Westinghouse

Westinghouse
Electric
Company

September 8, 2003

To: John Segala
US NRC
Rockville, MD

Re: **Transmittal of Westinghouse AP1000 Design Control Document Revison 4**

Enclosed is the transmittal of one (1) copy of the AP1000 Design Control Document, Revison 4 as the attachment to the Westinghouse letter DCP/NRC1574 dated April 15, 2003. This attachment Was inadvertently missing from your copy of this Letter.

This report is forwarded to you today via Federal Express.

Please contact me with any questions or concerns.

M. M. Corletti
Passive Plant Projects &
Development
Nuclear Power Plants
P. O. Box 355 (E325a, E3-08)
Pittsburgh, PA 15230-0355
412-374-5355
412-374-5456 fax
email: corletmm@westinghouse.com

D063

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 6.2.1.8.3-1 (Revision 2)

Original RAI Number(s): 650.001

Summary of Issue:

The water level in containment following a LOCA would be sufficiently high that DCD Tier 2 Section 3.4.1.2.2.1 states that inventory from the containment pool would ". . . flow back into the RCS via the break location . . . ." In light of this statement, the staff issued RAI 650.001 to request additional information concerning the potential for entrained debris to cause blockage at flow restrictions within the RCS once flow begins entering through the break location after flood-up (i.e., bypassing the recirculation screens). In a letter dated February 21, 2003, the applicant responded to RAI 650.001 by submitting an analysis which concluded that RMI debris is incapable of causing such blockage. Although the applicant's response partially addressed the staff's RAI, it was not complete because it did not address the potential for other sources of debris, such as fibrous debris and floatable debris, to enter the RCS through the break location and block requisite core cooling flowpaths. Pending the complete resolution of this concern, the staff considers debris blockage in the RCS to be DSER Open Item 6.2.1.8.3-1.

Westinghouse Response:

Westinghouse revised its response to RAI 650.001 in order to address the NRC concerns as discussed in our teleconference on April 3, 2003. The revised RAI response was submitted to the NRC on April 24, 2003 in letter DCP/NRC1580. Based on discussions with the NRC after the issuance of the DSER, it was agreed that this response satisfactorily addressed the NRC concerns except for the calculated debris pressure loss. Westinghouse agreed to revise the calculation of the pressure loss across a debris bed located in the core **and to perform additional sensitivity studies on particulate characteristics.** The revised calculation **and sensitivity studies are** based on the following:

1. A total of 500 lb of resident debris (fiber and particles) is assumed to be located inside containment.
2. This debris is assumed to be neutrally buoyant (both fibers and particles) such that they are easily transported with flow.
3. The resident debris is distributed around the containment in proportion to the floor areas.
4. If a floor area sees flow either from LOCA blowdown, ADS venting or containment recirculation, then debris assigned to that floor area is assumed to be transported to a screen.
5. If a floor area does not see flow (whether it floods or not) then none of the debris assigned to that floor area is assumed to be transported.
6. The head losses across the screens will be calculated using the "BLOCKAGE" code. The resident debris fiber material is assumed to be represented by NUKON.

7. Sensitivity studies will be performed with variations in the amount of debris transported to the screens, in the mass ratio of fiber versus particulate debris **and in the types of particulates assumed in the resident debris.**

Based on these assumptions, methods and approaches, the head loss analysis performed for RAI 650.001 (debris in the core) was revised.

Resident Fibrous and Particle Debris:

A potential source of debris is resident fiber and particles inside containment. Such debris might be close enough to the density of water that it would stay suspended in the containment water long enough that it could be transported to containment recirculation screens and possibly also into the RCS through a break that becomes flooded.

