AP1000 GSI-191 Issue Resolution Recent Informal NRC Questions

December 15, 2009

Terry L. Schulz, Consulting Engineer
AP1000 Nuclear Systems Engineering

Dec 15, 2009 Meeting With NRC on Remaining Issues on AP1000 GSI-191

- Agenda
  - 9:00 Welcome/Introduction (open)
  - 9:10 WEC Meeting Agenda / Purpose (4 slides)
  - 9:20 WEC discuss plan to resolve remaining GSI-191 issues (30 Slides)
  - 10:00 Break (15 min)
  - 10:15 WEC discuss plan to resolve remaining GSI-191 issues (cont.)
  - 11:20 WEC break / NRC Caucus
  - 11:50 NRC Presentation of Review Schedule (open)

Purpose of the Meeting

- Discuss how WEC has or will address recent NRC informal questions
  - 26 questions were emailed to WEC 11/24/09
    - The first 16 questions were addressed in the revised documents sent to the NRC on 11/25, 12/1, 12/2
    - The remaining 10 questions brought up new issues that required additional time
  - Revised set of 31 questions were emailed to WEC 12/10/09
    - Includes 8 of the unanswered questions from 11/24 plus others
  - Today, WEC will provide for each of the more significant 12/10 questions (including the unanswered from 11/24)
    - Expected response
    - Work WEC will do to justify the response, including testing
    - Due date for the response, current plan

Purpose of the Meeting

- WEC believes that the NRC could proceed directly to finalize Chapter 6 SER based on
  - The revised documents provided 11/25, 12/1, 12/2 and
  - The information provided today on the remaining questions without waiting for the formal responses
    - These responses are considered confirmatory because of the extensive analysis and testing already performed
      - These remaining questions could become open items
    - In addition, today's presentation provides
      - The expected response
      - A clear path to closure defining the work that will be performed including additional testing

List of Remaining Significant GSI-191 Questions for AP1000

	Title	Email*	Testing
1	WCOBRA/TRAC validation for LTC sensitivity analysis	12/10/09	-
2	1/3 length test FA with isothermal conditions	11/24/09	yes
3	Variation in repeat tests	11/24/09	yes
4	Adjustment to peak dP to min flow (3.1 gpm)	11/24/09	yes
5	Verify HL LOCA conditions are not limiting	11/24/09	yes
6	Uncertainity in cleanliness program	12/10/09	yes
7	Non-Uniform blockage across core	11/24/09	-
8	Does pump in FA debris test loop change fiber lengths	11/24/09	-
9	NRC guidance on using co-incident debris addition	11/24/09	-
10	Concrete debris generation by blowdown jet	11/24/09	-

* All these questions were also in the 12/10/09 email except #10.

Q1 - WCOBRA/TRAC Validation for LTC Sensitivity Studies

- NRC Question
  - WCOBRA/TRAC was validated for long-term cooling analysis as described in WCAP-14776 and WCAP-15644. In the DVI break, the core flow is normally 152.2 lb/sec. For the DVI break that has significant debris clogging of the core inlet (e.g., Sensitivity case 10), the core flow reduces to 65 lb/sec.
    a. Has WCOBRA/TRAC been validated against tests with such low flow rates and high steam qualities? Please provide the validation report that documents the validation and verification of WCOBRA/TRAC at these low flow, low pressure and low liquid qualities. Please identify specifically what tests and comparisons were used to validate WCOBRA/TRAC at these conditions.
    b. Will the sensitivity study cases with high core flow resistance, which results in low core flow (e.g., Case 10), be outside the range of applicability of the WCOBRA/TRAC code for LTC analysis? Provide an evaluation to ensure that these new LTC cases are within the range of applicability.

Q1 - WCOBRA/TRAC Validation for LTC Sensitivity Studies

- Response
  - WC/T has been validated against tests with conditions that bound those seen in the AP1000 LTC sensitivity studies with flows as low as 0.01 in/sec (basically pool boiling), pressures at atmospheric, and core exit qualities of approximately 100%.
- Work
  - Discuss specific tests and their conditions used to validate WC/T for these LTC conditions. Describe the comparisons made. Show that the conditions seen in the LTC sensitivity analysis cases are within the range of WC/T applicability.
- Schedule
  - To NRC 1/29/10 (RAI response), 2/26/10 (report update)

Q2 – Justify Use Of 1/3-Length Fuel Assembly With Isothermal Testing

- NRC Question
  - The fuel assembly tests were performed with 1/3-length scale model with isothermal conditions. Provide justifications on how it can be scaled up to a full length with boiling in the upper portion of the fuel assembly.
- Response will be provided in 4 parts
  a. Use of 1/3-length FA
  b. Boiling impact on dP due to higher velocity
  c. Boiling impact on BA/TSP plateout
  d. Boiling impact on AlOOH dP characteristics

