October 9, 2009

LICENSEE: Tennessee Valley Authority

FACILITIES: Watts Bar Nuclear Plant, Unit 1, and Sequoyah Nuclear Plant, Units 1 and 2

SUBJECT: SUMMARY OF SEPTEMBER 14, 2009, MEETING BETWEEN U.S. NUCLEAR REGULATORY COMMISSION STAFF AND TENNESSEE VALLEY AUTHORITY STAFF REGARDING DRAFT SECOND ROUND REQUESTS FOR ADDITIONAL INFORMATION FOR GENERIC LETTER 2004-02

By letters dated February 23, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML090540857), and March 31, 2008 (ADAMS Accession No. 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 Sequoyah Nuclear Plant (SQN), Units 1 and 2, and Watts Bar Nuclear Plant (WBN), Unit 1, respectively.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the licensee’s submittals addressing the staff’s first round requests for additional information (RAIs). 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 second round RAIs are needed in order to conclude there is reasonable assurance that GL 2004-02 has been satisfactorily addressed for SQN Units 1 and 2, and WBN Unit 1.

On September 14, 2009, NRC staff held a telephone discussion with TVA staff to discuss draft second round RAIs for GL 2004-02. The purpose of this telephone conference was to ensure that TVA understood the questions, as well as the regulatory basis, to ensure there was no proprietary information contained in the draft RAIs, and to determine if the information was previously docketed.

Enclosure 1 contains the list of attendees. Enclosure 2 contains the draft RAIs for SQN Units 1 and 2. Enclosure 3 contains the draft RAIs for WBN Unit 1.

The main topics discussed, related to the SQN Units 1 and 2, were the head loss testing for the emergency core cooling system (ECCS) suction strainers as well as the performance of the strainers under partially submerged conditions. Similarly, debris generation analysis, head loss testing, and potential air ingestion of the ECCS suction strainers were discussed for Watts Bar Unit 1. The NRC staff clarified details presented in the draft RAIs to ensure TVA fully understood the NRC’s position.

The NRC staff will send the RAIs to SQN Units 1 and 2 and WBN Unit 1 within the next several weeks.

Sincerely,

**/RA/**

L. Raghavan, Chief
Watts Bar Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos.: 50-327, 50-328, and 50-391

Enclosures:
1. List of Attendees
2. Sequoyah Remaining Issues Identified
3. Watts bar Unit 1 Remaining Issues Identified

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L. Raghavan, Chief
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ADAMS Accession No.: ML092650717 NRC-001

| OFFICE | WBSP/PM (A) | WBSP/LA | WBSP/PM | LPL2-2/PM | SSIB/BC (A) | WBSP/BC |
|---|---|---|---|---|---|---|
| NAME | JHeinly | BClayton | JLamb | SLingam | SBailey | LRaghavan |
| DATE | 10/ 1 /09 | 10 / 02 /09 | 10 / 1 /09 | 10/ 02 /09 | 10 / 06 /09 | 10/ 09 /09 |

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LIST OF ATTENDEES FOR
SEQUOYAH (SQN) AND WATTS BAR (WBN)
GENERIC LETTER 2004-02 MEETING
September 14, 2009

**Headquarters**

P. Milano, Senior Project Manager (PM), Watts Bar Special Projects (WBSP) Branch, Division of Operating Reactor Licensing (DORL), Office of Nuclear Reactor Regulations (NRR)
E. Brown, Senior PM, LP2-2, DORL, NRR
J. Heinly, Acting PM, WBSP Branch, DORL, NRR
M. Scott, Chief, Safety Issue Resolution Branch (SSIB), Division of Safety Systems (DSS), NRR
S. Bailey, Acting Chief, SSIB, DSS, NRR
J. Lehning, Engineer, SSIB, DSS, NRR
S. Smith, Engineer, SSIB, DSS, NRR

**Tennessee Valley Authority**

Corporate Staff
C. Carey, Corporate Engineering
K. Casey, Headquarters Licensing Manager, WBN Unit 1
F. Mashburn, Headquarters Licensing Manager, SQN Units 1 and 2

Sequoyah Staff
D. Lefever, Site Engineering
R. Proffitt, Site Licensing

Watts Bar Staff
D. Helms, Site Engineering
C. Maples-Abidi, Site Engineering
S. Robertson, Site Engineering
R. Stockton, Unit 2 Site Licensing

**AREVA**

F. Gartland
R. Phan
J. Shelton

**Remaining Issues Identified During Nuclear Regulatory Commission Staff Review of Sequoyah Generic Letter 2004-02 Supplemental Responses (sorted by previous Requests for Additional Information (RAIs))**

Head Loss and Vortexing

The staff believes that the responses to the following RAIs in the licensee's submittal dated February 23, 2009, did not demonstrate that a thin bed of debris is precluded for the design basis debris loading. The staff's underlying concern is that the nonprotypical testing may lead the licensee to the conclusion that Sequoyah has a margin to sump blockage that is significantly larger than actually exists.

