December 4, 2009

MEMORANDUM TO: Harold K. Chernoff, Chief
Plant Licensing Branch I-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Richard B. Ennis, Senior Project Manager ***/ra/***
Plant Licensing Branch I-2
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Office of Nuclear Reactor Regulation

SUBJECT: SALEM NUCLEAR GENERATING STATION, UNIT NOS. 1 AND 2, DRAFT REQUEST FOR ADDITIONAL INFORMATION (TAC NOS. MC4712 AND MC4713)

The attached draft request for information (RAI) was transmitted on December 4, 2009, to Mr. Jeff Keenan of PSEG Nuclear LLC (PSEG or the licensee). The draft RAI was transmitted to facilitate the technical review being conducted by the Nuclear Regulatory Commission (NRC) staff and to support a conference call with PSEG in order to clarify the licensee's submittals in response to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Salem Nuclear Generating Station, Unit Nos. 1 and 2.

The draft questions were sent to ensure that they were understandable, the regulatory basis was clear, and to determine if the information was previously docketed. This memorandum and the attachment do not convey or represent an NRC staff position regarding the licensee's submittals.

Docket Nos. 50-272 and 50-311

Attachment: Draft RAI

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DRAFT REQUEST FOR ADDITIONAL INFORMATION

RELATED TO GENERIC LETTER 2004-02

SALEM NUCLEAR GENERATING STATION, UNIT NOS. 1 AND 2

DOCKET NOS. 50-272 AND 50-311

By letters dated March 4, 2005, September 1, 2005, June 7, 2006, February 2, 2007, December 10, 2007, February 29, 2008, June 26, 2008, July 10, 2008, and March 31, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML050740368, ML052510438, ML061640118, ML070440138, ML073531261, ML080800469, ML081910152, ML082060082, and ML091000557, respectively), PSEG Nuclear LLC (PSEG or the licensee) submitted information in response to Nuclear Regulatory Commission (NRC) Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," for Salem Nuclear Generating Station (Salem), Unit Nos. 1 and 2.

The NRC staff has reviewed the information provided by the licensee and would like to discuss the following issues to clarify the submittals. The staff's review focused on the licensee's March 31, 2009, response to the NRC's request for additional information (RAI) dated December 17, 2008 (ADAMS Accession No. ML083300079). As applicable, issues identified in this document are linked directly to those RAIs. For example, "RAI 1" below refers to the first numbered RAI in the set of RAIs dated December 17, 2008. New RAIs identified in the current review and not linked to previous RAIs are simply numbered without being preceded by "RAI."

Debris Generation/Zone of Influence (ZOI)

The staff evaluated the licensee response to RAIs in the debris generation/ZOI area and considered that one RAI[1] was not adequately addressed, as noted below:

RAI 1 This RAI requested that the licensee describe what effect that the size of the test jet used for acquiring test report WCAP-16710-P data would have on applying the conclusions of that report to insulation systems at Salem, where potentially much larger jets could be experienced from reactor coolant system (RCS) loop piping breaks.

In its response to RAI 1 and in the updated supplemental response, the licensee provided a significant amount of information regarding the Westinghouse testing of the jacketed Nukon® insulation system and the installation of Nukon in the Salem containments. The RAI response concentrates on the fluid conditions and asserts that the size of the jet would have no effect on the determination of the ZOI as tested by Westinghouse. The staff does not agree with this position. Subsequent to requesting information from the licensee, the staff has developed a more detailed set of RAIs regarding the testing conducted and reported on in WCAP-16710-P. The set of RAIs provided below are being transmitted to provide the licensee the full range of the staff's concern regarding the testing.

1 Audit Open Item 3.2-1: Use of an 8 Pipe Diameter (8D) Zone of Influence (ZOI) for Steel Jacketed Nukon is essentially the same issue as RAI 1 discussed herein. The staff considers that this open item does not need to be separately tracked to closure.

The staff considers it likely for Salem Unit 2 that the overall evaluation of head loss was conservative because the additional fibrous debris that would result from a larger ZOI for jacketed Nukon is very small compared to the overall fibrous load for that unit. For this unit, the licensee may choose to provide a ratio of additional insulation not included in previous testing because of the reduced ZOI to that actually tested, and to thereby justify that the effect of the additional insulation on head loss would be insignificant. For Salem Unit 1, the overall evaluation may not be conservative because of the large amount of jacketed Nukon installed in the Unit 1 containment. However, the debris preparation for the head loss testing resulted in all fine fibrous debris. This is a significant conservatism in head loss testing. The licensee may choose to provide an evaluation of the additional amount of fibrous debris if a 17D ZOI (safety evaluation approved spherical ZOI) were applied to jacketed Nukon for Unit 1, and to balance that change against the conservatism just discussed regarding debris preparation. This information may allow the staff to determine whether the overall evaluations were conservative, irrespective of the resolution of the below-stated concerns reflected in the new RAIs below.

