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Your ref: Docket No. 52-006
Our ref: DCP/NRC1634

October 7, 2003

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

October 7, 2003

Correspondence with respect to the application for withholding should reference AW-03-1719, and should be addressed to Hank A. Sepp, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Please contact me at 412-374-5355 if you have any questions concerning this submittal.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Enclosure

1. Westinghouse Electric Company Copyright Notice, Proprietary Information Notice, Application for Withholding, and Affidavit AW-03-1719.

/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1634
2. Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated October 7, 2003
3. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated October 7, 2003

DCP/NRC1634
Docket No. 52-006

October 7, 2003

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

October 7, 2003

AW-03-1719

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-03-1719 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-03-1719 and should be addressed to the undersigned.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Enclosures

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AW-03-1719

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 7th day
of October, 2003

Sharon L. Fiori
Notary Public

SHARON L. FIORI COMMONWEALTH OF PENNSYLVANIA NOTARY PUBLIC

Notarial Seal
Sharon L. Fiori, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires January 29, 2007
Member, Pennsylvania Association Of Notaries

3160alf.doc

(1) I am Acting 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-03-1719 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/NRC1634
Docket No. 52-006

October 7, 2003

Copyright Notice

October 7, 2003

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).

DCP/NRC1634
Docket No. 52-006

October 7, 2003

Attachment 1

List of

Proprietary and Non-Proprietary Responses

Table 1	
"List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1634"	
15.2.7-1 Item 11 *21.5-2P Item 19 Revision 1 21.5-2 Item 19 Revision 1 *Proprietary	

DCP/NRC1634
Docket No. 52-006

October 7, 2003

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: 15.2.7-1 Item 11

Original RAI Number(s): None

Summary of Issue:

Unlike the conventional PWR plants which rely on simultaneous injection line-ups to flush the core to preclude boric precipitation, the AP1000 relies entirely upon the entrainment of high concentration boric acid in the core to be swept upward through ADS-4 flow paths, which are approximately 20 ft in vertical distance above the hot legs, to prevent boric acid precipitation. During the long term, it is not clear how high concentration boric acid is swept upward over these distances since it is expected that the steam produced in the core will collect in the upper head and upper plenum region above the top elevation of the hot leg. Steam will then collect and enter the hot leg from elevations above the top of the hot leg. As such, it is expected that much higher void fractions and even intermittent separated flow in the hot leg will show mostly steam flows in the top quarter to a third of the hot leg as it enters from the upper head and top of the upper plenum. During this horizontal run, it is not clear how the high concentrate boric acid in the upper plenum travels upward along the horizontal section of the hot leg to reach the entrance of the ADS-4 line on the top of the hot leg.

Moreover, two-dimensional effects would dictate that the high concentration boric acid entering the hot leg at the nozzle will tend to flow downward creating recirculation patterns returning most the concentration back toward the vessel. And, with the bulk of the steam flowing along the top of the hot leg, very little high boric acid content is expected to make it to the entrance of the ADS-4 line. Also, what little high boric acid content makes it to the initial vertical section of the ADS-4 line must now be pushed horizontally several feet where more concentrate will settle on the bottom of the horizontal section of the ADS-4 piping. The NRC expects that concentrations would build-up in the horizontal section as more steam separates from the liquid and flows along the top of the pipe. The high quality steam water mixture must then flow vertically several more feet in length with another 90 degree bend, which would be expected to de-entrain what little liquid has made it thus far. As such, it is not clear there is sufficient liquid exiting the torturous path through the ADS-4 lines to reduce the boric acid concentration in the manner suggested by Westinghouse. These issues are raised particularly since no dynamic calculations were performed which can be substantiated.

Please address the following limitations in the Westinghouse simplified model regarding the boron concentration analysis (provided in Attachment 1 to Westinghouse letter DCP/NRC1612 dated August 15, 2003):

A. The simplified model is one-dimensional and therefore does not account for the two-dimensional radial void distribution in the hot leg, nor in the horizontal sections of the ADS-4 piping. Separated flow is not modeled in the hot leg nor the ADS-4 piping. Also, the vertical flow regime map does not apply to the horizontal section of the hot leg nor the horizontal sections of the ADS-4 piping. As such, it does not appear that the void

distribution and attendant flow regimes in the horizontal sections were properly determined. The resulting ADS-4 exit qualities are also questionable.