DSER open item response 2.1.8.3-3 R1 discusses the amount of such debris that might exist in the containment. It describes an appropriate method to determine the amount of debris that might be transported. It also describes an appropriate method using the BLOCKAGE code to calculate the resulting pressure drop if this debris is transported to a containment recirculation screen. That same method has been applied to a situation with a break location that becomes flooded and could allow some of this debris to enter the RCS. Key assumptions made in this evaluation include:

- A total of 500 lb of resident debris is located in the containment (DSER OI 2.1.8.3-3 R1). The base case assumes that this debris is divided 50/50 between fibers and particles. Also, as described below, sensitivity studies are also performed assuming a range of particulate to fiber ratios.
- The debris is distributed around the containment in proportion to the floor areas. As discussed in DSER OI 6.2.1.8.3-3 R1, not all of this debris will be transported because some floor areas will not see flow during a LOCA.
- The limiting break location with respect to maximizing the debris that might enter the RCS has been determined to be a DVI break in a loop compartment. Such a break will result in none of the operating deck and only a portion of the CMT room floor (< 67%) seeing flow. As a result, less than 250 lb of resident debris will be transported.
- The debris deposited on any screen is assumed to be based on the flow split about containment. As noted above, for the DVI break in a loop compartment, less than 250 lb of resident containment debris is available for transport. Of this amount of debris, about 100 lb of debris will be transported to the IRWST screens. The remainder (150 lb) will be transported to the recirculation screens and to the RCS via the break. This 150 lb is further divided in the proportion of the relative flows as described below.
- Conservative analyses have shown that 60% of the total flow to the core is through the break and 40% through the recirculation screens. Assuming the debris transport is proportional to the flow, 60% of the resident debris will enter the RCS through the break

(90 lb). The other 40% (60 lb) would to be trapped on the two recirculation screens. These debris amounts are based on the relative flows through the break and through the PXS recirc lines as shown on DCD figures 15.6.5.4C-13 and -14 after 7000 sec. Although the flow through the break into the RCS starts earlier than through the PXS recirc lines, it would take many hours to transport all of the debris to the RCS / recirc screens. For example, the total water mass in the containment floodup areas is about 5,236,000 lb. At a recirc flow of 180 lb/sec it would take about 10 hours for all of this water to flow through the RCS. The situation for the recirc screens is much less limiting than that discussed in DSER OI response 2.1.8.3-3 R1, so that the resulting it is not discussed in this RAI.

- The first location where debris may be trapped in the RCS is on the bottom nozzle of the fuel assembly. Each nozzle has 632 flow holes that are 0.19 in inside diameter. These holes are spaced such that debris would accumulate across the whole nozzle area except the outside edge where there are no holes. The area that could accumulate debris is more than 66 ft^2 considering all of the fuel assemblies. Another location where debris could be trapped is in the P-Grid, which is located just above the bottom nozzle. The area where debris could accumulate is defined as the fuel assembly area less the area taken by the fuel rods and thimbles for shutdown rods and I&C. The minimum flow area through this part of the core is 41.55 ft2. The smaller area (around the P-Grid) is assumed for the purposes of calculating the pressure loss.

- The flow rate through the core is assumed to be 180 lb/sec. This flow is based on the maximum injection flows through both DVI lines as shown on DCD figures 15.6.5.4C-13 and -14 after 7000 sec.

- Using the core inlet temperature from COBRA-TRAC calculations for this event (~240 F), the volumetric flow rate would be 1370 gpm.

- At this flow rate, the screen face velocity with this flow is 0.073 ft/sec.

- With the above amounts of debris and flow rates, the pressure loss across the debris is calculated by the BLOCKAGE code to be less than 0.39 psi. A summary of BLOCKAGE Code input and resulting output for the base case are shown on table **6.2.1.8.3_1-1** that follows. Refer to DSER OI response to 2.1.8.3-3 R1 for additional discussion on the use of the BLOCKAGE code.

- In addition to the base calculation, sensitivity studies were performed on the amount of debris transported and the mass ratio of fiber to particulate debris.
  - Sensitivity calculations were performed varying the total mass of material from 80% (72lb.) to 120% (108lb.) of the base case (90 lb). This sensitivity addresses possible variability in the amount of debris available to transport.
  - Fiber to particulate mass ratios ranging from 30% fiber/ 70% particulate to 70% fiber/ 30% particulate were investigated for all three total mass cases. This sensitivity addresses the impact of fiber to particulate ratios different from the base case assumption of a 50/50 split.

The results of these sensitivity analyses are shown in table 6.2.1.8.3_1-1 that follows. The pressure drops for all the cases investigated ranged from 0.25 psid to 0.63 psid. For the range of masses and mass ratios investigated, the range of calculated pressure drop values was narrow and the trend of pressure drops within the range showed no unexpected results.

