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Our ref: DCP_NRC_002627

September 22, 2009

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-CIB1-24
RAI-SRP6.2.2-CIB1-25
RAI-SRP6.2.2-SPCV-19 R2
RAI-SRP6.2.2-SPCV-21
RAI-SRP6.2.2-SPCV-22
RAI-SRP6.2.2-SPCV-23
RAI-SRP6.2.2-SPCV-24
RAI-SRP6.2.2-SRSB-16
RAI-SRP6.2.2-SRSB-21
RAI-SRP6.2.2-SRSB-22
RAI-SRP6.2.2-SRSB-23
RAI-SRP6.2.2-SRSB-24

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,

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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D063
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-CIB1-24
Revision: 0

Question:

Head-loss testing for the recirculation screens and fuel assemblies indicate a significant head loss may occur due to a filtering debris bed. Under these conditions the assumption in the AP1000 DCD about coatings debris size and transport needs to be reconsidered. The AP1000 previously assumed a minimum chip size equal to the strainer opening size. Fine particles were assumed to be inconsequential on the basis that they would either settle before reaching the recirculation screens or travel freely through any downstream openings. In the guidance for coatings evaluation at operating plants, all coatings in the zone of influence fail as fine particles of the order of 10 to 100 micrometers (due to erosion) and are transported to the screen. In the guidance no credit is taken for settling of fine particles. (The guidance is Enclosure II to Content Guide for GL 2004-02 Supplemental Responses, March 2008)

Given these recent results for the AP1000 head loss testing, please provide the following information related to protective coatings debris in containment:

a. Identify the zone of influence being used by AP1000 for generation of coatings debris. If this value is less than in the coatings evaluation guidance referenced above, provide the justification.

b. Provide a summary of the coatings in containment and how they are affected by the LOCA jet (i.e., the amount of debris generated). For example, it is the staff's understanding that the interior surface of the containment shell would be characterized as a qualified IOZ coating, outside the ZOI, and therefore assumed to remain intact during a LOCA. What is the quantity of coatings located on equipment, interior walls, pipes, etc. that will be destroyed by jet impingement.

c. If you intend to use the industry test data on debris size for epoxy/inorganic zinc systems (Keeler & Long Report No. 06-0413), provide the justification for how this data applies to the AP1000 coatings. This is necessary because the NRC staff guidance states that this data applies only to degraded qualified coatings outside the zone of influence (all coatings inside the ZOI, and unqualified coatings outside the ZOI, are assumed to fail as particulate). The Keyler & Long test data shows that for coatings exposed to simulated LOCA conditions outside of the zone of influence IOZ coatings fail as particulate, but epoxy that was applied as a qualified coating remains in chip form.

d. Summarize your treatment of coatings transport for the types of coating debris predicted. If you determine that less than 100 percent of coating fines will arrive at the strainer surface, provide the basis for that settlement fraction. The testing documented in NUREG/CR-6916 evaluated transport over a range of coating density, chip size, and fluid velocity.

Westinghouse Response:

a. The spherical equivalent radius of the zone of influence (ZOI) used by AP1000 for generation of coatings debris is:

Coating	Spherical Radius
For untopcoated inorganic zinc (IOZ)	5 x Break Diameter (5D)
For epoxy coatings	4 x Break Diameter (4D)

The ZOI's used for generation of coatings debris will be included in APP-GW-GLE-002 Rev. 4 which will be reflected in the next revision of the DCD. These ZOIs are consistent with the NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Coatings Evaluation, March 2008, page 3.

b. A complete summary of the coatings used inside the AP1000 containment requires, in part, knowledge of the surface areas of coatings applied to OEM equipment that will be installed inside the containment. Since this will not be known until the components are purchased this list can not be finalized at this time.

A conservatively large limit for the ZOI generated coating debris has been established for the AP1000. During the design and construction of the AP1000, the coatings applied within the ZOI will be tracked to ensure that they are less than the allowance. This limit addresses both IOZ and epoxy. It is based on the ID of the largest LOCA pipe in the AP1000 that can flood and allow significant bypass of fiber debris into the core. The largest such line is a cold leg loop pipe with an ID of 22 inches.

The only larger LOCA pipe is the hot leg. The hot leg LOCA has been evaluated and shown to not limit the debris loading on the core or the screens. In this evaluation it was assumed that the ZOI coating amount for a HL LOCA would be twice that of a CL. This is based on using the same approach used on the following page to estimate the CL ZOI coating amount. This results in a HL ZOI coating amount that is less than 100 lb. The HL LOCA is not limiting for the core or screen debris loading for the following reasons:

- For the core, a HL LOCA will potentially allow fiber to be transported into the RCS but in this case it will at worst settle on top of the fuel assembly. In this sequence, no fiber will be transported to the core inlet and challenge the head loss across the core. For this reason the added particles that could be generated by a HL LOCA (as compared to a CL LOCA) would not increase the limiting FA debris head loss.
- The containment recirculation screens could see extra ZOI generated particle debris however, the surface area of these screens is so large that the addition of

the 50 lb of additional particles associated with a HL LOCA will not cause its head loss to be greater than the test results which were based on the IRWST screen conditions. The following provides a comparison of the limiting CR and IRWST screen conditions.

	CR	IRWST (test)
Number Screens Operating	2	1
Surface Area, Total (ft2)	5000	500
Debris Load, Fiber (lb) / (ft2/lb)	6.6 / 758	3.3 / 151
, Particles (lb) / (ft2/lb)	173.4 / 29	173.4 / 2.9
, Chemicals (lb) / (ft2/lb)	57 / 88	57 / 8.8
Flow Rate (gpm)	827	410
(ft2/gpm)	6.0	1.2

From this comparison, it can be seen that even if the CR particle load was increased by 50 lb, the IRWST screen would still have a much larger particle load per area. Considering that the other parameters (fibers, chemicals and flows) are higher, the IRWST screen head loss will be larger than for the CR screens. The extra ZOI generated particles will not result in the CR screen head loss being increased above the test results.

- The IRWST screens will have less fiber transported to them than the assumed 50% fiber because a HL LOCA will wash less of the operating deck to the gutter / IRWST than a LOCA such as one on top of the Pressurizer. In addition, both IRWST screens will be operable in a HL LOCA such that the fiber load per screen will be less than ½ of what has been tested. The extra ZOI generated coating particles will not affect the limiting IRWST screen head loss.

The amount of surface area within a ZOI of 4 IDs of a CL pipe is not specifically known at this time because the design is not finalized and because there will be some coatings on engineered components. As an alternative, a functional requirement has been established in a similar fashion to the way aluminum is being limited in the AP1000 to limit chemical debris. For epoxy coatings, a surface area equal to 3 times the inside surface area of a sphere with a diameter equal to 4 times the ID of the CL ID of 22 inches or 88.0 inches is assumed to be coated with epoxy. This assumption has been compared to what has been determined for operating plants and is conservative. The surface area of this sphere is 169 ft2. Three times this area is 507 ft2. With a coating thickness of 6 mils and a dry film density of 125 lb/ft^3, there would be 31.7 lb of epoxy debris.

IOZ within a radius of 5 IDs will be assumed to be damaged by the LOCA jet and turned into fine particles. The amount of IOZ is approximated differently than the epoxy because the amount of IOZ allowed in the AP1000 (other than the containment vessel)

is being limited to hot surfaces on engineered components (where epoxy coatings are not practical) as discussed in the following paragraphs. As a result, it is assumed that the amount of transportable particulate debris produced by IOZ is 10 lb.

The total epoxy and IOZ is then 31.7 + 10 = 41.7 lb. This amount is conservatively rounded up to 50 lb for operating margin.

The total amount of latent debris allowed in the AP1000 will be reduced by 20 lb so that the increase in the total amount of debris particles is not so large. As a result, the total amount of latent debris allowed in the AP1000 will be reduced to 130 lb. Note that at least 7 plants have used values as low as this or lower in their GSI-191 assessments, the lowest being 77 lb. The total amount of fiber and particle debris will then be increased to 180 lb. This increase is not expected to affect the head losses across the fuel assembly and the screens, however confirmatory testing will be performed to confirm this.

Changes will be made to the DCD in section 6.1.2.1, Table 6.1-2 and in 6.3 that will:

- Limit the use of IOZ to components where surfaces are hot enough to preclude the use of epoxies. IOZ used on components will also be required to be safety – service level I to prevent coating failure outside the ZOI which may not settle out due to the small particle size,
- For epoxy coatings, self-priming high solid epoxy will be used and the use of epoxy top-coating of IOZ will be eliminated (for same reason as the previous item),
- Reduce the latent debris total weight to 130 lb and allow for 50 lb of ZOI coating failure debris. The limit of 50 pounds of ZOI coatings will be tracked during procurement and operation. The total debris (fiber and particle) is therefore limited to 180 lb.

Changes will also be made to the ITAAC in Table 2.2.3-4, item 8.c, sub-item x)

- Requires IOZ used inside containment to be safety – service level I.

Additional changes will be made to update WCAP-17028 (FA) and WCAP-16914 (screen) to include the test results that confirm the increase in particles is acceptable. Note that these confirmatory tests will include increases in the debris load to cover the increase in ZOI particles plus some additional margin.

c. The use of industry test data on debris size for epoxy coating systems (Keeler & Long Report No. 06-0413) is reasonable for the AP1000 outside the ZOI for the following reasons:

- The epoxy coatings used in the AP1000 containment on walls, floors, ceilings, columns, beams, braces, or plates will be purchased as DBA Qualified epoxy

material as described in DCD section 6.1.2.1.6. This ensures that the basis material is consistent with the material used in the Keeler & Long tests.

- The epoxy coatings used in the AP1000 containment on OEM equipment will be specified as the same material as DBA Qualified epoxy material but without the paperwork. This provides reasonable assurance that the basic material is consistent with the material used in the Keeler & Long tests.
- The DCD (6.1.2.1.6) requires that a COL program be defined for the application, inspection and monitoring of non-safety – service level II coatings.
- The AP1000 coating specifications require that industry standards for application and initial inspection will be followed. Commitments to follow these procedures are incorporated into AP1000 procurement specifications. Adherence to these requirements is covered by the QA applicable to each component which is the industry standard QA required by AP1000 procedures.
- Section 8 of the Keeler & Long report shows photographs provided on a CD that show that the degraded coatings do not all fail as particulate.

d. In summary, all of the ZOI damaged coatings are assumed to fail as fine particles and 100% of them transport to the screens or to the core. A limit of 50 lb of such coating fines has been set as a limit for the design; this limit is conservative relative to operating plant ZOI amounts. This ZOI limit has been added to the DCD as a limit that will be tracked during the procurement and construction of the AP1000. The latent debris limit has been reduced by 20 lb and the total amount of debris has been increased to 180 lb which includes 130 lb latent debris and 50 lb ZOI generated coating debris.

Epoxy coatings outside of the ZOI are assumed to fail as chips. 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.

Design Control Document (DCD) Revision:

The DCD changes will be included in APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision:

The following reports will be revised as a result of this RAI:

- APP-GW-GLR-079, Revision 4, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA"
- APP-GW-GLE-002, Revision 3, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"
- WCAP-16914, Revision 2, "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens"
- WCAP-17028, Revision 2, "Evaluation of Debris-Loading Head-Loss Tests For Assemblies During Loss of Coolant Accidents"

The current revision of the two debris test reports is revision 1. It is anticipated that these reports will be revised in September 2009 to address clarifications and corrections. This will be revision 2 for both of these documents. Incorporation of the confirmatory test result will be done in the next revision (revision 3).

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-CIB1-25
Revision: 0

Question:

TR-26 indicates that for addressing downstream effects, the fully open squib valves have characteristics similar to a standard gate valve. However, please address the potential differences that may exist for the final squib valve design, especially in the larger, deeper crevices or cavities that the squib valves may have where debris and possible propellant residue/chemicals could interact and get caught, buildup, and eventually impede the recirculation flow through the valves. Also, please provide an evaluation of any other effects on downstream components from the propellant residue/chemicals that enter the recirculation coolant.

Westinghouse Response:

There are two questions here. 1) Explain the differences between the squib valve and a gate valve and 2) Evaluate the effects of the propellant by-products on the downstream components.

1) The 8" squib valve is a normally closed valve. It can not be closed once it is actuated /opened with out being removed from the line and refurbished. Its flow path is similar to a gate valve after is actuated in that there is a straight through flow with a crevice in the flow path. The diameter of the flow path through the low pressure 8" squib valve is approximately 7.3". This vale is connected to 8" schedule 40 pipe with an ID of 7.981". So the ID inside the squib valve is greater than 90% of the pipe ID. In addition, the interior of the squib valve tapers gradually from the pipe ID to the minimum valve ID. A gate valve has a similar interior shape and a similar or smaller ID. The squib valve crevice is approximately 2" deep by 5.5" wide compared to a gate valve crevice that is approximately 1.5" deep by 3.5" wide.

   Since the squib valves have no function to close, only transferring open and remaining open functions need to be evaluated. In addition, since the connecting pipe sizes are large, the minimum ID is a very large percentage of the pipe ID and the taper is gradual there seems to be no way that latent fiber and particles debris can span the large straight through opening in either type of valve (squib or gate). The crevice may trap some debris but again with the large straight through opening, there seems to be no way that latent fiber and particles debris can build up to the extent that they protrude in any significant way into the large straight through opening in either type of valve (squib or gate). Therefore, it is concluded that neither squib valves nor gate valves can have their flow paths restricted by latent debris.