RAI 1 The staff requested that the licensee provide the test protocol used for head loss testing and a justification that shows the aspects of the testing were conservative or prototypical. The licensee's response did not fully address the issues as discussed below.

RAI 1A The staff requested that the licensee provide information that justified that addition of debris to the test flume prior to the starting of the recirculation pump resulted in realistic or conservative test conditions. In response to this RAI, the licensee described the test methodology in greater detail than in the original supplemental response. The licensee stated that the debris (mixed with water) was added to the flume with the water level at about 6 inches. The debris was added 3 to 15 ft from the strainer, which was intended to minimize agglomeration and maximize transport. Reflective metallic insulation (RMI) was added first in an attempt to prevent it from impeding transport of other debris. The flume was then filled using overhead nozzles intended to keep the debris mixture in suspension. The debris was also manually stirred prior to starting the recirculation pump. The staff believes that these test methods resulted in nonconservative head loss for the same reasons documented in the Watts Bar Audit Report (ML062120469). The licensee should provide additional information that shows that the head loss determined by the testing was prototypical or realistic or the licensee should retest using prototypical or conservative procedures.

RAI 1B The staff requested that the licensee provide information that justified that the concentration of debris in the test flume did not result in excessive agglomeration and settling of debris during the head loss testing. The licensee stated that the heavier debris was added to the test flume prior to the lighter debris. This would result in less likelihood of the lighter debris being trapped by the heavier. In addition, the licensee conducted a test where all of the debris was added at or near the test strainer module. The staff considers these points are valid for the aspects stated except that stirring the debris could allow the larger debris to trap some of the smaller debris that was previously on top of it. Also, agglomeration of debris can occur with a single type of debris and may not depend on relative density.

For example, the staff has observed agglomeration of apparently fine fibrous debris into clumps that behave as single large pieces rather than individual fibers. In this example, dumping an agglomerated mass of fiber onto the screen would not be expected to have the same effect on head loss as allowing the individual fibers to transport and collect on the strainer, as would be more likely in the plant. The staff believes that the test methodology used resulted in a nonconservative head loss because the debris preparation and addition practices, higher than prototypical debris concentration, lower than prototypical flume flow rates, and addition of debris prior to starting the recirculation pump have been observed in testing for other plants to contribute to non-prototypical agglomeration and settling of debris. The licensee should provide additional information that shows that the head loss determined by the testing was prototypical or realistic, or the licensee should retest using prototypical or conservative procedures.

RAI 1C The staff requested information regarding the fibrous debris preparation and introduction with respect to prototypical sizing (transport and bed formation), including justification that the testing was performed prototypically or conservatively. The licensee, in the response to RAI 1.C, stated that finely shredded NUKON™ was used as a surrogate for latent fiber. However, the term finely shredded has little quantitative information associated with it. During staff observations of testing (prior to 2008) at Alden labs, it was noted that the fibrous debris used in the testing was larger than considered prototypical. (The licensee's testing was performed at Alden Labs prior to December 31, 2007.) The staff considers fibers in size classes 1-3 as defined in section 3 of NUREG/CR-6808 to be adequate as a surrogate for fine fiber. Use of larger debris sizes would result in nonconservative test results. The licensee also stated that the fibers were mixed with water prior to introduction to the flume. The response does not provide an adequate description of the concentration of fibrous debris in the test nor compare it with what would be expected in the plant. The staff could not determine that the concentration of debris added to the flume was justified. The licensee should show that the debris preparation and introduction methods resulted in a test head loss that was prototypical or conservative.

RAI 1D The staff requested information regarding the test flume velocity and turbulence. The licensee provided the calculated flume velocity and flume turbulence. However, these were not compared to the plant condition. It was noted that the flume velocity is much lower (by factors of about 2 to 10 times) than velocities used by other plants that attempt to model the flow in the near field of the strainer. In addition, the licensee confirmed that the Reynolds number (Re) for the flume was in the transitioning regime. Although it was not discussed in the response, the staff believes that the plant Re, due to significantly higher temperatures, larger hydraulic diameter, and higher flow velocities, is almost certainly in fully turbulent region, with an estimated Re likely more than one order of magnitude higher than the flume condition. Thus, even setting aside the concerns on debris preparation, sequencing, etc., from strictly a flow perspective, it is almost certain that the transport of fine debris in the test flume underrepresented the plant condition. Because adequate agitation to maintain debris suspended was not provided throughout the test and the flume velocity was likely nonconservative, it is probable that the head loss was affected nonconservatively. The licensee should provide additional information that justifies that the test was conducted using prototypical or conservative procedures or should perform additional testing using prototypical or conservative procedures.

