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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002755

January 29, 2010

Subject: AP1000 Response to Request for Additional Information (SRP 6)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 6. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP6.2.2-CIB1-28	RAI-SRP6.2.2-SRSB-32	RAI-SRP6.2.2-SRSB-37
RAI-SRP6.2.2-SPCV-27	RAI-SRP6.2.2-SRSB-33	RAI-SRP6.2.2-SRSB-38
RAI-SRP6.2.2-SPCV-28	RAI-SRP6.2.2-SRSB-35	RAI-SRP6.2.2-SRSB-39
RAI-SRP6.2.2-SPCV-30	RAI-SRP6.2.2-SRSB-36	

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

/For

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Request for Additional Information on SRP Section 6

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 6

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI SRP6.2.2-CIB1-28: Concrete as Debris
Revision: 0

Question:
Please 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?

Westinghouse Response:
a) Note that because of the extensive use of steel structural modules inside the containment, the amount of concrete surfaces that are flooded following a LOCA are significant less than in an operating plant. Most of these surfaces are floors such as those in the loop compartments.

Particles - Concrete is not considered a source of particulate debris. See discussion in item c) and d) below.

Coatings - All of the coatings applied to concrete surfaces are considered as a source of coatings debris. Note that these coatings are required to be high density coatings and will settle out in the low velocity AP1000 post LOCA conditions. Also see discussion in item c).

Chemicals – It is assumed that all the concrete surfaces that become flooded following a LOCA become exposed to the post accident water (their coatings fail to isolate them) and they become available to react chemically.

b) Within the ZOI, coatings on concrete surfaces are assumed to fail as fine particles and to transport. Outside the ZOI, the coatings on concrete surfaces outside of the ZOI are assumed to fail as chips; only epoxy coatings are used on concrete. Other than the inside surface of the containment shell, the use of IOZ coatings are restricted to high temperature parts on components and are required to be safety – service level I. As a result, failure of coatings located outside the ZOI will not contribute to the debris loading on the screens or on the core.

c) Concrete is not considered a source of latent particulate debris. Concrete surfaces are protected from being damaged during normal plant operations. Concrete surfaces that are expected to experience mechanical wear (e.g., floors) are coated with a self-leveling epoxy or a self-priming high solids epoxy (SPHSE) while all other exposed concrete surfaces inside containment are coated with an epoxy sealer to help bind the concrete surface together and reduce dust that can become contaminated and airborne. Exposed concrete walls inside containment are coated to a minimum height of 7 feet with an epoxy or SPHSE applied over an epoxy surfacer that has been struck flush. See response to part d).

d) This part of the RAI asks how concrete is treated as a source of LOCA-generated particles. To answer this question, an evaluation was performed considering the impingement of a jet issuing from a postulated break in the reactor coolant system. Comparison was made to devices that are designed to use water as a cutting medium for hard materials such as steel or concrete. The following discussion shows the differences between water jets used for cutting and the water jet that would issue from a postulated Loss of Coolant Accident (LOCA). These differences result in the flow from a postulated LOCA break not having sufficient energy to cause erosion of intact concrete surfaces that would, in turn, result in the generation of concrete debris.

POWER WASHERS AND WATER JET CUTTERS:

A survey of users and manufacturers of power washers using water and water jet cutting equipment was conducted to gather information about the conditions and operating pressures of the water jets used by their equipment. The following summarizes the information gathered;

> For water jet cutters, the pressure is typically between 20,000 and 90,000 psi. An operating pressure of 60,000 psi was the most common value given. The water is forced through a 0.010" to 0.015" diameter orifice (hole) in a jewel. Abrasive cutting involves a jewel-most commonly found was garnet, but, one company used sapphire and diamond. Abrasive cutting is used to cut hard materials such as steel, stainless, copper, aluminum, granite, marble, laminated glass and concrete. A pure water jet (with no added abrasive material) is only used to cut soft materials such as foam, package products, gaskets, gypsum board, carpet, food, rubber, and many other soft materials. A summary of the survey information collected is given in Table 1.
>
> Power washers are used to clean concrete. The nozzle size used in these washers determines the operating pressure. The smallest angle of the discharge will deliver the most force from the jet. Most manufacturers suggest a pressure of 3000 psi or more for cleaning concrete (do-it-yourself projects). Using such high pressure cleaning on intact concrete, very little if any concrete is eroded by the action of the jet on the surface of the concrete.
>
> In all cases, the operating temperature of the water used was below the flash point at atmospheric conditions.

For power washers and water jet cutters, the jets are designed to remain intact with little spreading until it impacts a target. Thus, the jet retains its pressure as it travels to the impact region of the material to be cut. It is the cohesiveness of the water jet that gives power washers and water cutters the ability to clean or cut materials.

LOCA JETS

The coolant in the primary piping of AP1000 is at a pressure of about 2250 psig and at temperatures ranging from more than 550°F (in the cold-leg) to less than 620°F (in the hot-leg). At these conditions, the coolant is somewhat subcooled because the temperatures are less than the saturated temperature (654°F) at this pressure. That is, when the pressure on the coolant is decreased, it will begin to flash to steam only when the applied pressure drops below the saturation pressure for the coolant.

For flow from a pipe break due to a postulated LOCA, the escaping fluid begins to flash at the break location. The flashing begins at the outer surface of the jet and continues inward of the jet until the core of the jet is reached. Characterizing the jet flow as a function of the distance, L, and the pipe break diameter (D), LOCA jets have been evaluated to be fully expanded with an associated major decrease in pressure within 4 L/D. The rapid depressurization associated with LOCA jets has been studied experimentally in tests such as the Marviken test program (Reference 1) and analytically in work such as that presented in NUREG/CR-2913 (Reference 2). How quickly the subcooled jet depressurizes is demonstrated in Figure 1, below. Figure 1 was presented in Reference 1 as Figure 2.8. For a jet with a fluid source at 150 bar (2180 psi) and a subcooling of 15°C (103°F), at and L/D = 4, the calculated stagnation pressure is reduced to approximately 6 bar (87 psi).

A photograph of a subcooled jet (nozzle effective diameter = 2.313 inches, supply pressure = 2000 psi, supply temperature = 545°) is included to demonstrate the rapid expansion of the jet and to demonstrate the lack of cohesiveness of the jet within a short distance from the jet nozzle outlet. For this test, at an L/D = 4, the stagnation pressure was measured as approximately 88 psi. This value is in close agreement with the analytical value noted above.

EVALUATION:

The jet flows used in water cutting are fundamentally different that those resulting from a postulated LOCA.

Water cutting flows are designed not to flash, but to maintain their cohesiveness until impacting the object to be cut. The pressure of these cutting jets is between 30,000 psi and 90,000 psi and the temperature is near ambient, which precludes flashing. These cutting jets are typically very small having a diameter ranging from 0.004 to 0.06 inches. In addition, cutting of concrete would also utilize the addition of abrasives to the water jet to enhance it cutting ability.

