Westinghouse

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U.S. Nuclear Regulatory Commission
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Your ref: Docket No. 52-006
Our ref: DCP/NRC1668

January 13, 2004

SUBJECT: Transmittal of Responses to AP1000 DSER Open Items

This letter transmits the Westinghouse responses to Open Items in the AP1000 Design Safety Evaluation Report (DSER). A list of the DSER Open Item responses transmitted with this letter is Attachment 1. The proprietary responses are transmitted as Attachment 2. The non-proprietary responses are provided as Attachment 3 to this letter.

The Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit are also enclosed with this submittal letter as Enclosure 1. Attachment 2 contains Westinghouse proprietary information consisting of trade secrets, commercial information or financial information which we consider privileged or confidential pursuant to 10 CFR 2.790. Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosures.

This material is for your internal use only and may be used for the purpose for which it is submitted. It should not be otherwise used, disclosed, duplicated, or disseminated, in whole or in part, to any other person or organization outside the Commission, the Office of Nuclear Reactor Regulation, the Office of Nuclear Regulatory Research and the necessary subcontractors that have signed a proprietary non-disclosure agreement with Westinghouse without the express written approval of Westinghouse.

D063

January 13, 2004

Correspondence with respect to the application for withholding should reference AW-04-1771, and should be addressed to James A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Please contact me at 412-374-4728 if you have any questions concerning this submittal.

Very truly yours,

R. P. Vijuk, Manager
Passive Plant Engineering
AP600 & AP1000 Projects

/Enclosure

1. Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit AW-04-1771.

/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1668
2. Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated January 13, 2004
3. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated January 13, 2004

January 13, 2004

Enclosure 1

Westinghouse Electric Company
Application for Withholding and Affidavit

Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

January 13, 2004

AW-04-1771

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. John Segala

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: Transmittal of Westinghouse Proprietary Class 2 Documents Related to AP1000 Design Certification Review Draft Safety Evaluation Report (DSER) Open Item Response

Dear Mr. Segala:

The application for withholding is submitted by Westinghouse Electric Company, LLC ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject documents. In conformance with 10 CFR Section 2.790, Affidavit AW-04-1771 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-04-1771 and should be addressed to the undersigned.

Very truly yours,

R. P. Vijuk

R. P. Vijuk, Manager
Passive Plant Engineering
AP600 & AP1000 Projects

/Enclosures

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared James W. Winters, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company, LLC ("Westinghouse"), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief.

James W. Winters, Manager
Passive Plant Projects & Development
Nuclear Power Plants Business Unit

Sworn to and subscribed
before me this 13th day
of January, 2004

Lorraine M. Piplica
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Lorraine M. Piplica, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Dec. 14, 2007
Member, Pennsylvania Association Of Notaries

(1) I am Manager, Passive Plant Projects & Development, of the Westinghouse Electric Company LLC ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of the Westinghouse Electric Company, LLC.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.790 of the Commission's regulations and in conjunction with the Westinghouse application for withholding accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by the Westinghouse Electric Company, LLC in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.790, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in Attachment 2 as Proprietary Class 2 in the Westinghouse Electric Co., LLC document: (1) "AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Response."

This information is being transmitted by Westinghouse's letter and Application for Withholding Proprietary Information from Public Disclosure, being transmitted by Westinghouse Electric Company letter AW-04-1771 to the Document Control Desk, Attention: John Segala, CIPM/NRLPO, MS O-4D9A.

This information is part of that which will enable Westinghouse to:

(a) Provide documentation supporting determination of APP-GW-GL-700, "AP1000 Design Control Document," analysis on a plant specific basis

(b) Provide the applicable engineering evaluation which establishes the Tier 2 requirements as identified in APP-GW-GL-700.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for Licensing Documentation.

(b) Westinghouse can sell support and defense of AP1000 Design Certification.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar methodologies and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended for performing and analyzing tests.

Further the deponent sayeth not.

DCP/NRC1668
Docket No. 52-006

January 13, 2004

Copyright Notice

January 13, 2004

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.790 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.790(b)(1).

January 13, 2004

Attachment 1

List of

Proprietary and Non-Proprietary Responses

Table 1 **"List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1668"**	
6.2.1.8.2-1, Revision 2 6.2.1.8.3-1, Revision 3 6.2.1.8.3-3, Revision 2 14.2.10-1, Revision 4 *Proprietary	*21.5-2P Item 19 Revision 3 21.5-2 Item 19 Revision 3

DCP/NRC1668
Docket No. 52-006

January 13, 2004

Attachment 3

AP1000 Design Certification Review
Draft Safety Evaluation Report Open Item Non-Proprietary Responses

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: **6.2.1.8.2-1 (Response Revision 2)**

Original RAI Number(s): **650.004**

Summary of Issue:

The applicant's February 21, 2003, response to RAI 650.004 also included an analysis of the IRWST screens' capability to accommodate debris accumulation. The staff's review of the applicant's analysis showed that the mass of resident debris assumed by the applicant (i.e., 227 kg, or 500 lb) was consistent with estimates made for current generation PWRs in the Generic Safety Issue (GSI) 191 parametric study (NUREG/CR-6772). However, the staff could not accept this analysis, primarily because the applicant assumed that a single density value is valid for all density-dependent calculations involving resident fibrous debris. According to the physical properties of analyzed types of fibrous materials, potentially different density values may be required to correctly determine the settling velocity (i.e., the material density), to calculate a volume from the assumed mass (i.e., the "as-found" density), and to determine the thickness and porosity of the associated debris bed (i.e., the rubblized density). As a result of the applicant's single-density assumption, which deviated significantly from the material properties of the low-density fiberglass on which the head loss data referenced by the applicant was based, the NRC staff concluded that the calculation was unacceptable. During a teleconference on April 3, 2003, the applicant agreed to resubmit its response to RAI 650.004, in light of the staff's concern. Pending an acceptable resolution of this concern, the staff considers the capability of the AP1000 IRWST screens to accommodate anticipated debris loadings to be DSER Open Item 6.2.1.8.2-1.

Westinghouse Response: (Revision 2)

COL items 6.3.8.1 (Containment Cleanliness Program) and 6.3.8.2 (Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA) were revised in the response to DSER OI 6.2.1.8.3-4. The revised COL item 6.3.8.2 requires an evaluation consistent with Regulatory Guide 1.82, revision 3, to demonstrate that adequate long-term core cooling is available considering debris resulting from a LOCA together with debris that might be present in the containment before the LOCA. The evaluation will be performed using applicable research and testing at the time of the evaluation. The COL items along with the AP1000 design features provide confidence that the AP1000 will be able to provide long-term core cooling following a LOCA.

In addition, a design change has been incorporated into the AP1000 to add additional margin to the ability of the IRWST screens to tolerate debris. This change is the incorporation of additional screen area (through the use of a folded screen design). The additional screen area allows the screen to tolerate more debris.

Changes to the DCD and ITAACs are shown in DSER OI response 6.2.1.8.3-3, Revision 3.

Westinghouse Response: (Revision 1 response)

Westinghouse revised its response to RAI 650.004 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 pressure loss. Westinghouse agreed to revise the calculation of the pressure loss across the IRWST screens. The revised calculation is based on the following:

1. There are 500 lb of resident debris (fiber and particles) 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 associated with that floor area is 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 both the amount of debris transported to the screens and in the mass ratio of fiber versus particulate debris.

Based on these assumptions, methods and approaches, the pressure drop analysis performed for RAI 650.004 (IRWST screens) was revised.

