UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 12, 2010

Mr. David J. Banriister
Vice President and CNO
Omaha Public Power District
Fort Calhoun Station
444 South 16th St. Mall
Omaha, NE 68102-2247

SUBJECT: FORT CALHOUN STATION, UNIT NO. 1 – REQUEST FOR ADDITIONAL INFORMATION RE: GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS(TAC NO. MC4686)

Dear Mr. Bannister:

On September 13, 2004, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors." The GL addressed the potential susceptibility of pressurized-water reactor recirculation sump screens to debris blockage during design-basis accidents requiring recirculation operation of emergency core cooling systems (ECCS) or containment spray systems (CSS) and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

By letters dated February 29 and October 16, 2008, the Omaha Public Power District (the licensee) submitted supplemental responses to GL 2004-02 for Fort Calhoun Station, Unit 1. The NRC staff has reviewed the submittals and determined that additional information is needed to complete its review. Enclosed is the staff's request for additional information (RAI). As discussed with your staff, we understand that you will be prepared to discuss your proposed responses in detail with the NRC staff in February 2010. The purpose of the call will be to discuss possible approaches for the licensee to address the questions. The NRC staff does not expect final reconciliation to be discussed during this call.

A conference call between the NRC staff and the OPPD staff to discuss the draft RAI questions was held on January 7, 2010. The purpose of the call was to ensure that the questions were understandable, the regulatory basis was clear, and to determine if the information was previously docketed. In addition, during the call, the NRC staff outlined the following process to reach resolution of the issues discussed in the RAI:

1) Following issuance of the RAIs in final form (i.e., this letter), a public meeting (ivia teleconference) will be held to discuss the licensee's planned approach to address each RAI question. This meeting is scheduled for February 24, 2010.

2) As necessary, based on the first meeting, additional public meeting(s) will be scheduled to resolve any open issues.

3) Once mutual understanding is reached on the licensee's proposed approach to address each RAI question, the licensee will formally submit a response to the RAI.

If you have any questions, please contact me at 301-415-1377 or via e-mail at lynnea.wilkins@nrc.gov.

Sincerely,

Lynnea Wilkins, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-285

Enclosure:
As stated

cc w/encl: Distribution via Listserv

REQUEST FOR ADDITIONAL INFORMATION (RAI)

NRC GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS

BLOCKAGE ON EMERGENCY RECIRCULATION DURING

DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS"

FORT CALHOUN STATION, UNIT 1

DOCKET NO. 50-285

On September 13, 2004 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML042360586), the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors." The GL addressed the potential susceptibility of pressurized-water reactor recirculation sump screens to debris blockage during design-basis accidents requiring recirculation operation of emergency core cooling systems (ECCS) or containment spray systems (CSS) and on the potential for additional adverse effects due to debris blockage of flowpaths necessary for ECCS and CSS recirculation and containment drainage.

By letter dated February 29, 2008 (ADAMS Accession No. ML080650369), Omaha Public Power District (OPPD, the licensee) submitted a supplemental response to GL 2004-02 for Fort Calhoun Station, Unit 1 (FCS). By e-mail dated July 28, 2008 (ADAMS Accession No. ML082560650), the NRC staff sent the licensee draft requests for additional information (RAIs), and the licensee responded to the draft RAIs by letter dated October 16, 2008 (ADAMS Accession No. ML082960244).

The NRC staff has reviewed the submittals and determined the following additional information is needed to complete its review of licensee's responses to the draft RAIs as well as additional RAIs which were not specifically identified in the FCS 2008 RAIs (the numbers below increment from the July 28, 2008, NRC staff RAIs):

Draft RAIs

RAI 3 The NRC staff requested that the licensee identify the source of the test data used to support the debris size distribution assumed for calcium silicate insulation and compare the banding, jacketing, and manufacturing process for the calcium silicate installed at FCS to the material used for the destruction testing. The licensee's response dated October 16, 2008, identified that the assumed debris size distribution was based on testing conducted by Ontario Power Generation, Inc. (OPG) and an analysis of this data contained in Appendix II to the December 6, 2004, safety evaluation (SE) on Nuclear Energy Institute (NEI) 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology" (the safety evaluation and NEI 04-07 are non-publicly available). The response also discussed the insulation jacketing and the manufacturing process for the calcium silicate base material. The staff did not consider the response to have fully addressed the RAI because the banding/latching design of the FCS calcium silicate and the jacketing thickness were not described sufficiently and compared to the corresponding design values for the OPG test debris. Please provide this additional design information and comparison with the OPG test.

