September 29, 2009

Mr. Preston D. Swafford
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: WATTS BAR NUCLEAR PLANT, UNIT 1 — REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 2004-02, "POTENTIAL IMPACT OF DEBRIS BLOCKAGE DURING DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS" (TAC NO. MC4730)

Dear Mr. Swafford:

By letter dated March 31, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML081090500), Tennessee Valley Authority (TVA or the licensee) submitted a supplemental response to Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors," for the Watts Bar Nuclear Plant (WBN), Unit 1.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's submittals. The process involved detailed review by a team of approximately 10 subject-matter experts, with a focus on the review areas described in the NRC's "Content Guide for Generic Letter 2004-02 Supplemental Responses" (ADAMS Accession No. ML073110389). Based on these reviews, the NRC staff has determined that additional information is needed in order to conclude there is reasonable assurance that GL 2004-02 has been satisfactorily addressed for WBN, Unit 1. The enclosed document describes these requests for additional information (RAIs).

The NRC staff requests that TVA respond to these RAIs within 100 days of the date of this letter. However, the NRC staff would like to receive only one response letter for all RAIs with exceptions stated below. If TVA concludes that more than 100 days are required to respond to the RAIs, the licensee should request additional time, including a basis for why the extension is needed.

If TVA concludes, based on its review of the RAIs, that additional corrective actions are needed for GL 2004-02, the licensee should request additional time to complete such corrective actions as needed. Criteria for such extension requests are contained in SECY-06-0078 (ADAMS Accession No. ML053620174), and examples of previous requests and approvals can be found on the NRC's sump performance website, located at: http://www.nrc.gov/reactors/operating/ops-experience/pwr-sump-performance.html.

Any extension request should also include results of contingency planning that will result in near term identification and implementation of any and all modifications needed to fully address GL 2004-02. The NRC staff strongly suggests that the licensee discuss such plans with the staff before formally transmitting an extension request.

The exception to the above response timeline is RAI 9 in the enclosure. The NRC staff considers in-vessel downstream effects to not be fully addressed at WBN, Unit 1, as well as at other pressurized water reactors. TVA's submittal refers to draft WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous, and Chemical Debris in Recirculating Fluid." At this time, the NRC staff has not issued a final safety evaluation (SE) for WCAP-16793.

TVA may demonstrate that in-vessel downstream effects issues are resolved for WBN Unit 1, 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 in the final SE. TVA may also resolve RAI 9 by demonstrating, without reference to WCAP-16793 or the NRC staff SE, that in-vessel downstream effects have been addressed at WBN, Unit 1. The specific issues raised in RAI 9 should be addressed regardless of the approach the licensee chooses to take.

TVA should report how it has addressed the in-vessel downstream effects issue and the associated RAI referenced above within 100 days of issuance of the final NRC staff SE on WCAP-16793. The NRC staff is currently developing a Regulatory Issue Summary to inform licensees of the staff's expectations and plans regarding resolution of this remaining aspect of Generic Safety Issue 191, "Assessment of Debris Accumulation on PWR [Pressurized-Water Reactor] Sump Performance."

If you have any questions, please contact me at 301-415-3100.

Sincerely,

/RA/

John G. Lamb, Senior Project Manager
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-390

Enclosure: Request for Additional Information

cc w/encl: Distribution via Listserv

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PUBLIC
LPWB
RidsNrrDorlLpwb
RidsNrrLABClayton
RidsNrrPMWattsBar1
RidsOgcRp
RidsAcrsAcnw_MailCTR
RidsRgn2MailCenter
RidsNrrDssSsib

ADAMS Accession No.: ML092650260

OFFICE	LPWB/PM	LPWB/LA	DSS/SSIB/BC (A)	LPWB/BC
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DATE	09/ 29 /09	09/ 29 /09	09/29/09	09 / 29 /09

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REQUEST FOR ADDITIONAL INFORMATION (RAI)

SUPPLEMENTAL RESPONSE TO GENERIC LETTER 2004-02,

DATED MARCH 31, 2008

WATTS BAR NUCLEAR PLANT, UNIT 1

DOCKET NO. 50-390

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Debris generation/Zone of Influence (ZOI)