Ability of IRWST Screens to Tolerate Debris

Even though there is a low probability of having debris in the IRWST and having that debris transported to the screens in the IRWST, the IRWST screens and the PXS have significant capability to tolerate debris. A bounding analysis of the pressure drop that could be caused by debris (fiber and particle) on the IRWST screens has been performed for the AP1000.

The assumptions used in the analysis include:

- A total of 500 lb of resident debris is located inside 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.

- All of the debris is neutrally buoyant (fiber and particle) such that it is easily transported by flow. No credit is taken for settling or trapping of debris other than on the screens.

- This 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 debris loading on the IRWST screens has been determined to be the break of a pipe connected to the top of the Pressurizer that washes a portion (33%) of the operating deck into the IRWST via the gutter. This event results in less than 260 lb (of the 500 lb) of debris being transported to PXS screens.

- The debris deposited on any screen is assumed to be based on the flow split about containment. As noted above, for the LOCA of a pipe connected to the top of the Pressurizer, a total of about 260 lb resident containment debris is available for transport. Of this amount of debris, about 130 lb is transported to the IRWST screens. The remainder (130 lb) is transported to the containment recirculation screens.

- There are two screens in the IRWST, each with an area of 70 ft2. With the limiting break location, there is injection from both IRWST lines into the RCS. Note that even with a DVI break there is flow through both IRWST lines although one spills.

- The plant response to the break of a pipe at the top of the Pzr will be similar to its response to a spurious ADS LOCA. In a spurious ADS, the flow rate through each IRWST screen is 90 lb/sec (DCD figure 15.6.5.4B-13, -14). Note that for a DVI LOCA the IRWST flows are greater, as much as 160 lb/sec (at about 2700 sec, DCD figure 15.6.5.4B-71). In order to bound the IRWST flows and screen debris loadings, the DVI LOCA flows are used in this analysis. At the IRWST water conditions for this event, the 160 lb/sec mass flow results in a volumetric flow rate of 1170 gpm.

- At this flow rate, the screen face velocity is 0.037 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 0.03 psi. A summary of BLOCKAGE Code input and resulting output for the base case are shown on the table that follows. Refer to DSER OI response to 2.1.8.3-3 for additional discussion on the use of the BLOCKAGE code.

- In addition to the base calculation, sensitivity calculations 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% (104lb.) to 120% (156lb.) of the base case (130 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 on the table that follows. The pressure drops across the screens for all the cases investigated ranged from 0.02 psid to 0.04 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.

- The pressure loss through the intact IRWST injection line from the IRWST to the RV downcomer is more than 5.8 psi at this flow rate. The increase in screen DP for the base case shown above is only 0.03 psi or less than 4%. The IRWST injection flow would only have to decrease an insignificant amount to compensate for this increase in screen DP. The potential impact on injection flow is insignificant.

In summary, it is concluded that the current AP1000 design is not susceptible to degradation of IRWST gravity injection flow due to IRWST screen blockage resulting from deposition of resident containment debris on the screens.

IRWST SCREEN									
	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
100% of Total Debris	130								
	130	30%	70%	39	91	1.39	0.05	0.02	APRS_201
	130	40%	60%	52	78	1.86	0.05	0.02	APRS_202
Base Case	130	50%	50%	65	65	2.32	0.06	0.03	APRS_203
	130	60%	40%	78	52	2.78	0.07	0.03	APRS_204
	130	70%	30%	91	39	3.25	0.08	0.03	APRS_205
80% of Total Debris	104	30%	70%	31	73	1.11	0.04	0.02	APRS_211
	104	40%	60%	42	62	1.49	0.04	0.02	APRS_212
	104	50%	50%	52	52	1.85	0.05	0.02	APRS_213
	104	60%	40%	62	42	2.23	0.06	0.03	APRS_214
	104	70%	30%	73	31	2.60	0.07	0.03	APRS_215
120% of Total Debris	156	30%	70%	47	109	1.67	0.06	0.03	APRS_206
	156	40%	60%	62	94	2.23	0.06	0.03	APRS_207
	156	50%	50%	78	78	2.78	0.07	0.03	APRS_208
	156	60%	40%	94	62	3.34	0.09	0.04	APRS_209
	156	70%	30%	109	47	3.90	0.10	0.04	APRS_210

		INPUT TO BLOCKAGE CODE	
Value	Parameter	Description	Note
AP1000 Calculation Fiber and Particulate Debris Parameters			
0.986	ε_f	Pure fiber bed porosity	NUKON, Reference 2
175	ρ_f	Fiber density (lb_m/ft^3) also Material density	NUKON, Reference 2
2.4	c_0	Fabricated Fiber Density	NUKON, Reference 2
68.64	ρ_p	Particle density (lb_m/ft^3)	Specific Gravity of 1.1
1.71E+05	Sv	Specific (volumetric) surface area (ft^2/ft^3)	NUKON, Reference 2
AP1000 IRWST Screen			
1170		Flow of Water though Recirc. Screen	
120		Temperature of water at screen (deg. F.)	
140		IRWST screen (2 x 70 ft2) total flow area (ft^2)	
130		Mass of Total Debris (lbm) Base Case	

Design Control Document (DCD) Revision:

None

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 6.2.1.8.3-1 (Revision 3)

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: (Revision 3)

COL items 6.3.8.1 (Containment Cleanliness Program) and 6.3.8.2 (Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA) were revised in the response to DSER OI 6.2.1.8.3-4. The revised COL item 6.3.8.2 requires an evaluation consistent with Regulatory Guide 1.82, revision 3, to demonstrate that adequate long-term core cooling is available considering debris resulting from a LOCA together with debris that might be present in the containment before the LOCA. The evaluation will be performed using applicable research and testing at the time of the evaluation. These COL items along with the AP1000 design features provide confidence that the AP1000 will be able to provide long-term core cooling following a LOCA.

Westinghouse Response: (Revision 2 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.

- 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 3 is not considered.

- 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 $\leq$ 50,000 ft2/ft3 and an average specific gravity $\geq$ 1.1. The determination of these characteristics will be based on sample measurements from operating plants.

References:

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

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	

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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:

< The following COL items were revised in DSER OI 6.3.8.1. >

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: **6.2.1.8.3-3 (Response Revision 2)**

Original RAI Number(s): **650.005**

Summary of Issue:

The staff's review found that insufficient information was available in the DCD to determine whether the containment recirculation screens are capable of tolerating anticipated post-accident debris loadings. Therefore, in RAI 650.005, the staff requested additional information from the applicant to determine the debris-blockage failure criterion of the containment recirculation screens. The applicant responded to RAI 650.005 in a letter dated February 21, 2003, by providing an analysis intended to demonstrate that the AP1000 recirculation screens could accommodate a mass of resident debris (i.e., 227 kg, or 500 lb) that is equivalent to estimates made for current generation PWRs in the GSI-191 parametric study (NUREG/CR-6772). However, the staff could not accept this analysis, primarily because the applicant assumed that a single density value is valid for all density-dependent calculations regarding resident fibrous debris. According to the physical properties of analyzed types of fibrous materials, potentially different density values may be required to correctly determine the settling velocity (i.e., the material density), to calculate a volume from the assumed mass (i.e., the "as-found" density), and to determine the thickness and porosity of the associated debris bed (i.e., the rubblized density). As a result of the applicant's single-density assumption, which deviated significantly from the material properties of the low-density fiberglass on which the head loss data referenced by the applicant was based, the NRC staff concluded that the calculation was unacceptable. During a teleconference on April 3, 2003, the applicant agreed to resubmit its response to RAI 650.005, in light of the staff's concern. Pending an acceptable resolution of this concern, the staff considers the capability of the AP1000 containment recirculation screens to accommodate anticipated debris loadings to be DSER Open Item 6.2.1.8.3-3.