NOTE: Despite the discussion in Appendix II of the NRC's SE on NEI 04-07, based on scaling issues similar to those raised in the review of recent Pressurized Water Reactor Owners Group (PWROG) zone of influence (ZOI) testing, it is not apparent that the scaling of the OPG testing (i.e., primarily the scaling of the relatively small jet from a 2.86-inch-diameter nozzle to the large 48-inch-long target at the distances tested) provides prototypical or conservative results with respect to the characteristic debris size distribution that would be expected under plant conditions. The NRC staff has not yet determined the significance of this issue. Should it be determined significant, the NRC may raise this as a future issue with FCS testing in the resolution of GL 2004-02.

RAI 5 The NRC staff requested that the licensee address the potential for operation of a low-pressure safety injection (LPSI) pump following the switchover to recirculation (either due to the potential single failure of an LPSI pump to trip or through procedurally permitted operator actions) and any consequent effects of this increased flow on post-loss-of-coolant accident (LOCA) debris transport. By letter dated October 16, 2008, the licensee stated that a "turbulent jet analysis" had been performed, which showed no additional debris entrainment in the flow, but showed the potential for additional tumbling transport. The licensee also indicated that the only scenario where the LPSI pump would be procedurally operated post-LOCA would be for alternate hot-leg recirculation, under which conditions the sump flow rate would be less than the currently bounding analyzed flow rate. The NRC staff questioned the adequacy of this response because, for the case of an LPSI pump single failure to trip, (1) it was not apparent to the staff that a turbulent jet analysis is appropriate for modeling the flow in question, (2) sufficient detail concerning the turbulent jet analysis was not presented, (3) sufficient information was not presented to justify the unexpected conclusion that the additional flow from a LPSI pump would not lead to additional debris remaining in suspension in the flow to the strainers, (4) it is not apparent that the potential for additional debris to transport to the strainer via tumbling with the additional flow from a LPSI pump can be neglected, and (5) it is apparent that a break in the steam generator (SG) A compartment could not become more limiting if the additional pool turbulence created by the flow from an LPSI pump were to result in additional debris remaining in suspension. Please provide additional information that sufficiently addresses these remaining items.

RAI 7 The NRC staff requested that the licensee provide further justification to support the assumption that only 5 percent of fine fibrous and particulate debris blown to upper containment would be washed down to the containment pool (e.g., by condensate drainage). The RAI stated that the staff considered 10 percent to be a more appropriate number and cited NUREG/CR-6762, "GSI-191 Technical Assessment: Parametric Evaluations for Pressurized Water Reactor Recirculation Sump Performance," dated August 2002 (ADAMS Accession No. ML022470077), which found that 5 percent was a low estimate for washdown without spray and 10 percent was a high estimate. In its response dated October 16, 2008, the licensee stated that the assumption of 5 percent washdown from condensate flow was based on assumed condensate flow from the volunteer plant study in Appendix VI, "Detailed Blowdown/Washdown Transport Analysis for Pressurized Water Reactor Volunteer Plant," to the NRC SE on NEI 04-07. The response further discussed the lack of post-LOCA containment spray operation and the effect of fan cooler operation. The licensee also stated that a washdown percentage of 10 percent for the debris loading in SG B compartment would be bounded by the more-limiting debris loading from SG A compartment (with a washdown percentage of 5 percent). Based on the factors below and engineering judgment, the NRC staff considers it prudent to assume a 10 percent washdown, consistent with the technical guidance discussed above.

a. The condensate flow from a plant without containment sprays would be significantly greater and longer-lasting than the volunteer plant, which would presumably lead to an increase in the transport fraction due to condensate drainage versus the volunteer plant.

b. Appendix VI to the NRC SE of NEI 04-07, as well as the results of NUREG/CR-6369, "Drywell Debris Transport Study," dated September 1999 (ADAMS Accession No. ML003728226), on which many of its assumptions are based, indicate that substantial uncertainties are associated with the transport estimates, which applies particularly to blowdown and washdown. The washdown percentages in Appendix VI did not factor in uncertainties typically accounted for in licensing basis calculations and were based on the assumption that most containment surfaces would be sprayed, and few would be subject to condensate drainage only.