RAI 1 The NRC staff requested additional information on the ZOI testing that was conducted to determine plant-specific ZOIs for some materials installed at WBN Unit 1. The licensee provided some additional information on the testing, but the information did not appear to justify the ZOIs assigned for the tested materials. The licensee stated that two "Min-K" tests were performed, one with Min-K and one with a surrogate for Min-K (fiberglass with a scrim) that "is considered conservative with respect to Min-K since it was damaged more easily." The results of the Min-K and surrogate Min-K tests seem to demonstrate conclusively the opposite is true, since, at a distance of 10 diameters (10D), the Min-K was completely blown off the target, and the surrogate was undamaged beyond the jacketing. If the behavior is not random or spurious (and if it is random or spurious, then a sufficient number of tests was evidently not performed to obtain useful results), then the licensee's discussion and application of the test results should be revised to conform to the experimental results. The staff's review of the test results indicates that use of a 10D ZOI for Min-K appears to be nonconservative, since a test at this radius demonstrated complete removal of the insulation from the target. The licensee should provide additional information regarding the Min-K testing that justifies that the ZOI selected for Min-K is prototypical or conservative, or should revise the ZOI to a size that is justified.

Enclosure

In addition to the specific issue regarding the Min-K testing that is discussed above, the staff noted that the licensee provided information regarding the ZOI testing for Min-K and 3M-M20C fire barrier material, which is similar to the information that the staff has reviewed as part of a generic review of ZOI testing conducted by Westinghouse. The NRC staff considered that the information contained some of the information requested by the RAI, but did not supply adequate information so that the staff could determine whether the testing was conservative with respect to the plant condition. Although the ZOI testing questions reference the WCAP-16710 report, the NRC staff believes that most or all of the testing performed at Wyle Labs was conducted under similar conditions, and therefore, similar issues need to be considered for the testing. If one or more of the generic questions regarding the ZOI testing below does not apply to WBN Unit 1, please provide a justification for the reason that the question does not apply.

1. 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. 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. Were any tests conducted at alternate temperatures and pressures to assess the variance in the destructiveness of the test jet to the initial test condition specifications? If so, provide that assessment.

2. 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. Demonstrate that the tested jacketing/insulation system adequately represented the plant jacketing/insulation system. The description should include differences in the jacketing and banding systems used for piping and other components for which the test results are applied, potentially including steam generators, pressurizers, reactor coolant pumps, etc. At a minimum, the following areas should be addressed:

    a. How did the characteristic failure dimensions of the tested jacketing/insulation compare with the effective diameter of the jet at the axial placement of the target? The characteristic failure dimensions are based on the primary failure mechanisms of the jacketing system, for example, 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 length/diameter (L/D) nozzle to target spacing would be nonconservative with respect to impacting the entire target with the calculated pressure.

    b. Was the insulation and jacketing system used in the testing of the same general manufacture and manufacturing process as the insulation used in the plant? If not, 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. The information provided should also include an evaluation of scaling the strength of the jacketing or encapsulation systems to the tests. For example, a latching system on a 30-inch pipe within a ZOI could be stressed much more than a latching system on a 10 inch pipe in a scaled ZOI test. If the latches used in the testing and the plants are the same, the latches 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.

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

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

   a. In the WCAP report, was the analysis based on an initial temperature condition that matched the initial test temperature? If not, please provide a justification.

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

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

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

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

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

   a. What were the assumed plant-specific RCS temperatures 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 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, what steps were taken to ensure that the isobar volumes conservatively match the plant-specific postulated LOCA degree of subcooling for the plant debris generation break selections? Were multiple break conditions calculated to ensure a conservative specification of the ZOI radii?

6. 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 that affected the test flow characteristics evaluated with respect to a postulated plant-specific LOCA break flow where such piping flow resistance would not be present?

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

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

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

8. Please provide the basis for concluding that a jet impact on the components as tested is a limiting condition for the destruction of insulation installed on alternate components that were not tested. 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 alternate components provide the same measure of protection against a LOCA jet as those of the piping insulation that was tested.

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

10. WCAP-16710-P noted damage to the cloth blankets that cover the fiberglass insulation in some cases resulting in the release of fiberglass. The tears in the cloth covering were attributed to the steel jacket or the test fixture and not the steam jet. It seems that any damage that occurs to the target during the test would be likely to occur in the plant. Was the potential for damage to plant insulation from similar conditions considered? For example, the test fixture could represent a piping component or support, or other nearby structural member. The insulation jacketing is obviously representative of itself. What is the basis for the statement in the WCAP report 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.