Westinghouse Response: (Revision 2)

COL items 6.3.8.1 (Containment Cleanliness Program) and 6.3.8.2 (Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA) were revised in the response to DSER OI 6.2.1.8.3-4. The revised COL item 6.3.8.2 requires an evaluation consistent with Regulatory Guide 1.82, revision 3, to demonstrate that adequate long-term core cooling is available considering debris resulting from a LOCA together with debris that might be present in the containment before the LOCA. The evaluation will be performed using applicable research and testing at the time of the evaluation. The COL items along with the AP1000 design features provide confidence that the AP1000 will be able to provide long-term core cooling following a LOCA.

In addition, two design changes have been incorporated into the AP1000 to add additional margin to the ability of the recirculation screens to tolerate debris. Those changes include incorporation of additional screen area (through the use of a folded screen design) and the addition of a cross connection pipe between the two recirculation screens. The additional screen area allows the screen to tolerate more debris. The cross connection, allows both screens to operate in the limiting LOCA location in a PXS room. A LOCA in a PXS room results in the recirculation squib valves being flooded before they are actuated. Since they are not qualified for operation with these conditions, they are assumed to fail. The recirculation valves in the unaffected PXS room will open to allow recirculation flow. With the addition of the cross connection, the recirculation line in the unaffected PXS room will draw flow from both recirculation screens and double the available screen area.

Changes to the DCD and ITAACs are shown at the end of this response.

Westinghouse Response: (Revision 1 response)

Westinghouse revised its response to RAI 650.005 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, Westinghouse agreed to revise the calculation of the pressure loss across the containment recirculation screens. The revised calculation is based on the following:

1. There are 500 lb of resident debris (fiber and particles) iassumed 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 are performed with variations in both the amount of debris transported to the screens and in the mass ratio of fiber versus particle debris.

Based on these assumptions, methods and approaches, the head loss analysis performed for RAI 650.005 (containment recirculation screen) was revised.

Ability of Containment Recirculation Screens to Tolerate Debris

Fibrous insulation is not used inside containment of the AP1000 where it can be damaged by LOCA blowdown jets and is therefore not considered in responding to this item.

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. Thus, resident containment debris will be used for calculations performed to respond to this DSER OI.

The parametric sump blockage evaluation performed for GSI-191 and reported in LA-UR-01-4083 (Reference 1) assumed a range of 100 lb to 500 lb for latent containment debris. The larger value will be used for this evaluation even though the AP1000 containment is smaller than a large dry containment used for a typical 4-loop plant. Further, it will be assumed for the base case that 50% or one half of the latent containment debris will be in the form of fiber. Sensitivity studies will be performed to show the impact of varying this distribution.

An evaluation was performed to determine the amount of the resident debris that might be transported to the recirc screen. This evaluation assumed that:

- The resident debris is distributed around the containment in proportion to the floor areas.
- If a floor area sees flow from LOCA blowdown, ADS venting or containment recirculation, then debris associated with that floor area is assumed to be transported to a screen.
- 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.

In the AP1000, there are two significant floor areas that do not usually see flow following a LOCA. These areas include the operating deck and the CMT floor. Since the AP1000 does not have a automatic spray system that will be used during design basis accidents, the operating deck will not see flow from a spray system as in current PWRs. The AP1000 does have a nonsafety-related spray feature that will only be used during severe accidents; the feature requires local manual actions. The CMT floor will not usually see flow from a LOCA unless the break is a DVI or CMT inlet break.

For the containment recirculation screens, the limiting case is a DVI break in a PXS room. This break location does not cause flow on the operating deck because of the arrangement of the AP1000 containment. It is assumed that a DVI break can cause flow on a portion of the CMT floor during the LOCA blowdown. This flow would exit the PXS room through vents in its roof (CMT floor) and would allow spray / overflow from the room to wash a portion of the CMT floor (< 50%). Note that there are conservatisms in this calculation including no credit for settling and no credit for debris being flushed down into the reactor vessel cavity by the initial LOCA blowdown flow. As a result of this evaluation, it is calculated that less than 250 lb (of the 500 lb in the containment) will be transported.

The postulated DVI line break in a PXS room is also limiting for the recirculation screens because it is assumed to render the recirculation valves located in the PXS room inoperable since they will be flooded before they are actuated. As a result, all of the recirculation flow will pass through a single recirculation screen. This condition maximizes the amount of debris transported to and collected on the single operating recirculation screen, and head loss across the resulting debris bed. In addition, a DVI break in one of the PXS rooms results in lower containment flood levels. For LOCAs in other locations, both recirculation screens will be available which will result in lower flow rates through each screen. In addition, the containment flood levels will be higher providing a greater driving head for injection.

For the DVI break in a PXS room, about 150 lb of resident debris will be transported to the one operable containment recirculation screen (of the 250 lb of debris transported). The remainder (100 lb) will be transported to the IRWST screens.

The volume of latent fibrous debris inside containment is calculated as:

$$\text{debris volume} = \text{debris mass} / \text{debris density}$$

Using the characteristics for NUKON from NUREG/CR-6224 as the fiber in our analysis :

$$\text{fabricated debris density} = 2.4\ lb/ft^3$$

Using this fabricated density (2.4 lb/ft3) and the fibrous debris mass (50% of 150 lb debris or 75 lb.) that reaches the recirculation screen, the volume of fibrous debris is calculated to be:

$$Volume = 31.2\ ft^3$$

A single AP1000 recirculation screen has a flow area of 70 ft2. Thus, assuming that all the fibrous debris is deposited onto the one operating recirculation screen, the thickness of the debris bed is calculated to be:

$$thickness = 31.2 ft^3 /(70\ ft^2) = 0.446\ ft = 5.35\ inches$$

NUKON was selected as the fiber for this evaluation. From previous work, it is known that saturated NUKON will be buoyant and thus will likely be transported to the screen. In addition the characteristics of NUKON are well documented in NUREG/CR-6224 and the correlation in the BLOCKAGE Code is verified for NUKON fibers.

It is recognized that even at low flow rates, buoyant-neutral debris will tend to be transported to the recirculation screen. Although from Table B-3, "Fibrous Debris Classification by Shape," of NUREG/CR 6224 (Reference 2), it is noted that even single strands of fiber will settle in calm pools. This evaluation took no credit for settling of fibrous debris.

Under long term cooling for a postulated DVI line break, the flow rate through the single operating recirculation screen is estimated to be about 180 lb/sec (refer to DCD figures 15.6.5.4C-13 and -14). With expected containment recirculation water temperatures, the flow through the recirc screen would be 1335 gpm.

The pressure drop through the mixed fiber bed is calculated using the BLOCKAGE Code, documented in NUREG/CR-6371, Reference 3, which uses the method described in Appendix B of Reference 2. Several assumptions used in the calculation are identified below:

- The fiber characteristics used in the analysis are the same as NUKON (fiberglass) in Reference 2. Due to the high porosity (98.6%), the use of NUKON fiber characteristics resulted in a relatively thick fibrous bed. This is taken to be a reasonable approximation.
- The specific gravity of the particulate debris is taken as 1.1. Assuming a low specific gravity maximizes the volume of particles and therefore the impact on calculated pressure drop.
- The cases run in BLOCKAGE were established in the "User Specified Volumes" mode. That is, the volume of material was iterated until the code specified mass of material deposited on the screen matched the mass for the case being run. This is necessary since the code iterates the deposited volumes based upon the concentration of material in the pool.

