Tennessee Valley Authority
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R. M. Krich
Vice President
Nuclear Licensing

June 3, 2010

10 CFR 50.4

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Sequoyah Nuclear Plant, Units 1 and 2
Facility Operating License Nos. DPR-77 and DPR-79
NRC Docket Nos. 50-327 and 50-328

Watts Bar Nuclear Plant, Unit 1
Facility Operating License No. NPF-90
NRC Docket No. 50-390

Subject: **Draft Responses to Requests for Additional Information Related to NRC Generic Letter 2004-02, "Potential Impact of Debris Blockage During Design Basis Accidents at Pressurized-Water Reactors"**

References:

1. NRC letter to TVA, "Sequoyah Nuclear Plant, Units 1 and 2 - Request for Additional Information Regarding Generic Letter 2004-02, 'Potential Impact of Debris Blockage During Design-Basis Accidents at Pressurized-Water Reactors' (TAC Nos. MC4717 and MC4718)," dated October 14, 2009

2. NRC letter to TVA, "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)," dated September 29, 2009

In References 1 and 2, the NRC requested additional information regarding the containment emergency sump strainer testing conducted in early 2006 for the Sequoyah Nuclear Plant (SQN), Units 1 and 2, and Watts Bar Nuclear Plant (WBN), Unit 1, respectively. Enclosures 1 and 2 provide the draft responses to the NRC's Requests for Additional Information (RAIs) for SQN, Units 1 and 2, and WBN, Unit 1, respectively. Enclosures 3, 4, 5, 6, and 7 provide supporting material referenced by or related to the draft RAI responses.

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The draft RAI responses and the draft Test Plans for SQN, Units 1 and 2, and WBN, Unit 1, provided in Enclosures 6 and 7 will be discussed during a public telephone conference call between the Tennessee Valley Authority and NRC presently scheduled for June 10, 2010. Please note that the draft Test Plans provided in Enclosures 6 and 7 are proprietary to AREVA NP Inc. (AREVA). The affidavit prepared by AREVA supporting the proprietary nature of these documents in accordance with 10 CFR 2.390 is provided in Enclosure 8.

If you have any questions, please contact Rod Cook at 423-751-2834 or Kevin Casey at 423-751-8523.

Respectfully,

D. E. Grissette for

R. M. Krich

Enclosures:

1. Draft Responses to Requests for Additional Information Related to Sequoyah Nuclear Plant, Units 1 and 2, Containment Emergency Sump Strainer Testing
2. Draft Responses to Requests for Additional Information Related to Watts Bar Nuclear Plant, Unit 1, Containment Emergency Sump Strainer Testing
3. Test Tank Protocol
4. General Debris Preparation Criteria
5. Additional Test Tanking Inputs
6. AREVA NP Inc. Test Procedure, Document No. 63-9138557-Dft, "Test Plan for Sequoyah Unit 1 and Unit 2 ECCS Strainer Performance Testing" (Draft) (Proprietary)
7. AREVA NP Inc. Test Procedure, Document No. 63-9138558-Dft, "Test Plan for Watts Bar Unit 1 ECCS Strainer Performance Testing" (Draft) (Proprietary)
8. AREVA NP Inc. Affidavit

cc (Enclosures):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Sequoyah Nuclear Plant
NRC Senior Resident Inspector - Watts Bar Nuclear Plant

ATTACHMENT 8

AREVA NP INC. AFFIDAVIT

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF LYNCHBURG)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the draft Test Procedures, Document No. 63-9138557-Dft, entitled, "Test Plan for Sequoyah Unit 1 and Unit 2 ECCS Strainer Performance Testing," and Document No. 63-9138558-Dft, entitled, "Test Plan for Watts Bar Unit 1 ECCS Strainer Performance Testing," and referred to herein as "Documents." Information contained in these Documents has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. These Documents contain information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in these Documents as proprietary and confidential.

5. These Documents have been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in these Documents be withheld from public disclosure. The request for withholding of proprietary information is

made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in these Documents is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in these Documents has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 2nd

day of June 2010.