Q2a – Justify Use Of 1/3-Length FA

- Response
  - Use of 1/3-length FA is conservative
- Work
  - Discuss clearances in inlet nozzle / P-grid vs other grids
  - Discuss importance of test data that shows that almost all of the FA debris dP is across the inlet nozzle / P-grid
- Schedule
  - To NRC 1/29/10 (RAI response), 2/26/10 (updated reports)

Q2b – Justify Use Of Fuel Assembly Without Heated Rods (High Velocity)

- Response
  - Boiling does not cause excessive dP
- Work

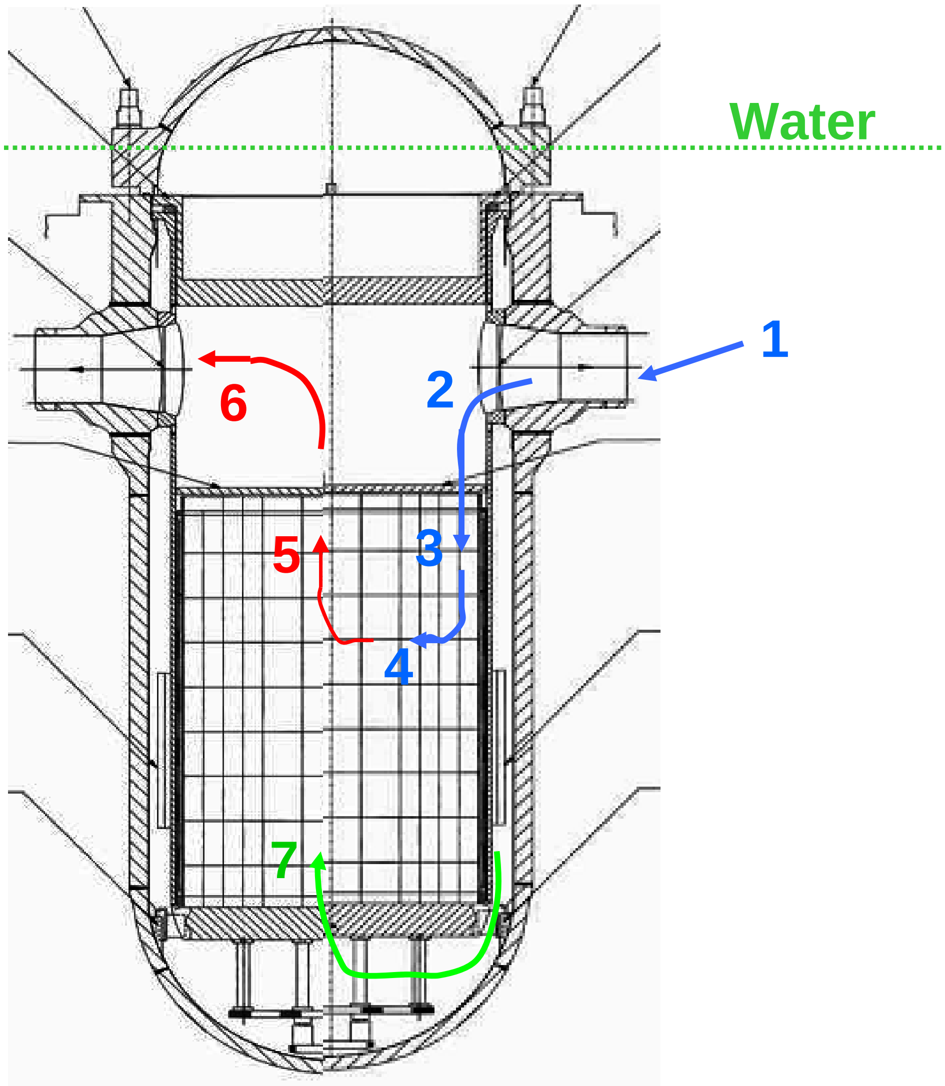
[–] a,c

    - Debris can enter upper portion of fuel from HL and flow down through low power, periphery FAs, then cross over to high power central FAs (depicted in next slide)

[• • •] a,c

- Schedule
  - To NRC 2/26/10 (RAI response and updated reports)