Power Washers also use non-flashing flows. Recommended pressures for cleaning concrete are in the range of 3,000 psi. The pressure is held relatively constant during the cleaning process. With these high pressures applied to intact concrete, very little if any concrete is eroded.

The fluid in the AP1000 reactor coolant system is somewhat subcooled (2250 psi with a temperature range of between about 550°F to about 620°F). As this fluid is released through the postulated break, it begins to flash to steam as it passes through the break plane and in doing so, begins to expand and looses its cohesiveness. Within about 4 L/D, the LOCA jet is fully expanded with an associated major decrease in pressure. Furthermore, the high-velocity, high-pressure flow period of the LOCA lasts for approximately 30 seconds, at the end of which the flow is equal to either a steam / water mixture (for a hot leg break) or steam (for a cold leg break). In both cases the flows are much lower and are related to the core decay heat. In addition, the pressure of the flow will decrease from 2250 psi to the containment pressure at the end of the blowdown.

For a postulated large break LOCA, the initial jet diameter is equal to the ID of the cold leg (22 inches) or the hot leg (31 inches). While the piping sizes for AP1000 are large compared to water cutters and pressure washers, the fundamental differences in jet behavior preclude LOCA jets from eroding intact concrete.

This was demonstrated in subcooled jet impingement testing of concrete blocks coated with epoxy coatings. The jet conditions a supply pressure of 2200 psi and a supply temperature of about 530°F. The supply pressure was maintained approximately constant for about 30 seconds; this assured choked flow throughout the test which provided maximum potential for erosion due to the action of the jet. The concrete test coupons were 12" long x 12" wide x 2" thick. The jet diameter was about 1.6 inches and the distance of the concrete coupons from the jet nozzle was 8 inches (L/D = 5) and 10 inches (L/D = 6.26). For both tests, no wear, erosion or abrasion of the epoxy coating was observed and hence, no erosion of the concrete substrate was observed.

For a small break LOCA the pipe sizes are smaller ranging down to ¾". For such LOCAs the RCS pressure would decrease quickly to the steam generator secondary side pressure ~1200 psia and become saturated. For AP1000, the RCS pressure would eventually be decreased to close to containment pressure once the automatic depressurization system (ADS) was actuated. The timing of ADS is dependent on the break size varying from as short as 15 minutes up to several hours for the small pipe breaks.

Considering that the pipe sizes are small and therefore the numbers of ID to the concrete floors is much greater, small break LOCAs are not considered challenging for the potential for concrete damage.

<u>SUMMARY:</u>

The RAI asks if a LOCA in a AP1000 can generate particles by damaging concrete. An evaluation was performed that considered if a LOCA jet might erode concrete surfaces inside the reactor containment building, resulting in concrete debris. A comparison was made with the use of water jets to cut hard materials. There is a fundamental difference in the behavior of the water jets associated with water cutters and power cleaners and the subcooled jet resulting from a postulated LOCA. These differences include the following;

- A rapid decay in pressure for the LOCA jet,
- The expansion of the LOCA jet due to liquid flashing once it passes the break plane, and
- No abrasives in the fluid.

These differences preclude the jet resulting from a postulated LOCA from eroding intact concrete surfaces and generating concrete debris.

REFERENCES:

1. The Marviken Full Scale Critical Flow Tests, Joint Reactor Safety Experiments in the Marviken Power Station Sweden, MXC-402, December 1979
2. NUREG/CR-2913, "Two-Phase Jet Loads," 1983

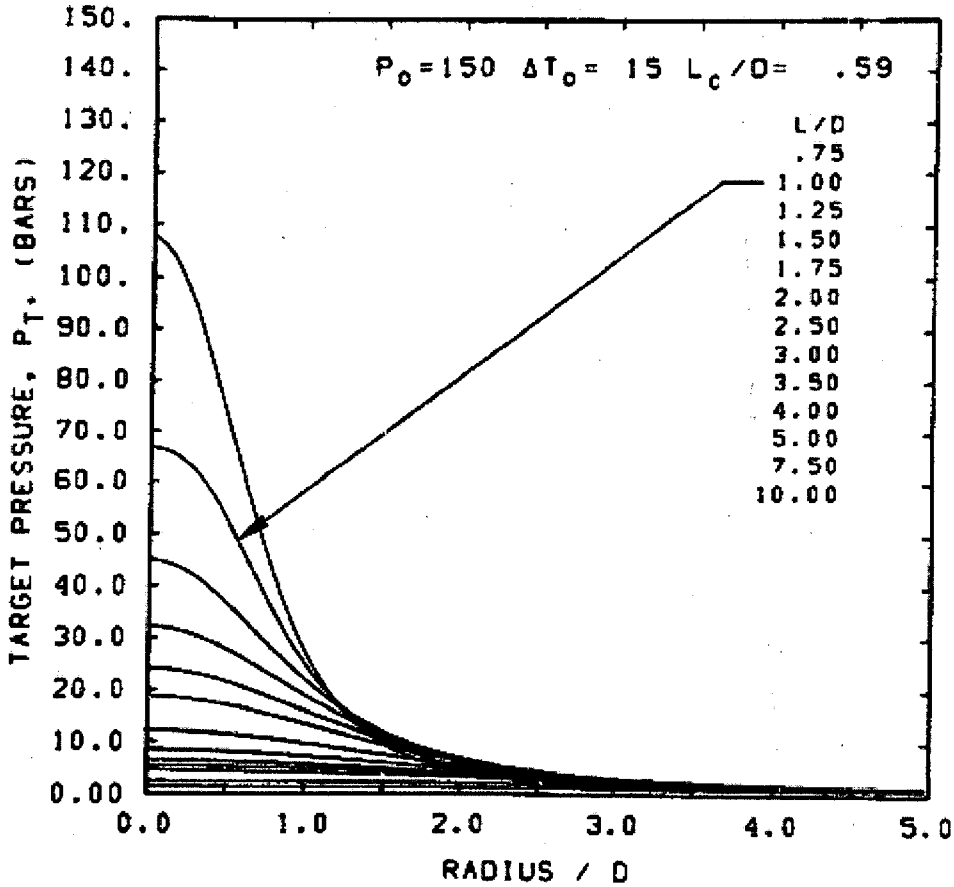

Figure 2.8 Target pressure distributions for stagnation conditions of P_0 = 150 bars and T_0 = 15°C. The target L/D associated with each curve is listed in the upper-right-corner key; the lowest L/D value corresponds to the uppermost curve.