Sherry L. McFaden
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 10/31/10
Reg. # 7079129

SHERRY L. MCFADEN
Notary Public
Commonwealth of Virginia
7079129
My Commission Expires Oct 31, 2010

ENCLOSURE 1

DRAFT RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION RELATED TO SEQUOYAH NUCLEAR PLANT, UNITS 1 AND 2, CONTAINMENT EMERGENCY SUMP STRAINER TESTING

Draft Responses to Requests for Additional Information related to

Sequoyah Nuclear Plant, Units 1 and 2, Containment Emergency Sump Strainer Testing

The following draft Request for Additional Information (RAI) responses address those RAIs as sent by the NRC to the Tennessee Valley Authority in "Sequoyah Nuclear Plant, Units 1 and 2 - Request for Additional Information Regarding Generic Letter 2004-02, 'Potential Impact of Debris Blockage During Design-Basis Accidents at Pressurized-Water Reactors' (TAC Nos. MC4717 and MC4718)," dated October 14, 2009.

Please note that the RAIs were primarily developed based on the Sequoyah Nuclear Plant (SQN) strainer performance head loss testing conducted in early 2006 and prior to the guidance provided in a letter from NRC to Nuclear Energy Institute, "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. Therefore, many of the NRC concerns associated with the small flume testing protocol will be addressed by the full scale retest of the strainer head loss. The retest is scheduled to be performed at Alden Research Laboratory (Alden) in the second half of 2010 using the test tank test facility.

Head Loss and Vortexing

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 feet (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 (ADAMS Accession No. 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.

Draft Response

RAI 1A states, "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." Thus, this RAI will be addressed by retesting in a test tank and implementing the test tank protocol shown in Enclosure 3.

Utilizing the test tank protocol, the following steps are expected to address RAI 1A:

- The test tank will be filled with water to the design-basis water level and maintained during the duration of the test. Debris will be added with the strainer operating at the design-basis flow rate.
- Turbulent energy and flow conditions within the tank will favor debris suspension during the test, rather than prototypical debris settling. This will be accomplished through hydraulic manipulation of tank flow patterns, introduction of mixing energy from turbulent water jets, and mechanical means. Two sections will exist in the tank: an upstream section with high agitation and high levels of energy and mixing, and a downstream section containing energy/turbulence adequate to diminish settling without disturbing the debris beds formed or forming.
- Inclusion of RMI in the test tank could result in nonconservative strainer head loss values due to debris entrapment by the RMI or creating open space on the strainer. Therefore, RMI will not be tested in the test tank apparatus.

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.

Draft Response

RAI 1B will be addressed by retesting in a test tank and implementing the test tank protocol similar to the protocol shown in Enclosure 3.

The concern presented in this RAI is regarding the debris sequencing, debris agglomeration, and debris addition prior to starting the recirculation pump. Utilizing the test tank protocol, the following steps will be implemented and are expected to address RAI 1B:

- The test tank will be filled with water to the design-basis water level and maintained during the duration of the test.
- Fine fiber will be shredded by a food processor, Munson shredder, or other type of device to achieve the same form of fines as discussed in NUREG/CR-6885, "Screen Penetration Test Report." The fine fibers will then be diluted with enough water such that no clumps will be visually observed.
- The debris will be introduced into the test tank only after the start of the recirculation pump and the designed flow rate has been established. Debris will be sequenced with the most transportable debris introduced first followed by the next most transportable, and so on, until all debris is sequenced into the test tank.
- Debris will be mixed with heated water with a ratio of 5 parts water to 1 part debris to ensure debris does not agglomerate. See Enclosures 4 and 5 for further discussion of debris preparation and debris dilution to minimize agglomeration.
- A trash pump will be utilized to inject the debris into the test tank below the water surface to ensure there is no air entrainment during debris introduction.

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.

Draft Response

RAI 1C will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3. Similar to RAI 1B, the concern presented in this RAI deals with debris preparation and introduction. See the draft response for RAI 1B.