B. The simplified model assumes homogeneous fluid behavior which dictates that liquid will always exit the ADS-4 piping. The model cannot simulate the collection of steam in the top portion of the hot leg piping which could become separated and chug intermittently causing step increases in boric acid content during the long term. It is not clear that intermittent chugging will flush the boric acid content from the vessel. This limitation applies to the horizontal sections of the ADS-4 piping as well.

C. The boric acid profile in the hot leg is expected to be non-uniform with a gradient that would promote the return of high concentrate boric acid toward the bottom of the hot leg which will flow back into the vessel. The one-dimensional model cannot simulate these effects.

D. The quality out the ADS-4 line is assumed to be the same as that at the core exit (with an adjustment to account for pressure difference). This assumption is not considered valid and, with the above-mentioned limitations of one-dimensional modeling approach, cannot be verified. Since steam will collect in the top portion of the hot leg and there is a large horizontal section in the ADS-4 piping, the quality of the fluid exiting ADS-4 is not expected to be the same as that exiting the entire core region.

E. To provide a theoretical steady-state prediction of the fluid quality exiting the ADS-4 piping given its complex geometry and the fact that correlations do not exist to predict such behavior is conjecture and cannot be used as a basis for computing the liquid flow from the RCS during the long term. Furthermore, if dynamic multi-dimensional computations were performed, there would be no data to verify the calculation, particularly since no test data exists for the ADS-4 geometry and fluid conditions during the very long term.

F. Cooler containment water will condense steam and cool the water in the horizontal section of the ADS-4 lines causing crystalization of boric acid in this region. This could increase the resistance in the ADS-4 lines, limit the venting capability of this system, and cause boric acid to accumulate faster in the RCS.

Westinghouse Response:

Outline of Response for A, B, D, and E:
1. AP1000 geometrical data
2. ADS4 off-take behavior and the system response
3. Flow regime along vent path based on Average flows
4. Conclusions on simplified modeling assumptions

In order to answer a series of questions regarding the simplified model, it is beneficial to revisit the key geometric data of AP1000. Some results from the previous analyses (both simplified

analysis as shown in the response to DSER Open Item 21.5-3 and ones with the system codes such as WC/T and NOTRUMP) are reviewed with respect to the expected flow regimes in key locations along the venting path. The vent path considered here is from the core to the ADS4 valve. The time period of interest is during the long term cooling (a period after the IRWST flow has established quasi-steady state).

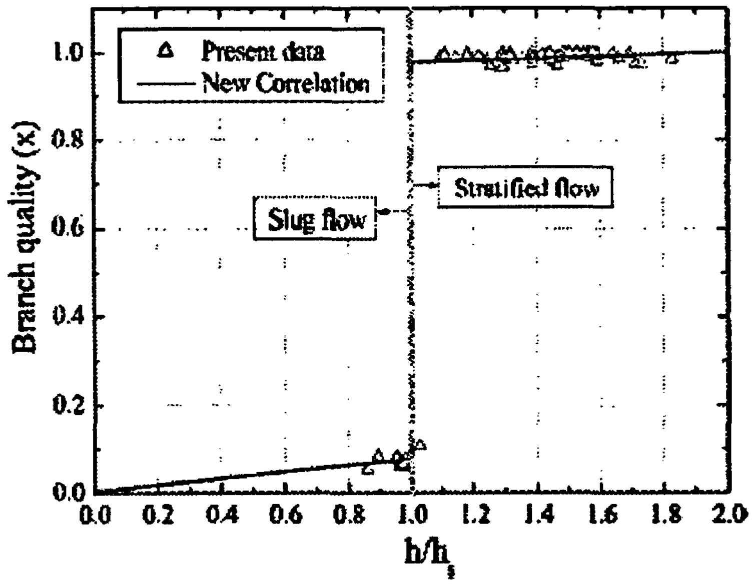
AP1000 Geometry (Elevations and Flow areas)
Selected elevations are listed in Table 1 to illustrate that (1) ADS4 discharge is less than 9.5 ft above the top of Hot Leg pipes, (2) the containment water level is above the top of Hot Leg pipe, and (3) DVI injection port in downcomer is approximately 4 ft above top of Core.
Table 2 shows the flow area along the vent path from Core to the ADS4 valve. The values listed assume that (1) both Hot Legs are venting, (2) both ADS4 are venting, and that (3) one of four ADS4 valves failed. Notice large area ratios exist between the core flow area and the Hot Leg and ADS4 pipes.