Using a flow of 1335 GPM relating to a velocity of 0.04 ft/sec and the BLOCKAGE 2.5 Code, the head loss through a mixed fiber bed on the recirculation screen is calculated to be:

$$\Delta P = 0.18 \text{ psid}$$

In addition to the base calculation, sensitivity studies were performed on the amount of debris transported and the ratio of fibers / particles.

- Sensitivity calculations were performed varying the total mass of material from 80% (120 lb.) to 120% (180 lb.) of the base case (150 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 assumption of a 50/50 split.

The results of these sensitivity analyses are shown on the table that follows. The pressure drops for all the cases investigated ranged from 0.11 psid to 0.29 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.

The assumption of a 50 / 50 split between latent fibrous and particulate debris is considered a reasonable engineering judgement. In addition, reasonable variations of this split (30/70 to 70/30) only have second order effects on the calculated DP.

The base calculated increase in pressure drop through the recirculation screen, assuming the collection of resident containment debris on the screens, is small (~6%) compared with the 2.8 psi in these lines during the DCD analysis. Note that the recirculation flow would only have to decrease ~ 3% to compensate for this increase in screen DP. Also note that if best estimate PXS line resistances were assumed, it would completely compensate for the debris DP. The potential impact on PXS flow, especially with best estimate line resistances, is insignificant.

The above calculated increase in pressure drop due to a mixed fiber-particulate is considered conservative for the following reasons:

- The limiting flow case was assumed. That is, only one of the two recirculation screens was taken to be operable due to the assumed break location. This provided for a maximum velocity to and through the operating recirculation screen, also maximizing the potential for debris transport to the operating recirculation screen.
- The value of 500 lb of resident containment debris inside containment is based on a value that was scaled from BWR's to be representative of a large dry containment for PWR's. The floor area of the AP1000 is less than that of a current large dry containment for PWR's. Thus, the initial mass of resident containment debris used for the AP1000 evaluation is conservative.
- The total amount of latent containment debris used in the evaluation is considered large. An aggressive foreign materials exclusion program and good housekeeping practices are expected to maintain latent containment debris sources well below the 500 lb level.
- A conservative estimate of the maximum debris loading on the containment recirculation screen is assumed. Debris on floor areas subject to flow from the event is assumed to reach the screens. No credit is taken for settling of this debris.

In summary, it is concluded that the current AP1000 design is not susceptible to loss of natural circulation of coolant from the containment due to recirculation screen blockage resulting from deposition of latent containment debris on the recirculation screen.

References:

1. LA-UR-01-4083, Revision 1, "GSI-191: Parametric Evaluations for Pressurized Water Reactor Circulation Sump Performance," dated August 2001
2. Regulatory Guide 6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," dated August 1994
3. NUREG/CR-6371, "BLOCKAGE 2.5 Reference Manual", December 1996.

RECIRCULATION SCREEN									
	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**
100% of Total Debris	150								
	150	30%	70%	45	105	3.21	0.33	0.14	APRS_101
	150	40%	60%	60	90	4.29	0.37	0.16	APRS_102
Base Case	150	50%	50%	75	75	5.35	0.42	0.18	APRS_103
	150	60%	40%	90	60	6.42	0.48	0.21	APRS_104
	150	70%	30%	105	45	7.53	0.57	0.25	APRS_105
80% of Total Debris	120	30%	70%	36	84	2.57	0.26	0.11	APRS_111
	120	40%	60%	48	72	3.43	0.29	0.13	APRS_112
	120	50%	50%	60	60	4.30	0.34	0.15	APRS_113
	120	60%	40%	72	48	5.14	0.39	0.17	APRS_114
	120	70%	30%	84	36	6.00	0.45	0.20	APRS_115
120% of Total Debris	180	30%	70%	54	126	3.85	0.39	0.17	APRS_106
	180	40%	60%	72	108	5.14	0.44	0.19	APRS_107
	180	50%	50%	90	90	6.43	0.50	0.22	APRS_108
	180	60%	40%	108	72	7.71	0.58	0.25	APRS_109
	180	70%	30%	126	54	9.00	0.68	0.29	APRS_110

		INPUT TO BLOCKAGE CODE	
Value	**Parameter**	**Description**	**Note**
AP1000 Calculation Fiber and Particulate Debris Parameters			
0.986	ε_f	Pure fiber bed porosity	NUKON, Reference 2
175	ρ_f	Fiber density (lb_m/ft^3) also Material density	NUKON, Reference 2
2.4	c_0	Fabricated Fiber Density	NUKON, Reference 2
68.64	ρ_p	Particle density (lb_m/ft^3)	Specific Gravity of 1.1
1.71E+05	*Sv*	*Specific (volumetric) surface area* (ft^2/ft^3)	NUKON, Reference 2
AP1000 Recirculation Screen			
1335		Flow of Water though Recirc. Screen	
175		Temperature of water at screen (deg. F.)	
70		Single recirculation screen flow area (ft^2)	
150		Mass of Total Debris (lbm) Base Case	

Design Control Document (DCD) Revision:

DCD 6.3.2.2.7.3 Changes:

6.3.2.2.7.3 Containment Recirculation Screens

The containment recirculation screens are oriented vertically along walls above the loop compartment floor (elevation 83 feet). Figure 6.3-8 shows a plan view and Figure 6.3-9 shows a section view of these screens. Two separate screens are provided as shown in Figure 6.3-3. The loop compartment floor elevation is significantly above (11.5 feet) the lowest level in the containment, the reactor vessel cavity. The bottom of the recirculation screen is two foot above the floor, providing a curb function.

During a LOCA, the reactor coolant system blowdown will tend to carry debris created by the accident (pipe whip/jets) into the cavity under the reactor vessel which is located away from and below the containment recirculation screens. As the accumulators, core makeup tanks and IRWST inject, the containment water level will slowly rise above the 108 foot elevation. The containment recirculation line opens when the water level in the IRWST drops to a low level setpoint a few feet above the final containment floodup level. When the recirculation lines initially open, the water level in the IRWST is higher than the containment water level and water flows from the IRWST backwards through the containment recirculation screen. This back flow tends to flush debris located close to the recirculation screens away from the screens. A cross connect pipe line interconnects the two recirculation screens so that both recirculation screens will operate, even in the case of a LOCA of a DVI line in a PXS valve room. Such a LOCA can flood the recirculation valves located in one of the PXS rooms before they are actuated and the failure of these valves is assumed since they are not qualified to operate in such conditions. The recirculation valves in the other PXS valve room are unaffected.

The water level in the containment when recirculation begins is well above (~ 10 feet) the top of the recirculation screens. During the long containment floodup time, floating debris does not move toward the screens and heavy materials settle to the floors of the loop compartments or the reactor vessel cavity. During recirculation operation the containment water level will not change significantly nor will it drop below the top of the screens.

The amount of debris that may exist following an accident is limited. Reflective insulation is used to preclude fibrous debris that can be generated by a loss of coolant accident and be postulated to reach the screens during recirculation. The nonsafety-related coatings used in the containment are designed to withstand the post accident environment. The containment recirculation screens are protected by plates located above them. These plates prevent debris from the failure of nonsafety-related coatings from getting into the water close to the screens such that the recirculation flow can cause the debris to be swept to the screens before it settles to the floor. Stainless steel is used on the underside of these plates and on surfaces located below the plates, above the bottom of the screens, 10 feet in front and 7 feet to the side of the screens to prevent coating debris from reaching the screens.