All debris will be prepared in accordance with Performance Contracting, Inc. Technical Document Number SFSS-TD-2007-004, "Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates."

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.

Draft Response

RAI 1D will be addressed by retesting in a test tank and implementing the test tank protocol similar to the protocol shown in Enclosure 3. The test tank does not credit near field settling and utilizes a perforated floor and mechanical mixers to ensure debris remains suspended. This change in protocol eliminates the need to compare the test tank velocities to the plant containment velocities because debris is maintained in a suspended condition for transport.

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.

Draft Response

RAI 1E will be addressed by retesting and implementing the test tank protocol. In addressing the parameters mentioned in the RAI 1D draft response, the near-field settling is addressed since the test tank is designed to keep debris in suspension and available for transport.

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.

Draft Response

Scaling of the debris quantities and test flow rate(s) in the tank test will be performed based on the ratio of the surface area of the test strainer module to that of the plant strainer surface area. The scaled strainer surface area will not include sacrificial surface area due to miscellaneous debris (tags and labels). The results of previous testing establish that tag and label debris will not readily transport to the sump strainer assemblies.

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.

Draft Response

RAI 1G will be addressed by implementing the test tank protocol shown in Enclosure 3. This RAI addresses the NRC concerns regarding vortexing and flashing associated with strainer submergence during the small break LOCA (SBLOCA). Vortex formation and flashing will be addressed by implementing a SBLOCA specific test. The SBLOCA test will be conducted by adding the SBLOCA debris loads and completing the test with the strainer partially submerged (same submergence as actual plant condition). The SBLOCA test will monitor head loss and observe the strainer for vortex formation and flashing.

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. Strainers manufactured by Performance Contracting Incorporated 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.

Draft Response

RAI 4 will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3.

The concern of a thin bed of debris forming on the entire surface area of the strainer module is presented in RAI 4. The test tank protocol will address the formation of a thin bed on the strainer surface area. During the design-basis test, observations will be made to determine whether a thin bed of fiber and particulate has formed or whether open strainer surface area is visibly observed. See the draft response for RAI 1B.

A thin bed specific test will be performed as part of the test tank testing. Fibrous debris will be added in small batches with sufficient fiber to create a 1/16-inch fibrous thin bed for the first two fiber batch introductions, followed by 1/8-inch fiber batch introductions. A fixed time period between fiber batch introductions will be established to allow the head loss across the strainer to stabilize. If a significant change in head loss is observed after the addition of a particular fiber batch, then the remaining batches will not be added to the test tank and the test will continue with the protocol.

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 SQN. The strainer for the SQN 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 SQN 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.

Draft Response

RAI 5 will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3.

Similar to RAI 1G, the concern presented in this RAI deals with performance of the strainer in partial submergence conditions. See the draft response for RAI 1G.

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.

Draft Response

RAI 6 will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3.

Similar to RAI 1G, the concern presented in this RAI deals with performance of the strainer in partial submergence conditions. See the draft response for RAI 1G. Post test evaluation of results will determine if the potential for flashing exists due to a debris loaded strainer.

Chemical Effects

RAI 9

The February 2009 SQN 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 SQN. 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.

Draft Response

RAI 9 will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3. The test tank will be completed to confirm a thin bed does not form on the strainer surface. In the event the test tank demonstrates a thin bed forms on the strainer surface, the chemical effects will be addressed on an alternate basis.

ENCLOSURE 2

DRAFT RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION RELATED TO WATTS BAR NUCLEAR PLANT, UNIT 1, CONTAINMENT EMERGENCY SUMP STRAINER TESTING

Draft Responses to Requests for Additional Information Related to

Watts Bar Nuclear Plant, Unit 1,
Containment Emergency Sump Strainer Testing

The following draft Request for Additional Information (RAI) responses address those RAIs as sent by the NRC to the Tennessee Valley Authority (TVA) in "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)," dated September 29, 2009.