Debris Transport in HL LOCA



1. Water with debris could enter through HL break
2. Water / debris that is not carried directly out the ADS4 on the faulted HL can flow into RV
3. Water / debris entering RV can flow down in outer, low power, FA
   a. Some debris may be trapped as water flows down
4. Water / debris will cross over to central, higher power, FAs
5. Water / steam / debris will flow up through central FAs
   a. Some debris may be trapped as water/steam/debris flows up
6. Water / steam leaving core will flow out ADS stage 4 lines
7. Water with no fiber will be injected into downcomer from PXS and flow up through bottom of fuel assemblies

Q2c – Justify Use Of Fuel Assembly Without Heated Rods (BA/TSP Plate-Out)

- Response
  - BA and TSP does not plate-out at AP1000 fuel conditions seen during post LOCA recirculation
- Work
  - [ ] [a,c] test has been performed that demonstrates that BA and TSP plate-out does not occur in post-LOCA conditions
    - Will show that test conditions apply to the AP1000
- Schedule
  - To NRC by 1/29/10 (RAI response), 2/26/10 (updated reports)

Q2d – Justify Use Of Fuel Assembly Without Heated Rods (Temperature Impact on AlOOH)

- Response
  - Higher temperatures do not result in higher dPs
- Work

[–

] a,c

- Schedule
  - To NRC by 2/26/10 (RAI response and updated reports)

Q3 – For the Repeat Tests 27, 29, 30 Explain Why Results Varied So Much

- NRC Question on WCAP-17028, Rev 3

  The repeat tests for tests CIBAP27, CIBAP29 and CIBAP30 with same amount of debris and debris addition procedures described in Sections 8.26, 8.28 and 8.29, respectively, show a significant variation in the test results, including the peak dP, the time, flow rate, and batches of chemical addition when the peak dP occurs, and the phenomenon of debris break-through. Section 9.1.5 concludes that all three tests had considerable margin to the current acceptance limit. However, Test #27 has significantly higher peak dP than test #29 even though test #27 has much lower flow rate at the time of peak dP, and the peak dPs differ more than 81% when adjusted to the same flow rate (by the respective correlations). This shows that the tests have poor repeatability and potentially large uncertainties.

  Provide an explanation of why the repeated tests are not repeatable and why the test results with large uncertainties are acceptable, and an evaluation of the confidence with which the test results with so much uncertainty can be used to assess the fuel assembly head loss with debris transported to the core.

Q3 – For the Repeat Tests 27, 29, 30 Explain Why Results Varied So Much

- Response
  - The variation is thought to be due to the complex geometry of the fuel assembly and how that affects the way the debris bed forms and the breakthroughs occur
  - This variation is acceptable because we can demonstrate through statistical analysis that the current acceptance limit will not be exceeded with a high confidence and probability
    - Considering the testing we have performed along with the additional testing proposed

Q3 – For the Repeat Tests 27, 29, 30 Explain Why Results Varied So Much

- Work
  - [ ] a,c
  - Provide document describing statistical analysis of AP1000 FA testing demonstrating high confidence and probability
- Schedule
  - 1/20/10 - preliminary statistical analysis available for audit
    - [ ] a,c
  - 2/26/10 - final statistical analysis including additional tests, RAI response and updated reports

Q4 – Adjustment of dP to 3.1 gpm

- NRC Question on WCAP-17028, Rev 3
  - With the majority of fuel assembly head loss tests performed at flow rate higher than 3.1 gpm, Section 5 describes the development of head loss-flow correlations to extrapolate the test results at higher flow to the 3.1 gpm condition. Sections 8.30.1 through 8.30.3 provide an explanation of developing a correlation of the pressure differential once the bed has been formed.
    a. The fuel assembly debris bed formation and dP are greatly affected by the flow rates decrease during the tests. Please explain and justify how the correlations, which are based on the debris bed fully formed, can be used to determine a maximum head loss of a developing bed by extrapolating the test results at higher flow rate to 3.1 gpm.
    b. Many tests were performed with constant flow rates so that no data is available to determine the test-specific exponent of the correlation. Justify the use of the average value of the exponents of other tests with flow variations for the constant flow tests.
    c. All fuel assembly head loss tests were run at a flow rate above 5.2 gpm at peak core pressure differential. Since the fuel assembly head loss test acceptance criteria is based on the flow rate at 3.1 gpm, explain why these tests are sufficient in light of large variability of the test results and the uncertainty associated with the application of the developed correlations.