A COL cleanliness program (refer to subsection 6.3.8.1) controls foreign debris introduced into the containment during maintenance and inspection operations. The Technical Specifications require visual inspections of the screens during every refueling outage.

The design of the containment recirculation screens reduces the chance of debris reaching the screens. The screens are orientated vertically such that debris settling out of the water will not fall on the screens. The protective plates described above provide additional protection to the screens from debris. The bottom of the screens are located 2 feet above the floor, instead of using a debris curb, to prevent high density debris from being swept along the floor by water flow to the containment recirculation screens. The containment recirculation screens are made up of a trash rack and a fine screen. The trash rack prevents larger debris from reaching the finer screen. The fine screen prevents debris larger than 0.125" from being injected into the reactor coolant system and blocking fuel cooling passages. The fine screen is a folded type that has more surface area than the trash rack in order to accommodate debris that could pass through the trash rack and be trapped on the fine screen.

The screen flow area is conservatively designed, considering the operation of the normal residual heat removal system pumps, which produce a higher flow than the gravity driven IRWST injection / recirculation flows. As a result, when the normal residual heat removal system pumps are not operating there is even more margin in screen clogging.

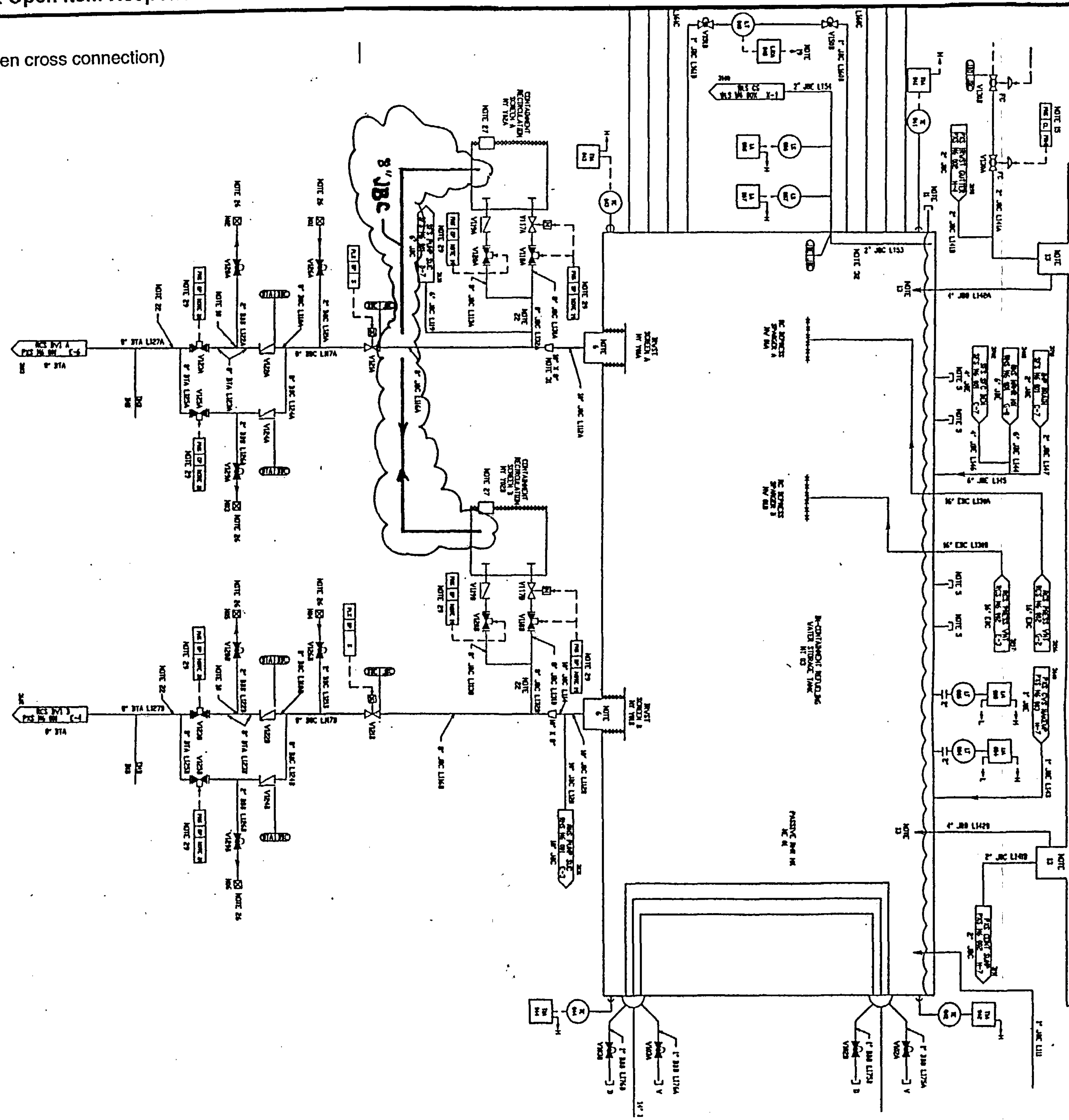
DCD Table 6.3-2 Changes:

Table 6.3-2 (Sheet 2 of 2)

COMPONENT DATA - PASSIVE CORE COOLING SYSTEM

pH Adjustment Baskets		
Number	4	
Type	Rectangular	
Volume minimum total (cubic feet)	560	
Material	Stainless steel	
AP1000 equipment class	C	
Screens	IRWST	Containment Recirculation
Number	2	2
Surface area, trash rack (square feet)	$\geq$70	$\geq$ 70
, fine screen (square feet)	$\geq$ 140	$\geq$ 140
Material	Stainless steel	Stainless steel
AP1000 equipment class	C	C

DCD Figure 6.3 (shows addition of recirculation screen cross connection)