Please note that the RAIs were primarily developed based on the Watts Bar Nuclear Plant (WBN) strainer performance head loss testing conducted in 2005 and prior to the guidance provided in a letter from NRC to Nuclear Energy Institute, "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. Therefore, many of the NRC concerns associated with the small flume testing protocol will be addressed by the full scale retest of the strainer head loss. The retest is scheduled to be Alden Research Laboratory (Alden) in the second half of 2010 using the test tank facility.

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.

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 breakspecific 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 now 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?

Draft Response

Based on Watts Bar's decision to not credit WCAP-16783-P, RAI 1, Subparts 1 through 12, related to ZOI testing are no longer applicable.

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.

Draft Response

This section of RAI 3 will be addressed by retesting in a test tank and implementing the test tank protocol similar to the protocol shown in Enclosure 3.

The concern presented in this RAI is regarding the debris sequencing, debris agglomeration, and debris addition prior to starting the recirculation pump. Utilizing the test tank protocol, the following steps will be implemented and are expected to address this portion of RAI 3:

- The test tank will be filled with water to the design-basis water level and maintained during the duration of the test.
- Fine fiber will be shredded by a food processor, Munson shredder, or other type of device to achieve the same form of fines as discussed in NUREG/CR-6885, "Screen Penetration Test Report." The fine fibers will then be diluted with enough water such that no clumps will be visually observed.
- The debris will be introduced into the test tank only after the start of the recirculation pump and the designed flow rate has been established. Debris will be sequenced with the most transportable debris introduced first followed by the next most transportable, and so on, until all debris is sequenced into the test tank.
- Debris will be mixed with heated water with a ratio of 5 parts water to 1 part debris to ensure debris does not agglomerate. See Enclosures 4 and 5 for further discussion of debris preparation and debris dilution to minimize agglomeration.
- A trash pump will be utilized to inject the debris into the test tank below the water surface to ensure there is no air entrainment during debris introduction.

RAI 3 (continued)

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.

Draft Response

This RAI will be addressed by retesting in a test tank and implementing the test tank protocol similar to the protocol shown in Enclosure 3. The test tank does not credit near field settling and utilizes a perforated floor and mechanical mixers to ensure debris remains suspended. This change in protocol eliminates the need to compare the test tank velocities to the plant containment velocities because debris is maintained in a suspended condition for transport.

RAI 3 (continued)

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.

Draft Response

This RAI concerns with the settling of debris in the Watts Bar small flume testing. This RAI will be addressed by implementing the test tank protocol similar to that shown in Enclosure 3. In addressing the parameters mentioned in the portion of the RAI 3 response above regarding "Flume Velocity and Turbulence," the near-field settling is addressed since the test tank is designed to keep debris in suspension and available for transport.

RAI 3 (continued)

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.

Draft Response

This RAI expresses the Staff's concerns regarding debris preparation, introduction, and agglomeration. This RAI will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3.

Utilizing the test tank protocol, the following steps are expected to address this section:

- The test tank will be filled with water to the design-basis water level and maintained during the duration of the test.
- Fine fiber will be shredded by a food processor, Munson shredder, or other type of device to achieve the same form of fines as discussed in NUREG/CR-6885. The fine fibers will then be diluted with enough water such that no clumps will be visually observed.
- The debris will be introduced into the test tank only after the start of the recirculation pump and the designed flow rate has been established such that the conditions in the test tank simulate the conditions expected in containment post-LOCA. Debris will be sequenced with most transportable debris introduced first followed by least transportable.
- Debris will be mixed with heated water with a ratio of 5:1 to ensure debris does not agglomerate. See Enclosures 4 and 5 for further discussion of debris preparation and debris dilution to minimize agglomeration.
- A trash pump will be utilized to inject the debris into the test tank below the water surface to ensure there is no air entrainment during debris introduction.

RAI 3 (continued)

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.

Draft Response

This RAI will be addressed by implementing the test tank protocol similar to the protocol shown in Enclosure 3.