c. To support a washdown transport fraction that may not contain significant margin to account for uncertainties, it is important that the blowdown transport of fine debris to the upper containment be performed in a sufficiently conservative manner. Given that the FCS containment contains significant solid flooring, which could potentially impede its transport to upper containment, it is not apparent that the assumed quantity of fine debris (80 percent) would actually be capable of reaching the upper containment during the blowdown phase to subsequently be retained there.

d. Some of the fine debris assumed to be inertially held up on vertical surfaces or the underside of horizontal surfaces during blowdown will lose adherence over time and may gravitationally float down to the containment pool. It was not apparent that this phenomenon was accounted for in the 5 percent washdown assumption made by the licensee.

e. Although, in response to the NRC staff's concerns about washdown uncertainties, the licensee stated that acceptable strainer performance could be assured when assuming 10 percent washdown for a non-limiting break scenario, it was not apparent to the staff whether 10 percent debris washdown could be tolerated for the limiting strainer debris loading case.

The impact on the debris source term of doubling (for example) the assumed washdown percentage would be significant for FCS. Based on this consideration and the questions above, please provide additional information that addresses these remaining items or demonstrate that the strainer will perform acceptably if a washdown transport fraction for fine fibrous and particulate debris that incorporates adequate allowance for uncertainties is assumed.

RAI 10 The NRC staff requested that the licensee provide further justification to resolve the staff's long-standing concerns (including those raised during the staff's pilot audit of FCS) associated with the use of a Stokes' Law approach and turbulent kinetic energy (TKE) metrics to determine the settling behavior of fine debris. In its October 16, 2008, response to this RAI, the licensee provided an extensive discussion that responded to each part of the staff's question. However, after reviewing the response, the staff continues to have concerns that the licensee's approach has not been adequately justified on a technical basis. The NRC staff's concerns are summarized below. Please provide information to address these concerns.

a. The licensee's TKE metrics do not appear to have been experimentally benchmarked. Benchmarking would likely show that a single metric for what is in reality a distribution of particulate sizes to be insufficient. Acoustic measurements of velocity made at low flow rates are not directly related to the fundamental phenomena governing suspension and settling (phenomena which are associated primarily with turbulence). Therefore, the NRC staff did not agree that such measurements would be sufficient to resolve this concern.

b. The licensee did not sufficiently address uncertainties in the TKE model(s) in the computational fluid dynamics (CFD) code used to provide confidence that the TKE model used was adequate for the purpose of determining the settlement of fine debris. The licensee's October 16, 2008, response dealt primarily with uncertainty in velocity (both computational and experimental), not TKE.

c. The licensee did not adequately justify the specification of shape factors and drag coefficients that are applicable for modeling the settling behavior of spherical objects in quiescent fluid to model the settling behavior of irregularly shaped debris, including fibers, in the plant containment pool. Although a detailed discussion was provided in the licensee's October 16, 2008, letter in response to this point, the NRC staff does not agree with certain arguments being made. Specifically, the NRC staff does not agree that shape factors and drag coefficients are not relevant to the settlement of irregularly shaped debris. Sufficient information was not presented to justify this conclusion. It is not apparent that shapes formed by strands of fibers would behave similarly to a spherical particle. In addition, sufficient justification was not presented to show that the presence of turbulence would not affect the TKE metrics that were calculated for quiescent conditions. The staff also did not agree with the licensee's explanation for the drag force being insignificant for slowly settling fine debris because it is the significance of drag (or the drag coefficient) for the fine debris (relative to the other forces acting on the fine debris) that leads to the very small settling velocity.

d. The licensee did not sufficiently justify the correlation of terminal settling velocity to TKE. In response to this item, the licensee indicated that the "TKE" used by Alion Science and Technology (Alion) was based on a bulk velocity, rather than the fluctuating components of the velocity. Based on its review of the licensee's October 16, 2008, submittal, it was not apparent how this quasi-TKE quantity was implemented in the CFD code and analysis, how it is consistent with CFD plots that were included in the supplemental responses to GL 2004-02, and whether several of the conclusions following from the use of this quasi-TKE quantity are valid. The NRC staff requests further discussion regarding the use of 0.01 feet per second (ft/s) as a transport metric for fines, the isotropy of turbulence, and the correlation of terminal settling with TKE.

