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

July 31, 2009

Mr. Rick A. Muench
President and Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
Post Office Box 411
Burlington, KS 66839

SUBJECT: WOLF CREEK GENERATING STATION – REQUEST FOR ADDITIONAL INFORMATION REGARDING RESPONSE TO GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MC4731)

Dear Mr. Muench:

By letters dated February 29 and December 22, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML080700356 and ML090060877, respectively), Wolf Creek Nuclear Operating Corporation (the licensee) submitted supplemental responses to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," for Wolf Creek Generating Station (WCGS). The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's submittals.

The NRC staff's review process involved a detailed review by a team of subject matter experts (SMEs), with focus on the review areas described in the NRC's "Revised Content Guide for Generic Letter 2004-02 Supplemental Responses," dated November 21, 2007 (ADAMS Accession No. ML073110389). For its review, the NRC staff used the review guidance from several sources, including "Revised Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, 'Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors,'" dated March 28, 2008 (ADAMS Accession No. ML080230234), and the NRC's safety evaluation (SE) dated December 6, 2004 (ADAMS Accession No. ML043280641), on the Nuclear Energy Institute (NEI) document, "Pressurized Water Reactor Sump Performance Evaluation Methodology," dated May 28, 2004 (ADAMS Accession No. ML041550661). The review process also included a separate review of the licensee's submittals informed by inputs from the SMEs that focused on whether the licensee has demonstrated overall that its corrective actions for GL 2004-02 are adequate.

Based on these reviews, the NRC staff has concluded that additional information is needed for the staff to conclude that there is reasonable assurance that GL 2004-02 has been satisfactorily addressed for WCGS. The request for additional information (RAI) is detailed in the enclosure to this letter. Draft RAIs were provided to your staff via e-mail on June 22, 2009, and discussed during the conference call held on July 2, 2009.

The NRC requests the licensee to respond to these RAIs within 90 days of their formal transmittal. The NRC staff prefers that the licensee provide its response to all of the RAIs in a single letter, with the exception of RAI No. 47, as discussed below. If the licensee concludes that more than 90 days is needed to respond to the RAIs, the licensee should request additional time, including a basis for why such time is needed.

As part of the written response to the additional RAIs, we request that you include a safety case. This safety case should describe, in an overall or holistic manner, how the measures credited in the WCGS licensing basis demonstrate compliance with the applicable NRC regulations as discussed in GL 2004-02 and should describe your approach to responding to the RAIs. As appropriate, the safety case may describe how the licensee reached compliance even in the presence of remaining uncertainties. The NRC staff views the safety case as informing, not replacing, responses to the RAIs.

Regarding RAI No. 47, the NRC staff considers in-vessel downstream effects not to be fully addressed for WCGS, as well as at other pressurized-water reactors. The licensee's submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for WCAP-16793. The licensee may demonstrate that in-vessel downstream effects issues are resolved for WCGS by showing that the licensee's plant conditions are bounded by the final WCAP-16793 and the corresponding final NRC staff SE, and by addressing the conditions and limitations stated in the final SE. The licensee may also resolve this item by demonstrating that in-vessel downstream effects have been addressed for WCGS without reference to WCAP-16793 or the staff SE. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793.

If you have any questions, please contact me at 301-415-3016 or via e-mail at balwant.singal@nrc.gov.

Sincerely,

Balwant K Singal

Balwant K. Singal, Senior Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-482

Enclosure
As stated

cc w/encl: Distribution via Listserv

REQUEST FOR ADDITIONAL INFORMATION

FEBRUARY 29 AND DECEMBER 22, 2008, SUPPLEMENTAL

RESPONSES TO GENERIC LETTER 2004-02

WOLF CREEK GENERATING STATION

DOCKET NO. 50-482

A. Break Selection

1. Please verify that the insulation types and amounts are distributed relatively symmetrically between all loops to validate that the focus on loop D provided a conservative break selection evaluation, or otherwise justify the assumption.

2. Please justify that the 3-inch charging line break provides the greatest debris generation for the partially submerged conditions. Please state whether there other breaks, potentially on larger lines, that could result in a larger debris term, yet still result in partial submergence. Please provide results of evaluations and testing that verify that the debris generated by the limiting break that results in partial submergence will not result in unacceptable head loss (strainer failure). Please either state that this evaluation is based on a U.S. Nuclear Regulatory Commission (NRC) staff-accepted test methodology or justify use of a different methodology. Note that the NRC staff considers testing conducted at Alden Labs prior to 2008 likely to be non-conservative. Alternately, please verify that the strainer will be fully submerged for all small break loss-of-coolant accident (SBLOCA) conditions as described on page 47 of the December 22, 2008, supplemental response (Agencywide Documents Access and Management System (ADAMS) Accession No. ML090060877), such that the large break loss-of-coolant accident (LBLOCA) testing bounds the SBLOCA.