2) There are a total of twelve (12) in-containment squib valves in the AP1000 plant, each containing less than approximately 300g of propellant in which potassium is the predominant constituent. Conservatively, assuming that the entire inventory of propellant byproducts initially enters the post-accident recirculating coolant, the resulting concentration of potassium, based on the minimum post-LOCA sump volume, is ~0.5 ppm (0.5 mg/L). This value is bounded by the potassium values reported in the integrated chemical effects testing (NUREG/CR-6914, "Integrated Chemical Effects Test Project", Vol. 1-6) and is well below the solubility limits of the potassium salts that would be expected in the recirculating coolant. Also, by way of comparison, the soluble sodium concentration, which is chemically similar to the potassium, as a result of trisodium phosphate buffering in the containment sump, is calculated to be approximately 1800 times greater than the potassium concentration.

   Because the resulting concentration of potassium is below the solubility limits for the most likely potassium salts, and is bounded by the potassium values measured in the ICET testing, the impacts to the post-LOCA downstream components are considered negligible. The remaining constituents of the propellant include gases (CO_2, N_2, O_2, CO, & NO) present in concentrations much lower than the potassium concentration and therefore will have no impact on the post-LOCA environment.

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-SPCV-19
Revision: 2

Question: (Please add in the Revision 1 additional question)

The response to RAI-SRP6.2.2-SPCV-11 states that the screen is able to withstand the affect of large debris, and item C-1.1.1.6 in the AP1000 RG 1.82 Assessment Matrix states that the screens are designed to withstand a significant head loss. What specific analysis is available to support these statements?

Additional Question: (Revision 2)

a) Please explain the source of the Pressure, Temperature, and Design Flow values provided in the Rev. 1 response.

b) The Response suggests that because the design spec flow rate is 51% higher than the DCD specified flow rate, it is possible for large debris to reduce the overall screen area by 51% and still support the DCD specified flow. The staff believes having less than the designed screen area available during operation would increase the velocity and increase the pressure drop due to debris over the design basis. Please explain how the design flow rate is used in the design spec. The reduced area essentially represents a sacrificial screen area, which was not included in scaling for head loss testing. Please explain if the component analysis is taking credit for a sacrificial screen area due to large debris.

c) Response did not identify the design spec requirement for head loss. Please demonstrate how screens are designed to withstand head loss resulting from debris loading.

Westinghouse Response: (Revision 1)

The Revision 1 response is retracted because it did not specifically address the staff's question, it provided extraneous and non-essential information.

Additional Response: (Revision 2)

A) The response to Revision 1 has been retracted; therefore the pressures, temperatures and flows have not been provided. The response related to the requirements for head loss are provided in Part c).

B) The response to Revision 1 has been retracted; therefore no additional information on this item is provided. The response related to the requirements for head loss are provided in Part c).

C) The design of the PXS screens will consider two factors with respect to head loss.

1. Ensure that the head loss with the limiting debris load and flow rates is less than what has been shown to be acceptable in long term core cooling sensitivity studies.
2. Ensure that the screen structure and supports can withstand the limiting forces that can be placed on the screens. In this consideration, several flow / DP conditions will be specified. Note that some of these cases will include higher flows and head losses than will be specified for the evaluation of LTC (in the above item).

The reason for this approach is to ensure that the head loss is acceptably low with the limiting flow rate used in the LTC sensitivity studies and also to ensure that the structural design of the screen and its supports are sufficiently strong.

For the LTC head loss limits the conditions listed in WCAP-16914 will be used to define the debris loads, flow rates and allowable head losses.

Preliminary IRWST screen limiting conditions for LTC:

Number screens	1	
Amount of fiber	3.3	lb
Particles	173	lb
Chemicals	57	lb
Flow rate	410	gpm
Max DP	0.26	psi

For structural design of the screens, arbitrary margin is added to the debris masses, flow rates and DPs to add appropriate margin to the structural design of the screen and its supports.

Preliminary IRWST screen requirements for structural design:

Case	Max Forward		Max Reverse	
Number screens	1		1	
Weight total debris	250	lb	†	
Flow rate / direction	2500	gpm (forward)	6000	gpm (reverse)
Max DP[1]	5	psi	1	psi

† For the reverse flow case, debris and chemicals will be filtered through the CR screens prior to entering the IRWST screens. Some debris and chemicals will transport through the CR screens but this will be a very small amount compared to the debris loading for the forward flow case and will not challenge the structural capabilities, or the allowable DP requirements for the IRWST screens.

Once the licensing activities are finalized, such parameters will be incorporated into the screen design specifications used for procuring the screens.

Since these screens have been installed into operating PWRs that use active safety systems with higher flow rates and DPs it is expected that there will be no difficulty in designing the AP1000 screens to meet such loads. In addition, preliminary analysis performed for the AP1000

screens also confirms this to be the case for the AP1000 conditions. However, the final analysis will not be available until after a purchase order is placed for these screens.

Given this situation, it is proposed that an ITAAC be written to cover the structural design of the screens. Note that there already is an ITAAC (Table 2.2.3-4, item 5.a) that covers the seismic design of the PXS screens. It is proposed to add to sub items ii) and iii) of that ITAAC that a report exist and conclude that the screens can withstand the post accident operating loads including head loss and debris weights.

Westinghouse Additional Response from Comments Received from the NRC on 9/2/09:

At the Westinghouse meeting with the NRC in Rockville, MD on September 2, 2009 the staff requested that this RAI response be revised to clarify the allowable DP of 5 psi is in addition to the DP associated with sparger actuation.

The actuation of the sparger will occur during discharge of ADS 1, 2,3 valves. Test A3 conducted at the ENEA's VAPORE facility showed the maximum pressure exerted on the IRWST walls during a sparger actuation of 400lbm/s steam. The pure steam blowdown caused the highest pressures exerted on the IRWST floor directly below the sparger arm during sparger actuation. The test results can be found in WCAP-13891 Rev. 0. Additionally, the tests simulated a sparger steam flow of 400lbm/s. This flow more than bounds the actual calculated maximum steam flow of 145 lbm/s for the AP1000 (APP-ME02-Z0C-001 Rev. 0). The nominal hydrodynamic load exerted during the above mentioned sparger test was approximately 0.35 bar or 5.07 psig. Given the steam flow was more than 2.7 times the actual design flow this bounds the structural design requirement for DP mentioned above.

The sparger load is in addition to the hydrodynamic loads experienced during IRWST injection, and the DP associated with debris loading. However, it is very unlikely that sparger actuation will occur coincident with IRWST injection as the sparger actuation comes from the ADS 1, 2, 3 discharge. IRWST injection cannot occur until the pressure in the RCS drops below the hydrostatic pressure exerted on the IRWST water due to the level in the tank. This only occurs after ADS 4 has been actuated.

Design Control Document (DCD) Revision: (Revision 1)

The DCD changes will be included in a revision to APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision: (Revision 1)

The following report will be revised as a result of this RAI:

- APP-GW-GLE-002, Revision 3, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SPCV-21
Revision: 0

Question:

WCAP-16914 Revision 1

a) The maximum flow rates identified in Table 5.2 are based on PXS operation after a DVI break in PXS room B, but these values are less than those provided in Table 1 of the Response to RAI-SRP6.2.2-SPCV-16(c), Revision 1, which describes the same event. Please explain the discrepancy and characterize the values extracted from the sensitivity report as average or bounding flows. Justify why the lower flow rates in Table 5.2 bound all PXS flow rates, including how IRWST flow to the broken line bounds IRWST flow through an intact line and how DVI flow through the intact line bounds flow through recirculation screen (RAI response shows recirculation screen flow is higher than DVI flow as recirculation screen also backflows to IRWST). Provide the source for the values used in the RAI response. Note 2 to Table 5.2 describes RNS initial injection from cask loading pit. Provide timing for when RNS injection switches from cask loading pit to IRWST.

b) DCD, Tier 2, Section 6.3.2.2.7.1 item 12 states that acceptable head losses have been demonstrated for the screens considering the maximum flow rate from operation of either the PXS or the RNS while the head loss tests were based on the lower flows from only PXS operation. The test report stated that the flow can reach the higher levels identified in the DCD if the RNS is operating, but that "the RNS does not have to operate in the unlikely event that the CR (or IRWST) screens collect the design amount of debris and that results in a higher head loss." The staff interprets this statement to mean that the head loss testing did not bound operation of the RNS system, as required by the DCD. How will the DCD requirement to encompass RNS operation be reconciled to head loss testing performed using lower flow rates?

c) While the Westinghouse response to RAI-SRP6.2.2-SPCV-16 (f) stated that the test report would explicitly describe the fiberous debris preparation process and include pictures of the fibers in suspension, the staff did not find this in the report. Please provide this information, including if any fiber agglomeration was observed during debris addition.

d) In order to determine that the test was appropriately terminated, please describe the test termination criteria.

e) Item 2 on page 6-2 states that the initial water depth was 52.5". Please provide the actual height of the test screen so that the staff may evaluate if the modeled submergence is representative of the AP1000 plant.

f) The resultant pressure drop across the screen is greater than the submergence of the IRWST screen, so flashing may be expected per item 14 of "NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and

Vortexing." Please provide a flashing analysis, including details on use of containment accident pressure in the evaluation. If containment accident pressure was used, summarize the methodology used to determine the available containment pressure.

g) How were differences in flow rates and temperatures between sensitivity study and testing captured in pressure limit for testing?

Westinghouse Response:

a) WCAP-16914, Revision 1, lists the PXS flow rates through the IRWST screens and through the containment recirculation screens. The IRWST flows are listed for both injection and for recirculation. The notes associated with this table describe the basis for each condition. The initial flow through the faulted DVI line will tend to be somewhat higher because the back pressure will be containment pressure which will be lower than the RCS pressure. However, the head loss through the screen will not affect core cooling. In fact, if the head loss across the screen connected to the spilling line is high it would make the analysis results better since it would reduce the rate at which the IRWST spills / drains, which would delay the time when recirculation would start. Also note that the screens will be designed to withstand (from a structural point of view) higher flowrates (see response to RAI-SRP-6.2.2-SPCV-19 Rev. 2).

RAI-SPCV16 lists the maximum IRWST screen flow rate during the initial injection of 1300 gpm. This flow rate is based on the DCD LTC analysis (see figure 15.6.5.4C-13). A nominal initial IRWST injection flow through the intact DVI line is about 175 lb/sec, which would be about 1280 gpm at 141 F. This flow was rounded up to 1300 gpm.

Note that the reason the RAI had a higher flow rate is that it used the LTC results from the DCD which cannot occur when significant head loss exists across the screens / core. Therefore, the flow rates listed in the WCAP are the values that should be used when testing screen or core head loss with debris.

The cast loading pit contains about 95,000 gal of water that can be injected by the RNS. Assuming the maximum allowed RNS flow of 1548 gpm, it will take about 1 hour to inject this water. Note that if there had been a DVI LOCA then the IRWST would have been spilling to the containment during the RNS injection time as well as injecting into the RCS because the RNS would have also been spilling its flow out the DVI break. In this case the RNS would be switched to the IRWST when the IRWST is partially drained down.

b) After review of the existing screen debris testing performed for the AP1000, Westinghouse has been concluded that several confirmatory tests should be performed to provide greater assurance of adequate LTC. These tests are intended to confirm that with higher flow core rates which may occur during initial IRWST injection and

recirculation operation, prior to debris accumulation and head loss increase, that adequate LTC is provided at the lower / final flow rates. These tests will also ensure that proper actions have been taken to break up the fiber and avoid the introduction of clumps into the test flume.

Two confirmatory tests are planned to address this uncertainty. The following describes these tests and how they address the uncertainty.

Test #9 – This test is intended to address this flow uncertainty (together with test #10). It will be performed with a high initial flow that will be reduced later in the test. The high initial flow has been selected to bound high IRWST injection rates. The final flow is based on the LTC sensitivity analysis case #3. This test will also show that the plant is not sensitive to some additional particles to cover uncertainties in the amount of ZOI coating debris. Additional precautions will also be taken to avoid the introduction of fiber clumps into the test flume. In this case the screen head loss limit will be 7.5 inches of water. After the test termination criteria has been satisfied, but before the test is terminated, the flow will be increased to the initial high flow (with the limitations of the test facility) and data recorded. Then the flow will be reduced back to the final test flow and data recorded.

Test #10 – This test is intended to address this flow uncertainty (together with test #9). This test will be the same as test #9 except the final flow rate will be equal to the higher flow based on the DCD LTC analysis, which was performed with no added head loss from debris on screens or the core. This test is required because the core can have essentially no debris / head loss for elevated LOCAs (CMT inlet line) or HL LOCAs. Since the core represents the majority of the recirculation head loss (assuming limiting debris amounts), the head loss across the core and the IRWST screens can vary independently. In this case the screen head loss limit will be 14 inches of water. After the test termination criteria has been satisfied, but before the test is terminated, the flow will be increased to the initial high flow (with the limitations of the test facility) and data recorded. Then the flow will be reduced back to the final test flow and data recorded.

Details of these planned confirmatory tests are shown in the attached table. Note that WCAP-16914-P provides a more complete discussion of the table, including the test inputs and results. This table also lists all of the valid screen tests that have been performed for the AP1000. Note that an additional test (#8) has been run after the WCAP report was sent to the NRC. This test was conducted with higher initial flows and lower final flows, however is has been concluded that additional precautions need to be taken to ensure that fiber clumps are not introduced into the test flume. In this table, the tests shaded in grey are planned to be run in Sept 2009. The purple highlighted cells are significant changes.