The termination criteria for testing are summarized below:

- Fifteen (15) test tank turnovers shall occur following the completion of the last batch of debris.
- Following the 15 turnovers, the test may be terminated only if the percent change in head loss over the last 30-minute average is less than 1%.
- The test may not be terminated if the head loss is displaying a high increase over time. The test may continue until the head loss levels off. Thirty-day head loss extrapolation may be incorporated to determine the maximum head loss.

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 maybe 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.

Draft Response

The maximum flow rate through the strainers due to a SBLOCA is 11,800 gpm. Since there are 23 strainer modules, the maximum flow through each core tube is 513 gpm. The total strainer height for the tall modules is 47.25 inches. The tall modules are separated by 25 sections with 4 core tube holes per section. The core tube holes vary in size, i.e., with larger holes at the top of the strainer module and smaller holes at the bottom of the module. The top 3/4-inch of the tall modules is slightly uncovered under a SBLOCA scenario of 11,800 gpm. A potential exists for air to be present inside the core tube and a potential vortex could form within the core tube. However, given that the design of the core tube consists of slots, the nonlinear path that the vortex would travel prior to arriving at the piping intake and the grating and mesh screen that exists in front of the piping intake, a qualitative assessment can be made that this is not a source of credible air ingestion.

RAI 4 will be addressed by implementing the test tank protocol shown in Enclosure 3. This RAI addresses the NRC concerns regarding vortexing and flashing associated with strainer submergence during the SBLOCA. Vortex formation and flashing will be addressed by implementing a SBLOCA specific test. The SBLOCA test will be conducted by adding the SBLOCA debris loads and completing the test with the strainer partially submerged (same submergence as actual plant condition). The SBLOCA test will monitor head loss and observe the strainer for vortex formation and flashing.

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).

Draft Response

- With regard to the portion of the RAI that states:

  "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."

  TVA offers the following:

  The SBLOCA scenario that includes stuck open pressurizer valves is not considered because operator actions are required to verify that all pressurizer power operated relief valves (PORVs) are closed. If the PORVs are not closed, operator actions are required to close the pressurizer PORV or associated block valve when RCS pressure is less than 2235 psig. If the valve is not able to be isolated, the event is no longer a RCS depressurization but a SBLOCA. The long-term plant response due to an unisolable valve opening is bounded by the limiting SBLOCA.

- With regard to the portion of the RAI that states:

  "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."

  TVA offers the following:

  This statement was specific to the scenario related to a stuck open pressurizer valve and is not applicable to other SBLOCAs at higher elevations.

- With regard to the portion of this RAI that states:

  "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."

TVA offers the following:

The following scenarios conservatively assume that the initial reactor coolant inventory remains constant and inside the RCS for all break locations. The reactor cavity is assumed to fill only for (a) a break in the hot or cold leg piping at the reactor vessel to nozzle transition, (b) the rupture of a CRDM housing, and (c) when the lower compartment water level reaches El. 715' - 8.5". The bottom of the hot leg penetrations is El. 715' - 8.5" and the entrance to the keyway is at El. 716' - 0". The reactor vessel nozzles and the control rod drive mechanism (CRDM) housings are attached to the reactor vessel and located within the reactor cavity area. All other postulated breaks in the Reactor Coolant Pressure Boundary are outside the reactor cavity enclosure.

- With regard to the portion of this RAI that states:

  "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."

  TVA offers the following:

  As stated above, the reactor coolant inventory is assumed to remain inside the RCS for all break locations and the cases below discuss the assumed holdup values.

  Case I. 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), Containment Spray (CS) operation on Refueling Water Storage Tank (RWST) level at Residual Heat Removal switchover.

  The Reactor Building response to a SBLOCA was determined using the MONSTER computer program. The volume of water in the reactor cavity is determined by calculating the time of emergency core cooling system (ECCS) switchover to the containment sump and picking the value of the reactor cavity water volume from the computer code output. This resulted in 2020 gallons in the reactor cavity or 1.67E+04 lbm. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

  Case II. 120 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups, CS operation on sump, passive failure outside the crane wall, long term level.