B. Debris Generation/Zone of Influence (ZOI)

Please respond to the following questions on debris generation testing. Note that the Pressurized-Water Reactor Owners Group (PWROG) is planning to respond to some of these issues generically. The licensee will be expected to respond to all of them. To the extent the NRC staff accepts the PWROG's generic resolution, the licensee's request for additional information (RAI) responses may refer to the resolution document as appropriate, while adding site-specific information as needed.

3. Although American National Standards Institute (ANSI)/American Nuclear Society (ANS) standard 58-2-1988, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Rupture," 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 (RCS) conditions, specifically the plant 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. Please describe results of 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.

4. Please describe the jacketing/insulation systems used at Wolf Creek Generating Station (WCGS) for which the ZOI reduction is sought and compare those systems to the jacketing/insulation systems tested, demonstrating that the tested jacketing/insulation system adequately represent 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. At a minimum, the following areas should be addressed:

    a. Please describe how the characteristic failure dimensions of the tested jacketing/insulation compared 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 to target spacing would be non-conservative with respect to impacting the entire target with the calculated pressure.

    b. Please explain whether 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 explain what steps were taken to ensure that the general strength of the insulation system tested was conservative with respect to the plant insulation. For example, 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 results of 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 Ontario Power Generation report, "Jet Impact Tests – Preliminary Results and Their Application, N-REP-34320-10000," dated April 18, 2001 (ADAMS Accession No. ML020290085), on calcium silicate debris generation testing.

5. 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 describe steps were taken to ensure that the calculations resulted in conservative estimates of these values. Please provide the inputs for these calculations and describe the sources of the inputs.

6. 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. As part of this description, please address the following points.

    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," please explain why the analysis was based on the initial condition of 530°F whereas the initial test temperature was specified as 550°F.

    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, 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, 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 represented 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, please 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.

7. 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. Please include discussions of the following points.

    a. Please provide the assumed plant-specific RCS 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. Please describe the calculational method used to estimate the plant-specific and break-specific mass flow rate for the postulated plant loss-of-coolant accident (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, please describe steps taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections. Please explain whether multiple break conditions were calculated to ensure a conservative specification of the ZOI radii.

8. 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. Please also address the following related points:

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. Please explain how the fact that the fluid near the nozzle was colder than the bulk fluid was accounted for in the evaluations.

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

c. Please provide the specified rupture differential pressure of the rupture disks.

9. WCAP-16710-P discusses the shock wave resulting from the instantaneous rupture of piping. Please address the following points regarding the shock wave.

a. Please describe results of analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave to different thermal-hydraulic conditions. Please state and justify whether temperatures and pressures prototypical of PWR hot legs were considered.

b. Please explain whether the initial lower temperature of the fluid near the test nozzle was taken into consideration in the evaluation, and if not, why not. Specifically, please explain and justify whether the damage potential was assessed as a function of the degree of subcooling in the test initial conditions.

c. Please provide 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. Please compare how the effect of a shock wave was scaled with distance for the test nozzle, and compare that with the expected plant condition.

10. Please provide the basis for concluding that a jet impact on piping insulation with a 45 degree 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 WCGS or Callaway cannot directly impact the steam generator, but will flow parallel to it, it seems that some damage to the SG 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 component insulation. Please provide a technical basis to demonstrate that the test results for piping insulation are prototypical or conservative of the degree of damage that would occur to insulation on steam generators and other non-piping components in the containment.

11. 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 would 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 with respect to the degree of damage that would occur to insulation on piping lines oriented axially with respect to the break location.

12. 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. Please justify the assumption that damage that occurs to the target during the test would not be likely to occur in the plant. Please explain whether the potential for damage to plant insulation from similar conditions was considered. For example, the test fixture could represent a piping component or support, or other nearby structural member. Please provide the basis for the statement in the WCAP that damage similar to that which occurred to the end pieces would not be 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.

13. For the Min-K panel testing, one specimen was ejected from the test fixture and impacted a tree some 150 feet away. This impact resulted in minor damage to the encapsulation. Please provide the results of evaluations of the potential for a similar occurrence in the plant, including at distances much closer than 150 feet as applicable to the plant. Please provide the result if the panel lodged within the jet ZOI, as well as whether the encapsulating material could fatigue, fail, and allow the insulating material to be released.