RAI 11 The NRC staff requested further justification to demonstrate the adequacy of the testing the licensee credited to support an erosion percentage of 10 percent for small and large pieces of fibrous debris. Based on the information provided in the licensee's RAI response dated October 16, 2008, the NRC staff is concerned that the erosion testing being credited by the licensee (Alion proprietary report, ALION-REP-LAB-2352-77, Revision 2, "Test Report: Erosion Testing of Low Density Fiberglass Insulation") could be the generic testing performed by Alion reported in the RAI response from San Onofre Nuclear Generating Station, dated February 23, 2009 (ADAMS Accession No. ML090580024). The staff is concerned that these test results may be spurious, because the longer duration tests showed a significantly lower cumulative erosion percentage than shorter duration tests (i.e., all tests performed for longer than 60 hours appear to have cumulative erosion percentages less than 5 percent, whereas 75 percent of those tests shorter than 60 hours appear to have cumulative erosion percentages greater than 5 percent). Although the licensee stated in its RAI response that the flows in the FCS containment pool are very low, since there is very little washdown of non-fine debris (e.g., 2 percent of small pieces of fiber and calcium silicate), much of the debris in the containment pool that would be subject to erosion would seemingly be located in the compartment with the break. Based on CFD plots included in the supplemental responses to GL 2004-02, flow velocities in the compartment affected by the break could easily exceed 0.1 ft/s, similar to the flow rate for the Alion test. This suggests that the velocity conditions used for the Alion erosion testing are not overly conservative for the FCS plant condition. Furthermore, the turbulence in the erosion test flume would seemingly be lower than that for a plant flow at an equivalent velocity, since a narrow flume with room-temperature water and flow straighteners would tend to have a lower Reynolds number than equivalent-velocity flows in a hot, plant containment pool with wide flow channels. As a result, it appears that the flow conditions used for the erosion testing have not been demonstrated to be prototypical or conservative for FCS. Please provide a graph of the percent of eroded fibrous debris as a function of time for the erosion tests that were performed in support of FCS and justification that the tests are valid if anomalous behavior is apparent in the test results.

RAI 12 The NRC staff requested further justification of the adequacy of the testing the licensee credited to support an erosion percentage of 15 percent for calcium silicate. The licensee's October 16, 2008, response described the test flume, the velocity conditions in the flume, and the types of calcium silicate that were tested. The staff did not identify a concern with the information provided, but concluded that the licensee should provide a plot of the calcium silicate erosion test data to demonstrate the adequacy of the erosion assumption for calcium silicate. The NRC staff's request is based on both recent test information from other erosion testing performed by Alion that appeared to have anomalous results, as well as previous erosion testing with anomalous results described in the Salem Nuclear Generating Station audit report dated August 12, 2008 (ADAMS Accession No. ML082170506), which are the two main sources of debris erosion testing with which the staff is familiar. To provide confidence that anomalies similar to those observed in other erosion testing do not adversely affect the calcium silicate erosion testing performed for FCS, please provide a plot of the results (e.g., cumulative eroded percentage as a function of time) for the tests that were performed in support of the erosion assumption of 15 percent for calcium silicate debris.

RAI 15 The NRC staff requested additional information on the temperature extrapolation methodology because it is not apparent that the bore holes that occurred at the low test temperatures would occur at the higher temperatures in the actual sump pool. The licensee provided additional information in its October 16, 2008, response regarding the methodology used for temperature extrapolation. The methodology used is considered valid for the pressure range in which the temperature measurements were taken. However, the temperatures which the results are being extrapolated to are much higher than those tested. The higher LOCA temperatures result in significantly lower head losses than those measured at the test temperature. The licensee provided graphs of head loss, flow, and temperature for some of the tests. The licensee stated that, based on short-term head-loss variation, the formation and filling of bore holes appeared to be about the same between the high-temperature testing, about 95 degrees Fahrenheit (°F) and the low-temperature test, about 65 °F. The same head-loss curves appear to indicate, based on short-term head-loss variation from the average, that bore holes form at higher head losses and may not be present or have as large an effect at lower head losses. Two of the examples appeared to result in larger short-term variations in head loss at about 40 to 50 inches of head loss, and one example appeared to result in larger variations at about 20 inches of head loss. Therefore, the staff cannot conclude that bore holes would form at lower differential pressures. The licensee should justify that the reduction in head loss due to bore hole formation would be expected to occur at lower differential pressures. It is likely that the debris bed morphology has a significant impact on bore hole formation. This could explain some differences in the short-term head-loss variation between tests. The licensee should provide additional information that justifies that the temperature compensation applied to the test results does not affect the evaluation non-conservatively.