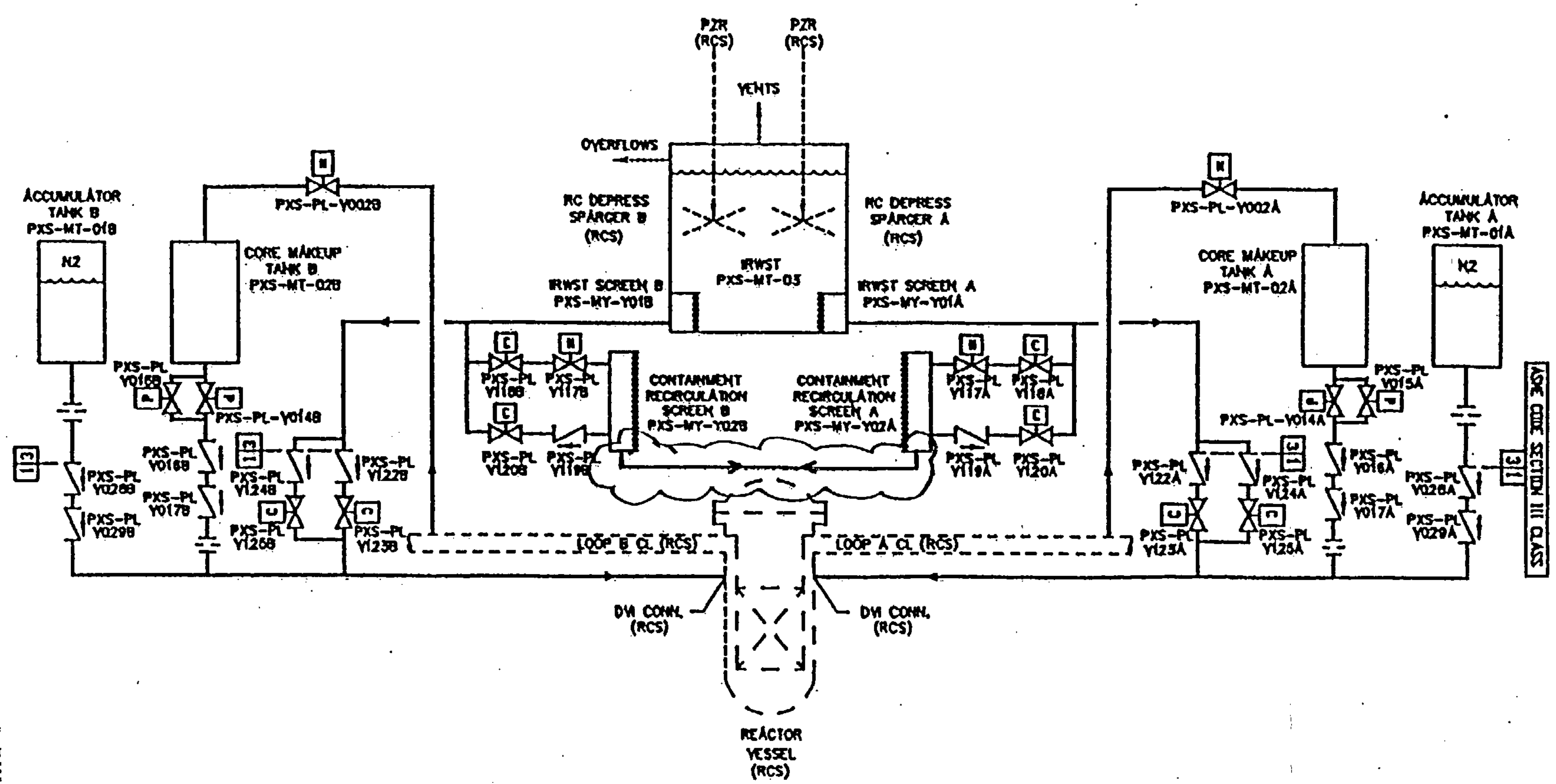


ITAAC Table 2.2.3-4 Changes:

Table 2.2.3-4 (cont.)
Inspections, Tests, Analyses, and Acceptance Criteria

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
	vii) Inspection of the as-built components will be conducted for plates located above the containment recirculation screens.	vii) Plates located above each containment recirculation screen are no more than 1 ft above the top of the screen and extend out at least 10 ft perpendicular to and at least 7 ft to the side of the trash rack portion of the screen.
	viii) Inspections of the IRWST and containment recirculation screens will be conducted.	viii) The screen surface area (width x height) of each screen trash rack is $\geq$ 70 ft^2 and each fine screen is $\geq$ 140 ft^2 (unfolded area). The bottom of the containment recirculation screens is $\geq$ 2 ft above the loop compartment floor.
	ix) Inspections will be conducted of the insulation used inside the containment on ASME Class 1 lines and on the reactor vessel, reactor coolant pumps, pressurizer and steam generators.	ix) The type of insulation used on these lines and equipment is a metal reflective type or a suitable equivalent.

ITAAC Figure 2.2.3-1 (shows addition of recirc screen cross connection)



AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 14.2.10-1 (Response Revision 4)

Original RAI Number(s): 261.009, 261.016

Summary of Issue:

RG 1.68, Appendix A, Item 4.c recommends performance of pseudo-rod ejection testing to verify calculation models and accident analysis assumptions during low power testing. The NRC staff could not locate an AP1000 low power test abstract that describes this testing. In RAI 261.009, the NRC staff requested that the applicant provide additional information regarding the performance of pseudo-rod ejection testing for the AP1000 design. In their November 13, 2002, RAI response, the applicant stated that sufficient test data has been obtained from previous plant startups and that licensees of new plants need only to confirm calculational models. The applicant also provided several licensing precedents associated with this position.

The NRC staff lacked sufficient information to accept the applicant's position regarding performance of low power pseudo-rod ejection testing. As described in the staff evaluation of RAI 261.007b, Item 2, below, the NRC staff requested that the applicant provide additional information relating to the conduct of pseudo-rod ejection testing. This request for additional information is identified as RAI 261.016. Pending resolution of RAI 261.016 and RAI 261.009, this is Open Item 14.2.10-1.

Westinghouse Response:

The responses to RAI 261.009 Rev. 0 and RAI 261.016 Rev. 0 were transmitted to the NRC via DCP/NRC1532 dated 11/15/02 and DCP/NRC1588 dated 05/13/03, respectively.

NRC Additional Comments:

Westinghouse should provide more of a basis for why the pseudo-rod-ejection test is performed at the 30 to 50% power range.

Westinghouse Additional Response: (Completely Revised in Revision 2)

The guidance of RG 1.68 item 4.c states that the pseudo-rod-ejection test should be performed at low power (less than 5%) to verify calculations models and accident analysis assumptions.

The guidance of RG 1.68 item 5e states that the pseudo-rod-ejection test should be performed at greater than 10% power. The guidance also states that this test need not be repeated for facilities using calculation models and designs identical to prototype facilities.

As advised in previous responses, for AP1000, pseudo-rod-ejection testing is performed in the 30% to 50% power range as per DCD section 14.2.10.4.6, "Rod Cluster Control Assembly Out of Bank Measurements". This testing is performed on the first plant only, which meets the guidance of RG 1.68 item 5e -- i.e. at greater than 10% power and need not be repeated for facilities using calculation models and designs identical to prototype facilities (in the case of AP1000, the first unit).

However, testing is not performed at low power (i.e. not consistent with RG 1.68 item 4.c) because Westinghouse has amassed sufficient data from the low power operation of operating plants to conclude that the Westinghouse nuclear physics codes are established nuclear design tools with validated performance records. Thus, there is no need to re-verify calculations models and accident analysis assumptions at low power. As the amassed data was obtained under conditions outside of the control of Westinghouse, it cannot be included in a WCAP but is available in a Westinghouse letter, "Core Physics Code Validation, PGD-82-109 dated March 16, 1982", which is proprietary. A copy of PGD-82-109 will be made available for viewing in the Westinghouse offices in Rockville, MD. The abstract and page 32 apply to this open item.

NRC (Nov 4, 2003) Additional Comments:

In reviewing Revision 1 to the applicant's Open Item 14.2.10-1 response (dated July 29, 2003), the staff agrees that Westinghouse has provided an adequate basis for not performing low power pseudo-rod ejection testing (described in RG 1.68, Appendix A, Item 4.c) for the purposes of verifying calculational models. However, the applicant has not provided sufficient information to demonstrate that this testing is not needed to verify accident analysis assumptions. Specifically, the staff lacked sufficient information to conclude that the AP1000 test program was capable of identifying an appropriate spectrum of potential fuel loading errors in a manner consistent with accident analysis assumptions.