Figure 1 Target Pressure Distributions from NUREG/CR-2913

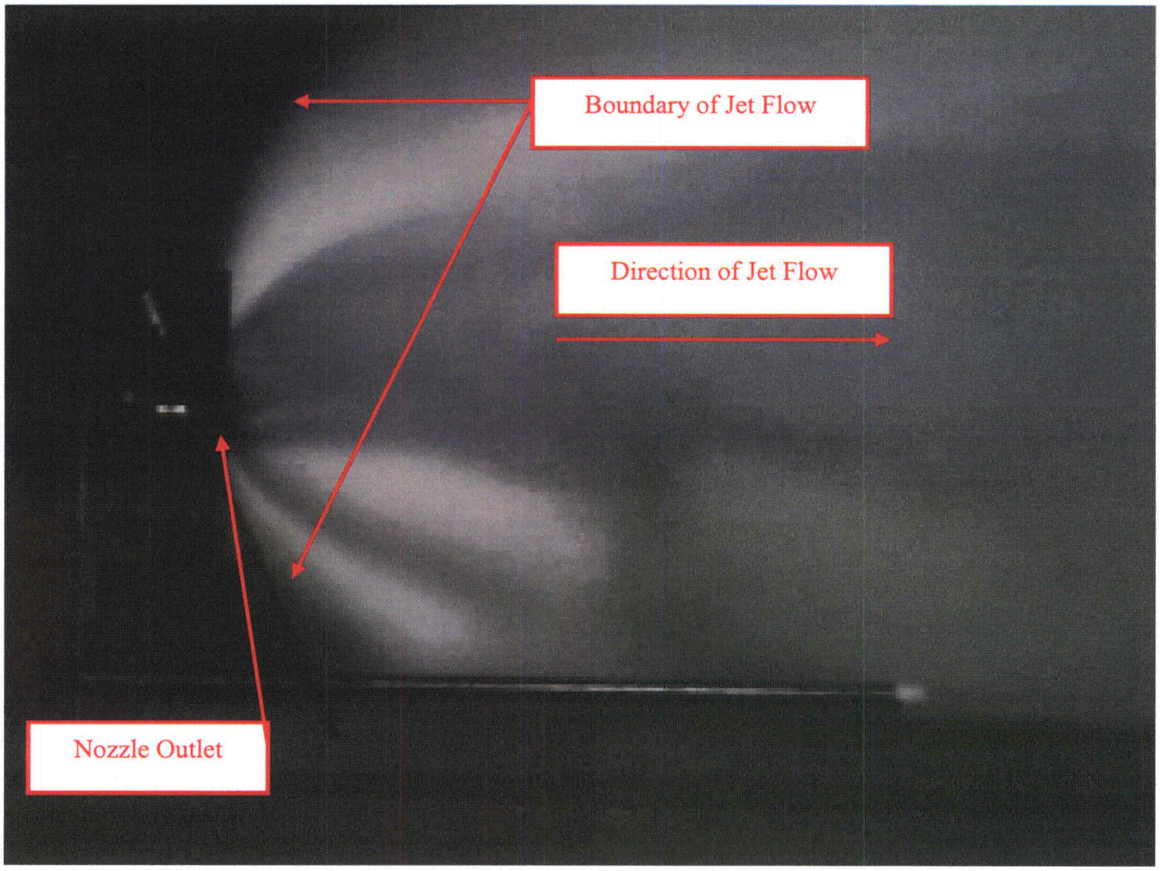

Figure 1 **Subcooled Jet expanding from a 2.313 inch Nozzle**
Supply Pressure = 2000 psi
Supply Temperature = 545°F

Table 1 Summary of Contacts for Water Jet Cutting

Jet Pressures to Cut Steel/Concrete				
Company Name	**Type of Machine**	**Pressure**	**Nozzle Diameter**	**Contact**
Aloma	Water Jet Cutting	43,500 PSI	0.004"-0.0315"	412-828-8660
S.A.Robotics	Water Jet Cutting	>30,000 PSI		N/A
NLB Corp.	Water Jet Cutting / Powerwashing	40,000 PSI		Keith O'Hara (800) 441-5059 x 139
Mueller Construction	Water Jet Cutting	60,000 PSI	0.02"-0.04"	Mike Mueller, mwm@muellerc.com, (903) 868 3585
Midwest Mobile Waterjet, LLC	Water Jet Cutting			651-755-7089
Advanced Waterjet Technologies	Water Jet Cutting	60,000 PSI		wjcut@awjt.com
ABC Sheet Metal	Water Jet Cutting	>30,000 PSI	0.04"-0.06"	Email: sales@abcsheetmetal.com
Adcut	Water Jet Cutting	60,000 PSI	0.004" - 0.015"	Email: info@adcut.net
Aqua-Jet Cutting	Water Jet Cutting	60,000 PSI		E-Mail: sales@aquajetllc.com
Landa	Powerwashing			JAMES.MORTENSEN@karcherna.com
Dix Metals	Water Jet Cutting	60,000 PSI	0.042"	Jon-David Nutter 800.477.4349 x780 Dir. 714.677.0780 Fax 714.677.0800 jdnutter@dixmetals.com
Hydroblast Pressure Cleaning	Powerwashing			Stuart Ellis @ 317.432.8755
Perfect Touch Power Washing	Powerwashing			1-877-871-3326
Holtec	Water Jet Cutting			Mark Ackerman m.ackerman@holtec.com
Flow International Corporation	Water Jet Cutting	55,000-94,000 PSI	0.01"-0.018"	James Daugherty 23500 64th Avenue South | Kent, WA 98032 | USA 800.446.3569 ext. 625 fax: 253.813.3307 jdaugherty@flowcorp.com

e) All of the concrete surfaces inside the containment that are located under the maximum floodup level are assumed to come in contact with the post accident water and to react chemically; the coatings on all of these surfaces fail to keep the water from coming in contact with the concrete.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

RAI Response Number: RAI-SRP 6.2.2-SPCV-27: Upstream Effects
Revision: 0

Question:

a) APP-GW-GLR-079 states that if MRI should get into the refueling cavity drain lines, it would create a porous "bed" that would not preclude the water flow. Provide details of this evaluation including the percent blockage evaluated and how this relates to expected quantity of debris. Quantify expected flow rates and water hold up for this blockage and the impact on flood level and long term cooling.

b) Provide an evaluation of the performance of the check valves on the refueling cavity drain lines for debris induced plugging and erosive wear.

c) The response to RAI-SRP6.2.2-SPCV-23 identified drain lines with double check valves from PXS-A, PXS-B and CVS compartments, but did not discuss how the lines or valves were designed to not be blocked by debris. Explain why these drains will not be blocked by debris or discuss the impact to flood level and long term cooling performance if they are blocked by debris.

Westinghouse Response:

a) The statement in APP-GW-GLR-079 is, "Thus, should the MRI debris be moved to the refueling cavity drain lines, the resulting debris collection would not be flat sheets, but rather a porous "bed" of deformed metal that would not preclude the flow of water through the debris bed."

The indication is that if metal reflective insulation (MRI) were to transport to the location of the refueling cavity drain line inlet, the resulting collection of MRI would form a porous bed that would not preclude the flow of water into the drain lines.