RAI 20 The NRC staff requested additional information regarding how the velocities and turbulence in the test flume compare to similar variables predicted in the plant sump pool (i.e., for tests that allowed settling (no stirring), provide a comparison of the flows predicted around the strainer in the plant and the flows present in the test flume during the testing). In its RAI response dated October 16, 2008, the licensee provided additional descriptions of how the velocities in the area of the strainer were determined. A CFD analysis of the sump pool, run at a higher flow rate than would be expected using the current assumptions, indicates that the average flow in the area of the strainers is about 0.075 feet per second (ft/sec). Adjusting this for the currently assumed flow rate, the velocity in the area of the strainer is calculated to be about 0.05 ft/sec. The RAI response stated that the flow in the test apparatus was set to be equal to the predicted flow rate by adjusting the width of the test flume walls. The basic concepts applied in the RAI response are accepted by the staff. However, it appeared that the CFD analysis referenced by the response had some non-uniform flow areas near the strainer. Areas of higher flow would promote transport. Additionally, the RAI response did not address the turbulence available to maintain debris in suspension. The licensee should provide a more detailed CFD analysis in the area of the strainer so that flow velocities would be more fully defined. In addition, the licensee should provide a comparison of turbulence around the strainers in the plant and the turbulence in the test flume. Alternately, the licensee could provide alternate information that shows that the test was not non-conservatively biased due to these factors.

RAI 25 The NRC staff requested additional information on the justification for treating unqualified alkyd original equipment manufacturer (OEM) coatings as chips at FCS despite the contradictory data presented in Electric Power Research Institute (EPRI) report #1011753, "Design Basis Accident Testing of Pressurized Water Reactor Unqualified Original Equipment Manufacturer Coatings" (OEM report), dated September 2005. The licensee stated that the alkyd OEM coatings fail in 5 mil chips. The staff does not accept alkyds failing as chips since in the EPRI OEM report, alkyds do not fail as chips. According to staff guidance ["NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing," dated March 2008 (ADAMS Accession No. ML080230038).], the alkyd OEM coatings failing as fine particulate would be more conservative since a thin bed has been observed to form. The impact of the alkyd OEM coatings could add an additional 40 pounds mass (lb_m) to the debris. Please provide additional justification for treating alkyd OEM coatings debris as chips rather than treating it as particulate.

RAI 34 The NRC staff requested additional information regarding a number of issues related to silicate inhibition of aluminum corrosion, including among other information the type and amount of plant debris assumed as the source of silicates. In its October 16, 2008, letter, the licensee provided a table which listed the debris generated for various breaks including a small break. The table indicates that there is only a small amount of calcium silicate destroyed by the small break. Since silicate inhibition of aluminum corrosion is credited for all potential breaks, please provide greater detail on the source of the silicate for the small break. Specifically, please explain whether the silica source for a small-break LOCA is strictly calcium-silicate or whether fiberglass or other materials are considered a source of silicate. This point is important because the inhibition of aluminum corrosion may not occur if insufficient silicate is present for the small-break case.

RAI 35 The NRC staff requested additional information concerning how aluminum solubility was credited. This information was needed to determine if the long-term solubility credit is based on the pool temperature never dropping below 140 °F. Based on review of the licensee's October 16, 2008, RAI response, it is unclear to the staff whether the licensee's analysis applies the aluminum hydroxide precipitate at a delayed time or if the aluminum is assumed to remain in solution for the duration of the post-LOCA mission time. The licensee did not provide justification for the credit taken as discussed in the staff's March 2008 chemical effects review guidance ["NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Plant-Specific Chemical Effect Evaluations," dated March 2008 (ADAMS Accession No. ML080380214).]. Please provide additional detail regarding the solubility of aluminum and how aluminum-based precipitates are accounted for, or discounted, in the final analysis.

RAI 36 The NRC staff requested additional information concerning the percentage of chemical precipitates that settled away from the strainer during the LOCA tests. Please clarify whether the response is for large-break LOCAs only and, if so, what the precipitate settlement observations were for the small-break LOCA case. The NRC staff notes that, if the "robust HVAC enclosure" can be shown to be effectively leak-tight for the aluminum source therein, the licensee may have an alternate path for demonstrating a conservative chemical effects evaluation.