New RAIs Regarding the Reduced ZOI for Jacketed Nukon

The Pressurized Water Reactor Owners Group is working on answers to the multi-plant issues that follow. These questions have been modified from the generic version based on staff review of information received from Salem.

1. Although ANSI/ANS Standard 58.2-1988 predicts higher jet centerline stagnation pressures associated with higher levels of subcooling, it is not intuitive that this would necessarily correspond to a generally conservative debris generation result. Please justify the initial debris generation test temperature and pressure with respect to the plant RCS conditions, specifically the hot and cold leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, then please also discuss the temperature and pressure conditions in these lines. Were any tests conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications? If so, provide that assessment.

2. Please describe the jacketing/insulation systems used in the plant for which the testing was conducted and compare those systems to the jacketing/insulation systems tested. The Salem supplemental response described the jacketed Nukon on the steam generators, but did not compare it to the tested insulation system. Demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, etc. At a minimum, the following areas should be addressed:

    a. How did the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target? The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, e.g., for a stainless steel jacket held in place by three latches, where all three latches must fail for the jacket to fail, then all three latches must be effectively impacted by the pressure for which the ZOI is calculated. Applying test results to a ZOI based on a centerline pressure for relatively low L/D (nozzle diameter to target spacing) tests would be nonconservative with respect to impacting the entire target with the calculated pressure.

b. The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30-inch pipe within a ZOI could be stressed much more than a latching system on a 10-inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches could be significantly under-stressed in the tests. If a prototypically-sized target were impacted by an undersized jet it would similarly be under-stressed. Evaluations of banding, jacketing, rivets, screws, etc., should be made. For example, scaling the strength of the jacketing was discussed in the Ontario Power Generation report on calcium silicate debris generation testing.

3. There are relatively large uncertainties associated with calculating jet stagnation pressures and ZOIs for both the test and the plant conditions based on the models used in the WCAP reports. What steps were taken to ensure that the calculations resulted in conservative estimates of these values? Please provide the inputs for these calculations and the sources of the inputs.

4. Please describe the procedure and assumptions for using the ANSI/ANS-58-2-1988 standard to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle.

a. In WCAP-16710-P, why was the analysis based on the initial condition of 530 °F, whereas the initial test temperature was specified as 550 °F?

b. Was the water subcooling used in the analysis that of the initial tank temperature or was it the temperature of the water in the pipe next to the rupture disk? Test data indicated that the water in the piping had cooled below that of the test tank.

c. The break mass flow rate is a key input to the ANSI/ANS-58-2-1988 standard. How was the associated debris generation test mass flow rate determined? If the experimental volumetric flow was used, then explain how the mass flow was calculated from the volumetric flow given the considerations of potential two-phase flow and temperature dependent water and vapor densities? If the mass flow was analytically determined, then describe the analytical method used to calculate the mass flow rate.

d. Noting the extremely rapid decrease in nozzle pressure and flow rate illustrated in the test plots in the first tenths of a second, how was the transient behavior considered in the application of the ANSI/ANS-58-2-1988 standard? Specifically, did the inputs to the standard represent the initial conditions or the conditions after the first extremely rapid transient, e.g., say at one tenth of a second?

e. Given the extreme initial transient behavior of the jet, justify the use of the steady state ANSI/ANS-58-2-1988 standard jet expansion model to determine the jet centerline stagnation pressures rather than experimentally measuring the pressures.

5. Please describe the procedure used to calculate the isobar volumes used in determining the equivalent spherical ZOI radii using the ANSI/ANS-58-2-1988 standard.

   a. What were the assumed plant-specific RCS temperatures, pressures and break sizes used in the calculation? Note that the isobar volumes would be different for a hot leg break than for a cold leg break since the degrees of subcooling is a direct input to the ANSI/ANS-58-2-1988 standard which affects the diameter of the jet. Note that an under-calculated isobar volume would result in an under-calculated ZOI radius.

   b. What was the calculational method used to estimate the plant-specific and break-specific mass flow rates for the postulated plant loss of coolant (LOCA), which was used as input to the standard for calculating isobar volumes?

   c. Given that the degree of subcooling is an input parameter to the ANSI/ANS-58-2-1988 standard and that this parameter affects the pressure isobar volumes, what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

6. Please provide a detailed description of the test apparatus, specifically including the piping from the pressurized test tank to the exit nozzle including the rupture disk system.

   a. Based on the temperature traces in the test reports it is apparent that the fluid near the nozzle was colder than the bulk test temperature. How was the fact that the fluid near the nozzle was colder than the bulk fluid accounted for in the evaluations?

   b. How was the hydraulic resistance of the test piping which affected the test flow characteristics evaluated with respect to a postulated plant specific LOCA break flow where such piping flow resistance would not be present?

   c. What was the specified rupture differential pressure of the rupture disks?