- **A second set of sensitivity studies was performed on the types of particulate debris assumed in the resident debris. Several different types of debris were modeled and the results compared to the base case debris type used in this analysis. The results of these sensitivity analyses are shown in table 6.2.1.8.3_1-2 that follows.**
  - **Blockage runs were made for alternate particle debris types; in the first set of alternate debris analysis the only change from the previous analysis was to increase the particle specific surface area from 20,000 to 50,000 ft2/ft3. This change creates a very conservative situation of a large specific surface area with a low specific gravity (1.1); both are drivers for a larger pressure drop. The results of these runs show that the pressure drop for the base case (50% fiber/50% particle) increases from 0.39 psi to 0.76 psi. The alternate case with more particles (30% fiber/70% particle) results in an higher pressure drop of 0.96 psi and the case with less particles (70% fiber/30% particle) results in a lower pressure drop of 0.74 psi.**
  - **Similar Blockage runs were made for particles with attributes of Analytical Test Problem Debris from NUREG/CR-6371, Reference 1, as shown in Table 4-3 of that report. The BLOCKAGE runs were made for the debris types of Paint, Junk, and Cal. Silicate with the following attributes:**
    - **Paint: Particle specific surface area = 50,000ft2/ft3; Particle fabricated density = 180lb/ft3; Particle Rubble Density = 45lb/ft3; Particle Material Density = 180lb/ft3.**
    - **Junk: Particle specific surface area = 900ft2/ft3; Particle fabricated density = 300lb/ft3; Particle Rubble Density = 95lb/ft3; Particle Material Density = 491lb/ft3.**
    - **Cal. Silicate: Particle specific surface area = 20,000ft2/ft3; Particle fabricated density = 90lb/ft3; Particle Rubble Density = 20lb/ft3; Particle Material Density = 110lb/ft3.**

    The results from these runs in Table 6.2.1.8.3_1-1, show that the pressure drops calculated for the particle characteristics used in the base case calculations are representative of the types of particles that may be present in the AP1000 containment. The resulting pressure drops for these three representative particulate types are very similar to the base case pressure drop values and are less than the pressure drop results from the arbitrary particle characteristic combination of 1.1 specific gravity and a 50,000 ft2/ft3 specific surface area.

Reference 1 contains characteristics for various types of particulate material that has been postulated to be present inside containment buildings of nuclear power plants. These types of particulate material are recommended for

consideration when a plant evaluates the susceptibility of ECCS sump performance degradation to the presence of resident fibers and materials inside containment. The studies performed by Westinghouse in the evaluation of the AP1000 as presented in this DSER Open Item response and related responses have included bounding material properties that are considered appropriate for the AP1000. Products of corrosion are not expected to play a role in the pressure drops considered in this analysis for the AP1000. Therefore, the pressure drops for the debris type of Sludge as defined in Reference 1 is not considered. These products of corrosions are included in Reference 1 for application to BWR containment buildings that contain carbon steel-lines suppression pools tanks that come in contact with oxygenated water. These corrosion products are not applicable to the AP1000 or other pressurized water reactor designs.

- The mechanism for driving flow through the core is the water level in the downcomer relative to the water/steam mixture level in the core region. In this case the downcomer water level is about 22 in below the top of the active fuel in the recirculation time frame (7000 sec), as shown in DCD figure 15.6.5.4C-1. This level is about 70 in below the DVI connection to the reactor vessel. The injection from the DVI lines would not be affected by the downcomer water level as long as the level is below the DVI connection. Therefore in case there is an additional pressure loss of 0.39 psi across the core, the downcomer water level would increase by about 12 in so that the flow through the core is maintained. The water level in the downcomer would still be 58 in below the DVI connection.

  Even if the pressure drop was 1.0 psi across the debris, the downcomer water level would increase by 30 in. (instead of 12 in.) and would still be well below (40 in.) the DVI connection. The flow through the core would be unaffected. This pressure drop bounds the pressure drop calculated assuming a high percentage of particles (70%) and the arbitrary particle characteristics of 1.1 specific gravity and a 50,000 ft2/ft3 specific surface area.