<u>Additional RAIs</u>

37. The latent fiber quantity assumed by FCS is only 2.79 percent, rather than the default suggested 15 percent from the NRC staff's SE on NEI-04-07. The NRC staff believes the apparent difference is due to fiber collection efficiency differences between the debris collection method used by FCS (scraping with a metal scraper) and vacuuming or wiping with masolin cloths used by the other plants in the NUREG-6877 survey. Although the collection efficiency of fiber is not discussed specifically, the NUREG notes that differences in collection method have a large impact and specifically notes that the metal scraper method resulted in a much lower fraction of fine particulate for FCS as compared to the other plants surveyed. Additionally, the fiber percentage of 2.79 percent is based on only eight samples (total mass: 27 grams), which is not enough for statistical accuracy for scaling a mass distribution up by a factor of over 2500. For properly collected debris samples, a fiber-mass proportion of 15 percent should be applied to the total inventory estimate in the absence of site-specific supporting evidence. Therefore, the NRC staff believes the licensee should have used the standard 15 percent value for the latent fiber mass percentage as opposed to relying upon the Plant C data in NUREG/CR-6877, "Characterization and Head-Loss Testing of Latent Debris from Pressurized-Water-Reactor Containment Buildings," dated July 2005 (ADAMS Accession No. ML052430751). Please justify the use of 2.79 percent latent debris distribution fiber for FCS.

38. For the head loss tests conducted that permitted debris settling, please describe whether and/or how erosion of debris that settles in the test flume was accounted for in the sump performance evaluation. Please estimate the quantity of eroded fines from large and small pieces of fibrous, calcium silicate, asbestos, and other types of debris that would result from explicitly accounting for the erosion of the settled debris in the head loss test flume. If this eroded debris was not accounted for in a prototypical or conservative manner, then please justify the neglect of this material in the head loss testing program and provide a basis for the conservatism of the analytical debris

erosion results, given that the analysis may significantly underestimate the total quantity of settled debris (when debris that settled in the test flume is considered).

The following set of issues relate to ZOI issues that were not specifically identified in 2008 RAIs for FCS. These issues were developed as a result of NRC staff review of certain documents developed by the PWROG that are used as a basis for certain assumed ZOI reductions for FCS. The PWROG is planning to respond to some of these generically, but it is unknown which of the issues below will be generically answered and which will be site-specific.

39. Although the American National Standards Institute/American Nuclear Society (ANSI/ANS) standard 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-specific reactor coolant system conditions in the plant hot- and cold-leg operating conditions. If ZOI reductions are also being applied to lines connecting to the pressurizer, please 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, please provide that assessment.

40. 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 and demonstrate that the conditions and materials adequately represented the plant jacketing/insulation system. Please describe differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including valves and other fittings. At a minimum, the following areas should be addressed:

    a. Please describe how 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 nozzle-to-target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.

    b. Please describe if the insulation and jacketing system used in the testing was of the same general manufacture and manufacturing process as the insulation used in the plant. If not, please describe what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation. It is known that there were generally two very different processes used to manufacture calcium silicate whereby one type readily dissolved in water but the other type dissolves much more slowly. Such manufacturing differences could also become apparent in debris generation testing, as well.

c. Please provide 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 in the testing could be significantly under-stressed. 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 OPG report on calcium silicate debris generation testing.

41. 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. Please explain the steps 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.

42. Please describe the procedure and assumptions for using the ANSI/ANS-58-2-1988 standard, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," to calculate the test jet stagnation pressures at specific locations downrange from the test nozzle.

a. In WCAP-16710-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) of Min-K and NUKON Insulation, for Wolf Creek and Callaway Nuclear Operating Plants," was the analysis based on the same initial condition as the initial test temperature, specified as 550 °F? If not, please provide an evaluation of the significance of the difference.

b. Please explain whether the water subcooling used in the analysis was that of the initial tank temperature or 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. Please explain how the associated debris generation test mass flow rate was determined. If the experimental volumetric flow was used, please 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, please explain how the transient behavior was considered in the application of the ANSI/ANS-58-2-1988 standard. Specifically, please explain whether 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.

43. 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 reactor coolant system temperatures and 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 and 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 rate for the postulated plant 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?

44. 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?

45. 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 pressurized-water reactor hot legs considered?

    b. Was the initial lower temperature of the fluid near the test nozzle taken into consideration 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?

46. 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 appear to 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.

47. 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. Please explain 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 more likely for the insulation to be damaged by either the jacketing or other objects nearby.

3) Once mutual understanding is reached on the licensee's proposed approach to address each RAI question, the licensee will formally submit a response to the RAI.

If you have any questions, please contact me at 301-415-1377 or via e-mail at lynnea.wilkins@nrc.gov.

Sincerely,

/RA/

Lynnea Wilkins, Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-285

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