Please address how the following are considered with respect to fuel loading error identification in the AP1000 test program:

a. The spectrum of mis-loading events analyzed. A sufficient number of fuel loading errors must be studied by the applicant and presented to show that the worst situation undetectable by incore instrumentation has been identified. The kinds of errors considered include loading of one or more assemblies into improper locations, and where physically possible, with incorrect orientation. For the AP1000 design, for burnable poison or fuel rods added to or removed from fuel assemblies, errors in these processes must be considered.

b. Changes in the power distribution and increased local power density.

c. The provisions made to search for loading errors after initial fuel loading.

d. How the test acceptance criteria would verify that the requirements of General Design Criteria (GDC) 13 are met via plant test and operating procedures include a provision requiring reactor instrumentation be used to search for potential fuel loading errors after initial fuel loading. A principle objective of GDC 13 is to ensure the appropriate use of instrumentation (e.g., the incore instruments used to detect fuel loading errors after initial fuel loading).

Westinghouse Response to NRC (Nov 4, 2003) Additional Comments:

a) Misloading events are not specifically analyzed since the startup physics testing program is designed to identify such an occurrence before it becomes significant. This is a basic objective of the ANS/ANSI-19.6.1 standard, "Reload Startup Physics Tests for PWR's". The startup physics test program for the AP1000 builds upon this standard program as a minimum, adding those tests that are unique for an initial plant startup.

b) Specific analysis of the power distribution measurements are made to identify deviations from expected that can be attributed to a misloading event. These processes are to be utilized for every refueling as a protection from such an event.

c) Once the reactor initiates the power increase, power distribution measurements are made and comparisons are made to the predictions. Deviations are identified and compared to the physical loading information acquired during and after the loading process. This is a process used for the initial and every subsequent refueling.

d) AP1000 meets GDC 13 as follows:
   - the rod out of bank tests performed for the first AP1000 plant establish that the instrumentation system is capable of detecting an anomaly,
   - the incore instrumentation system tests performed for each AP1000 plant would detect fuel loading errors.

NRC (Jan 7, 2004 telecon) Additional Comment:

The AP1000 DCD subsection 14.2.10.4.2 should be revised to indicate that the startup test is used to detect potential fuel loading errors.

Design Control Document (DCD) Revision:

AP1000 DCD subsection 14.2.10.4.2 will be revised as shown below:

14.2.10.4.2 Incore Instrumentation System

Objectives

- Obtain data for incore thermocouple and flux maps at various power levels during ascension to full power determine flux distributions and verify proper core loading and fuel enrichments.

Prerequisites

- Incore instrumentation system signal processing software is installed and operational

- For incore thermocouple and flux mapping, the plant is at various power levels greater than approximately 20 percent of rated thermal power

Test Method

- With the plant at approximate power levels of 25, 50, 75 and 100 percent of rated thermal power, obtain data from the incore instrumentation system and process to produce incore thermocouple and flux maps. (Actual power levels will be specified in the power ascension program test sequence.)

- Use data from the incore maps to verify that core power distribution is consistent with design predictions and the limits imposed by the plant Technical Specifications, including detection of potential fuel loading errors, and to calibrate other plant instrumentation. Refer to Technical Specifications Section 3.2, Power Distribution Limits.

Performance Criteria

- Core power peaking factors derived from the incore data are consistent with design predictions and the limitations of the plant Technical Specifications

- Data required for calibration of other plant instrumentation are obtained

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 21.5-2 Item 19 Revision 3

Original RAI Number(s): None

Summary of Issue:

As mentioned in the ACRS Meeting in Monroeville in July, 2003, the APEX test facility contains an oversized downcomer. The oversized downcomer will produce high liquid inventories for extended periods of time which will maximize the liquid and two-phase levels in the core and upper plenum. This suggests the APEX facility cannot be used to simulate the minimum liquid and two-phase levels in the inner vessel that could occur following small breaks in the AP1000 plant. With a larger downcomer, more liquid mass will be retained in the vessel for small breaks. The statements in the Westinghouse August 13, 2003 letter (DCP/NRC1611) that the APEX-1000 facility is well scaled to AP1000 and the two-phase level remains in the upper plenum while the core remains covered for all phases of the simulated accident may not be appropriate and is misleading.

Please discuss the impact of the larger downcomer on the relevant APEX tests and explain why the facility test results can be used to demonstrate that significant amounts of inventory in this facility apply to the anticipated AP1000 response. Please also explain the statement that the APEX tests show the insensitivity of the AP1000 system behavior to entrainment is unaffected in lieu of the excessive amounts of liquid in the inner vessel during the tests referred to in the August 13, 2003 letter.

NRC Follow-on comment (12/17/03 meeting handout):

Westinghouse response to 'Item 19' concluded that the APEX test facility is adequately scaled for downcomer inventory depletion relative to AP1000 during a potential situation in an SBLOCA where only the liquid inventory in the downcomer is available for core cooling. This is inconsistent with OSU scaling report (OSU-APEX-03001 on page 6-7), which states that the APEX facility downcomer is oversized relative to AP1000. Westinghouse needs to explain the inconsistency.

NRC Follow-on comment (1/8/04 conference call):

In its December 22, 2003, submittal, Westinghouse provided Revision 2 of its response. Westinghouse concluded that the APEX facility is adequately scaled for downcomer inventory depletion relative to AP1000 during a potential situation in a SBLOCA where only the liquid inventory in the downcomer is available for cooling. This conclusion was based on its scaling analysis showing that the ratio of the downcomer drain time constant between the APEX test facility and the AP1000 to be approximated ½. However, this time constant ratio was based on a value of the core mass flow ratio between the APEX and AP1000, which the staff finds to be based on the results of the "Simple Model" as opposed to using the mass flow ratio for which the APEX-AP1000 facility was scaled. Using the core flow scale ratio of 1/96, the staff calculated the downcomer depletion time constant ratio to be close to a value of 1, which indicates that the APEX downcomer is oversized since the APEX facility was designed to operate with a ½ time scale. This conclusion is consistent with the report OSU-APEX-03001,"Scaling Assessment for the Design of the OSU APEX-1000 Test Facility," May 12, 2003, which indicated that the APEX downcomer is oversized.

1. Please provide an evaluation of the effect of oversized downcomer on the test DBA-2. That is, assuming the DBA-02 test was performed with the APEX facility having a properly sized downcomer, what would be the expected core collapsed liquid level compared to Figure 21.5-2.19 in the August 13, 2003, submittal.

2. Westinghouse needs to address the "APEX-AP1000 Scaling Report Questions" provided by the staff in the December 17, 2003 meeting.

Westinghouse Response (Revision 3):

1. The following discussion from Revision 2 of this response is revised as shown below to address item 1 of the 1/8/04 NRC comments:

The scaling report for the OSU APEX-1000 test facility (see OSU-APEX-03001) correctly notes in various portions of Section 6.3 that the actual downcomer volume scale (~1/100) in APEX-1000 is larger than the ideal test facility scaling ratio of 1/192. The scaling report indicates that although the downcomer area is distorted in APEX, the height of the downcomer is appropriately scaled to the ¼ ideal test facility height scaling ratio. Therefore, the gravity head associated with gravity drainage from the downcomer should be well scaled in APEX-1000.

The scaling evaluation presented in Section 6.3 addresses the early portion of the ADS-4 phase when the ADS-4 flow is in a choked condition and mass flow is scaled by the ideal test scaling ration of 1/96. However, it is possible that the ADS-4 flow becomes unchoked before IRWST injection occurs. Therefore, an assessment was made regarding the most important parameter(s) to scale regarding the downcomer under these conditions. This assessment concluded that preserving the scaling of the downcomer gravity head and associated downcomer liquid inventory depletion rate were more important in preserving the integral effect behavior of the test facility than preserving the ideal volume scale of the downcomer. As noted above, the downcomer gravity head is appropriately scaled in APEX-1000 due to the ¼ height scale. The discussion below addresses the scaling of the downcomer relative to liquid inventory depletion.