14. Please provide a comparison of the Thermal-Wrap and Nukon insulation systems that justifies that the Thermal-Wrap system is at least as structurally robust as the Nukon. The licensee's response only describes the similarity of the base material fibers and claims similarity was asserted in the NRC staff's safety evaluation (SE) dated December 6, 2004 (ADAMS Accession No. ML043280641), on NEI 04-07. This conclusion in the SE was reached on the basis of a large 17D ZOI being assumed, one that was likely conservative for both materials, whether the jacketing is similar or perhaps even present. However, when conservatisms are removed to arrive at a smaller ZOI (i.e., effectively 5D), it becomes necessary to demonstrate similarity of the jacketing, banding, scrim, and cloth covers to show sufficient similarity. Based on testing done by Westinghouse/Wyle for Arkansas Nuclear One (ANO) (Entergy Operations, Inc. letter dated February 28, 2008, ADAMS Accession No. ML080710544), some damage was seen for Thermal Wrap at 12D and at 7D, which suggests a potential for increased vulnerability. It was not clear to the NRC staff why this Thermal Wrap test is not more applicable to the Thermal Wrap at WCGS than a test performed for a different material (i.e., Nukon). Therefore, please justify treating Thermal Wrap with a reduced ZOI based on Nukon testing, in terms of the jacketing, banding and/or latching, scrim, and cloth cover for the Thermal Wrap insulation to provide confidence that it is comparable to the jacketing system for the Nukon insulation system that was tested.

15. The supplemental response dated February 29, 2008 (pg 14 of 82), stated that the Min-K at WCGS is located near the reactor vessel. Please state whether spherical resizing was performed for the Min-K ZOI and, if so, justify that it is appropriate for this location considering that substantial physical obstructions could result in a significantly non-spherical ZOI. The NRC staff's May 16, 2007, audit report for San Onofre Nuclear Generating Station discusses a potentially similar issue (Open Item 1 in Section 3.2, ADAMS Accession No. ML071240024) regarding Microtherm insulation that was located on the reactor vessel, for which spherical resizing was considered inappropriate by the NRC staff due to the constraints imposed by the biological shield wall and reactor vessel. The WCAP report states that a 1/8-inch offset was assumed rather than full separation for the Min-K break thus spherical scaling would not have been specified per the ANSI/ANS-58-2-1988 model. The supplemental response and debris generation test report do not discuss how the scaling for the 1/8-inch offset case is handled. It is not clear that the ANSI/ANS-58-2-1988 (non-spherical) model for the limited separation case was done for the Min-K. Please justify that an offset circumferential break is the only type of break necessary to consider, or provide results of evaluations of other configurations. For example, should a longitudinal break be postulated? If the Min-K is damaged by a restrained break, please justify that a 30-second duration jet impingement is adequate to model the blowdown from the break. Please explain and justify whether

the blowdown should be longer for a restrained break with a smaller effective break area.

C. Debris Characteristics

16. The assumed debris size distribution of 60 percent small fines and 40 percent large pieces for low-density fiberglass within a 5D ZOI is inconsistent with Figure II-2 of the NRC staff's SE dated December 6, 2004 (ADAMS Accession No. ML043280641), on NEI 04-07, which considers past air jet testing and indicates that the fraction of small fines should be assumed to reach 100 percent at jet pressures in the vicinity of 18–19 pounds per square inch (psi). At 5D, the jet pressure is close to 30 psi, which significantly exceeds this threshold. Furthermore, the licensee's assumption that the size distribution for debris in a range of 5D to 7D is 100 percent intact blankets also appears to be inconsistent with existing destruction testing data. These assumptions for low-density fiberglass debris size distributions appear to be based on the recent Westinghouse/Wyle ZOI testing discussed in WCAP-16710-P. However, that testing was not designed to provide size distribution information, and much of the target material was exposed to jet pressures much lower than would be expected for a prototypically sized break. Furthermore, given the assumption that insulation between 5D and 7D is 100 percent intact pieces that do not transport or erode, the licensee has effectively assumed a 5D ZOI rather than a 7D ZOI for low-density fiberglass. In light of the discussion above concerning previous testing experience, please provide a basis for considering the assumed debris size distribution of 60 percent small fines and 40 percent large pieces within a 5D ZOI to be conservative or protypical.

17. The NEI 04-07, along with the NRC staff SE on that document, provides information regarding the treatment of the characteristics of fibrous debris generated from a break. The guidance report states that small fines are individual fibers. However, the staff SE notes that this is likely to result in problems in the treatment of fibrous debris. The amount of fines and small pieces of debris should be defined separately so that inputs for transport analyses and head loss testing are well defined. The estimation of fine debris amounts is especially important for testing that allows near-field settling. The guidance documents, such as Appendix II to the SE on NEI 04-07, indicate that reduced ZOIs generally result in increased percentages of small and fine debris. The supplemental response dated December 22, 2008, stated that 30 percent of the small fibrous debris added to the head loss test was estimated to be in the form of fines, but the response did not provide a basis for this assumption, such as an analytical evaluation of expected quantities of the plant fibrous debris determined to be fines. The ZOI reduction taken for Nukon should reflect the phenomenon demonstrated in SE Appendix II of increased debris fragmentation near the break location when the debris sizing is estimated, or the licensee should justify otherwise. Please identify the amounts of fine fibrous debris predicted to be generated from the analyzed limiting breaks.