Successful completion of these tests is considered to provide reasonable assurance that GSI-191 is addressed and long-term core cooling can be provided in the AP1000.

APP-GW-GLR-079, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA," and WCAP-16914, Revision 2, "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens" will be updated in Oct. 2009 to include these test results and to provide justification as to why this testing is sufficient.

AP1000 Screen Debris Tests

WCAP 16914 >>	R0	R0	R0	R1	R1	R1	R1	done	planned	planned	
Test # ->	1	2	3	4	5	6	7	8	9	10	
				(6,8)	(6,8)	(5,7,8)	(6,9)	(5,7,10)	(7)	(7)	
Test represents plant design basis				no	no	no	no	no	yes	yes	
Total Debris in Containment (lb)	36.2	36.2	36.2	150.0	150.0	150.0	150.0	150.0	200.0	200.0	lb
Total ZOI coatings + margin (lb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	70.0	lb
Total latent Fiber (lb)	36.2	72.5	72.5	150.0	150.0	150.0	150.0	150.0	130.0	130.0	lb
Total Fiber in Containment (lb)	0.4	0.7	0.7	7.0	15.0	24.2	15.0	8.00	6.60	6.60	lb
% Fiber by Mass	1.00%	1.00%	1.00%	4.67%	10.00%	16.12%	10.00%	5.33%	5.08%	5.08%	
% Total Transported	80.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
% Transported to Recirc Screens	82.5%	82.5%	82.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
% Transported to IRWST	18.5%	18.5%	18.5%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	
CR Screen debris loads											
Total debris (lb)	23.92	59.79	59.79	150.00	150.00	150.00	150.00	150.00	200.00	200.00	lb
Fiber debris (lb)	0.24	0.60	0.60	7.00	15.00	24.18	15.00	8.00	6.60	6.60	lb
Particle debris (lb)	23.68	59.19	59.19	143.00	135.00	125.82	135.00	142.00	193.40	193.40	lb
IRWST Screen debris loads											
Total debris (lb)	5.36	13.41	13.41	75.00	75.00	75.00	75.00	146.00	196.70	196.70	lb
Fiber debris (lb)	0.05	0.13	0.13	3.50	7.50	12.09	7.50	4.00	3.30	3.30	lb
Particle debris (lb)	5.31	13.27	13.27	71.50	67.50	62.91	67.50	142.00	193.40	193.40	lb
Test basis (CR or IRWST)	Both	Both	Both	IRWST	IRWST	IRWST	IRWST	IRWST	IRWST	IRWST	
Scale factor (screen face areas) (4)				0.09950	0.09950	0.09950	0.09950	0.19900	0.19900	0.19900	gm
Total debris (gm)	258.9	488.4	488.4	3384.9	3384.9	3384.9	3384.9	13178.7	17755.1	17755.1	gm
Fiber debris (gm)	29.9	30.4	30.4	158.0	338.5	545.7	338.5	361.1	297.9	297.9	gm
Particle debris (gm)	229.0	458.0	458.0	3227.0	3046.4	2839.3	3046.4	12817.6	17457.2	17457.2	gm
Chemical debris (gm)	-	-	-	-	-	-	-	5145.1	5145.1	5145.1	gm
Chemical, total added (% of design)				(6)	(6)	(6)	(6)	100%	100%	100%	
(gm)	20.3	40.5	374.5	472.8	472.8	378.6	472.8	5145.1	5145.1	5145.1	gm
Debris addition sequence	F/P/C	F/P/C	F/P/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	
Chemical mixed (in-loop or WCAP)	in-loop	in-loop	WCAP	in-loop	in-loop	in-loop	WCAP	WCAP	WCAP	WCAP	
Chemical, first addition (% of design)				5%	5%	5%	5%	5%	5%	5%	
(gm)				23.6	23.6	18.9	23.6	257.3	257.3	257.3	gm
Particle type				SiC	SiC	SiC	SiC	SiC	SiC	SiC	
Fiber type	(1)	(1)	(1)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	ft
Flow rate (gpm)	50.0	50.0	50.0	155.0	155.0	155.0	155.0	(10)	(11,13)	(12,13)	gpm
Date test was run	yes	yes	yes	yes	yes	yes	yes	yes	no	no	
Measured Head Loss (psi)	0	0	0	0	0	0.73	0.47	0.01			psi
Head Loss Limit (psi) (3)	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.26	0.26	0.49	psi
Test successful	yes	yes	yes	yes	yes	no	yes	yes			

Note:
1) Orginal 3 tests included fiberglass and Min K. The Min K came from LOCA jet damaged vents in the RV insulation. Test data shows that this SS enclosed Min K will not be damaged by the LOCA jets, so this debris will not be included in subsequent tests. There was 29.3 gm of Min K (Silica powder) in these tests.
2) For the new tests (#4-#8) the Min K is assumed to not become debris, so all fiber is latent fiber (fiberglass), use fiber length(s) that other screen tests have used - would be good if someone has provided a basis that the NRC has already agreed with (NEI, a plant, ..).
3) The head loss limit is based on LTC sensitivity analysis that shows that the core/screen flows drop to <90 gpm with a DP of 0.26 psi. If the flow was higher the head loss limit would be 0.49 psi.
4) For tests 4-7, the IRWST area was scaled to 2 screens. For later tests it was scaled to 1 screen.
5) The percent fiber used in tests #7 & #8 was finalized after the pervious tests.
6) The chemical amount was scaled to the amount the CR screen would see so that the testing bounded both screens.
7) In these tests 100% of the chemicals produced in the plant are assumed to transport to the screens.
8) First addition provides same chemical concentration as seen in plant. Second additon will equal first. Before adding more chemicals loop will be operated until DPs become steady and data recorded. All chemicals will be mixed in the loop.
9) Test #7 will be the same as test #5 except that all the chemicals added will be mixed outside the loop per WCAP.
10) For test #8, use an initial flow of 260 gpm (max IRWST inject), reduce flow to 90 gpm (max IRWST recirc) before chem addition.
11) For test #9, use an initial flow of 320 gpm (max RNS inject), reduce flow to 90 gpm (max IRWST recirc with debris on core) before chem addition.
12) For test #10, use an initial flow of 320 gpm (max RNS inject), reduce flow to 115 gpm (max IRWST recirc with clean core) before chem addition.
13) After the test termination criteria is met for tests #9 and #10, increase the flow to 320 gpm and record data. The DP in this case is expected to exceed the test limit but that is OK as long as the test loop parameters are not exceeded. After this flow increase, reduce the flow back to the test flow and record data.

c) Unfortunately, photo and video of the fiber preparation and introduction are not available from the reported test. However the following write up will be added to the WCAP.

3.1 Debris Preparation

3.1.1 Particulate Preparation
The particulate used in the AP1000 screen tests, silicon carbide (SiC) with a 9.5-micron median particle size, was used to simulate the particulate component of the containment latent debris. All particulate material was well mixed in a bucket of loop water until completely suspended (Figure 3.1) before being introduced in the test. Based on the above, the particulate used in the AP1000 screen head loss tests is applicable to the AP1000 plant.

3.1.2 Fiber Preparation
The fiber used in the AP1000 screen tests, NUKON® fibrous insulation supplied by PCI (Figure 3.2), was used to simulate the fibrous component of the containment latent debris. The NUKON® fiber was heat treated prior to processing by PCI. Heat treated "Shredded" fiber glass was processed through PCI's Munson "shredder and produced fiber glass 'fines' debris. Heat treated "Chipped" fiber glass was processed through a wood chipper and produced fiber glass that is less fine with small clumps of material. A combination of the fibrous material was wetted in loop water (Figure 3.3) before being introduced in the test. Based on the above, the fibrous material used in the AP1000 screen head loss tests is applicable to the AP1000 plant.

3.1.3 Chemical Preparation
The chemical surrogate used in the AP1000 screen was made outside of the loop according to the approved procedure in WCAP-16530-NP-A prior to introduction into the test loop. The batches of chemical debris were added to the test loop at various rates, depending on the requirements of the particular test. The chemical surrogate was added in a number of batches spaced out to allow at least five turnovers of the fluid in the loop prior to the next addition. Based on the above, the chemical surrogate used in the AP1000 screen head loss tests is applicable to the AP1000 plant.

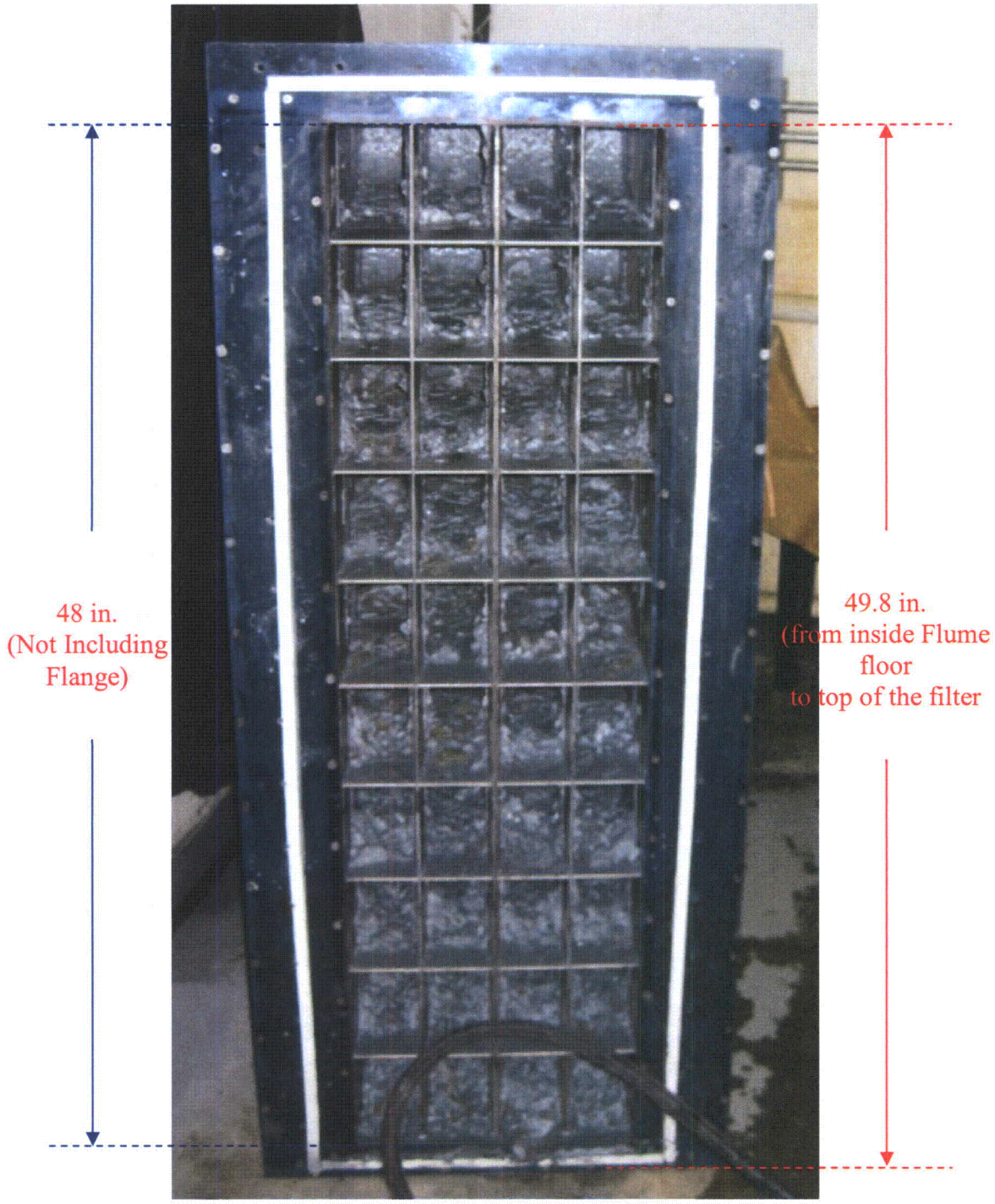
It is observed that in screen test #7, that there was a substantial head loss across the screen which indicates that there was a contiguous debris bed on the screen. This implies that the fiber was adequately broken up. Also note that two additional screen tests will be run. For these tests, careful photo records will be kept to document the fiber condition when it was added to the test loop.

d) For test termination, the rate of change of the head loss across the screen is tracked. When the absolute value of this slope drops to less than 0.05 psi per hour, the test can be terminated.

e) The filter is 49.8 inches tall, from the floor of the test flume to the top of the filter opening (see attached sketch). The water level in the test was 52.5" above the floor of the test flume or 2.7" above the top of the screen face.

   In the plant the minimum water level is at elevation 107.9' which is 58.8" above the IRWST bottom. The top of the IRWST screen face is 56" above the floor of the tank. The minimum water level is 2.8" above the top of the screen.

   The water level is the screen test was slightly lower than the minimum level that will occur in the plant just after the initiation of recirculation operation.


48 in.
(Not Including
Flange)
49.8 in.
(from inside Flume
floor
to top of the filter

f) The water in the IRWST is normally subcooled throughout most of a LOCA transient. For larger LOCAs the PRHR HX does not operate very much, if any, prior to ADS actuation and ADS 1/2/3 does not fully saturate the IRWST. In addition, in the long term the steam condensate returning from the containment shell is subcooled by 30 to 40F. However, for smaller LOCAs (< 1") there will be extended operation of the PRHR HX (for ≥ 2 hours) prior to the actuation of ADS which can result in heatup of the IRWST water to saturation. Even in this case, the IRWST water will not remain saturated during long term recirculation because the subcooled steam condensate returning to the IRWST through the gutter will reduce the IRWST temperature. Therefore for smaller LOCAs, it is possible for the water in the IRWST to be saturated for a limited period of time such that it is necessary to consider the potential of steaming of the saturated water as it flows through the IRWST screen.