The appropriate parameters for assessing the scaling of the downcomer liquid inventory are obtained from the governing conservation equations. The situation of particular interest is the liquid inventory depletion in the downcomer during the ADS-IRWST transition phase of a limiting SBLOCA such as a DEDVI event where downcomer liquid inventory is most seriously challenged. Downcomer inventory depletion rate is the key scaling parameter, rather than downcomer volume, because the depletion rate determines the rate at which the core approaches a boiloff condition during the ADS-IRWST transition phase.

Derivation of Scaling Parameters

To obtain the appropriate scaling parameters, apply the conservation of mass equation to the downcomer region such that downcomer liquid inventory is depleted to satisfy core cooling and is not replenished via safety injection. The conservation of liquid mass in the downcomer region for this situation is as follows:

$$\frac{dM_{\substack{downcomer\\liquid}}}{dt} = -m_{out} = -m_{core}$$

The liquid inventory can be represented via the liquid volume and density such that:

$$\rho_f \frac{dV_{\substack{downcomer\\liquid}}}{dt} = -m_{core}$$

Variables in the above equation can be non-dimensionalized as follows:

$$m^{+}_{core} = \frac{m_{core}}{m_{core,\,ref}}$$

$$\rho^{+}_{f} = \frac{\rho_f}{\rho_{f,\,ref}}$$

$$V^{+}_{dc\ liquid} = \frac{V_{dc\ liquid}}{V_{dc\ liquid,\,ref}}$$

So,

$$dV^{+}_{dc\ liquid} = \frac{dV_{dc\ liquid}}{\Delta V_{dc,\,ref}}$$

Where the reference values are:

$m_{core,\,ref}$ = core massflow, where the core mass flow reflects that required to match core power.

$\rho_{f,\,ref}$ = liquid density

$\Delta V_{dc,\,ref}$ = downcomer volume

Substitution of the dimensionless variables results in the following:

$$(\rho_{f\,ref})\rho_f^{+}(\Delta V_{dc,ref})\frac{dV^{+}_{dc\,liquid}}{dt} = -(m_{core,ref})m^{+}_{core}$$

Dividing by the reference core mass-flow ($m_{core,ref}$) and collecting reference parameters, the following downcomer liquid inventory depletion rate scaling equation is obtained:

$$\left[\frac{\rho_f \Delta V_{dc}}{m_{core}}\right]_{ref} \rho_f^{+} \frac{dV^{+}_{\substack{downcomer\\liquid}}}{dt} = -m^{+}_{core}$$

The above equation can be re-expressed in terms of a time constant (τ) that represents the time to drain or deplete the downcomer liquid inventory to satisfy core cooling in the absence of safety injection to replenish the downcomer:

$$[\tau]\rho_f^{+}\frac{dV^{+}_{dc\,liquid}}{dt} = -m^{+}_{core}$$

Where the time constant represents the liquid inventory storage relative to the depletion rate:

$$\tau = \left[\frac{\rho_f \Delta V_{dc}}{m_{core}}\right]_{ref}$$

The appropriate scaling ratio for downcomer liquid inventory is therefore obtained by comparing the above time constant for the APEX-1000 test facility to AP1000:

$$\tau_{Ratio} = \frac{\left[\frac{\rho_f \Delta V_{dc}}{m_{core}}\right]_{ref,APEX-1000}}{\left[\frac{\rho_f \Delta V_{dc}}{m_{core}}\right]_{ref,AP1000}}$$

The ideal time scaling ratio for APEX-1000 relative to AP1000 is ½. Ratios less than ½ indicate that APEX liquid inventory is depleted faster than AP1000 on a scaled basis, and vice-versa.

Simple Model Inputs and Results

To obtain reference core mass flow values for the downcomer inventory scaling ratio derived above for APEX-1000 and AP1000, the Simple Model (see Open Item Response 21.5-3) was used with scaled gravity head and scaled core power for the test facility (see Table 1). Table 1 shows the primary differences in inputs to the Simple Model were core inlet temperature (~50 degrees additional subcooling for APEX) and backpressure where 14.7 psia is used for APEX-1000 (as only atmospheric backpressure has been tested at APEX) and 25 psia for AP1000.

Table 1 indicates a larger scaled mass-flow rate in APEX-1000 relative to AP1000. Table 1 also shows that the calculated core collapsed liquid level is somewhat higher in APEX-1000 relative to AP1000. This is acceptable as it is consistent with the larger scaled flow through the core and ADS-4 vent path and the integral effect behavior of APEX-1000 relative to AP1000 is preserved as shown below.

Numerical Evaluation of Scaling Parameters

The actual downcomer volume scaling ratio of APEX-1000 relative to AP1000 is about 1/112 as shown in Table 2 below. The mass flow scaling ratio associated with the actual APEX-1000 test conditions (pressure, density, etc.) relative to the AP1000 for a DEDVI event is about 1/58.

Applying these volume and massflow ratios (as liquid density ratio is about unity), it can be seen that the downcomer drain time ratio between APEX-1000 and AP1000 is about ½.

[ ] a,b,c

Impact of Downcomer Size on Scaling and Behavior of APEX-1000 Tests

The impact of downcomer size in APEX scaling is significantly reduced for simulating a potential safety injection gap period of an AP1000 DEDVI event as a lower containment pressure is actually simulated in the APEX-1000 test facility relative to that expected in the AP1000. Due to difference in pressure conditions, the mass flow ratio scale associated with the actual APEX-1000 test conditions is less than the mass flow scale ratio (1/96) which would be obtained if pressure was perfectly preserved. It is expected that if the downcomer were sized according to the volume ratio of 1/96, APEX-1000 test DBA-02 would exhibit a faster than ideal scaled downcomer drain time (~1/1 vs. ½). Based upon system behavior as exhibited by the "Simple Model", this would lead to reaching IRWST injection cut-in pressure sooner in the DEDVI transient in this hypothetical test configuration because system pressure reduces as downcomer/inner vessel level reduces.

In summary, the downcomer volume scale in APEX is distorted (oversized) for integral effect simulations of safety injection gap periods in which the containment pressure is to be preserved. However, due to the lower containment pressure actually simulated in APEX-1000, the test facility is adequately scaled to simulate downcomer inventory depletion in the context of the integral system effect behavior of AP1000 during a potential safety injection gap period in a DEDVI event.

Table 1: Inputs/Outputs to Simple Model										
Variable (Units)	**Qcore (Btu/sec)**	**Zdc (ft)**	**Tcin (F)**	**Pdc (psia)**	**Xcex (-)**	**Zsat (ft)**	**2Φ Rgn. Void (-)**	**CLL (ft)**	**CLL% (-)**	**Core Flow (lbm/sec)**
APEX-1000	[									] a.b.c
AP1000	60000	6.5	180	37.2	0.595	1.83	0.617	6.49	46.3	93.5

Table 2: Reference Values		
Reference Parameter	**APEX-1000**	**AP1000**
ΔV_{dc}	[ ] a.b.c	600.4 ft^3
ρ_f		58.5 lbm/ft^3
m_{core}		93.5 lbm/sec

2. Westinghouse response to the APEX-AP1000 Scaling Report Questions was provided by Westinghouse letter DCP/NRC 1667, January 9, 2004.

Design Control Document (DCD) Revision:

None

PRA Revision:

None