  The volume of water assumed to be held up in the reactor cavity is 128,000 gallons or 1.06E+06 lbm. The fluid head necessary to achieve equilibrium outflow through the penetrations in the reactor shield wall, if all RWST water injected after a LOCA was released within the reactor cavity, was determined. The cavity would fill to the level of the hot and cold leg penetrations, then start to flow out to the lower compartment. The water level in the reactor cavity would continue to rise until the head developed was high enough to achieve an equilibrium water level where the flow in would equal the flow out.

Case Ia. 2000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), CS operation on RWST, level at residual heat removal (RHR) switchover.

The volume of water assumed to be held up in the reactor cavity is determined by calculating the time of RHR switchover to the containment sump and multiplying the time by 2000 gpm (RCS leakage rate). Time to RHR switchover was determined to be the time it takes to expend the RWST inventory with two trains of containment spray in operation. This results in a value of 42,810 gallons or 3.50E+05 lbm. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

Case IIa. 2000 gpm SBLOCA inside the reactor cavity, no accumulators, limited ice melt, maximum holdups (except for reactor cavity), CS operation on sump, level at CS switchover.

The volume of water assumed to be held up in the reactor cavity is determined by calculating the time of CS switchover to the containment sump and multiplying the time by 2000 gpm (RCS leakage rate). Time to CS switchover was determined to be the time it takes to expend the RWST inventory with two trains of containment spray in operation. This results in a value of 60,573 gallons or 4.95E+05 lbm. Since the containment water level is lower than El. 715' - 8.5", no additional water is held up in the reactor cavity.

ENCLOSURE 3

TEST TANK PROTOCOL

TEST TANK PROTOCOL

The following steps provide a general approach used with Sequoyah Nuclear Plant, Unit 1 and Unit 2, and Watts Bar Nuclear Plant, Unit 1, test tank strainer testing.

1. **VERIFY** that the tank, strainer, piping, and test equipment have been set up in accordance with test set up procedure.

2. **PREPARE** the debris according to the following steps unless otherwise indicated by the Test Engineer.

   Note: The non-chemical debris has been prepared by Performance Consulting, Inc. (PCI) in accordance with PCI Technical Document No. SFSS-TD-2007-004; Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates and shipped to ALDEN. Changes to this document implemented in the test plan or test(s) shall be documented in the Test Plan with justification, as applicable.

3. **WEIGH** the non-chemical debris dry in accordance with the quantities specified in the debris allocation tables.

4. **ALLOCATE** debris into equal amounts into multiple 5-gallon buckets filling each bucket with no more than 1/6 full of debris. This procedure applies to all fiber and particulate debris.

5. **COMBINE** each batch of the non-chemical debris with water and store for introduction into the test tank in mixing containers. The debris may be "mixed" with hot water (~ 120°F) to help remove trapped air from fibrous debris. Use the following steps to mix the debris:

   a. **DILUTE** the debris with hot water (~ 120°F) to an approximate ratio of 5 parts water to 1 part debris (by volume).

   b. **MIX** the debris and heated city water in mixing containers.

   c. If needed, **FURTHER** dilute the debris to ensure there is no agglomeration.

6. **PREPARE** the chemical debris in accordance with chemical debris procedure.

7. **FILL** the test tank with city water and heat to ~ 120°F unless specified by the Test Engineer to the target water level (typically the minimum water level for Emergency Core Cooling System recirculation or equivalent).

8. **DOCUMENT** the recirculation water level in the test tank of all tests and manually verify sump strainer submergence depth (if applicable).

9. **BEGIN** performing downstream sampling.

   Document Sample Rate ________

10. **START** the test tank recirculation pump and maintain the minimum target flow rate.

11. **MEASURE** and **RECORD** the pH of test tank water.

12. **OBSERVE** the strainer area for vortexing.

13. **OBSERVE** tank mixing energy and confirm applicability to hinder near field settling.

14. **RECORD** the following data at approximately 2-minute intervals. NOTE that a computer data acquisition automatically records data at 10 second intervals:

    - Flow rate
    - Water temperature
    - Differential pressure across the strainer module
    - Observations of vortexing at the surface of water near strainer (as specified by the Test Engineer)
    - Observations of bore hole formation (as specified by the Test Engineer)
    - Additional appropriate information

15. **FILL** test tank injection hopper with bypass water from the test loop.