In summary, the bounding pressure loss through a **conservatively large amount of resident** debris that might deposit in the core would not reduce the flow to the core. **In order to provide additional confidence that the above calculated pressure drops are bounding, a COL item will be added to verify that potential resident particles have an average specific surface area ≤ 50,000 ft2/ft3 and an average specific gravity ≥ 1.1. The determination of these characteristics will be based on sample measurements from operating plants, such as the research planned by the NRC to characterize latent debris (Reference 2).**

References:

1. **NUREG/CR-6371, "BLOCKAGE 2.5 Reference Manual", December 1996.**

2. "Recent Results and Future GSI-191 Research" (Presentation at NEI PWR Sump Performance Workshop, Baltimore, Maryland, 7/30-31/03), B. Letellier, Los Alamos National Laboratory

Table 6.2.1.8.3_1-1. Core Pressure Drop

	Mass Debris (lbm)	Percent Fiber	Percent Particulate	Mass Fiber (lbm)	Mass Particulate (lbm)	Thickness (in)	Pressure Drop (ft-water)	Pressure Drop (psi)	Blockage Case Name
	90	30%	70%	27	63	3.26	0.72	0.31	APCO_301
	90	40%	60%	36	54	4.34	0.79	0.34	APCO_302
Base Case	90	50%	50%	45	45	5.43	0.91	0.39	APCO_303
	90	60%	40%	54	36	6.51	1.04	0.45	APCO_304
	90	70%	30%	63	27	7.59	1.21	0.52	APCO_305
80% of Total Debris	72	30%	70%	22	50	2.61	0.57	0.25	APCO_311
	72	40%	60%	29	43	3.47	0.63	0.27	APCO_312
	72	50%	50%	36	36	4.30	0.72	0.31	APCO_313
	72	60%	40%	43	29	5.21	0.83	0.36	APCO_314
	72	70%	30%	50	22	6.08	0.97	0.42	APCO_315
120% of Total Debris	108	30%	70%	32	76	3.90	0.86	0.37	APCO_306
	108	40%	60%	43	65	5.24	0.96	0.42	APCO_307
	108	50%	50%	54	54	6.52	1.09	0.47	APCO_308
	108	60%	40%	65	43	7.82	1.25	0.54	APCO_309
	108	70%	30%	76	32	9.12	1.45	0.63	APCO_310

INPUT TO BLOCKAGE CODE

Value	Parameter	Description	Note
AP1000 Calculation Fiber and Particulate Debris Parameters			
0.986	ε_f	Pure fiber bed porosity	
175	ρ_f	Fiber density (lb_m/ft^3) also Material density	
2.4	c_0	Fabricated Fiber Density	
68.64	ρ_p	Particle density (lb_m/ft^3)	
1.71E+05	Sv	Specific (volumetric) surface area (ft^2/ft^3)	
AP1000 Core Pressue Drop			
1370	685	Flow of Water though Recirc. Screen (GPM)	
200		Temperature of water at screen (deg. F.)	
41.55		Core Flow Area (ft2)	
90		Mass of Total Debris (lbm) Base Case	

Table 6.2.1.8.3_1-2. Sensitivity Studies: Blockage Runs on Varying Attributes of the Particulate Debris												
	Mass Debris (lbm)	Percent Fiber	Percent Particulate	Mass Fiber (lbm)	Mass Particulate (lbm)	Particle Sv (ft2/ft3)	Particle Fab. Density (lb/ft3)	Particle Material Density (lb/ft3)	Thickness (in)	Pressure Drop (ft-water)	Pressure Drop (psi)	Blockage Case Name
	90	30%	70%	27	63	20,000	68.64	68.64	3.26	0.72	0.31	APCO_301
	90	40%	60%	36	54	20,000	68.64	68.64	4.34	0.79	0.34	APCO_302
Base Case	90	50%	50%	45	45	20,000	68.64	68.64	5.43	0.91	0.39	APCO_303
	90	60%	40%	54	36	20,000	68.64	68.64	6.51	1.04	0.45	APCO_304
	90	70%	30%	63	27	20,000	68.64	68.64	7.59	1.21	0.52	APCO_305
Part. SG=1.1, Sv=50,000	90	30%	70%	27	63	50,000	68.64	68.64	3.26	2.21	0.96	APCOe301
	90	50%	50%	45	45	50,000	68.64	68.64	5.43	1.76	0.76	APCOe303
	90	70%	30%	63	27	50,000	68.64	68.64	7.59	1.71	0.74	APCOe305
Paint (Note 1)	90	30%	70%	27	63	50,000	180.00	180.00	3.26	0.98	0.42	APCOf301
	90	50%	50%	45	45	50,000	180.00	180.00	5.43	1.19	0.52	APCOf303
	90	70%	30%	63	27	50,000	180.00	180.00	7.59	1.45	0.63	APCOf305
Junk (Note 1)	90	30%	70%	27	63	900	300.00	491.00	3.26	0.43	0.19	APCOg301
	90	50%	50%	45	45	900	300.00	491.00	5.43	0.83	0.36	APCOg303
	90	70%	30%	63	27	900	300.00	491.00	7.59	1.25	0.54	APCOg305
Cal. Silicate (Note1)"	90	30%	70%	27	63	20,000	90.00	110.00	3.26	0.59	0.26	APCOh301
	90	50%	50%	45	45	20,000	90.00	110.00	5.43	0.87	0.38	APCOh303
	90	70%	30%	63	27	20,000	90.00	110.00	7.59	1.22	0.53	APCOh305