18. To the extent Foamless and Cerablanket are included in the limiting debris loading case, please provide an evaluation of their characteristics, such as characteristic size distribution (small pieces and fines, etc.) and density, and please provide justification for deviation from staff-approved evaluation methodologies.

D. Debris Transport

19. The NRC staff's December 6, 2004, SE for NEI 04-07 states that a maximum of 15 percent holdup of debris should be assumed in inactive holdup regions during pool fill up. For the case of single-train sump operation for WCGS, a two-sump plant, the sump that is not operating essentially becomes an inactive holdup region. From this point of view, the staff observed that WCGS appeared to credit a 15 percent inactive holdup volume in the containment pool, plus 14 percent holdup in the inactive recirculation sump for single-train cases, for a total of 29 percent of debris held up in inactive volumes for these single-train cases (e.g., the Loop D cross-over break, the case considered by the licensee to be bounding). The staff considers this credit a deviation from the approved guidance in the SE, which stated that the limit for inactive hold up should be 15 percent unless a computational fluid dynamics (CFD) analysis was performed that considered the time-dependent containment pool flows during pool fill up. Please provide additional basis for the assumed total inactive holdup fraction of 29 percent or revise this value to within the accepted SE range.

20. The licensee's supplemental responses, including the one dated December 22, 2008, discuss crediting Stokes' Law, but do not specifically quantify the credit taken for application of this methodology. Please state the quantities of fine debris assumed to settle onto the containment floor by applying the Stokes' Law methodology. If credit is taken for such settling, please provide technical justification regarding the following points: (1) lack of experimental benchmarking of analytically derived turbulent kinetic energy (TKE) metrics; (2) uncertainties in the predictive capabilities of TKE models in CFD codes, particularly at the low TKE levels necessary to suspend individual fibers and 10-micron particulate; (3) the basis for analytical prediction of settling velocities in quiescent and non-quiescent water due to the specification of shape factors and drag coefficients for irregularly shaped debris; and (4) the basis for the theoretical correlation of the terminal settling velocity to turbulent kinetic energy that underlies the Alion Science & Technology methodology for fine debris settling. Please address these points to demonstrate that any credit taken for fine debris settling is technically justified.

21. Please provide a description of the testing performed to support the assumption of 10 percent erosion of fibrous debris pieces in the containment pool. Please specifically include the following information:

    a. Please describe the test facility used and demonstrate the similarity of the flow conditions (velocity and turbulence), chemical conditions, and fibrous material present in the erosion tests to the analogous conditions applicable to the plant condition.

    b. Please provide specific justification for any erosion tests conducted at a minimum tumbling velocity if debris settling was credited in the test flume for velocities in excess of this value (e.g., in front of the curb around the sump pit).

    c. Please identify the duration of the erosion tests and how the results were extrapolated to the sump mission time.

22. The supplemental response dated December 22, 2008, indicates that a significant percentage of small and large pieces of Nukon were assumed to transport to the strainers (i.e., nearly 100 percent of small pieces and approximately 75 percent of large pieces in several cases). This analytical result minimized the quantity of settled small and large pieces of fiberglass that were analytically assumed to erode in the containment pool. However, for the strainer head loss testing conducted by Performance Contracting, Inc. (PCI), the NRC staff considers it likely that a significant fraction of small pieces and most or all of the large pieces of debris that were analytically considered transportable actually settled in the test flume rather than transporting to the test strainer. The head loss testing did not model the erosion of this debris. The licensee's consideration of debris erosion, therefore, appears to be non-conservative, because neither the analysis nor the head loss testing accounted for the erosion of debris that settled during the head loss testing. Please estimate the quantity of eroded fines from large and small pieces of fiberglass debris that would result had erosion of the settled debris in the head loss test flume been accounted for and justify the neglect of this material in the head loss testing program.