As discussed in APP-GW-GLR-079 and in response to RAI-SRP6.2.2-SPCV-13, the AP1000 is classified as a highly compartmentalized containment as defined in the NEI 04-07 SER. For highly compartmentalized containments such as the AP1000, 25% of the MRI debris generated is large pieces and 75% of the MRI debris generated is in the form of small fines. 25% (~18% of the total MRI destroyed) of the small fines is assumed to be ejected to upper containment and 75% (~56% of the total MRI destroyed) of the small fines are deposited directly to the sump pool floor. MRI is constructed of stainless steel. Tests reported in NUREG/CR-6808, "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," demonstrate that MRI damaged by LOCA tests will settle and require a velocity of 0.2 ft/s to move ½" x ½" crumpled foil MRI debris; larger velocities are required to move larger MRI debris. The NRC guidance on headloss testing (NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing, March 2008) says 'Some types of debris are relatively non-problematic. For example, reflective metal insulation (RMI) debris tends to be very porous unless overlaying sheets of foils accumulate on strainers. This overlay is not realistic at the low approach velocities expected with the new strainers.'

This type of overlay is not realistic for MRI debris in the AP1000 refueling cavity either since only small fines, defined in the NEI 04-07 SER as 'debris able to pass through the largest openings of the gratings, trash racks, and radiological fences, which are less than a nominal 4 inches', could be ejected into upper containment.

The only water that continues to fall on the operating deck and the refueling cavity is steam condensation or "rain" that might fall down from the central portion of the containment dome. The amount of "rain" will be a small part of the total steam released to the containment because most of the condensate flows down along the containment walls and into the IRWST; the amount of "rain" is about 5% of the condensate based on passive containment testing. The rain flow is too small to transport MRI debris across the operating deck and into the refueling cavity, thus the only MRI that could enter the refueling cavity is the portion of the ejected MRI that would land in the refueling cavity. The maximum rain is less than 10 gpm out through 5 min and then decrease to less 2 gpm in a couple hours.

As noted in APP-GW-GLR-079, the AP1000 has two 6-inch drain connections located in the refueling cavity with downward-facing 90° elbows which prevents debris that might enter the cavity from falling right into the drain lines. Additionally the opening of these downward-facing 90° elbows are 30-inches above the bottom of the upender pit, approximately 3 feet below the main surface of the refueling cavity.

As it is possible for the IRWST to spill over into the refueling cavity during ADS operation, flow rates may be sufficient to transport any RMI present in the refueling cavity into one of the two pits within the refueling cavity: one for the fuel upender and one for the fuel storage rack. However, any MRI that may transport within the refueling cavity to the upender pit would not form a blockage that could preclude the flow of water into the drain lines. In addition, once IRWST injection starts, the spill over will stop and the there will at least 2 hours for the spilled water to flow out into the containment through the drain lines.

In the longer-term, rain from the containment dome could fall into and collect in the refueling cavity and would need to drain out into the containment once the level in the cavity rose above the containment water level. This would take a week or so due to the small flow rate. At that time, the rain flow is less than 1 gpm.

In summary, blockage of the refueling cavity drain lines by MRI debris is prevented by the design of the AP1000. In addition, it is possible to develop a porous bed that with the long drain times and low flow rates would not hold up water in the cavity and there would be no impact on flood level or long term core cooling.

b) There are two 6 inch check valves in series in the refueling cavity drain line. All of the check valves open in the direction of flow away from the refueling cavity to provide drainage of any post-accident water accumulation in the refueling cavity directly to the steam generator 2 compartments. The only debris that may pass through these check valves is the latent debris present in the refueling cavity, debris that is brought in by IRWST overflow, flooding spillover from the refueling canal or runoff from the operating deck. With refueling operations filling and draining the refueling cavity, it is reasonable to assume that the amount of latent debris present in the refueling cavity at the time of accident initiation would be very low. Likewise, the IRWST contains debris free water and the possible IRWST overflow due to the ADS would be early in the accident before IRWST injection begins.

With the limited amount of debris available to pass through these valves there is no concern that erosive wear would occur that would impact the flood level or long term core cooling. It is also unlikely that enough MRI fines could be transported into the drain pits, up into the drain lines and into the check valves to interfere with the operation of the check valves.

Note that numerous AP1000 check valves have been evaluated for the expected 30 day mission time for erosive wear and plugging assuming that the entire post-LOCA debris load passes through them (RAI-SRP6.2.2-SRSB-13) and none were found to susceptible to erosive wear or debris induced plugging.

c) As previously stated in the RAI response, these check valves are located in floor drain lines and drain directly to the containment sump. For PXS-A room, PXS-B room, and CVS compartment, the check valves on the drain lines prevent water inside containment post-LOCA from backing up into the rooms. In this situation, there will be no flow backwards through these lines and as a result debris can not be transported from the containment back into these valves.

The valves can see forward flow if there is a LOCA in one of the rooms. Note that there are no LOCA break locations in the CVS valve room. There are LOCA break locations in the PXS rooms, however in case of such a LOCA these valve do not have to function to pass water forward or to prevent back flow.

As a result, these redundant series check valves are not exposed to debris that may cause erosive wear or plugging and as such will not impact flood level or long term core cooling.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
APP-GW-GLR-079 (TR-26), summary of the AP1000 response to GSI-191, will be revised based on the above.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SPCV-28
Revision: 0

Question:

RAI-SRP 6.2.2-SPCV-28: Design changes

DCD, 6.3.2.2.7.1, Item 12 discusses why RNS is not considered when determining maximum flow rates. It notes that no credit is taken for RNS operation in the PRA of a DVI LOCA, and non-DVI LOCAs will have less head loss because both PXS recirculation lines will be operating. However, the recent design changes to cross connect the IRWST screens and to qualify operation of the IRWST injection and containment recirculation squib valves while submerged means that both PXS recirculation lines now operate during a DVI LOCA, so non-DVI LOCAs no longer have more screen area.

a) Please explain the DCD statements discussed above regarding RNS operation with respect to the latest design changes.

b) Explain why RNS operation will not have an adverse reaction on safety systems

Westinghouse Response:

a. Section 6.3.2.2.7.1, Item 12, of the DCD will be revised in accordance with the following information.

   The range of flow rates during post-LOCA injection and recirculation are as follows:

   - CR screens: 1548 to 622 gpm,
   - IRWST screens: 1548 to 310 gpm,
   - Core: 2012 to 484 gpm.

   These flows bound operation of the PXS and the RNS. Note that if the RNS operates during post-LOCA injection or recirculation, the RNS flow is limited to 1548 gpm. This limit ensures that the screen head loss testing results bound the operation of the plant. In addition, the screens will be designed structurally to withstand much higher flow rates and pressure losses to provide appropriate margin during PXS and RNS operation.

   No chemical precipitates are expected to enter the IRWST because the primary water input to the IRWST is steam condensed on the containment vessel. However, during a DVI LOCA, recirculation can transport chemical debris through the containment recirculation screens and to the IRWST screens. As a result, 100% of the chemical debris is conservatively assumed to be transported to the IRWST screens.