The minimum water level in the IRWST occurs during recirculation operation. This level can vary from several feet above the top of the IRWST screen to just at the top of the screen. In addition, after a couple weeks the IRWST level might drop lower (below the top of the IRWST screens) if the three unflooded rooms (two PXS rooms and the CVS room) eventually flood due to leakage. The following considers two different water level conditions that bound the operation over these different levels. One case is with the water level below the top of the IRWST screen and another is with the water just above the IRWST screen top.

With a saturated water level below the top of the screen enclosure, there will be no flashing since the flow will be in an open flume and not in a closed pipe - in this case the water level will decrease behind the screen relative to the level in front of the screen (as it does in the screen tests). The limiting case is considered to be with a level just below the top of the top of the screen early after start of recirculation with the highest passive system recirculation flow rates through the IRWST screen; this flow is higher than would occur in the wall-to-wall case because of the higher decay heat. This situation is shown in the figure 1.

The other case is with a saturated water level just above the top of the screen enclosure. This level seals off the air/steam atmosphere of the IRWST gas space from entering into the top of the screen enclosure and allowing the level behind the screen to decrease. In this situation steam bubbles might form in the top 14" of the screen since that is the maximum pressure loss that can occur in across the screen. Bubbles that form in this part of the screen will have a bubble rise velocity that is greater than the water flow down behind the screen pockets as shown in the following paragraphs. As a result, the bubbles would rise up to the surface and escape into the IRWST. Figure 2 shows this situation.

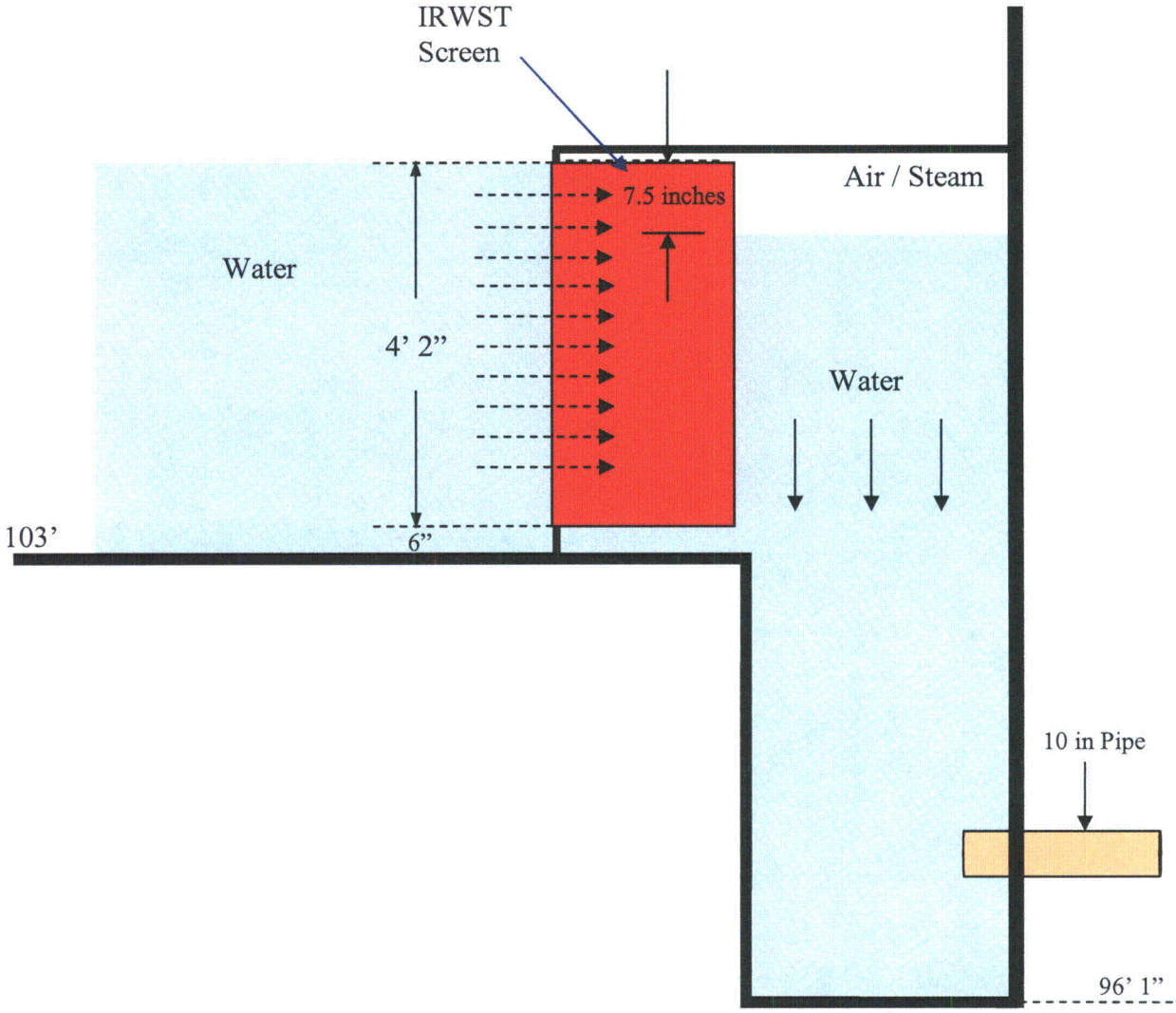


Figure 1 – IRWST Screen Operation With the Water Level Just Below the Screen Top

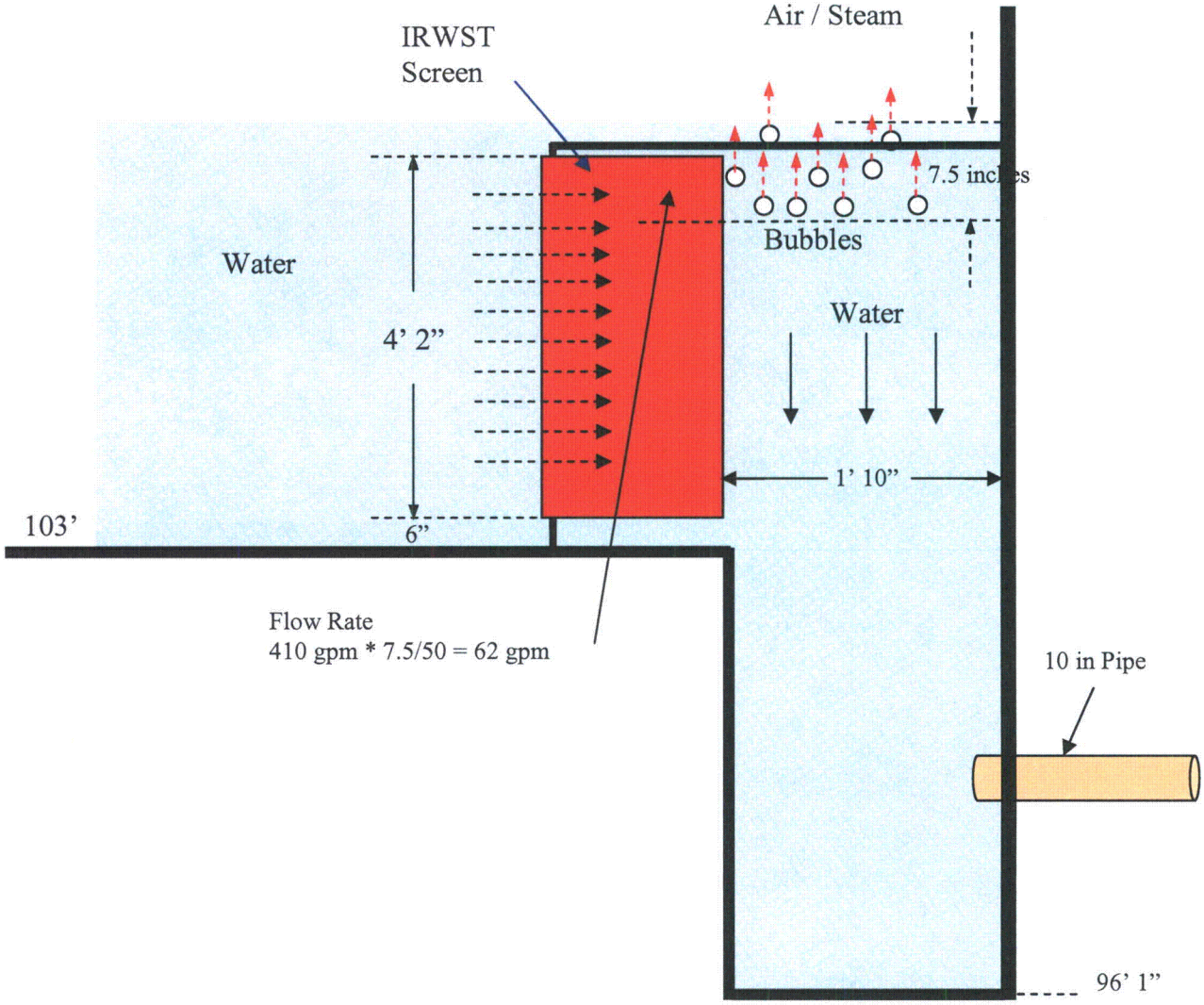


Figure 2 - IRWST Screen Operation With the Water Level Just Above the Screen Top

For the second case, a calculation was made of the steam bubble rise velocity and the water down flow velocity. This calculation shows that the steam bubble rise velocity is much higher than the water down flow velocity such that the bubbles will not be entrained into the PXS injection flow. Instead they will rise up the top of the IRWST screen and leak out into the IRWST gas space.

The calculation of the steam bubble rise includes the following assumptions:

- The minimum bubble size is equal to the screen hole size (1/16") and the bubbles are assumed not to agglomerate. This bubble size is appropriate for this low velocity and DP.
- The lowest level where bubbles can occur is 7.5" below the top of the screen. This assumption is based on:
    - The water in the IRWST is saturated
    - The water level is at the top of the IRWST screen
    - The flow rate is equal to the recirculation flow rate at the start of recirculation (410 gpm), the maximum IRWST screen flow with passive system operation as shown in WCAP-16914-P, in Table 5.2.
    - The maximum screen head loss is 7.5" of water with the maximum debris loading; this pressure loss is calculated from a head loss of 14" of water at 75 lb/sec vs the 55 lb/sec at 7.5" loss. A flow squared relation is used because COBTA-TRAC uses that assumption.

The bubble rise velocity is calculated to be at least 15 cm/sec. This calculation is based on test data contained in "Bubbles, Drops, and Particles", R. Clift et al., Dover Publications, 2005 (Figure 7.3, "Terminal Velocity of Air Bubbles in Water at 20C).

The water flow is calculated at the lowest level behind the screen where steam bubbles might form. That level is 7.5" below the IRWST top. Since the screen is 50" high, the downward flow at this elevation will be 410 gpm * 7.5" / 50" = 62 gpm. The downward flow area behind the screen is the distance between the back of the screen (1' 10") times the width of the screen (7' 8") = 14.1 ft2. The downward flow velocity is then 0.30 cm/sec.

This water flow is much lower than the steam bubble rise velocity of 15 cm/sec and as a result the steam bubbles will not be drawn into the IRWST injection line.

g) Flow rates from the limiting LTC sensitivity analysis case were converted from pounds per second at the pressure and temperature calculated in the analysis to gallons per minute. The flow rate in gallons per minute was then scaled to the test facility as described in the test reports. The head loss limit was taken as the pressure loss (in psi) calculated in the limiting LTC sensitivity analysis case at the selected flow rate. This same pressure loss was used as the pressure loss limit in the testing.

RAI response SRP6.2.2-SRSB-23 discusses additional tests that will be performed where the flow through the fuel assembly starts out high and decreases as the debris induced DP builds up. Item b) of this RAI response discusses additional tests that will be performed where the flow through the screens starts out high to simulate higher IRWST injection flows and decreases to the final recirculation flow (the minimum recirculation flow in on test and the maximum in the other test).

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

The following report will be revised as a result of this RAI:

- WCAP-16914, Revision 2, "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens"

The current revision of this debris test report is revision 1. It is anticipated that this report will be revised in September 2009 to address clarifications and corrections. This will be revision 2 for the documents. Incorporation of the confirmatory test result will be done in the next revision (revision 3).

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SPCV-22
Revision: 0

Question:

Debris Generation/ZOI/Debris Characteristics

In the AP1000 design, where there are intervening components, supports, structures, or other objects, the ZOI is defined as the spherical region within a radius equal to 20 ID of the pipe break.

a) In order to determine if the AP1000 ZOI definition is consistent with the SE, please provide the ZOI radius/break diameter for the insulation types the AP1000 allows outside the ZOI, which is jacketed fiberglass, non-jacketed fiberglass, rigid cellular glass, or a suitable equivalent that does not add to the chemical precipitates.

b) From Table 3-2 of the SE, both Koolphen-K and Min-K have spherical ZOIs that exceed those used in the AP1000. Are either of these insulations allowed in the AP1000?

Westinghouse Response:

a) The guidance report, NEI 04-07 recommends that ZOI sizing as seen in the table be determined using the American National Standards Institute/American Nuclear Society (ANSI/ANS) 58.2-1988 standard for a freely expanding jet (ANSI/ANS 58.2-1988).