23. Based upon discussions with the licensee and PCI in January and February 2008, the head loss testing conducted by PCI modeled flow conditions during the recirculation phase of a LOCA and modeled all debris (other than a small quantity of latent debris added with the recirculation pump stopped) as entering the containment pool one flume-length (nominally 33 feet) away from the containment sump strainers. Flow conditions during the pool-fill phase of the LOCA were not considered by the testing, nor was the potential for debris to enter the containment pool closer than one flume-length from the strainer due to the effects of blowdown, washdown, and pool fill transport. The lack of modeling of these two transport aspects of the head loss testing appeared to result in a non-prototypical reduction in the quantity of debris reaching the test strainer and, ultimately, non-conservative measured head loss values. Please provide the technical basis for not explicitly modeling transport modes other than recirculation transport, considering the following points:

    a. As shown in Appendix III of the NRC staff's SE on NEI 04-07, containment pool velocity and turbulence values during fill up may exceed those during recirculation, due to the shallowness of the pool. Some debris that would not transport during recirculation may transport during the pool-fill phase. In addition, latent debris on the containment pool floor could be stirred into suspension by these high-velocity, turbulent flows, unlike the latent debris added to the quiescent PCI flume.

    b. The pool fill phase will tend to move debris from inside the shield wall into the outer annulus away from the break location and nearer to the recirculation sump strainers.

    c. For plants that have strainers located below the floor grade level, the transport of large and small pieces of debris during pool fill can result in this debris accumulating directly on the strainer surfaces, potentially resulting in the formation of a limiting debris layer at the entrance to the sump pit.

d. Representatively modeling the washdown of some fraction of the debris nearer the strainer than one flume-length away would be expected to increase the quantity of debris transported to the strainer and the measured head loss. This statement applies both to debris that tends to settle in the head loss test flume, as well as debris considered to settle analytically, such as various types of paint chips.

24. Please provide the technical basis for the conclusion that large pieces of fibrous debris and, as applicable, reflective metal insulation (RMI) debris, coating chips, and other debris types, have a transport fraction of zero during the pool-fill phase of a LOCA.

25. The supplemental response dated December 22, 2008, states that, based on testing documented in NUREG/CR-2791, "Methodology for Evaluation of Insulation Debris Effects, Containment Emergency Sump Performance Unresolved Safety Issue A-43," dated September 1982, Nukon was assumed not to float on the surface of the containment pool. However, page 51 of NUREG/CR-2791 indicates that large floating fragments of fiberglass under hot (60 °C) sprays will sink in 2 to 5 days. As a result, NUREG/CR-2791 stated that it is reasonable to assume that all large floating fragments of fiberglass sink in the vicinity of the strainers. In light of these test results from NUREG/CR-2791, please provide additional basis for the assumption that large or intact pieces of fiberglass debris cannot float for a sufficient period of time to reach the strainers prior to sinking in the containment pool. If floating debris sinks on strainers located in a sump pit, there is the potential for forming a limiting layer of debris at the entrance to the strainer pit.

26. The supplemental response dated December 22, 2008, indicates that most miscellaneous debris settled prior to reaching the test strainer. Based on previous observations of other testing performed at PCI, the NRC staff observed that tags, labels, and miscellaneous materials were added to the test flume by submerging them beneath the surface of the test fluid. Submerging miscellaneous debris would not allow the potential for transport to the strainers by floatation to be evaluated. Due to the pit strainer configuration at WCGS, if miscellaneous debris can float toward the strainers and subsequently sink over the strainers, then part of the opening to the strainer pit could be blocked off. Please describe the addition process for miscellaneous debris (e.g., tags, labels, and stickers), and discuss how the potential for transport via floatation was considered in the head loss testing program or by analysis.

27. Based on discussions with the licensee and PCI in January and February 2008, the NRC staff considered the modeling of the boundary conditions for the localized CFD model for the vicinity of the sump strainers to be non-conservative. Although the total flow rate from each side of the annulus was taken from the full-containment CFD model by using a constant, averaged velocity boundary condition, the localized CFD model did not simulate the significant channeling of the flow predicted by the full-containment model. As a result, velocities in the vicinity of the strainer were significantly underestimated. Since the localized CFD model was used as the basis for the head loss test flume velocities, the staff considered the test flume velocities as underestimating the velocities at which much of the debris would actually transport to the plant sump strainers. Although the staff recognized that some improvements had been made to the localized

CFD model (e.g., a finer mesh resolution), these improvements did not compensate for the inaccuracy in the specification of the inlet boundary conditions. Please provide any information in addition to the information already discussed with the staff that could demonstrate the adequacy of the flow conditions used for the head loss test.

28. Based on discussions with the licensee and PCI in January and February 2008, the NRC staff understood that the test debris was not categorized into specific subgroups of fines and small pieces. Based on a rough visual inspection, the licensee estimated that 30 percent of the small pieces of fibrous debris added to the test were fines. However, the staff does not consider the licensee's estimate to be sufficient because (1) visual estimation of the relative quantities of fine and small piece debris in a given sample is inherently inaccurate and subjective, and would be expected to vary significantly from sample to sample and (2) the high concentration of debris in the prepared debris slurries resulted in significant debris agglomeration, which likely prevented the fines from transporting prototypically in the test flume in any case. As a result, the NRC staff questions whether the licensee's head loss testing resulted in debris settling under debris preparation conditions that are not prototypical of the limiting plant condition. Please provide any information in addition to the information already discussed with the staff that could demonstrate the adequacy of the transport behavior of the fine debris added to the head loss test.