Q4 – Adjustment of dP to 3.1 gpm

- Response
  - For all tests after #17, the exponent has been derived from flow sweep data from that test
    - Note that this is a test by test determination not a general correlation
  - Constant flow tests do not simulate how AP1000 operates and had smaller debris loads so they are not used in the statistical confidence and probability analysis
  - Exponents derived from data at the end of the test applies to bed at the peak dP
- Work

  [a,c
  -
  -
  ]
- Schedule
  - To NRC by 2/26/10 (RAI response and updated reports)

Q5 – How do the FA tests performed using CL conditions apply to a HL break

- NRC Question

On page 17 of TR 26, APP-GW-GLR-079, Revision 6, Westinghouse discusses several reasons why the DEHLB is not the most limiting break with respect to debris plugging the core and causing a fuel heat-up. These include: (1) the HL break location not resulting in the spill of the IRWST injection thus the start of recirculation being later with lower decay heat than a DVI break, (2) potential counter-current flow due to inflow from the break and outflow from the core resulting in the debris brought in through the HL break being deposited in the top portion of the core.

a. Provide a comparison of the times of start of recirculation for a DVI break versus a DEHLB, and the corresponding decay heat values and the required flows to match boiloff at the respective times.

b. For a DEHLB, the reverse flow from the loop compartment through the break represents the percentage of total flow into the reactor vessel. How much the flow that goes into the reactor vessel is unfiltered for the DEHLB?

c. The fuel assembly debris load head loss testing provided evidence that significant plugging would occur at the core inlet. The P-grid on top of a debris-filtering bottom nozzle appears to trap much of the debris causing a local dP increase for the bottom up flow testing that represents a DVI or CL break. The top of the core is more open, which could allow debris to enter the reactor vessel during the DEHLB and to flow into the core region unimpeded. For debris entering the top of the core for a DEHLB, is there enough counter-current flow to carry debris into the core? If so, how much debris enters the core from the upper plenum?

d. For a DEHLB, what effect does the two phase flow have on the debris entering the upper part of the core? Does the presence of two-phase liquid enhance or reduce the probability of debris sticking on the spacers and top grid.

e. The FA tests were based on the limiting break being cold leg break or DVI line breaks in which significant amount of debris enters the core directly, bypassing the containment recirculation screen. Since a hot leg break would result in the debris entering the top of the core, how are the FA head loss tests with debris entering from the bottom of the core applied to the flow conditions pertaining to hot leg breaks?

Q5 – How do the FA tests performed using CL conditions apply to a HL LOCA

- Response
  - Discuss HL LOCA
    - Time to start of recirc
    - Debris transport into / within core
  - The HL LOCA is less limiting for GSI-191 for the AP1000

Q5 – How do the FA tests performed using CL conditions apply to a HL LOCA

- Work

a,c

  –

    •

    •

      –

      –

- Schedule
  – To NRC 2/26/10 (RAI response and updated reports)

Q6 – Uncertainty in Cleanliness Program

- NRC Question
  - The cleanliness program at the power station will be implemented to verify the containment latent fiber debris to be less than 6.6 lbm. For many quality controlled programs there is a measure of uncertainty. Assume the uncertainty of the QC program is 20%.

    Provide an evaluation of the impact of the uncertainty in the variation of fiber content on the core inlet dP, i.e., if the fiber entering the core is 20 % higher or lower than 6 lbm, what would the corresponding change in core inlet dP?

Q6 – Uncertainty in Cleanliness Program

- Response
  - The FA dP with additional fiber is less than the acceptance limit
- Work
  - A FA test with $\geq$ 20% additional fiber will be performed
    - Limiting ratio of P/F will be maintained
  - A FA test with less fiber is considered unnecessary
- Schedule
  - To NRC 2/26/10 (RAI response and updated reports)

Q7 – Can More Debris Be Transported To Part of Core (Center?) and Cause Inadequate Core Cooling

- NRC Question on WCAP-17028, Rev 3
  - The fuel assembly test maintains a basic assumption of uniform blockage across the core inlet. Is there any possible scenario where non-uniform core inlet blockage could create a worse case? For example, if the central part of the core has more blockage while the peripheral of the core is not blocked, this will result in the flow from the peripheral outer edge of the core to the central bundles. This will cause the fluid along with the debris to cross the core and this greater distance of travel will provide more opportunity for the debris to be caught on the spacers.