16. **START** debris addition trash pump at slow flow.

17. **INSERT** all of the particulate debris into the pumping receptacle in the order prescribed in the debris allocation table.

18. **RINSE** the bucket(s) with heated city water to ensure that all of the debris has been introduced into the test tank.

19. **INSERT** the fibrous debris into the pumping receptacle in the order prescribed in the debris allocation table.

20. **RINSE** the bucket(s) with heated city water to ensure that all of the debris has been introduced into the test tank.

21. **DISASSEMBLE** the trash pump to ensure all debris has been transferred to the test tank.

22. **INSERT** all debris trapped in the trash pump into the test tank.

23. **MAINTAIN** the recirculation flow rate and **MONITOR** the head loss across the test strainer for at least five (5) test tank turnovers after 100% of the non-chemical debris has been placed into the test tank.

24. **MEASURE** and **RECORD** the pH of test tank water.

25. **OBSERVE** the strainer area for vortexing and the formation of bore holes.

26. Carefully/slowly **INSERT** the base chemical concentration through a debris introduction downcomer into the test tank unless otherwise specified by the Test Engineer.

    Note 1: For tests which require more than one chemical surrogate (i.e., Calcium Phosphate and Aluminum Oxyhydroxide), a minimum of one (1) test tank turnover should be allowed between introduction of each chemical precipitate into the test tank.

    Note 2: Be sure the water level is managed by the overflow system.

    Note 3: **MEASURE** and **RECORD** the pH of the test tank water when approximately 25%, 50%, 75%, and 100% of the chemical debris has been added.

27. **MAINTAIN** the recirculation flow rate and **MONITOR** the head loss across the test strainer for at least two (2) test tank turnovers.

28. **REPEAT** chemical addition procedure for the remaining batches of chemical surrogate.

29. **RINSE** and **FLUSH** the chemical debris storage tanks and lines to ensure that 100% of the chemical debris has been introduced into the test tank.

30. **MAINTAIN** the recirculation flow rate and **MONITOR** the head loss across the test strainer for at least 15 test tank turnovers after rinsing and flushing the chemical debris storage tanks and lines.

31. **RUN** the test until the change in head loss is less than 1% in 30 minutes unless directed otherwise by the Test Engineer. The Test Engineer has the discretion to continue the test, if experimental observation necessitates.

32. After the termination criteria is met, **REDUCE** the flow to 50% of the design flow rate to observe if bore holes may have formed.

33. **MAINTAIN** the recirculation flow rate and **MONITOR** the head loss across the test strainer for at least one (1) test tank turnover.

34. **OBSERVE** the effects of the reduced flow rate on the measured head loss, **RECORD** head loss observations.

35. **MAINTAIN** the recirculation flow rate and **OBSERVE** the area above the strainer for vortexing.

36. **TERMINATE** the test once all observations of the head loss are deemed acceptable unless directed otherwise by the Test Engineer.

    Note: The head loss should decrease approximately four times since the head loss is proportional to the velocity squared. If the head loss fluctuates and does not stabilize, bore holes may have formed through the debris bed.

ENCLOSURE 4

GENERAL DEBRIS PREPARATION CRITERIA

GENERAL DEBRIS PREPARATION CRITERIA

The following steps present a general approach for preparing debris prior to introduction into the test tank. Common debris sizes include fines, smalls, and larges. As stated in the general test protocol, debris is introduced, starting with the most transportable (fines) to least transportable (larges). Debris types will be individual debris types and will not be mixed to for a homogeneous mixture (i.e., dirt and dust particulate will not be mixed with coating particulate).

The purpose of these steps is to prevent agglomeration of the non-chemical debris. It is ESSENTIAL that the debris is diluted such that agglomeration/clumping of the debris do not occur.

1. **PREPARE** the debris according to the following steps unless otherwise indicated by the Test Engineer.