The AP1000 containment recirculation screens and IRWST screens have been shown to have acceptable head losses. The head losses for these screens were determined in testing performed using the above conservative considerations. It has been shown that a head loss of 0.25 psi at the minimum screen flows listed above is acceptable based on long term core cooling sensitivity analysis.

Considering downstream effects as well as potential bypass through a CL LOCA the core was shown to have acceptable head losses. The head losses for the core was determined in testing performed using the above conservative considerations. It has been shown that a head loss of 4.1 psi at the minimum core flow listed above is acceptable based on long term core cooling sensitivity analysis.

b. As discussed in the response to RAI-SRP 6.2.2-SPCV-26 the screens are currently designed to include RNS operation. Therefore there is no adverse reaction on safety systems from RNS operation.

Design Control Document (DCD) Revision:
Tier 2, Section 6.3.2.2.7.1. Clarify discussion about RNS operation as described above.

PRA Revision:
None

Technical Report (TR) Revision:
The DCD changes described above will be reflected in the next revision of APP-GW-GLE-002.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SPCV-30
Revision: 0

Question:

RAI-SRP 6.2.2-SPCV-30: Administrative

a) In APP-PXS-GLR-001, the text describing Sensitivity Cases 1-3 identifies the K-factors and areas for the containment recirculation screen, but no mention is made regarding these values for IRWST screens. Please confirm that resistance was added to the IRWST screens in these cases and provide the associated K-factors and areas.

b) Please discuss your plans for making the quantity of chemical precipitates listed in DCD Section 6.3.2.2.7.1 consistent with the value in APP-GW-GLR-079 and other documents. In APP-GW-GLE-002, Rev. 5 (Impacts to the AP1000 DCD to Address Generic Safety Issue 191), the fourth item on page 35 states that the total amount of chemical precipitates that could form in 30 days is ≤55 pounds. According to Table 5 in APP-GW-GLR-079 and other documents, the predicted quantity of chemical precipitates is approximately 57 pounds.

Westinghouse Response:

a. The K factors listed for the containment recirculation screens were also applied to the IRWST screens. APP-PXS-GLR-001 will be revised to state the same K factor applies to both sets of screens for each case.
b. APP-GW-GLE-002 will be revised to be consistent with the quantity of chemical precipitates listed in APP-GW-GLR-079. The quantity of chemical precipitates listed in APP-GW-GLR-079 is correct.

Design Control Document (DCD) Revision:
Revision to quantity of chemical precipitates in Section 6.3.2.2.7.1. This DCD change will be reflected in a revision to APP-GW-GLE-002.

PRA Revision:
None

Technical Report (TR) Revision:
1. APP-PXS-GLR-001, the K factors for the CR screens will be described.
2. APP-GW-GLE-002, the DCD changes described above in b) will be reflected in this document.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-32
Revision: 0

Question:

RAI-SRP 6.2.2-SRSB-32: WCAP-17028-P, Rev. 3

The assumption of 90% debris from the containment is assumed to enter the reactor vessel through the CLB. Based on the WCOBRA/TRAC calculation this is a conservative number. Given the uncertainties for input to the WCOBRA/TRAC program and for the calculation in a flow regime that is not normally used by WCORBRA/TRAC, an uncertainty factor could be applied to the 90% value.

Provide an evaluation of the impact of the uncertainty in the variation of fiber content on the core inlet dP if the fiber entering the core is actually higher than 6 lbm. Discuss the corresponding change on core inlet dP.

Westinghouse Response:

A maximum of 90% of the debris entering the RCS through a CL or DVI LOCA has been calculated in a bounding / conservative fashion.

- WCOBRA/TRAC has been validated for the conditions seen during the AP1000 post LOCA operation (refer to the response to RAI-SRP6.2.2-SRSB-39).
- The DECLG break flow split LTC analysis using WCOBRA/TRAC was performed with conservative assumptions. The PXS line resistances are conservatively high and the break flow resistance is conservatively low. The limiting single failure is assumed to be a valve in the DVI line. The calculated ECCS performance is conservative because Appendix K decay heat is used.
- The flow results from the WCOBRA/TRAC DECLG break flow split LTC case were used to calculate that at the time one mass of containment water has passed through the reactor vessel 90% of the flow into the vessel is from the broken CL. In actuality it will require more than one containment water volume to pass through the RCS which would reduce the flow split through the break. In addition, the break and PXS flow rates are assumed to be constant as the debris is transported into the core. In actuality the flow rates will decrease due to buildup of DP which will also reduce the flow split through the break. This is explained in more detail in the response to RAI-SRP6.2.2-SRSB-41. Since the bases of the flow rate calculation in WCOBRA/TRAC is conservative, then the calculation of the 90% flow split is also conservative.
- The flow split calculations result in 90% of the coolant entering the vessel from the broken CL and 10% entering from the PXS. The 90% of flow entering the broken CL is not screened and therefore is conservatively be assumed to contain 90% of the debris.

Therefore no uncertainty factor is needed to compensate since the use of WCOBRA/TRAC is valid for these conditions, the code inputs are conservative and the assumptions used in determining the integrated flow split are conservative. Since the basis of the 90% of fiber, a quantity of 6 lbm, entering the core is based on conservative assumptions, an evaluation of a larger quantity of fiber in the core is not needed.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-33
Revision: 0

Question:

RAI-SRP 6.2.2-SRSB-33: WCAP-17028-P, 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 area 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.

Westinghouse Response:

The AP1000 fuel assembly (FA) debris-induced head loss tests do not assume that uniform blockage will occur. In fact the AP1000 FA debris testing, especially considering the repeat tests, indicates that there will be considerable variation the FA flow / DP even with the same debris addition. Every test has shown non-uniform blockages within the FA and gaps in the debris bed. This shows that the debris bed at one FA will be different from that in other FAs (i.e. they will be non-uniform).

The debris transport and dP buildup will occur gradually over a time much greater than the 8.6 hours assumed for LTC analyses in APP-PXS-GLR-001, Rev. 3. (refer to the response to RAI-SRP6.2.2-SRSB-40 for additional information on the time to maximum dP).

Throughout one FA the debris can also be distributed at locations in the FA above the bottom nozzle and P-grid. Some of the concurrent debris addition tests measured a dP at upper locations in the test FA, however this measured dP was insignificant in comparison to the total dP across the entire test FA length.

None of the FA testing has shown blockage in free-span portions of the test assembly. Evidence of uneven blockage was seen in the FA tests in the form of recirculation patterns around bore holes and gaps in the debris along the edge of the FA. These uneven blockages and cross flows have not produced blockages in free span sections of the assembly. Therefore crossflow within the core would not be impeded.

Just as non-uniform debris beds and non-uniform vertical debris distribution were observed in the FA testing, it is expected that the distribution of debris across the core inlet of all FAs will be non-uniform. Uniform blockage across the core inlet is the worst case. The debris is not expected to distribute uniformly across the entire core inlet and therefore some FAs will have more debris buildup than other FAs. The FAs with less debris buildup will experience less dP across the FA and will be able to pass more flow through those FAs. The higher flows through these low dP FAs would cross over to assist cooling FAs that have higher dP and lower flow at the core inlet.