RAI 1E The staff requested the licensee to quantify any near-field settling that occurred during the test. The licensee stated that test 6, which placed all debris on or in the immediate vicinity of the strainer, accounted for any near-field effects that could have altered the outcomes of the other tests. Because the head loss from test 6 was slightly higher than the other test head losses, it was selected as the limiting debris head loss. However, placing debris directly onto a strainer is not likely to result in a conservative or even realistic head loss. Based on staff observations of similar tests, tests 1-5 probably had considerable near-field settlement. The licensee should provide additional information that justifies that the test was conducted using prototypical or conservative procedures, or should perform additional testing using prototypical or conservative procedures.

RAI 1F The staff requested that the licensee provide additional information regarding test scaling, including debris amounts and strainer flow velocity. The licensee provided the scaling for flow and debris amounts. The scaling was based on the ratio of flow areas between the plant strainer and the test strainer. This scaling factor was applied to both the flow rate and the debris quantities. However, the scaling factor generally includes a term for the miscellaneous debris assumed in the design basis for the strainer. Had the miscellaneous debris term of 850 $ft^2$ (multiplied by the 0.75 factor) been included in the scaling, the flow rate and debris amounts would have been considerably higher. The licensee did adjust the scaling factor by subtracting about 70 $ft^2$ from the plant strainer area, but the adjustment should have been 637 $ft^2$ based on the licensee's calculated miscellaneous debris area. The licensee should justify the use of the lower area assigned to miscellaneous materials.

RAI 1G The staff requested additional information on how partial submergence of the strainer affects the scaling of flow and debris amounts. The licensee stated that the test program was based on a large break loss-of-coolant accident (LOCA) that would result in a fully submerged strainer, and that scaling for a partially submerged strainer was not considered. Because a small break LOCA would probably result in a lower debris load, this might be considered acceptable. However, the critical debris component for this strainer is the latent fiber, which could be present for both large and small break LOCAs in an equal amount. Based on the response to RAI 3 (minimum pool submergence = 9.06 ft), it appears that the design of the strainer did not account for the possibility of partial submergence. However, the licensee did recognize that partial submergence was possible for a small break LOCA in its supplemental response, section 3.f.2. The licensee should provide information that justifies that the strainer will perform adequately under partially submerged conditions considering the reduced strainer area available for debris deposition.

RAI 4: The staff requested that the licensee provide a basis for the statement that a thin bed cannot form on the strainer, considering the design basis debris loading and strainer size. The licensee responded that, although slightly more than 1/8 inch of fiber is available for thin bed formation, under expected plant conditions, non-uniform accumulation would occur, leading to large portions of clean area. The licensee stated that this effect was observed during strainer testing. The staff did not consider the licensee's strainer testing to have been performed in a prototypical manner and, despite the addition of extra fiber, does not have confidence that a thin bed would not form on the plant strainers. PCI strainers are designed to encourage uniform debris bed accumulation, and testing performed at Alden Research Laboratory for U.S. pressurized water reactors using the revised protocol has indicated that uniform beds can be formed with relatively small quantities of fiber (precise amounts are unquantifiable due to settling). Strainer testing for other plants has also shown that debris beds thinner than 1/8 inch can lead to significant head losses. This again leads the staff to conclude that the licensee has not demonstrated a thin bed of debris is precluded for the design basis debris loading. The licensee should provide additional information that justifies that the thin bed testing was conducted using prototypical or conservative procedures, or should perform additional testing using prototypical or conservative procedures.