Q7 – Can More Debris Be Transported To Part of Core (Center?) and Cause Inadequate Core Cooling

- Response
  - The debris transport and dP buildup will occur gradually over many hours (~7) as shown in the coincident debris addition tests
  - Non-uniform debris buildup will be self correcting; if more flow / debris went to part of the core, the dP would increase there which would then divert more flow / debris to the other parts of the core.
  - Even in areas of uniform debris transport, there will be variations in dP
  - Even if the dP / flows ended up non-uniform, the high flow through low dP FAs would cross over to assist cooling FAs with lower flow
- Work
  - Discuss how AP1000 debris is transported and relate to the test data that shows how the dP builds up over time
  - Discuss how flow/dP is self correcting and cross flow cools FAs
- Schedule
  - To NRC by 1/29/10 (RAI response), 2/26/10 (updated reports)

Q8 – Does The FA Test Pump Change The Fiber Lengths As They Pass Through The Pump

- NRC Question on WCAP-17028, Rev 3
  - A Performance Pro Cascade ¾ HP pump draws water out the bottom of the mixing tank. There are a number of cycles that occur through the pump before maximum pressure across the core occurs. Does the debris change shape and become smaller as it flows through the pump? If so, how is this accounted for in determining length and size of the debris?
- Response
  - The limiting fiber length was determined by testing different initial fiber lengths
    - The impact, if any, of the test pump operation on the fiber length is included in the selection process

Q8 – Does The FA Test Pump Change The Fiber Lengths As They Pass Through The Pump

- Work
  - Provide discussion of this issue relative to the operation of the test pump.
  - Also discuss why it is unlikely that fiberglass fibers would be broken up by the pump impeller.
- Schedule
  - To NRC by 1/29/10 (RAI response), 2/26/10 (updated reports)

Q9 – NRC Guidance On Acceptability Of Using Co-Incident Debris Addition Was Made For Screens. Discuss Adequacy Of FA Test Matrix.

- NRC Question on WCAP-17028, Rev 3
  - On page 3-2, Westinghouse references the approved approach for testing as the NRC guidance on head-loss testing (Ref 10), which is for the recirculation strainers. Justify why this is relevant for testing the fuel assembly pressure drop. Since the fuel assembly pressure drop is governed by many more variables than the recirculation screens, such as flow rate, two-phase behavior, spacer pressure drop, etc., a more extensive review and test matrix should be completed to determine if the most conservative approach to the determining the fuel assembly pressure drop has been provided.

Q9 – NRC Guidance On Acceptability Of Using Co-Incident Debris Addition Was Made For Screens. Discuss Adequacy Of FA Test Matrix.

- Response
  - Adequacy of AP1000 FA test matrix is justified in WCAP-17028 in sections 7.0, 8.30 and 9.0.
  - The reference to the NRC guidance was made since the guidance allows the use of co-incident debris addition; the use of co-incident debris addition was justified by showing that is how the AP1000 operates
- Work
  - Provide discussion supporting above response
- Schedule
  - To NRC by 1/29/10 (RAI response), 2/26/10 (updated reports)

Q10 – Evaluate Whether A LOCA Blowdown Jet Generates Concrete Debris and If Generated, What Would Be the Consequences

- NRC Question
  - Clarify how you include the effects of concrete as a debris source term for small-break and large-break loss-of-coolant accidents. In your response, please address the following:
    a. Identify the locations of the concrete that is considered a potential source of particulate, coatings, or chemical debris.
    b. How is the concrete treated as a source term for coatings debris (inside and outside the ZOI)?
    c. How is the concrete treated as a source term for latent particulate?
    d. How is the concrete treated as a source term for LOCA-generated particulate?
    e. What locations were considered when calculating the amount of chemicals dissolved from concrete?

Q10 – Evaluate Whether A LOCA Blowdown Jet Generates Concrete Debris and If Generated, What Would Be the Consequences

- Response
  - A LOCA jet will not generate concrete debris
- Work
  - Compare AP1000 LOCA jet velocities, fluid properties and distances to concrete vs what is required to cause concrete damage
    - Different break sizes / location will be evaluated
- Schedule
  - To NRC by 1/29/10 (RAI response), 2/26/10 (updated reports)

Summary of Additional Planned FA Tests Expected to be Completed by 1/29/10

Additional STC Fuel Assembly Tests			
Test #	**Similar to**	**Objective**	**Comment**

a,c

Summary of WEC Approach To Addressing Remaining GSI-191 Issues For AP1000

- There are several significant questions from the recent informal NRC questions that WEC has not addressed
- A high quality approach to answering each significant question has been presented today
  - Includes performing 10 additional FA tests
- The expected response for each question has also been provided today
- It is recommended that these remaining ques. be treated as OIs
  - Formal responses will be provided by 1/29/10 or 2/26/10
  - Updates to GSI-191 reports will be provided by 2/26/10
- *It is requested that the NRC proceed with finalizing the Chapter 6 SER based on*
  - *Previously transmitted AP1000 GSI-191 documents*
  - *Information presented today*