Insulation Types	ZOI radius / Break Diameter
Jacketed Nukon (fiberglass)	2.4
Unjacketed Nukon	17.0
K-wool	5.4
Koolphen-K	22.9
Min–K, Rigid Closed Glass Foam	28.6

To simplify the AP1000 DCD the ZOIs will be listed as 29 for Min-K, Koolphen-K and rigid closed glass foam, and 20 for other insulation types.

b) Although Koolphen-K is not an insulation that is currently used in the AP1000 design, it is listed in the table above to be inclusive and will be addressed in the DCD.

Min-K has limited use in the AP1000. When used in the AP1000 design, the Min-K is encapsulated by stainless steel plates with a weld along the length of the seams. NEI 04-07 and the associated NRC Safety Evaluation Report refer to either wrapped or jacketed and banded Min-K. The encapsulation feature used in the AP1000 provides superior protection of the insulation material to jet loading compared to either wrapping or jacketing and banding. This was demonstrated in jet impingement testing performed for a currently operating plant.

Rigid closed cell glass foam is expected to be used in the AP1000 design. As no data is currently available to determine a ZOI, the value equal to the maximum ZOI for insulating materials, Min-K, will be used. Therefore, a ZOI radius equal to 29 (rounded up from 28.6) times the break diameter will be used for rigid closed cell glass foam. It is also noted that the PWR community has treated rigid cellular glass foam debris as floating post-accident which does not collect on the recirculation screens and therefore is not a contributor to head loss at either the recirculation screens or the fuel.

Design Control Document (DCD) Revision:

The DCD changes will be included in a revision to TR APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision:

The following report will be revised as a result of this RAI:

- APP-GW-GLE-002, Revision 3, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SPCV-23
Revision: 0

Question:

Upstream Effects

a) RG 1.82 C-1.1.1.5 requires that drains and other narrow pathways in flowpath potential break locations and the sump be designed so they are not blocked by debris. Westinghouse has addressed this issue for the flow from the Stage 4 ADS to the CR screen, but not for the flow from potential break locations to the CR screen. Please provide this evaluation, including a discussion of how the potential blockage of reactor cavity, refueling canal or refueling cavity drains were addressed.

b) For the wall-to-wall flooding case described in DCD 15.6.5.4C.3, the water level appears to be below the bottom of the IRWST screen. Because a pressure drop is now expected across the IRWST screen, evaluate the impact of vortexing, flashing, and potential water hold up in the IRWST as it drains down, and any impact this has on the DCD analysis.

Westinghouse Response:

a) For break location in the loop compartments, the flow paths are the same as those described for the ADS stage 4 discharge.

There are several other LOCA break locations that have different flow paths to the CR screens. These include:

1. Core Makeup Tank (CMT) inlet lines, PRHR discharge and return lines, and Chemical and Volume Control System (CVS) lines located outside the loop compartments
2. DVI injection lines located in the PXS equipment rooms
3. Pressurizer (Pzr) lines connected to the top of the Pzr including the ADS stage 1/2/3 inlet lines and the RCS safety valve inlet lines.
4. PRHR HX Tube Rupture

CMT inlet lines: The lines are routed from the loop compartments over to the CMTs which are located outside the loop compartments on the floor at elevation 107' 2". From this floor, there are many flow pathways to the CR screens in the loop compartments. These flow paths include:

- Open stair well from this floor to loop compartment A
- Open stair well from this floor to loop compartment B
- Open stair well from this floor to the corridor that cross connects the two loop compartments

- Grating located at this floor elevation that extends over the corridor that connects the two loop compartments

Any one of these flow paths is sufficient to allow the discharge from the 8" CMT inlet line to flow down to either loop compartment or to the corridor that cross connects these two loop compartments. Once the flow gets into one of these three locations its pathway to the CR screens is the same as the ADS stage 4 discharge. The PRHR discharge and return lines and the CVS lines outside of the loop comparment will behave in the same manner as the CMT inlet lines.

Also note that there are openings through this floor that extend down into three rooms that do not normally flood. The rooms are the two PXS rooms and a CVS room. Curbs are provided around all of these openings to prevent water flooding down into these rooms. The curbs extend up about 3 feet. The elevation of these openings is slightly different so that the first room that would flood would be the CVS room. There is no safety related equipment located in this room. The next room to flood would be the PXS B room. The water level would not reach this level even under conservative maximum flood assumptions. The final room that would flood is the PXS A room.

Note that there are several cross connections provided between the refueling canal and the containment area. These connections are all shown on the Spent Fuel Cooling System (SFS) P&ID (DCD figure 9.1-6). These include:

- A 6" drain line containing 2 series check valves that allow water to drain out of the refueling canal until the containment floods up above its elevation. This line contains a locked open manual valve. In a minimum containment flood case, water could slowly drip down from the containment shell and slowly raise the water level in the refueling canal. When the water in the refueling canal rise above the level in the containment water will flow out through the check valves into the containment.

- A 20" overflow line containing a locked open manual valve connects the containment and the refueling canal. This line is located at a slightly lower elevation that the overflow to the CVS room. In a maximum containment flood case, water will rise to the elevation of this line and flow from the containment into the refueling canal.

- Curbs are provided around openings through the maintenance floor at elevation 107' 2" to control flooding. Overflow into the refueling canal occurs through a pipe centered at elevation 110' 0". Curbs around openings into the chemical and volume control system compartment extend up to elevation 110' 0". Curbs around openings into the PXS-A compartment extend up to elevation 110' 2". Curbs around openings into the PXS-B compartment extend up to elevation 110' 1". With these curb elevations, water flooding the maintenance floor is directed first into the refueling canal, then into the CVS compartment, then into the PXS-B compartment, and

finally into the PXS-A compartment. The PXS-A, PXS-B and CVS compartments also have floor drains to the containment sump with double check valves in them.

- There is one locked-open valve in the line that goes through the wall of the refueling canal to provide a water flowpath between the refueling canal and the containment floodup water volume following an accident. This valve is locked open so that as the containment floods, the refueling canal will flood before the compartments that contain passive core cooling system components, which are used for safe shutdown. This valve is locked-closed during refueling operations when the refueling cavity is flooded.

PXS Rooms: There are lines in these rooms that can be LOCA breaks. If a LOCA occurs in one of these rooms, the room will fill up and overflow up onto the 107' 2" floor elevation. The flow paths include a stair well and well as other smaller openings around ducts and cable trays. Once the water flows up onto the 107' 2" flood the path to the CR screens is the same as for the CMT inlet line break.

Pressurizer Top Line Break: A LOCA located at the top of the Pzr can spray water over the operating deck at elevation 135' 3". There are a number of path ways that will allow this discharge to drain down to the 107' 2" floor elevation. They include areas with grating and several stairwells.

- Some of the water also could also flow into the gutter that runs around the operating deck level next to the containment wall. There is a curb near to the containment wall that is intended to prevent minor spills that could occur during normal operation from entering the gutter. However water discharging from a Pzr top LOCA location could get into the gutter and from there to the IRWST. This flow path is acceptable since the IRWST becomes connected to the DVI injection lines. Note that once the RCS pressure has been reduced by operation of the ADS stage 1/2/3 valves this flow would be significantly reduced and would stop once the ADS stage 4 valves were opened, since there would not be enough pressure in the RCS at that time to lift water to the top of the Pzr.

- Some water could also flow over to the refueling canal. Early in the accident, water entering the refueling canal will drain out into the containment through the 6" drain line that contains the check valves. As described above, this flow would slow and finally stop once ADS stage 1/2/3/4 valves are opened.

PRHR HX Tube Rupture: The result of a PRHR HX tube rupture would cause level in the IRWST to increase and possibly overflow. In the case of such an event water would overflow to the refueling cavity and then drain back into containment as described above for the 6" drain line with the 2 series check valves.

b) The response to RAI-SRP6.2.2-SPCV-21 (f) addresses the potential for flashing across the IRWST screens. Vortexing would not occur based on the screen testing.

In the minimum containment flood wall-to-wall case, the water level is slightly above the bottom of the IRWST floor (about 4"). However, the water level in the IRWST would have to rise somewhat above this level since the bottom of the IRWST screen is located 6" above the tank floor. Note that as stated in the DCD the wall-to-wall flood case starts at 2 weeks after the accident, so that the decay heat is only about 27% of what it is at the time recirculation starts. As a result, the amount of steaming from the reactor will be significantly reduced, which will reduce the water returning to the IRWST. In addition, the flow through the core can also be reduced. The net effect of this is that the flow through the IRWST can be significantly reduced while still providing adequate core cooling.

The following provides justification that the reduction in containment flood level during the wall to wall flooding case does not depreciate the hydrostatic head sufficiently to challenge minimum required recirculation flow to maintain adequate core cooling and that the reduced flow would still be sufficient to allow adequate steaming.

- The containment water decrease was determined to be 1 foot lower for the wall to wall flooding case.
  - The IRWST water level was assumed to cover one half of the IRWST screen height. If there is no debris / head loss on the screen, then only a few inches of water will be required. This higher level is expected to be sufficient even with the limiting amount of debris / head loss since the wall-to-wall case has so much less decay heat (occurs 14 days after the LOCA).
  - The increase in IRWST water volume was removed from the water in the rest of the containment.
  - The lower containment water level was determined based on the reduced water volume.
- The recirculation flow rate was estimated to be reduced from 102 lb/sec (current DCD rate) to about 87 lb/sec
  - The RCS pressure was assumed to remain constant. This assumption is conservative since the RCS recirc / ADS vent flow will be less – DP across the ADS stage 4 line should drop.
  - The flow resistance in the PXS recirc lines remain constant.
  - Since DH = R * Q^2 , solving for R = DH / Q^2
  - DH1/Q1^2 = DH2/Q2^2; solving for Q2 = (Q1^2 * DH2/DH1)^0.5

Westinghouse believes this to be conservative based on the large amount of inventory already in and above the core based on the DEDVI LTCC analysis from the DCD. In the limiting DEDVI break analysis presented in the AP1000 DCD, Section 15.6.5.4C, during containment recirculation the two-phase mixture level in the upper plenum extends approximately five feet above the top of the active fuel length into the hot legs, with a liquid content that equals a

collapsed liquid level in the upper plenum >1.5 ft (see DCD Figure 15.6.5.4C-8). A significant amount of liquid is also present in both hot legs. The 102 lbm/s flow rate is adequate to sustain approximately 5 feet of margin for the two phase mixture above the core and 1.5 ft of collapsed liquid above the core. A reduction in core flow to 87 lbm/s is not believed to challenge the minimum requirements for core cooling. In addition, the core steaming rate is approximately 3 lb/sec.

Additionally a WCOBRATRAC sensitivity run is being performed in parallel with this hand calculation to confirm the core flow rate reduction along with justification of sufficient margin regarding associated core two phase and collapsed liquid levels. This confirmatory sensitivity analysis is planned for completion on 9/30/09. At that time this RAI response will be revised to contain a summary of these confirmatory results.

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-SPCV-24
Revision: 0

Question:

Debris Source Term

a) The insulation allowed in the ZOI is described in the first part of the ITAAC from DCD, Tier 1, Table 2.2.3-4, item 8.c.ix. The required ITA is "inspection" of select insulation and the required AC is that the insulation be MRI or a suitable equivalent for all locations. While an ITA of "inspection" is appropriate for MRI insulation, the staff does not believe this ITA and AC combination is sufficient to determine that the insulation is a suitable equivalent. This option would most likely require additional ITA of "test" or "type test" and "analysis," and if a report is required to demonstrate the analysis, the AC would need to reference this report. Please provide the appropriate types of ITA and AC for this ITAAC.

b) Neither definition of suitable equivalent insulations (for either ZOI or flood up zone) in DCD Tier 2 Section 6.3.2.2.7.1 item 3 adequately captures the technical criteria required for an objective finding. For example, for suitable equivalent insulations in the ZOI, the staff expectation is that jet impingement testing be performed to either demonstrate there is no debris or to characterize the damage. Because there is no clearly defined protocol for this type of testing currently available, the results would need to be carefully evaluated to insure they were representative of plant conditions. If debris was generated in the testing, a transport analysis must also be included to demonstrate this debris will not arrive at any of the AP1000 filtering locations. Please include the specific testing and analyses required to demonstrate a suitable equivalent insulation and the objective criteria to be used to confirm the testing, transport analysis, and chemical analysis (as required for flood up zone) is adequate.

c) The portion of the ITAAC from DCD, Tier 1, Table 2.2.3-4, item 8.c.x dealing with caulking, tags and signs used in the flood-up zone or where there is sufficient water flow to transport this caulking, signs, and tags requires an inspection of the signs and confirmation a report exists concluding caulking and coatings have sufficient density. The staff feels this AC is not complete enough because the report should also include how the "area where there is sufficient water flow to transport" was determined. Explain where the ZOI definition, debris generation, and transport analysis required to meet this ITA will be captured.