29. Please discuss any sources of drainage that enter the containment pool near the containment sump strainers (i.e., within the range of distances modeled in the head loss test flume). Please identify whether the drainage would occur in a dispersed form (e.g., droplets) or a concentrated form (e.g., streams of water running off of surfaces). Please discuss how these sources of drainage are modeled in the test flume. Please provide contour plots of the calculated turbulence (which include a numerical scale with units) for the CFD calculation for the test flume with that for the full-containment plant CFD calculation. Please address whether the test flume turbulence values are prototypical of the plant condition.

30. The supplemental response indicates that a correlation for determining the tumbling velocity for paint chips was developed based on NUREG/CR-6916, "Hydraulic Transport of Coating Debris," dated October 2006, data. Please describe the correlation and its application to the WCGS strainer analysis. Please further identify whether paint chips were included in the head loss tests conducted for WCGS. If paint chips were included, then please describe the size distribution of the chips used for head loss testing.

31. Please provide a description of the debris transport barriers installed in the secondary shield wall exits for Compartments A and D, including the following information:

    a. the total surface area of these barriers

    b. their height compared to the maximum containment pool water level

    c. their design differential pressure

d. their perforation size (on page 36 of the December 22, 2008, supplemental response, the perforated openings are stated to be 1/8 inch; however, page 72 appears to imply they are 0.045 inch)

32. Please provide the basis for considering the single-train test for Loop D to be bounding. The amount of debris settling in the head loss flume is an unknown variable. Depending on the extent of debris settling in the test flume, a more limiting condition could potentially have resulted from doubling the velocity in the test flume and dividing the debris between two strainers.

E. <u>Head Loss and Vortexing</u>

33. The thin bed test described in the supplemental response dated December 22, 2008, was actually a fiber-only test. This test was used to observe the transport of fibrous debris without particulate debris clouding the water. The supplemental response stated that the fibrous debris did not clump and moved gently downstream from the introduction point where most of it settled on the flume floor. The licensee concluded that the observations verified that fibrous fines contained as part of the smalls were free to transport and were not captured by the small fibrous pieces. The observations appear to have been qualitative. If the fines added with the smalls are to be credited as fines, the please provide quantitative evidence that fine fibers credited as fines were not entangled in the larger debris pieces. Please state and justify how much of the small debris transported separately and actually behaved as fines. This issue is important in the determination of the amount of fine fibrous debris added to the head loss test. The addition of less transportable debris prior to or at the same time as more easily transportable debris is not consistent with the understanding that the staff reached with PCI/AREVA NP (NRC February 20, 2008, memorandum, "Summary of Phone Calls with Performance Contracting, Inc. (PCI)/AREVA/Alden to Discuss Head Loss Test Protocol," ADAMS Accession No. ML080310263) on head loss testing procedures.

34. Please provide the amount of fine fibrous debris predicted to be generated and transported to the strainer, including erosion and considering the reduced ZOI credited for debris generation. Please also provide information that verifies that the properly scaled amount of fine fibers was added to the test in a manner that did not inhibit their transport.

35. Please provide information that justifies that the agglomeration of the fine fibrous debris, observed during head loss testing, did not adversely affect the transport of the debris to the strainer.

36. Please provide information that justifies that the addition of debris to the test flume without the recirculation pump running is realistic or conservative or prototypical with respect to the plant condition.

37. Please provide information that justifies that the debris addition sequence was conservative or prototypical and that it resulted in a valid thin bed test being conducted. A review of the debris addition sequence described in the supplemental response dated December 22, 2008, indicates that some less transportable debris may have been

added prior to more transportable debris. Also, the design basis test appears to use a stratified addition sequence (page 60). First, part of the latent fiber is added (with the pump stopped), then some of the coating particulate, then fines (from erosion and latent fines), then coating chips, then latent particulate and Thermolag, then coating chips, and then small Nukon fibers (including 30 percent fines), followed by miscellaneous debris and other fibers. This is contrary to the guidance in "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), that states that all particulate should be added prior to the addition of fibrous debris for thin bed testing.

38. Please provide the clean strainer head loss (CSHL), including a breakdown of the portion attributable to the correlation (core tube) and the portion attributable to the standard calculation (plenum). The CSHL should be provided for the lowest temperature case for conservatism.