INPUT TO BLOCKAGE CODE			
Value	Parameter	Description	Note
AP1000 Calculation Fiber and Particulate Debris Parameters			
0.986	ε_f	Pure fiber bed porosity	
175	ρ_f	Fiber density (lbm/ft3) also Material density	
2.4	c_0	Fabricated Fiber Density	
68.64	ρ_p	Particle density (lbm/ft3)	
1.71E+05	S_v	Specific (volumetric) surface area (ft2/ft3)	
AP1000 Core Pressue Drop			
1370		Flow of Water though Core (GPM)	
200		Temperature of water at screen (deg. F.)	
41.55		Core Flow Area (ft2)	
Note 1		Debris Type Attributes from NUREG/CR-6371 Table 4-3, Reference 1	

Design Control Document (DCD) Revision:

DCD Table 1.8-2 will be revised as follows:

Table 1.8-2 (Sheet 3 of 6)

SUMMARY OF AP1000 STANDARD PLANT COMBINED LICENSE INFORMATION ITEMS

Item No.	Subject	Subsection
4.3-1	Changes to Reference Reactor Design	4.3.4
4.4-1	Changes to Reference Reactor Design	4.4.7
5.2-1	ASME Code and Addenda	5.2.6.1
5.2-2	Plant Specific Inspection Program	5.2.6.2
5.3-1	Reactor Vessel Pressure - Temperature Limit Curves	5.3.6.1
5.3-2	Reactor Vessel Materials Surveillance Program	5.3.6.2
5.3-3	Surveillance Capsule Lead Factor and Azimuthal Location Confirmation	5.3.6.3
5.3-4	Reactor Vessel Materials Properties Verification	5.3.6.4
5.3-5	Reactor Vessel Insulation	5.3.6.5
5.4-1	Steam Generator Tube Integrity	5.4.15
6.1-1	Procedure Review for Austenitic Stainless Steels	6.1.3.1
6.1-2	Coating Program	6.1.3.2
6.2-1	Containment Leak Rate Testing	6.2.6
6.3-1	Containment Cleanliness Program	6.3.8.1
6.3-2	**Verification of Containment Resident Particulate Debris Characteristics**	**6.3.8.2**
6.4-1	Local Toxic Gas Services and Monitoring	6.4.7
6.4-2	Procedures for Training for Control Room Habitability	6.4.7
6.4-3	Main Control Room Inleakage Test Frequency	6.4.7

DCD section 6.3.8 will be revised as follows:

6.3.8 Combined License Information

6.3.8.1 Containment Cleanliness Program

The Combined License applicants referencing the AP1000 will address preparation of a program to limit the amount of debris that might be left in the containment following refueling and maintenance outages.

6.3.8.2 Verification of Containment Resident Particulate Debris Characteristics

The Combined License applicants referencing the AP1000 will determine that resident particles that could be present considering the plant location and the containment cleanliness program, have an average specific surface area ≤ 50,000 ft2/ft3 and an average specific gravity ≥ 1.1. The determination of these characteristics will be based on sample measurements from operating plants. If these characteristics are not satisfied, then a determination will be made that the resident debris particle characteristics, when considering the plant-specific cleanliness program, will allow for adequate core cooling.

PRA Revision:

None