Westinghouse Response:

a) WEC concurs that the proposed ITAAC provided in APP-GW-GLE-002 Rev. 3 should be further revised to provide additional details. Words will be added to both ITAAC Table 2.2.3-4 item 8.c.ix and to the corresponding DCD subsection 6.3.2.2.7.1, item 3. For the ITAAC, these words will require that a report exist and conclude that any alternative insulation used in the AP1000 is a suitable equivalent. For the DCD section,

words will be added stating that testing is required to show whether debris is generated or not. If debris is generated, testing and/or analysis is required to show debris doesn't transport to an AP1000 screen or into the core through a flooded break under conditions that bound the AP1000 conditions. It would also have to be shown that the material used would not generate chemical debris. In addition, the DCD will say that the testing and/or analysis, if applicable, must be approved by the NRC.

b) This question is addressed by the response to item a).

c) The approach to addressing this question is the same as that proposed for item a); similar words will be added to the ITAAC table and to the DCD subsection as proposed in item a). For the ITAAC, if the non-transport of lightweight (< 100 lb/ft^3) caulking, signs, or tags is relied upon, it must be supported by a report demonstrating that the materials would not transport. For the DCD section, the words will state that testing and/or analysis is required under conditions that bound the AP1000 conditions; this testing/analysis must demonstrate that the debris would not be transported to an AP1000 screen or into the core through a flooded break. It would also have to be shown that the material used would not generate chemical debris. In addition, the DCD will say that the testing and/or analysis, if applicable, must be approved by the NRC.

Design Control Document (DCD) Revision:

The DCD changes will be included in a revision to APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision:

The following report will be revised as a result of this RAI:

- APP-GW-GLE-002, Revision 3, "Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-16
Revision: 0

Question:

The proposed amendment to AP1000 DCD Section 6.3.2.2.7.1, item 12, provided in the AP1000 DCD Impact Document APP-GW-GLE-002, Revision 3, specifies that the design basis for percentage of the total resident debris that could be transported to (1) the containment recirculation screens is ≤100%; and (2) the core (via a DVI [direct vessel injection] or a cold leg LOCA break that becomes submerged) is ≤60%.

Contrary to this, in APP-GW-GLR-079, Revision 4, the debris that could be transported into the RCS through a submerged LOCA break is changed to be 75% of the debris transported to the containment, which is derived based on a DVI break in the loop compartment. On Pages 17 through 19 in APP-GW-GLR-079, Revision 4, Westinghouse indicates that its evaluation of the double-ended cold leg guillotine (DECLG) break shows 90% of containment flow entering the reactor vessel through the flooded DECLG break, and lists nine conservative assumptions (in 9 bullets) in its DECLG evaluation to justify the most limiting break with regards to debris loading on the fuel assemblies to be the double-ended DVI break in the loop compartment despite the DECLG result.

Westinghouse concludes that minor reductions in one or more significant margins of those on the list for a DECLG break (e.g., if 17% of the debris either does not transport into the recirculation water or settles out after entering the water) would result in the same amount of fiber being transported into the RCS as in the DEDVI case. Westinghouse thus considers that DEDVI break is the most limiting with regards to debris transport to the core.

These qualitative arguments do not provide sufficient justification. The leak-before-break and lower rupture probability of a cold leg break (Bullet 1) are not an acceptable arguments because 10 CFR 50.46 requires the break spectrum of all sizes and locations be postulated without considering probability in the design basis analysis. The limiting single failure assumption and the 1971 ANS Standard decay heat plus 20% (Bullets 6 and 8) are the requirements of General Design Criterion 35 and Appendix K to 10 CFR 50, respectively. The assumptions related to total debris load, debris transportation, and chemical precipitates (Bullets 2, 3, 4, 5, and 7) are the general design basis values specified in the AP1000 DCD Section 6.3.2.2.7.1. Taking credit for the viscosity difference between the head loss testing and plant operation (Bullet 9) should be done in accordance with the guidance regarding Generic Letter 2004-02 closure. In addition, all the above reasons other than item 1 are applicable to all breaks, including DVI and DECLG breaks.

Therefore the staff finds that Westinghouse's conclusion that the DEDVI break in the loop compartment is the limiting break with regards to debris transport to the core is not sufficiently justified. Unless otherwise justified, the staff finds that the DECLG break appears to be the

limiting debris-bypass break with 90% of unfiltered flow through the submerged break into the core.

a) The staff requests Westinghouse to either re-evaluate the DVI and DECLG breaks using the same assumptions for each evaluation to justify which break is more limiting; or support the current proposed design basis of ≤75% of the total resident debris that could be transported to the core via a submerged DVI or DECLG break (not identifying either break as the worse case) by providing a quantitative evaluation justifying that no more than 75% of the total debris would enter the core unfiltered regardless of the type of break. However, any change in the assumptions must be justified and be consistent with the design basis criteria specified in the amended DCD Section 6.3.2.2.7.1.

b) As the DECLG break is the limiting debris-bypass break, provide justifications on why the long-term cooling sensitivity studies are not performed on the DECLG break.

c) What is the value of the filtered debris bypassing the IRWST and recirculation screens into the core through the intact DVI lines? Does the total debris entering the core include both the unfiltered debris through the submerged break and the filtered debris through the intact DVI line(s)? If not, why?

Westinghouse Response:

a) Westinghouse is revising APP-GW-GLR-079, Revision 4, to indicate that the Double Ended Cold Leg (DECLG) break will be considered the most limiting break with respect to debris transport. This provides the largest percentage of flow and debris that bypasses the recirculation and IRWST screens. The fraction of flow transported to the core via the submerged DECLG break will be ≤90% of the total resident debris. For a DECLG break, the flow split between the PXS recirculation flow path and through a double-ended rupture of a cold leg pipe is calculated to result in less than 85% of the flow through the cold leg and 15% or more through the screens. This split is calculated with the containment at its final flooded level. As is observed for the DVI LOCAs, recirculation starts through the break before the PXS recirculation begins, so that the integrated split over the time required to pass one containment volume through the RCS is a few percentage points higher. So the integrated flow split for the DECLG break will be 90% through the break and 10% through the screens. The increase in the bypass percentage when compared to the bypass percentage from the DVI break is caused by the larger cold leg piping diameter and reduction in the resistance of the flow restrictor which exists in the DVI line but not in the cold leg. Note that the cold leg is at a higher elevation than the DVI line and this additional height has been credited in the cold leg bypass fraction.

Westinghouse will limit the total amount of latent fiber content to ≤6.6 lbm (8.0 lbm * 0.75 (percent through DVI break) / 0.9 (percent through Cold Leg Break). The

following documents will be updated with the revised fiber amount and fraction of the flow transported to the core via the cold leg break: APP-GW-GLR-079, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA," APP-GW-GLE-002, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)," and WCAP-17028, "Evaluation of Debris-Loading Head-Loss Tests For AP1000 Fuel Assemblies During Loss of Coolant Accidents". DCD changes will be included in APP-GW-GLE-002.

b) The long-term cooling event is more limiting for the DVI line break because it is the most limiting long-term case in the relationship between decay heat and the available liquid driving head. Because the IRWST spills directly onto the containment floor through a faulted DVI line, this event has the shortest time to start of recirculation. The shorter time results in the highest decay heat when recirculation is initiated. Additionally, the DVI LOCA is assumed to be located in a PXS room flooding this room with water. This results in a lower containment flood level. A DECLG break will not flood a PXS room.

The long-term cooling sensitivity studies are not performed for the DECLG because for a large cold leg break, both DVI lines would be injecting directly into the downcomer with flow then going through the core or bypassing the core through the downcomer. The flow then exits the reactor coolant system through the cold leg break or ADS valves. The flow resistances for these flow paths increases the time (about twice) to recirculation initiation and thus reduces the decay heat at the start of recirculation when compared to the DEDVI line break. The containment flood level will also be higher as described in the previous paragraph. The limiting break from a long term cooling perspective is the DEDVI line break with the highest pressure drops across the core and screens which is the break analyzed in the sensitivity studies provided in APP-PXS-GLR-001.

c) The amount of filtered debris bypassing the IRWST and recirculation screens into the core through the intact DVI lines is accounted for in the AP1000 debris loading assessment. First, 100% of the particulate and chemical debris in the plant is assumed to pass through the IRWST and recirculation screens and be transported to the core. Second, the amount of fiber that can "pass through" the AP1000 IRWST and recirculation screens is insignificant and is more than accommodated by the rounding assumed in the calculation of the total debris provided in part a above.

For the limiting bypass break case, a DECLG break, up to 90% of the fiber in the plant can bypass the screens through the break. Only 10% of the fibrous debris (or .66 lbm) is assumed to go to the containment recirculation screens for this case. Of the 10% that goes to the screens only 1% of the fibrous debris is expected to pass through the screen (or 0.0066 lbm maximum for 1%). The 1% is based on testing performed for the NRC by Los Alamos. The results of this testing was reported in LA-UR-04-5416,

"Screen Penetration Test Report". The percent pass through varied with fiber length, screen size and velocity in this report. Factors that lead to expecting 1% pass through include:

- The AP1000 fiber is expected to be more like "shredded" instead of "blended" fiberglass since its source is latent debris and not LOCA jet damaged fiberglass insulation.
- The AP1000 containment recirculation screen velocity is lower than the minimum tested and higher velocities led to higher pass through.
- The AP1000 screen hole size is equal to the smallest size tested (1/16" ID).

Therefore the fibrous debris from the screens into the core is within the rounding assumed in the calculation of the total debris provided in part a) above.

Design Control Document (DCD) Revision:

The DCD changes will be included in a revision to APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision:

The following reports will be revised to reflect the commitments in response a) of this RAI:

- APP-GW-GLR-079, Revision 4, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA"
- APP-GW-GLE-002, Revision 3, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"
- WCAP-17028, Revision 1, "Evaluation of Debris-Loading Head-Loss Tests For AP1000 Fuel Assemblies During Loss of Coolant Accidents"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-21
Revision: 0

Question:

On page 9-1 of WCAP-17028-P, Rev. 1, Westinghouse states that 16 fuel assembly head loss experiments were performed. However, only 13 tests results are presented in the technical report and Table 9-1. Explain and justify why three (Test Nos. 7, 12, and 15) of the tests were discarded and not presented in Table 9-1?

Westinghouse Response:

CIBAP07 - This test was excluded due to a modification of the test loop that had been implemented prior to CIBAP07. A bypass line was added after the pump to reduce the back pressure on the pump during these relatively low flow rate tests. In this case, the valve in the bypass line was open too wide and when the back pressure increased due to the increased head loss, too much flow was diverted through the bypass line and reduced the flow to the test column below allowable levels as set in the test plan. With the rapid drop in flow rate below the allowable level set forth in the test plan, the data was deemed to be unusable.

CIBAP12 –This test was excluded due to the addition of the constituent chemicals to the loop. The procedure for testing chemicals in the loop requires that the chemicals be mixed outside the loop per WCAP-16530-NP-A. For this test, the chemical constituents were added to the loop individually to see the effect of in-situ mixing of the chemicals. When the chemical constituents were added to the mixing tank there was a large fluctuation in the measured flow rate. This fluctuation was due to the rapid change in conductivity when the chemicals were added to the loop. The magnetic flow meter can account for changes in conductivity, but not if the changes occur too rapidly. Since the flow control system adjusts the flow rate based on feedback from the flow meter, the flow control system was attempting to compensate for the perceived spikes in the flow rate resulting in large fluctuations in the recorded data. With the rapid fluctuations in the recorded data, the data was deemed to be unusable. Additionally, this test would not have been allowed as part of the licensing basis since the chemicals were not created outside of the loop per the accepted WCAP-16530-NP-A procedure.

CIBAP15 - A total of sixteen fuel assembly tests have been performed for the AP1000 thus far; two tests were excluded for the reasons provided above. Test CIBAP15 is being incorporated into WCAP-17028-P Revision 2 for a total of 14 tests included in WCAP-17028-P Revision 2.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

The following report will be revised:

- WCAP-17028, Revision 1, "Evaluation of Debris-Loading Head-Loss Tests For AP1000 Fuel Assemblies During Loss of Coolant Accidents"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-22
Revision: 0

Question:

In the fuel assembly head loss tests described in WCAP-17028-P, Rev. 1, the first addition of AlOOH results in the increase of the measured head loss. For tests 11 and 14, further additions of AlOOH result in further increase in the measured head loss. However, the measured head losses decrease after the second addition of AlOOH for tests 6, 7, and 8; and the loss decreases after the fourth AlOOH addition for test 16.

Explain the behavior shown in the test results and why further additions of AlOOH in some tests causes the head loss to decrease.

Westinghouse Response:

With the conservative debris loads used in the AP1000 testing, it is expected that a fiber bed will form and the maximum head loss will occur at some point after AlOOH addition. Further the AP1000 testing indicates that the maximum head loss typically would occur before the addition of all the AlOOH and then decrease with time. Visual observations of the outside of the fuel assembly during the tests indicate that initially the AlOOH attaches to the fibers and reduces the flow passages through the debris bed. This causes an increase in head loss when the AlOOH is initially added. It seems that when the DP increases enough, channels or boreholes develop in the bed, leading to a decrease in head loss. The reason why this process happened more quickly in some tests appears to be related to the rate of AlOOH addition. The bore hole formation in the fiber bed is desirable because coolant enters the core more rapidly. Long-term cooling flow conditions are normally the most limiting just prior to bore hole formation.

In the earlier AP1000 tests the AlOOH was added in large batches that were introduced into the loop over a very short time. This rapid rate of addition is not prototypical of the plant since the actual production of chemicals is very gradual over 30 days. The typical head loss response in these tests was a larger DP spike after the initial AlOOH addition and then a gradual decrease; test #6 is an example of such a test.

When this sensitivity to the rate of AlOOH addition was recognized, the initial additions were reduced to smaller batches (as used in tests 8-11) and finally to slow continuous additions (as used in tests 13, 14, 16). In all cases the additions remained above twice the calculated plant production.