RAI 5 The staff requested that the licensee provide an evaluation of the performance of the strainer under partially submerged conditions. The licensee stated that, for a fully submerged strainer, vortex formation would be precluded due to the size of the perforations (0.095 inches) on the surface of the strainer. The RAI response further stated that for a partially submerged strainer operating at a flow rate of 12,900 gallons per minute (gpm), a minimum sump level of 4.18 ft is required to prevent drawing the core tube level down to the level of the flow channel that connects the strainers to the emergency core cooling system suction. The minimum sump level was stated to be 5.04 ft. The response to the RAI did not state further assumptions or inputs for this calculation. It was not clear that the calculation considered whether a vortex could form within the core tube. The flow rate for the calculation was stated to be 12,900 gpm, but the design flow rate for the strainer is somewhat less than this so this input should be conservative. (Note that the response to RAI 6 states that the maximum flow rate is 18,750 gpm, but this appears to be an error. This should be verified to ensure that the evaluation was performed for limiting conditions. It also appears that small break LOCA flow rates would be significantly lower based on the initial supplemental response.) The RAI response also stated that numerous strainer qualification tests had been conducted for both fully and partially submerged strainers with acceptable results. However, these tests were not shown to be applicable or bounding for Sequoyah. The strainer for the Sequoyah test appeared to be very short (about three disks high), so it was not clear that a partially submerged test could have been conducted during the Sequoyah testing. Further details of the calculations and testing performed for the partially submerged condition are needed. The licensee should provide information that justifies that the strainer will perform adequately under partially submerged conditions considering the reduced area for debris deposition on the strainer surface and other considerations contained in Regulatory Guide 1.82, Rev. 3.

RAI 6 The staff requested that the licensee provide an evaluation that shows that flashing across or within the strainer will not occur. The response to this RAI addressed only the large break LOCA case where the minimum strainer submergence is 1.91 ft. A more limiting case could be the small break LOCA case with lower strainer submergence. Flashing across a partially submerged strainer may be prevented due to equalization of the pressure both inside and outside of the strainer and also internal to the core tube during partial submergence. However, once the strainer is fully submerged, head loss may result in flashing if the fluid is close to saturation. It was noted that the maximum design post-LOCA pool temperature is 190 °F. If atmospheric pressure is maintained within the containment, this may provide adequate subcooling such that flashing is prevented. More realistically, the licensee could determine conservative margins to flashing by crediting the minimum predicted containment pressure and maximum sump temperature at various times throughout the event. The licensee should provide information that justifies that flashing will not occur for all postulated LOCA scenarios.

C. Chemical Effects

(New)

RAI 9 The February 2009 Sequoyah supplemental response concludes that detailed chemical effects evaluations are not necessary due to the lack of a fiber bed on the strainer surface. The staff accepts that maintaining sufficient bare strainer area will mitigate potential chemical effects on the sump strainer. Staff guidance provided in a March 28, 2008, letter (ADAMS Accession No ML080380214) states, “Plants that plan to credit bare strainer area and perform a simplified chemical effect evaluation should demonstrate, for the maximum debris generation/transport break that the screen design allows for chemical precipitates to pass unimpeded due to the excess available bare strainer area. For the purpose of this simplified analysis, strainer area with a very thin layer of debris that covers the strainer flow area is considered to be different from bare strainer area.” However, the bare strainer argument is contingent on NRC staff agreeing that a filtering fiber bed will not form on the entire strainer surface and the staff has not agreed that a filtering bed will not form for Sequoyah. Therefore, unless the NRC staff is able to accept the maintenance of sufficient bare strainer area through the RAI resolution process, please address chemical effects on an alternate basis.

**Remaining Issues Identified During Nuclear Regulatory Commission Staff Review of Watts Bar Unit 1 Generic Letter 2004-02 Supplemental Responses (sorted by previous Requests for Additional Information (RAIs))**

**Debris generation/ZOI**

RAI 1 The staff requested additional information on the zone of influence (ZOI) testing that was conducted to determine plant-specific ZOIs for some materials installed at Watts Bar. 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 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.

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 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 WCAP-16710, the 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 Watts Bar, 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 cooling 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 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 Ontario Power Generation report on calcium silicate debris generation testing.

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

4. 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 was the analysis based on an initial temperature condition of 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 which affected the test flow characteristics evaluated with respect to a postulated plant specific LOCA break flow where such piping flow resistance would not be present?

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

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

   a. Was any analysis or parametric testing conducted to get an idea of the sensitivity of the potential to form a shock wave at different thermal-hydraulic conditions? Were temperatures and pressures prototypical of pressurized-water reactor (PWR) 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 1 ft of the strainer. This fiber was stated to deposit mostly on top of the strainer. The NRC staff audit report of Watts Bar (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 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 ft/sec. This value was corroborated by the NRC staff trip report (Appendix II to the Watts Bar Audit Report, ML062120469) that witnessed the Watts Bar 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 Watts Bar testing, the staff noted that the computation fluid dynamics evaluation conducted for Watts Bar 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 ft 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 ft 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 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 Watts Bar 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 staff requested that the licensee provide additional information regarding the potential for air ingestion due to vortex formation. For one small break LOCA 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 small break LOCA 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 LOCA, 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.

**Net Positive Suction Head (NPSH)**

RAI 8 The 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 small break LOCA 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 SB[small break]LOCA 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 small break LOCA 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 small break LOCA 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 small break LOCA 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).