39. Please provide information that justifies that the extrapolation of head loss results provided a realistic or conservative head loss prediction for the end of the mission time. Alternately, re-perform the extrapolation in a conservative manner consistent with NRC staff guidance referenced in RAI# 27 and provide an explanation that is consistent with the methodology. Please provide adequate data to demonstrate that a suitable time frame was considered during the extrapolation. Please address the following points in your response:

    a. The supplemental response describes an exponential function for extrapolation of the final test head loss value to the strainer mission time. The submittal states that the debris head loss is proportional to the average debris bed thickness at a given moment in time. Apparently this assumption is part of the basis for the extrapolation of the test data. Please justify this assumption, which the staff does not believe to be correct. The head loss may have a relationship to debris bed thickness, but there are other variables that may have a larger affect on head loss; for example, debris bed morphology and compaction.

    b. The supplemental response provides a relationship for extrapolation of the head loss to the mission time. The constant C1 is stated to be the clean strainer head loss. However, in the examples provided, the constant C1 represents the maximum head loss attained during the test.

    c. The examples and extrapolation curves provided do not appear to correspond to the description of the relationship. The curve fit drawn on the data plot does not appear to actually fit the data or to be conservative. It appears that an exponential function was assumed and made to fit the data as well as possible. However, multiple data points taken during the first day of the test exceed the final, 30-day extrapolated head loss. This is clearly non-conservative.

40. Please provide a plot of the head loss test data from the initiation of the test to the end of the test with significant test evolutions annotated on the plot.

41. Please verify that the core tube is fully flooded under all conditions for which recirculation is required, or re-evaluate the potential for vortex formation. If testing is credited, details of the test conditions should be provided. It should be noted that, if the core tube has air in it, a vortex may not be observed on the surface of the test tank and that some other measurement of air entrainment would have to be employed. On page 48, of the supplemental response dated December 22, 2008, stated that the SBLOCA case will result in 2.5 inches of the strainer stack top module being exposed. On page 47, the licensee stated that the SBLOCA may result in a water level less than approximately 6 inches below the top of the strainer at switchover. Please verify which statement is accurate. In addition, please verify that the accumulators will discharge to add to the sump liquid inventory under all LOCA conditions. If the accumulators do not discharge for all LOCAs, please evaluate strainer submergence, and potential for vortex formation and air entrainment, at alternate sump level conditions that do not assume accumulator discharge.

42. Because no containment accident pressure was applied during the evaluation and the sump temperature can reach 212 °F, the supplemental response dated December 22, 2008, stated that boiling and flashing could occur across the strainer debris bed. The supplemental response concluded that any voids would re-condense in the interior of the strainer modules before leaving the strainer assembly and entering the suction piping of the containment spray/emergency core cooling system pumps. Because the strainers are relatively tall vertical stacks in a sump pit this is likely true. However, the supplemental response did not discuss the potential affect of voiding on the head loss across the debris bed and how changing the head loss could lead to additional voiding. Please provide information regarding the amount of accident pressure required to prevent voiding within the debris bed and strainer and verify that the required containment pressure is available at the required times during the postulated event to prevent flashing. Please provide the minimum margin to flashing. In addition, please provide an evaluation of gas evolution downstream of the strainer that could reach the pump suction. Please provide the percentage of evolved gas estimated at the pump inlet.

43. Please provide the head loss value that was used as the basis for the value extrapolated to alternate fluid temperatures including any extrapolation to the mission time and the temperature at which the head loss was measured. Please provide the temperature corrected head loss including the conditions to which it is corrected. Please provide the methodology for extrapolation and temperature scaling of the head loss. For example, please state whether the test clean strainer head loss was subtracted from the measured value prior to extrapolation and/or temperature correction. Please explain how the calculated clean strainer head loss was combined with the final debris head loss to determine the final overall head loss. If the net positive suction head (NPSH) analysis is time- or temperature-dependent, please provide details as to how the debris and strainer head loss was calculated for the evaluated conditions.

F. Net Positive Suction Head

44. Page 81 of the December 22, 2008, supplemental response indicates that a water volume required to fill the RCS steam space is accounted for as a hold-up volume not

contributing to the containment building water level. However, page 83 of the same document indicates that an approximate volume of 8900 cubic feet (ft^3) from the 12,135 ft^3 inventory of the RCS is credited in the containment water level calculation at switchover. Please clarify this apparent discrepancy, as it pertains to both the calculated large-break and small-break post-LOCA containment water levels.

G. Coatings Evaluation

45. For degraded qualified coatings, the Keeler and Long report, "Design Basis Accident Testing of Coating Samples from Unit 1 Containment, TXU Comanche Peak SES," dated April 13, 2006 (ADAMS Accession No. ML070230390), and industry testing are cited by the licensee as justification of epoxy chip sizes. While the NRC review guidance has accepted use of the Keeler and Long report as justification for degraded qualified epoxy coatings failing as chips, the resulting chip sizes from the Keeler and Long report are smaller than those described in table 3h-2 of the submittal dated December 22, 2008. Please provide justification for using chips larger than those determined in the Keeler and Long report. In addition, please supply the industry testing reference used on page 87 of 128 of the December 22, 2008, supplemental letter, to determine the size distribution of degraded qualified coatings.