Test #14 used the more representative slow continuous initial addition. It is thought that with the slower rate of addition that it took longer before the head loss increased enough for channels / boreholes to form and allow the head loss to start decreasing (roughly 22 hours after the first

addition). Note that the head loss increased during the initial continuous addition and after the second addition; it did not increase after subsequent 4 additions of AlOOH and actually decreased slightly.

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-23
Revision: 0

Question:

Page 5-1 of WCAP-17028, Revision 1, states that "For most of the AP1000 fuel assembly tests, the maximum flow rate was assumed since higher flow is conservative for head loss." The maximum core flow rate is the design basis core flow rate specified in DCD Section 6.3.2.2.7.1. In Test #16, Westinghouse reduced the flow rate to accommodate a best estimate value from simulated analyses. If an extrapolation was performed (ΔP is proportional to flow rate squared) to the maximum core flow for the other tests, i.e., approximately 8.4 gpm, the calculated pressure differential for Test #16 is 6.2 psi.

Therefore, the calculated pressure drop of 6.2 psi has small margin to the design pressure drop of 6.5 psi. Explain and justify why Test #16 was not conducted at the full flow rate.

Westinghouse Response:

This question contains two separate issues. One issue is what flow rate should used in the fuel assembly testing (including what is the appropriate basis) and the other is whether the flow used should be a nominal or a peak flow.

For the first issue, the question states that if the results of the test are extrapolated from the lower flow rate used in test #16 to the flow rate used in the previous tests that the margin to the pressure loss acceptance limit becomes small. The extrapolation is 2.5 psi * (8.5 gpm / 5.3 gpm)^2 = 6.43 psi which is just under the limit of 6.5 psi. This extrapolation is not considered appropriate because it assumes a flow squared relationship with DP which is not considered to be accurate for this situation. This assumption is based on there being a fixed flow resistance and turbulent flow. The flow resistance is not likely to be constant because as the flow increases the pressure across the fiber bed will increase and compress the bed; this effect will tend to increase the flow resistance. In addition, since the flow through the bed is slow it is likely to be laminar and therefore not follow a flow squared relation. It was to avoid such issues that it was decided to test the AP1000 FA at the flow rate and pressure loss calculated in the LTC sensitivity analysis (refer to APP-PXS-GLR-001, "Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris").

Note that the flow rate for test #16 was not reduced because of a change from a conservative to a best estimate flow rate. The flow was reduced because the flow that had been used in the earlier testing was based on AP1000 LTC analysis that was performed with no added pressure loss across the screens and core. The AP1000 uses natural circulation to provide flow through the reactor during LTC following a LOCA. As a result, when additional pressure loss is introduced in the flow circuit, the flow rate decreases. This characteristic is different than it is for the operating plants which rely on pumps to provide flow to the reactor. With pumps the flow to

the core will vary little if any as debris is added until enough debris is added and the pumps start to cavitate and the flow can stop completely.

The flow rate used in the earlier tests was 8.5 gpm. As stated in the preceding paragraph, this flow was based on the DCD LTC analysis which had no added resistance across the screens and the core. Test #16 was based on the flow rate calculated in the LTC sensitivity case #3. Scaled to the FA test facility the flow rate is 5.3 gpm. This flow rate is appropriate for the testing because it is how the plant is expected to operate with significant pressure losses across the screens and the core and it avoids the need to extrapolate the flow / pressure loss from one flow to another.

In preparing this response it was discovered that the head loss limit in Table 9-1 of WCAP-17028-P, Revision 1, does not list the correct head loss limit for test #16. As described in section 7.14, the pressure loss limit was reduced to 3.5 psi for test #16. In addition section 8.1 and Table 8-1 need to be revised to clarify that the head loss limit (and flow rate are different for test #16). The WCAP will be revised accordingly.

In order to improve the ease of understanding this situation, the LTC sensitivity analysis report will be revised to list the added screen and core pressure loss at the calculated flow core and screen flow rates instead of at the DCD analysis case.

For the second issue, it should be recognized that during LTC operation the AP1000 core flow does vary or oscillate with time. Note that for the original FA testing the flow rate used was 8.5 gpm/FA. This flow was based on the DCD LTC analysis which had a high core flow of 179 lb/sec. This bounded most but not all of the flow oscillations. The nominal flow for this case was 152 lb/sec which would relate to a test flow of 7.2 gpm/FA.

In test #16, a flow rate of 5.3 gpm/FA was used. This flow rate was based on the LTC sensitivity case #3 which had a nominal core flow of 111 lb/sec. In this LTC sensitivity case, the high flow is about 122 lb/sec or 5.8 gpm/FA and the low flow is 92 lb/sec or 4.4 gpm/FA. Note that the variation between nominal and high is about half of what it is in the DCD case.

The head loss is modeled in the LTC analysis with a fixed flow resistance such that the head loss varies with the square of the flow. As a result, the head loss across the core and screens varies with the flow rate. So as the reactor flow varies from to 4.4 gpm to 5.3 gpm to 5.8 gpm the pressure loss across the core would range from 2.4 to 3.5 to 4.2 psi.

Use of the nominal flow rate is considered adequate because:

- Use of the average flow reduces in half the magnitude of the flow difference between is tested and the extreme flows calculated in the LTC sensitivity analysis. By testing the average flow the most different flow is 9% higher or lower. If the maximum flow was used in the tests, the most different flow would be the minimum flow which would be 18% lower.

- In the LTC sensitivity analysis, when the flow is increased the pressure loss across the screen or core is increased by the flow squared. It is recognized that this extrapolation may not be 100% accurate, however given the relatively small change in flow the potential error induced will be small,
- The flow will be lower than the nominal flow the same amount of time that it is higher. If the increase in pressure loss is underestimated when the flow is higher, the decrease in pressure loss will also be underestimated when the flow is lower. As a result, potential errors in the calculated pressure loss will cancel out.
- The core is well covered with water during LTC analyses such that minor differences in flow / pressure loss would not lead to uncovery of the core.

The screen / core flow rates will be changed in the DCD in section 6.3.2.2.7.1, item 12 as follows:

	Current	Revised
• CR screens	1548 gpm	827 gpm
• IRWST screens	1548 gpm	410 gpm
• Core	1325 gpm	827 gpm

The response to RAI-SRP6.2.2-SPCV-21, item b), addresses the implications of this change on the ability of the RNS to operate post LOCA. The response to RAI-SRP6.2.2-SPCV-19 addresses the flow rates and pressure losses assumed in the structural design of the screens.

Additional NRC Question (from public meeting 9/2/09):

Does the debris bed form in a different way at the 5.3 gpm flow rate used in test #16 (scaled from LTC case #3 with maximum debris) than at the 8.5 gpm flow rate used in test #15 (scaled from the DCD LTC case, without debris), such that the DP would be different. Justify whether sufficient testing has been performed to provide reasonable assurance that LTC can be provided in the AP1000.

Additional Westinghouse Response:

After review of the existing fuel assembly debris testing performed for the AP1000 as well as for the Westinghouse Owners Group, Westinghouse has concluded that several confirmatory tests should be performed to provide greater assurance of adequate LTC. These tests are intended to address the following uncertainties:

1. That with higher initial core flow rates, which may occur during initial recirculation operation prior to debris accumulation and head loss increase, that adequate LTC is provided at the lower / final flow rates.

2. That the use of a nominal final flow rate is adequate for determining that the head loss limit is met.
3. That uncertainty in the behavior of the head loss with debris amounts is addressed.

Four confirmatory tests are planned to address these uncertainties. The following describes these tests and how they address these uncertainties.

Test #17 – This test is intended to address items 1, 2 and part of 3. It will be performed with a high initial flow that will be reduced as the head loss increases. The high initial flow (11 gpm) has been selected to bound RNS operation and a large CL LOCA. The final flow (5.3 gpm) is based on the LTC sensitivity analysis case #3 (as was done in test #16). In addition, after the test has reached the test termination criteria, but before the test is stopped, the flow rate will be increased and decreased to the minimum and maximum cyclic flows occurring in the LTC sensitivity case #3. Head loss measurements will be taken at these flows to verify that the head loss used in the LTC sensitivity analysis is satisfied; the DP limit will be based on a constant flow resistance such that the DP at the maximum flow of 6.0 gpm is 4.49 psi and at the minimum flow of 4.6 gpm is 2.64 psi. The use of a constant flow resistance is consistent with how WCOBRATRAC models the flow vs DP in the LTC analysis. Tests #18 - #20 will not vary the flow in this fashion. This test will also show that the plant is not sensitive to additional particles resulting from the ZOI coating debris.

Tests #18/19/20 – These tests are intended to address item 3 (together with test #17). These tests will be the same as test #17 except that in each of these 3 tests, one of the debris loads (particles, fibers, chemicals) will be reduced to 1/3 of the value used in test #17.

- Test #18 will have reduced particles,
- Test #19 will have reduced chemicals,
- Test #20 will have reduced fibers.

These tests will be considered successful if the head loss is less than 3.5 psi at 5.3 gpm (same DP limit used in test #17). As done in test #17, the DP limit will be based on the actual flow rate assuming a constant resistance; if the final flow is 5.4 gpm (instead of 5.3 gpm) the DP limit will be 3.63 psi instead of 3.5 psi. These tests are proposed to demonstrate that lower amounts of debris do not result in unexpected increases in the head loss. This is not expected to occur based on past AP1000 tests, however one of the Westinghouse fuel assembly tests did result in an increase in the head loss when the amount of particles were reduced. That situation is not expected to occur in AP1000 because the debris loads are already in the lower particle load region where there is higher head loss.

Details of these planned confirmatory tests are shown in the attached table. Note that WCAP-17028-P provides a more complete discussion of the table including the test inputs and results. This table also lists all of the valid FA tests that have been performed for the AP1000.

Appendix A lists the conservatisms contained in the AP1000 GSI-191 evaluation.

Successful completion of these tests is considered to provide reasonable assurance that GSI-191 is addressed and long-term core cooling can be provided in the AP1000.

APP-GW-GLR-079, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA," and WCAP-17028, "Evaluation of Debris-Loading Head-Loss Tests For AP1000 Fuel Assemblies During Loss of Coolant Accidents" will be updated in to include these test results and to provide justification as to why this testing is sufficient.

Appendix A – Conservatisms in AP1000 GSI-191 Evaluation

The AP1000 incorporates many conservatisms in its evaluation of GSI-191. These conservatisms in total are very significant and add considerable conservatism to the AP1000 evaluation. The AP1000 testing shows that the lower expected debris loads and flows will result in lower head losses.

- The total amount of latent debris assumed to be in the containment is conservatively large (130 pounds). This amount is conservative because the operating plant walk downs show that the average amounts are about 90 pounds.
- The amount of ZOI produced epoxy coating debris (fines) is overestimated because the testing performed to determine the ZOI showed no damage down to 1.3 diameters where as a ZOI of 4 is used.
- The AP1000 assumes that 100% of the latent fibrous and particulate debris transports. This is conservative because the AP1000 does not have a containment spray system, and as a result, much of the latent debris located on the containment operating deck or above will not be washed into the recirculation flows. In addition, there are several rooms in the containment that will not be flooded in this event; these rooms include both PXS valve rooms and the CVS room. As a result, the latent debris located in these rooms will not be transported.
- None of the debris that is transported is assumed to settle out before reaching a screen or a flooded break. As observed in the screen tests, the fiber debris tends to settle out even in the higher velocities approaching the IRWST screens. Generally the velocities in the AP1000 containment are significantly lower and there is at least two hours of settling time between the time of the break and the start of recirculation.
- In considering the maximum amount of debris that may be transported into the core through a flooded break, it is assumed that 100% of the debris in the containment would be transported to the loop compartments and therefore be available to the CR screens and/or a flooded break. None of the debris is assumed to be transported into the IRWST screen in this case. Some of this debris is expected to be transported into the IRWST because some of the latent debris located above the operating deck will be washed into the IRWST.
- For the design and testing of the IRWST screens it has been assumed that 50% of the total debris in the containment is washed into the IRWST. This is conservative because more than half of the debris will be located below the operating deck (where the gutter collects water from the containment vessel). In addition, much of the debris locate on or above the operating deck will be washed down to the lower portions of the containment and not into the IRWST gutter.
- The cold leg and the DVI line double ended breaks are limiting for the transport of debris to the core and to the IRWST screens. Limiting for the core because of the larger debris bypass of the containment recirculation screens. Limiting for the IRWST screens because more particles and chemicals can be transported by the recirculation flow into the IRWST and because only one screen can be in operation. These lines are leak-

before-break lines and as a result they have much lower probabilities of rupture than other small cold leg, DVI branch lines or the HL lines. There are several reasons for this difference:

- There are fewer welds on these lines; for example cold leg pipes have only 2 welds on each line and there are 4 lines. There are many more potential break locations in the smaller branch lines connected to the cold leg, DVI lines and the HLs.
- The RCS leakage detection instruments are designed to detect leakage at a rate that is significantly less than that exhibited at the critical flaw size for a 4" pipe. Since the CL are 22" and the DVI lines are 8", leakage for these lines will be detected with flaw sizes that are much smaller than its critical flaw size.

