and then out onto the RPV head) which has been performed to evaluate the expected leakage from VHPs having potentially greater interference fit values. Based on the information provided in your report, such a modeling effort, benchmarked against the information provided in response to item (2) above, could be used (along with accurate crack growth data) to evaluate the leakage from any VHP to demonstrate that adequate leakage would occur prior the growth of a PWSCC flaw to a size that could challenge primary system integrity.

(5) Regarding your reliance on the experience at Oconee and ANO-1 to address the issue of boric acid crystal/corrosion product plugging of the PWSCC flaw or the annular region, the staff finds that this information does not preclude the potential for substantial plugging of such a leak path based upon different specific crack morphologies, different interference fits, or different operational stresses (leading to potentially smaller crack opening areas). Provide additional information, based on a consideration of the physical processes involved, as to why such plugging should not be considered when evaluating

the potential leakage from other VHPs.

Section 4.0

(1) The simplified ranking model proposed in the subject report is based on the consideration of plant operating time and head temperature. In calculating the operating time at equivalent temperature, an Arrhenius equation was used with an activation energy of 50 kcal/mole. The staff has noted that this 50 kcal/mole value is based on the evaluation of PWSCC in steam generator tubes. The staff is continuing to evaluate whether or not this value is acceptable given the mechanistic nature of the cracking observed in the CRDM penetrations. Although the staff is not, at this time, requesting additional information from you to support the 50 kcal/mole value, discuss the sensitivity of the relative plant susceptibility rankings to the selection of a specific value of the activation energy.

(2) Based on your simplified ranking model, all U.S. PWRs are assigned into one of the eight assessment groups relative to the time it takes in terms of effective full power years (EFPYs) to reach the Oconee 3 condition. The number of plants in each group, including a summary of their inspection status, was provided in Figure 4-1. In order for the staff to complete its review of this information, identify by name which plants are in each of the assessment groups and provide the head temperature, operating time (in EFPY), effective degradation years based on your model**, and interference fit classification** for each facility. Also provide on a plant-by-plant basis a review of the inspection status (i.e., when were inspections conducted, how were they conducted, what were the results) for each facility and a schedule of each facility's upcoming refueling outages.

(3) In Table 2-1, a summary of worldwide CRDM nozzle PWSCC experience was provided. Provide the rankings, by use of the simplified model proposed in your report, of those foreign PWRs experiencing cracking in their CRDM nozzles. Discuss the reliability of your simplified model when benchmarked against the inspection results of those foreign PWRs.

(4) In the subject report, the recommended inspection of nine plants for fall outage 2001 is based on consideration of the 25 plants in the first three assessment groups that have equivalent time at temperature to be within 10 EFPY of the Oconee 3 condition. Explain the basis for selecting the 10 EFPY cut off criteria for near-term inspection. Furthermore, provide justification for not selecting for re-inspection plants with high rankings that were only partially inspected in the past.

(5) In the last sentence of the "Summary" section of Section 4, it is stated that "[s]ince the Oconee units lead the industry in effective time at temperature, and 10 EFPYs margins [sic] has been added to account for uncertainties when planning inspections, there is assurance that significant cracking at any of the US PWRs will be detected before there is any significant impact on plant safety." The staff notes that, in the subject report, the potential crack growth rate in the affected nozzles was not discussed. It is well known that, in addition to operating temperature, the crack growth rate in Alloy 600 and Inconel 182 is affected by a number of factors such as surface cold work, residual stresses resulting from welding, operating stresses, component geometry and material properties (strength and sensitization). Explain what technical basis you would use for establishing

an assumed crack growth rate for the circumferential CRDM nozzle cracking. Provide a detailed justification, based on this assumed crack growth rate, as to why the proposed inspection plan based on operating time and temperature will provide assurance that significant cracking will be detected at any US PWR prior to having an impact on plant safety.

Section 5.0

(1) The staff noted that in your evaluation of structural margins no consideration was given to the impact of crack growth rate. Explain what impact your assumed crack growth rate would have on your assessment of structural margins. In particular, explain how long Oconee 3 could have operated based on the assumed crack growth rate before it reached a critical flaw size.

Additional Questions

- **Risk-Informed Review**

Based on the staff's risk-informed review of the subject report, the staff requests a response to the following questions:

(1) Discuss the factors affecting the likelihood, consequence, and compensatory measures for a potential CRDM LOCA, including:

  a. the probability of having undetected circumferential flaws (e.g., the fit-up between the CRDM nozzle housing and the RPV head being sufficiently tight that there is too little evidence of boron crystal deposits to be detectable using a VT-2 visual examination);

  b. the potential likelihood of CRDM nozzle housing rupture due to undetected circumferential cracks propagating to a critical flaw size (discussion should include installation/repair stresses and weld history, age and temperature history, and chemistry excursions); and,

  c. the potential likelihood of CRDM ejection following a postulated rupture.

(2) Discuss the accident progression given a CRDM ejection following a postulated rupture including, but not limited to, the likelihood of core uncovering, ATWS, and/or disrupted geometry. As part of this discussion, provide a detailed explanation of plant system response to such an event. This discussion should focus on mitigating or compensatory measures and core damage prevention strategies in the event of assembly ejection, ATWS, and LOCA scenarios. The discussion should also include consideration of secondary effects (e.g., insulation blown off by LOCA blocking recirculation system, collateral damage on adjacent CRDMs caused by the ejected CRDM, etc.).

- **Loose Parts Assessment**

At a public meeting on April 12, 2001, industry representatives described an evaluation of loose parts, wherein circumferential cracking of the CRDM nozzle below the weld could

link two or more axial cracks to form a loose part. Discuss the potential generation of and potential consequences of loose parts generated from degradation of CRDM nozzles.