11. Did the end caps that were attached to the insulation targets affect the structural strength of the test specimens?

12. For the Min-K testing, some of the material was ejected from the test fixture and landed up to 150 ft away. Was the potential for a similar occurrence in the plant evaluated? What would be the result if the insulation impacted an object much closer than 150 ft? Would this impact be more severe? What would be the result if the panel lodged within the jet ZOI? Could the encapsulating material fatigue, fail, and allow the insulating material to be released?

Head Loss and Vortexing

RAI 3 The response to RAI 3 provided additional information regarding the strainer testing and comparisons between the test and plant conditions. The licensee addressed the following areas:

Fibrous Debris Preparation and Introduction with Respect to Prototypical Sizing

The response stated that the fibrous debris was shredded using a wood chipper and smaller clumps of Nukon were separated by hand. The debris was then mixed with water and stirred. The response also stated that following test 2 that additional fiber, that had been separated into single fibers by hand, was added to the flume within one foot of the strainer. This fiber was stated to deposit mostly on top of the strainer. The NRC staff audit report of WBN Unit 1 (ML062120469) states that the staff found that surrogate for latent fiber to be prepared inadequately. Based on the direct observation of the testing by the staff, the fibrous debris preparation was not realistic for latent fibrous debris. In addition, the licensee statement that the fibrous debris added following test 2 accumulated on the top of the strainer indicates that the introduction of debris was not representative of the plant. It is more likely that the debris would approach the strainer from the side and top, not primarily the top.

Flume Velocity and Turbulence

The request for additional information (RAI) response stated that the strainer design employs a core tube that results in a constant approach velocity to the strainer under all conditions. The response stated that the flume flow velocity was 0.036 feet per second (ft/sec). This value was corroborated by the NRC staff trip report (Appendix II to the WBN Unit 1 Audit Report, ML062120469) that witnessed the WBN Unit 1 strainer test. The response also noted that the flow in the test flume was representative of transitional flow so that some turbulence should be available to help maintain debris in suspension. The response did not provide the plant flow or turbulence conditions for comparison. However, the flume flow velocity of 0.036 ft/sec is much lower than flow rates for other plants. The low flow rate was likely due to the relatively small height of the strainer resulting in a much larger ratio of circumscribed area to strainer area. The use of a taller strainer module (larger strainer area) in the test may have helped to create a more realistic flow rate in the flume. In the trip report from the WBN Unit 1 testing, the NRC staff noted that the computation fluid dynamics evaluation conducted for WBN Unit 1 shows that the majority of the flow velocity approaching the strainer exceeded 0.28 ft/sec and that some areas exceeded 0.5 ft/sec. The trip report also noted that the circumscribed velocity for the test strainer was about 6.4 times lower than that of the replacement strainer. Considering that significant settling of debris occurred in the test (see near-field settling below), these significant differences between the test and plant configurations cannot be ignored.

Near-Field Settling

The RAI response stated that the debris was introduced 3 -15 feet upstream of the strainer. In addition, following one test the debris was pushed on top of the strainer and the flow was doubled. The response also stated that the head loss was very low even with the debris directly on top of the strainer. The description provided does not address the issue. Based on the staff trip report, significant near-field settling occurred during the test. It is not expected that manually placing debris onto a strainer will result in realistic head losses because this methodology would not allow a debris bed to form similarly to how a debris bed would form in the plant (the debris bed in the plant would be expected to form more uniformly). The excessive near-field settling that occurred during the testing is considered to be nonconservative. Reference the discussion above regarding flume velocity and turbulence which shows that the test configuration was significantly non-conservative with respect to debris transport.

Debris Addition to the Test Flume

The RAI response described the method of addition of debris to the flume. The debris was added with 6 inches of water in the flume. The debris was added 3-15 feet from the strainer with reflective metallic insulation (RMI) debris being added first. The response states that adding the RMI first prevented it from covering the other debris and preventing transport. However, the staff has determined that adding less transportable debris first may inhibit the transport of debris that is added later. Once the debris was added, the flume was filled using overhead spray nozzles. The spray nozzles were then secured, manual debris mixing was performed (which may have trapped some more transportable debris under less transportable debris), and then the recirculation pump was started. This type of debris addition has not been accepted as conservative by the staff because it is likely to result in nonprototypical debris transport to the test module and the formation of a nonprototypical debris bed. In addition, during the trip to witness testing, the staff noted that the debris had likely agglomerated in the buckets prior to addition to the flume. The licensee has not justified that the manual stirring was effective in breaking up the agglomerated debris.