7. WCAP-16710-P discusses the shock wave resulting from the instantaneous rupture of piping.

   a. Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions? Were temperatures and pressures prototypical of PWR hot legs considered?

   b. Was the initial lower temperature of the fluid near the test nozzle considered in the evaluation? Specifically, was the damage potential assessed as a function of the degree of subcooling in the test initial conditions?

   c. What is the basis for scaling a shock wave from the reduced-scale nozzle opening area tested to the break opening area for a limiting rupture in the actual plant piping?

d. How is the effect of a shock wave scaled with distance for both the test nozzle and plant condition?

8. Please provide the basis for concluding that a jet impact on piping insulation with a 45° seam orientation is a limiting condition for the destruction of insulation installed on steam generators, pressurizers, reactor coolant pumps, and other non-piping components in the containment. For instance, considering a break near the steam generator nozzle, once insulation panels on the steam generator directly adjacent to the break are destroyed, the LOCA jet could impact additional insulation panels on the generator from an exposed end, potentially causing damage at significantly larger distances than for the insulation configuration on piping that was tested. Furthermore, it is not clear that the banding and latching mechanisms of the insulation panels on a steam generator or other RCS components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested. Although WCAP-16710-P asserts that a jet at Wolf Creek or Callaway cannot directly impact the steam generator, but will flow parallel to it, it seems that some damage to the steam generator insulation could occur near the break, with the parallel flow then jetting under the surviving insulation, perhaps to a much greater extent than predicted by the testing. Similar damage could occur to other insulated components. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that could occur to insulation on steam generators and other non-piping components in the containment.

9. Some piping oriented axially with respect to the break location (including the ruptured pipe itself) could have insulation stripped off near the break. Once this insulation is stripped away, succeeding segments of insulation will have one open end exposed directly to the LOCA jet, which appears to be a more vulnerable configuration than the configuration tested by Westinghouse. As a result, damage would seemingly be capable of propagating along an axially oriented pipe significantly beyond the distances calculated by Westinghouse. Please provide a technical basis to demonstrate that the reduced ZOIs calculated for the piping configuration tested are prototypical or conservative of the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.

10. WCAP-16710-P noted damage to the cloth blankets that cover the fiberglass insulation, in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. It seems that any damage that occurs to the target during the test would be likely to occur in the plant. Was the potential for damage to plant insulation from similar conditions considered? For example, the test fixture could represent a piping component or support, or other nearby structural member. The insulation jacketing is obviously representative of itself. What is the basis for the statement in the WCAP that damage similar to that which occurred to the end pieces in not expected to occur in the plant? It is likely that a break in the plant will result in a much more chaotic condition than that which occurred in testing. Therefore, it would be likely for the insulation to be damaged by either the jacketing or other objects nearby.

The staff also identified a new issue during its review of the Salem Supplemental Response in the debris generation/ZOI area:

11. The response noted that lead blankets were credited for shielding Min-K® microporous insulation on two of the intermediate RCS legs. The response did not justify this position. The licensee should justify that the lead blankets would provide adequate protection such that the Min-K would not become debris or show that the amount of Min-K added to the testing bounds the potential for Min-K debris generation.

The updated supplemental response showed that the debris generation evaluation contained some conservatism. For example, the Min-K amounts have a 40% margin for both units, although this conservatism did not specifically address the issue with the lead blanket providing protection for the Min-K described above. The licensee may be able to balance the issue identified above with this conservatism.

Debris Transport

The staff review of the supplemental response dated March 31, 2009, noted that the licensee had reduced the erosion percentage assumed in the audit report. A new RAI is identified to assess this change:

12. During the staff's audit of strainer performance calculations in October 2007, cumulative 30-day erosion percentages of 40% for Nukon and 15% for Kaowool® refractory fiber insulation were assumed to address NRC staff concerns associated with the erosion test results for Nukon and Kaowool. However, the March 31, 2009, supplemental response indicates that the currently assumed 30-day erosion percentages are 30% for Nukon and 10% for Kaowool. A basis was not provided in the supplemental response to justify the reduced erosion percentages that are currently assumed. Please provide a technical basis for the currently assumed 30-day erosion percentages for Nukon and Kaowool to address the concerns identified with the testing in the audit report and demonstrate that the percentages are prototypical or conservative for the plant condition.