46. Please describe how the quantity of curled chips was determined. In addition, please justify the simplification of the size distribution of the curled chips to a 1.5-inch chip size.

H. Downstream Effects/In-vessel

47. The NRC staff does not consider in-vessel downstream effects to be fully addressed at WCGS, as well as at other pressurized-water reactors (PWRs). WCGS's submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for WCGS by showing that the licensee's plant conditions are bounded by the final WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating without reference to WCAP-16793 or the NRC staff SE that in-vessel downstream effects have been addressed at WCGS. Please report how the in-vessel downstream effects issue has been addressed for WCGS within 90 days of issuance of the final NRC staff SE on WCAP-16793.

I. Chemical Effects

48. The caption for Figure 3o-1 on page 120 in the December 22, 2008, supplemental response appears to imply that this figure provides the results of settling tests for the aluminum oxyhydroxide (AlOOH) used in head loss testing for WCGS. This figure is identical to Figure 7.6-1 of WCAP-16530-NP-A, which is not plant-specific. Please provide the 1-hour settlement values for all batches of AlOOH used in head loss testing for WCGS.

49. The licensee did not consider Min-K and Darmat KM1 as part of the debris generated based on where they are located in the containment and that they are outside the ZOI for destruction. Please state and justify whether either of these materials is subject to wetting by containment spray. If so, please state and justify whether the leached ionic material from these insulations been included in the inventory of chemicals found in the containment sump liquid following the spray phase of the LOCA for input to head loss testing.

50. Table 3o-1 on page 120 in the December 22, 2008, supplemental response, identifies the amounts of precipitate formed from various components in containment. Although the NUKON fabric coating prevented loss of the insulation fibers, please state and justify whether the material leached from the NUKON during the spray and recirculation phase was accounted for in the concentration of ionic materials in the containment sump. Please state whether the mass of aluminum in the sodium aluminum silicate calculated for the Reactor Cavity column includes dissolved aluminum from all the Cerablanket that would be wetted in containment. If not, please discuss why the aluminum in wetted Cerablanket outside the reactor cavity does not contribute to chemical effects.

single letter, with the exception of RAI No. 47, as discussed below. If the licensee concludes that more than 90 days is needed to respond to the RAIs, the licensee should request additional time, including a basis for why such time is needed.

As part of the written response to the additional RAIs, we request that you include a safety case. This safety case should describe, in an overall or holistic manner, how the measures credited in the WCGS licensing basis demonstrate compliance with the applicable NRC regulations as discussed in GL 2004-02 and should describe your approach to responding to the RAIs. As appropriate, the safety case may describe how the licensee reached compliance even in the presence of remaining uncertainties. The NRC staff views the safety case as informing, not replacing, responses to the RAIs.

Regarding RAI No. 47, the NRC staff considers in-vessel downstream effects not to be fully addressed for WCGS, as well as at other pressurized-water reactors. The licensee's submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in the Recirculating Fluid." The NRC staff has not issued a final SE for WCAP-16793. The licensee may demonstrate that in-vessel downstream effects issues are resolved for WCGS by showing that the licensee's plant conditions are bounded by the final WCAP-16793 and the corresponding final NRC staff SE, and by addressing the conditions and limitations stated in the final SE. The licensee may also resolve this item by demonstrating that in-vessel downstream effects have been addressed for WCGS without reference to WCAP-16793 or the staff SE. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on WCAP-16793.

If you have any questions, please contact me at 301-415-3016 or via e-mail at balwant.singal@nrc.gov.

Sincerely,
/RA/

Balwant K. Singal, Senior Project Manager
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-482

Enclosure
As stated

cc w/encl: Distribution via Listserv

DISTRIBUTION:
PUBLIC
LPLIV r/f
RidsAcrsAcnw_MailCTR Resource
RidsNrrDorlLpl4 Resource
RidsNrrDssSsib Resource
RidsNrrPMWolfCreek Resource
RidsNrrLAJBurkhardt Resource
RidsOgcRp Resource
RidsRgn4MailCenter Resource
SSmith, NRR/DSS/SSIB
JLehning, NRR/DSS/SSIB

ADAMS Accession No.: ML092030628

OFFICE	NRR/LPL4/PM	NRR/LPL4/LA	NRR/SSIB/BC	OGC	NRR/LPL4/BC	NRR/LPL4/PM
NAME	BSingal	JBurkhardt	MScott	Not Required	MMarkley	BSingal
DATE	7/29/09	7/28/09	7/30/09	--	7/31/09	7/31/09

OFFICIAL RECORD COPY