Head Loss Termination Criteria

The RAI response stated that since all debris is considered to be fine, erosion of fibrous debris would not occur so that head loss should not increase. The response also stated that a large increase in net positive suction head (NPSH) margin (6.5 ft) occurs above the baseline case because of increases in the pool level. The response did not consider other potential sources of head loss increase such as bed compression over time. In general, most licensees add all of the eroded fiber at the start of the test, but still extrapolate results as appropriate based on the behavior of the test. The NRC staff believes that an evaluation would probably show that the increase in NPSH margin would likely bound any increase in debris bed head loss over time, but this should be confirmed by performing an acceptable test and either extrapolating the data or verifying that the head loss is stable or decreasing at the conclusion of the test.

Based on the above considerations and the design basis inputs provided by the licensee, it is very likely that the test results used for the evaluation of the WBN Unit 1 strainer were nonconservative. The licensee should perform a test and head loss evaluation for the strainer using procedures that will result in prototypical or conservative results, or demonstrate that the strainer will have significant open strainer area such that a filtering bed will not occur.

RAI 4 The NRC staff requested that the licensee provide additional information regarding the potential for air ingestion due to vortex formation. For one small break loss-of-coolant accident (SBLOCA) case, the tall strainer modules are not expected to be fully submerged in the sump pool. The response to RAI 4 provided additional information regarding the potential for vortex formation. The staff believes that it is very unlikely for a vortex to form on a PCI strainer at typical flow rates if the strainer is fully submerged. However, the Watts Bar strainer may be slightly (3/4 inch) uncovered under some SBLOCA scenarios. The response provided information on the barriers to vortex formation. However, the response did not consider that if the strainer is uncovered, air may be present inside the core tube and a vortex may occur within this structure. Based on the height of the strainer that is partially uncovered and the lower flow rates associated with a SBLOCA, it is less likely that a vortex occur than would be the case for a shorter strainer with a higher flow rate. However, it should also be noted that if head loss across the strainer debris bed increases, the potential for a vortex in the uncovered portion of the strainer will increase as the water level inside the core tube will be reduced. The licensee should consider the possibility of a vortex occurring due to the presence of air inside the core tube and verify that it is not credible for air ingestion to occur from this source. If the debris head loss value is changed as a result of addressing the RAIs above, a re-evaluation of this area should also be performed.

NPSH

RAI 8 The NRC staff requested that the licensee provide a technical basis for considering a contribution of 42,810 gallons of leakage from the RCS in determining a conservative minimum water level for analyzing sump performance under SBLOCA conditions. In responding to this RAI, the licensee stated that consideration of scenarios with stuck open pressurizer valves was unnecessary because the plant would most likely be cooled down and depressurized prior to recirculation becoming necessary. The basis for this statement was not discussed in the response. In addition, it was not clear whether a similar conclusion would apply for other LOCAs that could occur at an elevation higher than that considered in the licensee's evaluation. The licensee's response also includes the statement that "The only volume that can get into the Reactor cavity for a SBLOCA is from the RCS leakage." This part of the response was not clear to the staff, since the RAI had been posed concerning holdup within the RCS, whereas inventory originating in both the refueling water storage tank and the RCS could (and based on the information provided in the tables accompanying the response, presumably does) be ejected from the pipe rupture in the RCS and contribute to the filling of the reactor cavity. Therefore, although the additional information provided by the licensee was helpful, it remains unclear to the staff what quantity of water is assumed to be held up inside the RCS for the analyzed SBLOCA minimum water level scenarios, and whether the assumed water holdup quantity is justified. Please state the mass of water assumed to be held up in the RCS for the analyzed SBLOCA minimum water level cases and provide justification for the assumed holdup value. Should the licensee desire to demonstrate that recirculation is not necessary for the set of break locations of concern to this question, further clarification should be provided regarding the break elevation for the analyzed SBLOCA cases and the basis for concluding that recirculation would not be necessary for other postulated break locations that could potentially result in additional holdup in the RCS (e.g., breaks at a higher elevation).