Head Loss and Vortexing

The staff review of the RAI responses in the head loss and vortexing area determined that in general, the evaluation was conducted in a realistic or prototypical manner. The staff determined that all audit open items and RAIs have been addressed adequately except as identified below. Also, one new RAI is identified based on the staff's review of the licensee's most recent submittal. In addition, if the ZOI used for Nukon cannot be justified (issue addressed above in Debris Generation/ZOI), additional evaluation of the effect on head loss will be required.

RAI 14 In its March 31, 2009, submittal, the licensee provided a calculation of void fraction due to vortexing and degasification of the fluid as it passes through the debris bed. Staff evaluation of the response is split into two sections. Further information is required for both the vortex formation and degasification areas.

Vortex Formation

The supplemental response stated that there is a potential for intermittent vortex formations during two pump operation at the minimum submergence level with little or no debris on the strainer. The March 31, 2009, submittal stated that video analysis of the test showed that the maximum air ingestion rate during the test was 0.05% by volume. The response further calculated that the total air entrainment would be 0.00356% if the entire strainer train was included in the calculation. The staff needs more information regarding the video analysis and the calculation to determine whether the methodology used to derive the estimate is realistic. It is not clear how video could be used to estimate the amount of entrained air.

Degasification
The licensee determined that degasification of the fluid could occur as it passes through the debris bed. The licensee postulated that any evolved gasses would be reabsorbed by the liquid prior to reaching the pump suction due to the static head of water above the pump. It was not clear to the staff that any gasses that evolved from the sump fluid would be reabsorbed into the fluid prior to flowing into the pump suction. It was not clear that the dynamics of reabsorption were fully addressed or that all possibilities for evolved gasses were considered. For example, could the gasses collect within the strainer and be entrained in the flow as larger bubbles later in the event? This issue could be mitigated if it were shown that higher submergence would result for the large break LOCA such that degasification were reduced or eliminated and that the head loss across the strainer for a small break LOCA would be significantly lower. Please provide justification for the conclusion in the submittal that all gasses would be reabsorbed prior to the fluid entering the pump, or provide an alternative evaluation of degassification and its effects on the pump.

Additionally the staff noted it was not clear that the Unit 1 testing identified the limiting head loss for the strainer. The design basis test with chemicals was based on a full load condition, but the thin bed condition may have been limiting for that unit. This issue was not identified in the earlier set of RAIs because the initial supplemental response was submitted prior to the completion of testing for Salem. Therefore, the details of the testing were not included in the initial response.

13. The Salem Unit 1 chemical effects head loss test was conducted utilizing the full debris load. However, the Unit 1 thin bed test had a significantly higher head loss (78 mbar) than the non-chemical full load head loss (30 mbar). Please provide information that justifies that the chemical effects testing conducted with the full debris load bounds the head loss that could occur on a chemically laden thin bed. Alternately, a thin bed test can be conducted with chemicals to ensure that the head loss included in the evaluation is bounding for potential plant conditions.

Net Positive Suction Head (NPSH)

The staff review of the March 31, 2009, supplemental response in the NPSH area determined that it generally addressed the information requested in the NRC's March 2008, content guide request acceptably. However, the staff identified two new questions based on review of this submittal.

14. The March 31, 2009, supplemental response states that the calculated minimum containment flood level when the refueling water storage tank (RWST) reaches its low-level alarm setpoint is greater than the required level for adequate strainer submergence and emergency core cooling system recirculation operation, except for Case 1. To address this case, the response states that Emergency Operating Procedures are

currently in place to direct operators to continue injecting until the RWST low-low-level setpoint is reached.

a. Please discuss whether the operation of the residual heat removal pumps has been evaluated with respect to vortex formation at the RWST suction intake with the water level at the low-low-level setpoint to ensure adequate pump performance.

b. Please also discuss whether the minimum water level for Case 1 credits the injection of the accumulators. If credit is taken, please provide a basis to demonstrate that their injection would be expected and a basis for considering the Case 1 to be a limiting water level that bounds small-break LOCA cases for which the accumulators may not inject or may not fully inject. If a more limiting water level is possible for small-break LOCA conditions without accumulator injection, please identify this water level.

15. Page 2 of Attachment 1 to the licensee's submittal of March 31, 2009, indicates that level switches used for indication of containment flood levels "alert the control room operator when sufficient sump level has been achieved to support initiation of cold leg recirculation". This statement suggests that two conditions must now be satisfied before recirculation switchover is initiated: RWST low water level AND containment sump level. Please describe what action the operator would take if both of these conditions are not met; in particular, a case where the RWST is exhausted, but indicated containment water level is too low to have activated the level switches.