The NRC has performed TRACE analyses (ADAMS Accession No. ML070860521) which show that crossflow through and around the rod bundles can exist in core areas where blockages do not exist. Crossflow in the reactor core downstream of the blocked inlet area provides sufficient flow and cooling to adequately maintain acceptable clad temperatures for all cases analyzed. The TRACE analysis was performed for a double ended cold leg break (DECLB) for the periods before and after the start of recirculation. Core Inlet blockage conditions were assumed to occur at the start of recirculation when cooling water is started to be pumped from the reactor water sump. An unblocked core inlet and three inlet core blockage conditions of 75%, 87.5% and 94.8% were analyzed. The analysis results using the TRACE computer code show that the PWR core can be sufficiently cooled in the recirculation phase with inlet blockage conditions up to 94.8%. Detailed three-dimensional CFD analyses of the PWR reactor core with three assumed inlet blockages were performed using the FLUENT computer code in order to verify the acceptability of the TRACE predictions, which employed a less detailed core model.

The non-uniform debris distribution observed in the AP1000 FA test program and the uniform core blockage assumptions of the NRC TRACE analysis both show that the non-uniform flow / DP conditions expected in the core will result in significant additional margin for core cooling because:

- The average FA debris bed resistance will be much lower than the maximum FA debris bed resistance because of the variability / non-uniformity of the FA debris bed resistances demonstrated in testing.
- Based on the margins shown between the test results and the current acceptance limits, the probability of the maximum FA debris bed exceeding the current acceptance limit is very low.
- Even in the low probability of the maximum FA debris bed resistance being higher in some FAs that the current acceptance limit, sufficient core cooling will occur as was demonstrated by the analysis of complete blockage of the inlet to most FAs.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
APP-GW-GLN-079 (TR26)

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP 6.2.2-SRSB-35
Revision: 0

Question:

RAI-SRP 6.2.2-SRSB-35: WCAP-17028-P, 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 determining the fuel assembly pressure drop has been provided.

Westinghouse Response:

The NRC document "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'," March 2008. [ML080230234]) was cited by Westinghouse for the guidance it provides the industry on the methods to use when introducing debris into a test loop to ensure that the most conservative head-loss testing would be achieved. Note that the guidance cited in the WCAP is not an 'approved approach for testing' since the approach taken for testing is entirely up to the licensee and includes things such as the test facility configuration, test article configuration, debris loads, and scaling.

The NRC does however provide industry with guidance to perform a conservative head-loss test by:

- indicating that particulate debris should be prototypically sized and thoroughly mixed prior to introduction.
- indicating that fibrous debris should be prototypically sized and thoroughly mixed and non-agglomerated prior to introduction.
- indicating that chemicals should be mixed outside of the test rig per WCAP-16530-NP-A to form particulates prior to introduction.
- indicating that strainer head-loss is very sensitive to debris introduction sequences and assumptions about debris composition.
- indicating that debris should be introduced in a specific order, either:
    - sequentially, with particulate, followed by fiber, followed by chemical or,
    - concurrently, with particulate, fiber, and chemicals simultaneously.

As with any guidance provided by the NRC, its use by licensees is not mandatory. Alternate approaches may be used if adequately supported and the NRC's regulations are met. Westinghouse cited the NRC guidance to help explain its justification for using both sequential and concurrent debris additions in its fuel assembly head-loss testing.

As stated in the NRC question, the cited guidance was issued for strainer testing: fuel assembly testing had not yet been initiated at this time. With respect to strainer head-loss testing, the guidance is generic regardless of the strainer manufacture or strainer type. There are many strainer vendors and many strainer designs to which this guidance is applicable. The bottom nozzle and protective grid used in current fuel designs is an effective strainer that will collect debris and cause a loss of driving head just as a recirculation strainer will. Since the guidance was intended to be used by industry for strainer head-loss testing, it is applicable to fuel assembly head-loss testing since the bottom nozzle and protective grid serve as effective strainers. Westinghouse cited the guidance on debris introduction in its fuel assembly head-loss tests.

The AP1000 head-loss test matrix provided in WCAP-17028-P, Revision 3 includes all of the necessary specific items noted above that are necessary to perform adequate head-loss testing but which are not expressed in the NRC guidance. Additionally, the test matrix also includes those items that the NRC provides to industry in its guidance on head-loss testing that are specifically identified to support closure of GL 2004-02 for their plants.

Data from the results of these experiments indicate that the test matrix assumed for AP1000 fuel assembly head loss testing provided the most conservative approach to determining the fuel assembly pressure drop. The testing included: a facility configured to simulate the AP1000; scaling based on the AP1000; the design basis amount of debris for the AP1000; sensitivities to varying debris loads including particulate, fiber, and chemical effects; sensitivity to debris addition sequencing; and sensitivities to flow rates, all explored to present the most comprehensive and conservative approach to determine fuel assembly pressure drop in the AP1000. The adequacy of the AP1000 fuel assembly test matrix is justified in WCAP-17028-P, Revision 3 in sections 7.0, 8.30 and 9.0.

Note that WCAP-17028-P will be revised to include the final tests performed for the AP1000 fuel assembly testing. The revised WCAP will provide the complete AP1000 fuel assembly test matrix.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-36
Revision: 0

Question:

RAI-SRP 6.2.2-SRSB-36: APP-PXS-GLR-001, Rev. 3

APP-PXS-GLR-001, Revision 3 provides seven (7) more long-term cooling (LTC) sensitivity cases (in addition to the 3 cases in Rev. 2), which were performed for a DEDVI break in a PXS room at 31,000 seconds (8.66 hours) after the break, using a window mode of the WCOBRA/TRAC calculation. The results of these sensitivity cases were used to establish the acceptance criteria for the fuel assembly head loss testing. It is described in Section 1 that the 8.66 hours bounds the nine (9) hours of elapsed time after DEDVI break initiation, which includes two (2) hours for water to flood up above a DEDVI LOCA at the RV, and an additional seven (7) hours to pass one containment water volume through the RCS so that the available debris has been transported from containment to block the core entrance.

Although at 8.66 hours the available debris has entered the core to result in the maximum core inlet flow resistance, the decay heat is also lower. Provide an evaluation of the earlier times with a combination of higher decay heat and lower core inlet flow resistance to demonstrate the LTC sensitivity cases at 8.66 hours are indeed the limiting cases.

Westinghouse Response:

The response to RAI-SRP 6.2.2-SRSB-40 explains why the 8.6 hours assumed for the LTC sensitivity cases is conservative, since the FA test program results show that the peak dP for the FA tests occurs at least 18 hours after the LOCA. LTC Sensitivity Case 10 is conservative for core inlet blockage after recirculation starts since Case 10 is performed in a window mode at 8.6 hours post-LOCA with the assumption that all of the debris is present at the core inlet in order to impose the maximum core inlet dP.