- The amount of chemical precipitates is very conservative because:
  - The amount of aluminum inside containment is likely to be less than the design limit.
  - The corrosion rate of aluminum is conservatively high considering that testing has shown that the corrosion rates drops over time with trisodium phosphate (TSP).
  - The concentration of chemical precipitates does not credit the likelihood of the TSP being in solution at a low 30 day concentration of 10 ppm.
  - The testing of the core head loss is performed using AlOOH mixed at a very high concentration which forces a large amount of precipitates.
- The magnitude of recirculation flow is biased high because the LTCC analysis uses the Appendix K decay heat (P/P_o) which has an associated 20% uncertainty biased high. Since decay heat is what drives the passive system operation, this assumption results in a higher flow rate. The larger flow rate results in a larger pressure drop across the screens and fuel due to debris loading associated resistances, and supplies a larger fluid velocity for debris transport.
- The viscosity of the recirculation water will be significantly lower than in the tests that were conducted on the head losses through the screens and fuel assemblies due to the temperature being much lower that it will be in the plant. As a result the head loss across the fuel assemblies and the screens will be significantly less. The lower viscosity will also improve settling of debris.

AP1000 Fuel Assembly Debris Tests

Include in WCAP 17028 >	rev 0	rev 0	rev 0	rev 0	rev 1	rev 1	rev 1	rev 1	rev 1	rev 1	rev 1	rev 1	rev 2	rev 1	planned	planned	planned	planned	
	Test #1	Test #2	Test #3	Test #4	Test #5	Test #6	Test #8	Test #9	Test #10	Test #11	Test #13	Test #14	Test #15	Test #16	Test #17	Test #18	Test #19	Test #20	
	Bounding	Sensitivity	Super	Sensitivity	Super		<<<<<<< fiber length series >>>>>				(5)	(5)	(7)	(7)	(6,7)	(6,7)	(6,7)	(6,7)	
Test represents plant design basis	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	yes	no	no	no	
Total debris in containment (lb)	124.2	200.0	200.0	200.0	200.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	200.0	71.0	200.0	195.6	lb
Total ZOI coatings + margin (lb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	20.0	70.0	23.0	70.0	70.0	lb
Total latent debris (lb)	124.2	200.0	200.0	200.0	200.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	130.0	130.0	130.0	48.0	130.0	125.6	lb
Total fiber in containment (lb)	1.2	2.0	14.0	2.0	14.0	7.00	7.00	7.00	7.00	7.00	8.40	8.40	8.40	8.00	6.60	6.60	6.60	2.20	lb
% Fiber by Mass	1.0%	1.0%	7.0%	1.0%	7.0%	4.67%	4.67%	4.67%	4.67%	4.67%	5.60%	5.60%	5.60%	5.33%	5.08%	13.75%	5.08%	1.75%	
% Total transported	80.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
% Transported to recirc screens	82.5%	82.5%	82.5%	82.5%	82.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
% Recirc screen transported to core	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	60.0%	75.0%	75.0%	90.0%	90.0%	90.0%	90.0%	
Core debris loads																			
Particle debris (lb)	48.71	98.01	92.07	98.01	92.07	85.8	85.8	85.8	85.8	85.8	85.0	85.0	141.6	142.0	193.4	64.4	193.4	193.4	lb
Fiber debris (lb)	0.49	0.99	6.93	0.99	6.93	4.2	4.2	4.2	4.20	4.20	5.0	5.0	6.3	6.0	5.9	5.9	5.9	2.0	lb
Total debris (lb)	49.20	99.00	99.00	99.00	99.00	90.0	90.0	90.0	90.0	90.0	90.0	90.0	147.9	148.0	199.3	70.3	199.3	195.4	lb
Test debris loads																			
Particle debris (gm)	140.7	283.2	266.0	283.2	266.0	247.9	247.9	247.9	247.9	247.9	245.5	245.5	409.1	410.3	558.8	186.1	558.8	558.8	gm
Fiber debris (gm)	1.4	2.9	20.0	2.9	20.0	12.1	12.1	12.1	12.1	12.1	14.6	14.6	18.2	17.3	17.2	17.2	17.2	5.7	gm
Total debris (gm)	142.1	286.0	286.0	286.0	286.0	260.0	260.0	260.0	260.0	260.0	260.0	260.0	427.3	427.6	575.9	203.2	575.9	564.5	gm
Chemical debris (gm)	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	158.9	164.7	164.7	164.7	164.7	164.7	164.7	gm
Chemical, added (% of design) (9)	174%	348%	348%	348%	173%	130%	150%	150%	150%	150%	100%	100%	100%	100%	100%	100%	33%	100%	
(gm)	276.0	553.3	553.3	553.3	275.0	207.0	238.4	238.4	238.4	238.4	158.9	158.9	164.7	164.7	164.7	164.7	54.3	164.7	gm
Debris addition sequence	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	P/F/C	
Chemical mixed (in-loop or WCAP)	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	WCAP	
Chemical, first addition (% of design)	87%	87%	87%	87%	87%	29%	7.4%	7.4%	7.4%	7.4%	1.24%	1.24%	(6)	(6)	(6)	(6)	(6)	(6)	
(gm)	137.5	137.5	137.5	137.5	137.5	46.2	11.8	11.8	11.8	11.8	2.0	2.0	(6)	(6)	(6)	(6)	(6)	(6)	gm
Particle type	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	SiC	
Fiber length type	A	A	A	A	B	B	B	C	D	E	B	E	B	B	B	B	B	B	
Flow rate (3)	8.5	8.5-4.7	8.5	8.5	8.5	8.5	8.5-4.7	8.5-4.7	8.5-4.7	8.5-4.7	8.5	8.5	8.5	5.3	(8)	(8)	(8)	(8)	gpm
Test has been run?	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	
Measured head loss before chem add	0	0	1.3	0	0.2	0.2	0.0	0.1	0.1	0.0	0.1	0.1							psi
Measured head loss max	0	0	1.6	0	5.2	2.5	1.8	1.9	1.5	2.2	3.9	3.5	6.54	2.5					psi
Head loss limit (2)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	3.5	3.5	3.5	3.5	3.5	psi
Test successful	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes					

Tests shaded in grey are planned to be run in Sept 2009. Tests in the red box were run with the same slow continuous initial chemical addition (note 6). The purple highlighted cells are significant changes.

Note:
1) Fiber used in tests is all fiberglass except type E. Type A is very short (typical of what leaks through screens). Type B is mix of very short and longer. Type C is about 3/8" long. Type D is 67% Type C & 33% Type A. Type E is 67% cotton poly material strands (1/2" & 1") and hair (2") and 33% Type B.
2) The head loss limit is based on LTC sensitivity analysis that shows that the core flows reduce to 5.3 gpm with a head loss of 3.5 psi. If the flow was high higher the head loss limit would be 6.5 psi.
3) Test #8 performed better (23%) than test #6, so it was decided to use a varing flow in the subsequent tests. In final design basis tests (#13 & 14) constant flow was used.
4) Tests #12 was be run with chemicals added directly to loop. It is expected that with this addition procedure there will be no precipitation and therefore no DP increase due to the chemicals until the design amount of chemicals is greatly exceeded. As a result, the use of the very short fibers (type A) is expected to be limiting since they have higher DP without chemicals.
5) Tests #13 and #14 were run with continuous addition of the initial chemicals. The rate of addition was maintained at more than 2 times the plant production.
6) Tests #15 and later will be run with the initial addition of chemicals added by a metering pump at a constant rate. The initial rate will be 4.3 g/hr for 20 min, immediately followed by 1 g/hr for 30 min; this adds 1.93 g of AlOOH. Later additins will be in batches poured in over 5 min; time will be 2.0 g at 2 hours, 5.5 g at 3 hours, 11.0 g at 4 hours, 33.0 g at 5 hours and 111.3 g at 6 hours. Test #20 adds same total chemicals but addition rate cut by factor of 4.
7) Tests #15 and later assume all the particles in the containment get transferred to the FA (ie none get trapped on the CR screens).
8) Tests #17 - #20, use a high initial flow (11 gpm) and assume the flow reduces to 5.3 gpm as DP increases. At completion of test flow is increased to 6.0 gpm and data taken. The flow will be reduced to 4.6 gpm and data taken.
9) In all of these tests (except #19) 100% of the chemical debris produced in the plant are assumed to transport to the FA.

Design Control Document (DCD) Revision:

The DCD changes will be included in a revision to APP-GW-GLE-002.

PRA Revision:

None

Technical Report (TR) Revision:

The following reports will be revised as a result of this RAI:

- APP-GW-GLR-079, Revision 4, "AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA"
- APP-GW-GLE-002, Revision 3, " Impacts to the AP1000 to Address Generic Safety Issue (GSI-191)"
- APP-PXS-GLR-001, Revision 1, "Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris"
- WCAP-17028-P, Revision 1, "Evaluation of Debris-Loading Head-Loss Tests for AP1000 Fuel Assemblies During Loss of Coolant Accidents"

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.2-SRSB-24
Revision: 0

Question:

The design basis for the total amount of resident fibrous debris that could be transported to the reactor core is described in APP-GW-GLR-079 (TR26), Revision 4, as 6 lbm based on the 75% of debris bypassing the sump recirculation screen determined from a direct vessel injection (DVI) line break in the loop compartment. However, among the 13 fuel assembly head loss tests described in WCAP-17028-P, Rev. 1, only 3 tests (Test Nos. 3, 5, and 16) were performed with the equivalent core fiber amount ≥6 lbm. A review of the test results also provides the following insights:

- With the same test conditions except for different fiber types, Test #5 with fiber type F produces a head loss 200% higher than Test #3 with fiber type A.
- With the same fiber type B, the constant flow test #6 produces a head loss 24% higher than the oscillating flow test #8 with a more gradual addition of chemical debris.
- Among the oscillating flow rate test cases #8, 9, 10 and 11 with different types of fiber, the test results indicate a head loss difference of 35% between fiber Type E and Type D.
- With the same fiber type B, Tests #13 with 5 lbm fiber (core equivalent) and the first chemical addition of 1.9 grams shows a 60% higher head loss than Test #6 with 4.2 lbm fiber and the first chemical addition of 46.2 grams, and 110% higher head loss than the oscillating flow test #8 with 4.2 lbm fiber and the first chemical addition of 11.8 grams.
- As stated in RAI-SRP6.2.2-SRSB-22, there are contradictory test results in that the head loss decreases with more chemical addition after the first addition for some tests.

The head loss Test 16 with Type B fiber at the design basis 6 lbm of core-equivalent amount and 111 lbm/s core inlet flow shows only small margin in the head loss test result to the acceptance criterion. Considering the uncertainty and potential effects of actual plant fiber type and chemical addition increments on the fuel assembly head loss, which was demonstrated in the test cases documented in WCAP-17028, Revision 1, and the observation of the inconsistent test results described above, justify why one test (Test 16) with the design basis fiber amount provides assurance that the long-term cooling acceptance criterion of 10 CFR 50.46 is met, and therefore no additional tests are necessary.

Westinghouse Response:

As noted in WCAP-17028, section 7.6 Test #5 CIBAP05, the goal of Test#5 was to use the debris loading that was used in Test #3 but with longer fibers to determine the effect of the fiber length on the pressure drop characteristics of the debris. For Test#5, a different fiber preparation procedure was developed and used to produce Fiber F, which had a higher average fiber length than the Fiber A used in test CIBAP03 but consisted of unbaked NUKON® with its binder intact. Along with the longer individual fibers, this fiber type was composed of large

agglomerated clumps of NUKON® that did not separate when prepared for introduction into the test loop. The intact binder prohibited the prepared fiber from separating into individual fibers. This fiber type was deemed non-typical of the of the individual latent fiber expected in the AP1000 containment as defined in NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing March 2008 ("For example, fibers introduced into the test to represent latent fibers should not only be of characteristic diameters but should effectively transport as individual fibers. The staff is unaware of any reasonable justification for latent fiber to accumulate and transport as clumps".). Due to the large clumps and agglomerations associated with this fiber, it was not used in any subsequent testing. The large head-loss associated with test was attributed to the non-typical fiber.

There are two differences between tests #6 and #8 that explain the differences in head loss. One is the oscillating flow and the other is the more gradual addition of chemicals. The object of the oscillating flow tests was to determine if the typical behavior of the post LOCA AP1000 oscillating flow rate was more conservative than a constant maximum flow rate. The testing indicated that the constant flow rate provides a more conservative result. In addition, the more gradual addition of chemicals also resulted in a smaller initial peak after the initial chemical additions. The more gradual addition of chemicals in test was still much faster than the plant production.

The results of tests #8, #9, #10, #11 are discussed in WCAP-17028-P in section 8.1. The purpose of these 4 tests was to investigate the impact of using different fiber lengths and materials. The two fiber types with the highest DPs (type B and E) were further evaluated in tests #13 and #14. These 2 tests were identical except that different fibers were used. These two tests differed from tests #8-11 in that the amount of fiber was increased and the initial chemical addition was done with a metering pump instead of small batches. These two tests showed that fiber type B had the highest DP. Since these two tests are closer to the AP1000 debris amounts they were used to select fiber type B for the remaining tests.

Test #13 used a higher fibrous debris load than Test #6. The testing showed that the larger the quantity of fiber used in the test, the higher the head loss.

The response to RAI-SRP6.2.2-SRSB-22 provides our best understanding/ of the reason the head loss increases during initial AlOOH additions and eventually decreases with the later additions.

Considering the discussion in the preceding paragraphs especially on fiber types and chemical addition rates, Westinghouse believes that test #16 was performed using the limiting AP1000 conditions with respect to debris loading, flow rates and head loss limit. To provide greater assurance of long-term cooling acceptability, several confirmatory fuel assembly tests have been planned. These tests are described in the response to RAI-SRP6.2.2-SRSB-23.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None