   Note: The non-chemical debris has been prepared by Performance Consulting, Inc. (PCI) in accordance with PCI Technical Document No. SFSS-TD-2007-004; Sure-Flow® Suction Strainer – Testing Debris Preparation and Surrogates and shipped to Alden Research Laboratory. Changes to this document implemented in the test plan or test(s) shall be documented in the Test Plan with justification, as applicable.

2. **WEIGH** the non-chemical debris dry in accordance with the quantities specified in the debris allocation tables.

3. **ALLOCATE** debris into equal amounts into multiple 5-gallon buckets filling each bucket with no more than 1/6 full of debris. This procedure applies to all fiber and particulate debris.

4. **COMBINE** each batch of the non-chemical debris with water and store for introduction into the test tank in mixing containers. The debris may be "mixed" with hot water (~ 120°F) to help remove trapped air from fibrous debris. Use the following steps to mix the debris:

   a. **DILUTE** the debris with hot water (~ 120°F) to an approximate ratio of 5 parts water to 1 part debris (by volume).

   b. **MIX** the debris and heated city water in mixing containers.

   c. If needed, **FURTHER** dilute the debris to ensure there is no agglomeration.

ENCLOSURE 5

ADDITIONAL TEST TANKING INPUTS

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1. Approach Velocity

USNRC Position:

Justify that the weighted average approach velocity calculation is conservative.

Approach:

The test tank protocol does not rely on the weighted average approach velocity to simulate plant approach velocities. The test tank has been designed to keep debris suspended and does not credit near field debris settling.

2. Flume Turbulence

USNRC Position:

Justify the test flume turbulence levels are bounding of plant containment turbulence levels.

Approach:

The test tank protocol does not rely on the weighted average approach velocity to simulate plant approach velocities. The test tank turbulence is not intended to simulate the containment turbulence, and has been designed to ensure sufficient turbulence to keep debris in suspension in the test tank using a perforated floor and mechanical mixing.

3. Alternate Break Location to Bound Approach Velocity

USNRC Position:

Justify that the break associated with the maximum debris load is more conservative than an alternate break location in terms of debris transport characteristics and bounding flume velocities.

Approach:

Use of the test tank protocol does not require evaluation of the approach velocities for each break location. Therefore the maximum debris load will result in the largest debris load being used in the strainer testing.

4. Effects of Sources of Water Draining into Recirculation Pool From Above

USNRC Position:

Demonstrate that there are no sources of water falling from above that could introduce additional turbulence in the approach flow stream used to define the test flume configuration or show that they are conservatively represented in the test flume configuration/operation.

Approach:

The turbulence associated with falling water is irrelevant for test tank strainer testing. The test tank does not simulate the strainer approach velocities or turbulence, and is designed to keep the debris suspended for the duration of the test.

5. Fiber Erosion in Test Flume

USNRC Position:

Debris introduced as transportable in the test flume and found to settle would erode over the mission time of the post-Loss of Coolant Accident response. Therefore some accounting of the erosion of flume settled debris must be made.

Approach:

The test tank protocol will preclude debris settling within the test tank. Turbulence in the test tank will maintain debris suspension for transport to the strainer.

6. Debris Concentration on Introduction

USNRC Position:

The concentration of debris upon introduction is important to eliminate non-prototypical agglomeration in the introduction vessel.

Approach:

The debris will be mixed with water with a minimum dilution of 5 parts water to 1 part debris constituent. The debris will be introduced to the test tank via a trash pump and discharge pipe to ensure the debris is mixed as it enters the tank. The discharge pipe will be below the surface of the test tank water to ensure air is not entrained in the debris mixture as it enters the tank.

The debris dilution rates will follow March 2008 guidance conservatively. Debris introduction will be documented in the report along with photos and/or videos taken during the test to validate no significant agglomeration of debris occurred prior to introduction.

7. Description of ALDEN's use of Alion's Computational Fluid Dynamics (CFD) Results to Define Flume Walls

Approach:

CFD results are not used and are not applicable for the test tank protocol.