Sensitivity cases with the same core inlet resistance but at earlier times are not needed. Although the decay heat will indeed be higher before 8.6 hours, the maximum debris buildup with the maximum dP has been shown through experimental testing to occur after 8.6 hours.

Therefore the acceptance criterion of 4.1 psid at 3.1 gpm/fuel assembly (FA), which is based upon LTC sensitivity study Case 10 applies to all FA tests (sequential debris addition and concurrent debris addition) since this pressure drop represents the largest core head loss modeled.

However, for the concurrent debris addition FA tests, the tests were set up in order to model the plant timing of debris addition after the start of recirculation. In contrast, the sequential debris addition tests were set up to determine the maximum dP value that would be achieved under the test conditions. Since the concurrent debris addition FA tests account for plant timing, then the maximum dP result from those tests requires a second acceptance criterion to apply to times less than the 8.6 hours used in LTC Sensitivity Case 10. LTC Sensitivity Case 3 occurs at the start of recirculation for a DVI LOCA at 7200 seconds into the transient. Case 3 presents a minimum core inlet flow of 111 lbm/sec at 3.5 psid. This was converted to an acceptance criterion of 3.5 psid at 5.3 gpm/FA for the test program. This window of the LTC analysis is at 7200 seconds and therefore contains the highest decay heat value within the 7200 seconds to 8.6 hours timeframe. This acceptance criterion can be applied to the concurrent debris addition FA tests and provides a means of evaluating the debris-induced dP when the decay heat is higher compared to the Case 10 acceptance criterion.

Therefore applying the Case 3 acceptance criterion to the concurrent debris addition FA tests provides a method of determining the acceptability of the test dP at a time before 9 hours. This acceptance criterion is applicable to the concurrent debris addition tests because those tests add debris based upon the sequence of events that occur in an AP1000 during a LOCA where the maximum dP would occur after 9 hours into the transient. This acceptance criterion is not applied to the sequential debris addition tests since those tests do not add debris in a fashion based on the timing that occurs in the plant.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
APP-GW-GLN-079 (TR26) to add discussion on acceptance criteria based on the above.

WCAP-17028-P, Rev. 4 will clarify the existing discussion of the two acceptance criteria for concurrent debris addition tests. More explanation to be added for Tables 9-1 and 9-2.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-37
Revision: 0

Question:

RAI-SRP 6.2.2-SRSB-37: APP-PXS-GLR-001, Rev. 3

In section 3, it is stated (for Cases 4 through 10) that the window mode technique described in WCAP-15644, Revision 2, is employed together with the appropriate containment boundary conditions as computed with WGOTHIC. It also indicates the prevailing containment pressure of 16 psia at 31,000 seconds.

Provide the values of other input boundary conditions, such as decay heat, sump liquid level and temperature, and the fluid temperature and level in the reactor vessel, and how they are obtained for the window cases at 8.6 hours. It is recognized by the staff that some of these parameters have been provided in previous submittals, but it is desirable that we see the completed table with the above parameters provided in one table.

Westinghouse Response:

Sensitivity cases 4-10 of APP-PXS-GLR-001, Revision 3 are performed at a time 31,000 seconds into a DEDVI break, with various added core entrance resistances applied to consider possible effects of debris. The decay heat applied in each case is the 1971 ANS Infinite +20% (10CFR50, Appendix K) standard value of 0.00959 times the AP1000 normal, full-power operation core power. This is equivalent to a core linear power value of 0.057 kW/ft.

As indicated in Table 4-1 of APP-PXS-GLR-001, Revision 3, two different DEDVI break locations were analyzed. Sensitivity Cases 4, 5, and 7 model the break to occur in the PXS Room, while Cases 6, 8, 9 and 10 locate the break inside the containment reactor coolant system (RCS) loop compartment. The containment sump liquid levels shown in the attached table are calculated in separate floodup calculations performed for the two break locations. The input sump liquid temperature values are taken from separate WGOTHIC analyses performed for the two break locations. Therefore, the tabulated containment boundary conditions input to the sensitivity calculations are specific to the assumed DEDVI break location. When the break occurs in the PXS Room, that room becomes filled with the liquid draining from the IRWST, and the broken DVI line is supplied with that liquid at the PXS Room temperature indicated. When the break occurs in the RCS loop compartment, the containment sump liquid is the source of the water delivered through both DVI lines; the PXS Room remains empty of water as the loop compartment receives the IRWST drain liquid, leading to a cooler temperature in the containment sump.

The fluid temperatures and liquid levels in the reactor vessel are computed values calculated by WCOBRA/TRAC based on the specified boundary conditions. The best presentation of collapsed liquid levels in the reactor vessel is found in the pertinent figures within the report itself; for instance, Figures 3.5-1, 3.5-2 and 3.5-8 show the collapsed liquid levels for Sensitivity Case 5 for the reactor vessel downcomer, core, and upper plenum, respectively. The reference zero elevation for the upper plenum level is the bottom of the upper core plate. Note that in all sensitivity cases the two-phase mixture level extends all the way to the hot leg location in the vessel upper plenum upward from the saturation elevation of the liquid in the core, and that the temperature of the two-phase fluid is the saturation temperature. The core inlet liquid temperature values from the sensitivity cases are provided in the attached table, along with the other requested parameters.

Table 1: Parameters from APP-PXS-GLR-001, Rev. 3 Sensitivity Cases 4 through 10

Case No.	DEDVI LOCA Break Location	Sump Liquid Level, feet	Sump Liquid Temp, deg. F	PXS Room Temp, deg. F	Core Collapsed Liquid Level, ft.	Upper Plenum Collapsed Level, ft.	Core Inlet Liquid Temperature, degrees F
4	PXS Room	107.8	200	144	7.62	1.47	194
5	PXS Room	107.8	200	144	7.29	1.38	197
6	RCS Loop	108.6	175	N/A	7.22	1.37	200
7	PXS Room	107.8	200	144	7.12	1.30	199
8	RCS Loop	108.6	175	N/A	7.04	1.27	203
9	RCS Loop	108.6	175	N/A	6.93	1.20	206
10	RCS Loop	108.6	175	N/A	6.86	1.09	208

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

RAI Response Number: RAI-SRP6.2.2-SRSB-38
Revision: 0

Question:

APP-PXS-GLR-001, Rev. 3

The sensitivity case 10, which has the highest core inlet resistance due to debris, and is used to establish the acceptance criteria for the fuel assembly head loss tests, is the DVI line break in the loop compartment.

Since a DVI break in the PXS room results in a lower water floodup level and higher broken loop flow resistance, explain why the DVI line break in the PXS room is not chosen for the limiting case. Provide a description of the break event progression for the DVI break in the PXS room versus the DVI break in the loop compartment.

Westinghouse Response:

On page 10 of this document is a discussion that describes why a DEDVI LOCA is limiting for the debris DP sensitivity studies. This discussion also provides information that indicates that a DEDVI break in a loop compartment is more limiting that a break in a PXS room. The following provides an expansion of this discussion.

- The flow split between recirculation through the break and the PXS is greater for the loop compartment break such that more water can enter the RCS unfiltered. For example, a DEDVI break in a loop compartment can have 75% of the recirculation flow through the break. Note that a DECL break has been evaluated to have up to 90% flow through the break. On the other hand a DEDVI break in a PXS room can only have 60% flow through the break. This means that without considerations for access to debris (addressed in next bullet) that a PXS loop compartment break will have at least 50% more debris transported into the RCS / core.

- A break location in a loop compartment is assumed to have access to all of the latent debris in the containment. However, a break in a PXS room will have access to much less latent debris. The reason is that the only fiber debris that can be transported into the break is what was originally in the PXS room. All of the flow that enters the room from the IRWST and from the containment will pass through screens which will remove almost all (99%) of the fiber. Since a PXS room has a very small portion of the total containment surface area, it will have a very small portion of the latent debris.

- A DVI LOCA in a loop compartment and in a PXS room have the same connection elevation into the reactor vessel. As a result, they will have the same impact on drain down of water out of the RCS. Note that blowdown through the break located at the RV will be somewhat larger because of its lower resistance; this makes the break at the RV somewhat worse from this point of view.

- A DEDVI LOCA results in higher decay heat than for a CL LOCA because the spill of IRWST directly to the containment causes the IRWST to reach the low level recirculation initiation setpoint earlier.
- A DEDVI LOCA in a PXS room results in a larger containment flood volume and as a result a lower flood level. For example, a DVI LOCA in a PXS room results in a flood level of 107.8' where as a loop compartment LOCA results in a 108.6' flood level.

The final bullet is the only one of the above items where the PXS room break location is more limiting that a loop compartment break location. The other items more that out weight this item based on the following discussion. This is especially true for the first 2 debris transport items which show that the amount of fiber that could be transported into the RCS from the PXS room break is so limited. AP1000 fuel assembly debris tests with small amounts of fiber (tests #1, 2, 4) show that there was no DP; the DP associated with the amount of fiber available to a loop break is several psi.

In addition, the impact of the PXS room conditions vs the loop break conditions is minor. This can be seen by comparing sensitivity cases 7 and 8. These cases assumed the same core inlet resistance. Both allowed adequate core cooling. The only difference was that the ADS 4 vent quality was slightly higher for the PXS room break case (42% vs 41%).

The following provides a description of a DEDVI LOCA in a PXS room and also in a loop compartment. Note that the two events generally proceed very similarly as follows:

Sequence of Events for DEDVI LOCA in PXS Room and Loop Compartment

	Event	PXS Room (sec)	Loop Comp (sec)
1	Reactor trip on low pressurizer pressure	13	same
2	Safety injection signal on low pressurizer pressure	19	same
3	Reactor coolant pumps tripped on SI signal plus time delay	25	same
4	ADS stage 1 opens	183	same
5	ADS stage 2 opens	253	same
6	Intact accumulator injection starts	254	same
7	ADS stage 3 opens	373	same
8	ADS stage 4 opens	493	same
9	Intact accumulator empties and significant CMT injection starts	600	same
10	IRWST injection starts	1470	same
11	Intact core makeup tank empties	2123	same
12	Recirculation back through break starts	1000	2700
13	Recirculation through PXS starts	6800	7000

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
APP-PXS-GLR-001, Rev 3, will be revised to include the additional discussion shown above on why the DEDVI LOCA in the loop compartment is more limiting.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP 6.2.2-SRSB-39
Revision: 0

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? Provide the validation report that documents the validation and verification of WCOBRA/TRAC at these low flow rates, low pressure and low liquid qualities. 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.

Westinghouse Response:

For AP1000 long term core cooling, the WCOBRA/TRAC modeling was validated against selected G1 (Reference [2]) and G2 (Reference [3]) boiloff tests as discussed in Reference [4] Section 2.3.3. The selected G1 test runs were 28, 35, 38, 58, and 61; and G2 test runs 728, 729, 730, 732, 733 and 734. The WCOBRA/TRAC validation of the selected G1 and G2 test results for AP1000 long term core cooling compared the calculated and measured core level swell, which is a measure of the average core void fraction and an integral assessment of the interfacial drag model. Reference [4] page 2-10 shows the relationship between the level swell and the average void fraction. The adequacy of the code prediction was shown in the Reference [4] Figure 2-6 and Figure 2-7 results. Applying a multiplier (YDRAG=0.8), WCOBRA/TRAC predicts the core level swell to within ± 20% of the measured test data. In the AP1000 debris sensitivity cases, YDRAG was set to 0.8. The WCOBRA/TRAC AP1000 sensitivity study cases are performed with modeling consistent with the validation calculations of the low pressure, low flow G1 and G2 tests.

Reference [4] page 2-9 provides the range of test conditions of interest in these selected G1 and G2 tests. Table 1 summarizes the corresponding ranges from the AP1000 debris sensitivity cases (Reference [1]). Comparing Table 1 and Reference [4] page 2-9 shows that the conditions from the AP1000 debris sensitivity cases are within the range of the G1 and G2 test data validation and/or non-debris AP1000 long term core cooling calculations. As discussed in

Reference [4] page 2-8, 2-9, since the G1 and G2 series were boiloff tests with core exit steam quality approximately 1.0, they represent more limiting conditions with respect to core cooling than the long term core cooling sensitivity calculations where the maximum exit quality was approximately 50% (case 10).

Based on this comparison, the sensitivity study cases with high core flow resistance which result in low core flow are within the range of applicability of the WCOBRA/TRAC code for AP1000 long term core cooling analysis.

Table 1. Range of Conditions of Interest from AP1000 WCOBRA/TRAC Debris Sensitivity Cases *

AP1000 Sensitivity Case	Upper Plenum Pressure (psia)	Power (kW/ft)	Core Flow (lbm/s)	Corresponding Core Velocity (in/s)	Core Inlet Subcooling (°F)
1	22	0.08	145.6	0.7	50
10	18	0.06	65.0	0.3	20

* Debris sensitivity cases 1 and 10 are selected as they bound the range of conditions observed in the debris sensitivity results presented in Reference [1].

References:

1. APP-PXS-GLR-001 Revision 3, "Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris," November 2009.
2. WCAP-9764, "Documentation of the Westinghouse Core Uncovery Tests and Small Break Evaluation Model Core Mixture Level Model," July 1980.
3. Andreychek, T. S., "Heat Transfer above the Two-Phase Mixture Level under Core Uncovery Conditions in a 336 Rod Bundle," Volumes 1 and 2, EPRI Report NP-1692, January 1981.
4. WCAP-15644-P Revision 2, "AP1000 Code Applicability Report," March 2004.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None