Note that in the very long-term when wall-to-wall flooding is postulated (> 14 days), the operator should have taken several actions that will improve the core heat removal process. Those actions include:

1. Raising the containment water level to 110.2 ft by adding borated water from the spent fuel cask loading pit with the RNS pumps.
2. Use the RNS pumps to recirculate containment water through the RNS heat exchangers, thereby sub-cooling the containment water.

Emergency response guidelines direct the operators to take these actions in response to accidents that result in the actuation of the ADS. Action 1 significantly reduces the difference in elevation from the containment water level up to the ADS-4 discharge elevation; this elevation difference is 8.7 ft with the postulated wall-to-wall containment water level and will be 1.8 ft when the level has been increased up to 110.2 ft.

ADS4 Off-Take Behavior and the system responses
It is instructive to look at several off-take experiments where the impact of the upstream flow regime (in Hot Leg pipe) was considered. These are ATLATS facility at OSU [1], and one investigated by Moon and No [2]. These experiments suggest bi-modal operations depending on the upstream flow regime. While the upstream (Hot Leg) is stratified, the onset of entrainment can be adequately predicted by an existing correlation such as one suggested by Smoglie [3]. The branch quality is very high while the upstream is stratified. As the vapor flow increases, the slugging begins in the horizontal leg, and the branch quality becomes very low as a lump of liquid enters the branch line and ejected away. There is no smooth transition between the two off-take operations as seen in the figure below (Figure 10 from [2]).
The figure shows the branchline quality as a function of ratio of the distance of the liquid surface from the top, h, to the critical distance for the onset of slugging, h_s.



This behavior is expected at the ADS4 off-take. Since there is no smooth transition between the two off-take operation modes, the ADS4 pipe experiences two flow patterns of the high quality flow and the low quality flow in an oscillatory manner. On the average, the ADS4 pipe experiences the flow quality consistent with removing the core energy and gradually reducing the system pressure in a quasi-steady state manner. This is shown in OSU tests and by simulations with NOTRUMP and WCOBRA/TRAC. It is important to recognize that the two-phase discharge results from the mass, energy and momentum balances. This is shown in the simplified model analysis in the response to DSER Open Item 21.5-3.

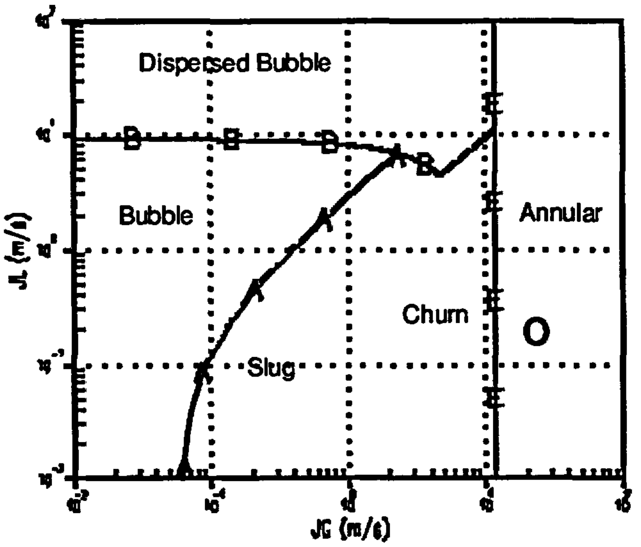
Flow Regimes along the Vent Path

Based on the average flowrate discussed above, vapor flowrate along the vent flow path was calculated for the core power corresponding to 14 and 30 days after the SBLOCA. Using the ANS1971+20% decay power curve, the superficial vapor velocities along the vent flow path were estimated and listed in Tables 3 and 4.

Vertical Flow Regime in ADS4

Taitel-Dukler Vertical Flow Regime Map
at 40 psia and Dia = 14.5 in

O - Operating points for 14 and 30 days after SBLOCA

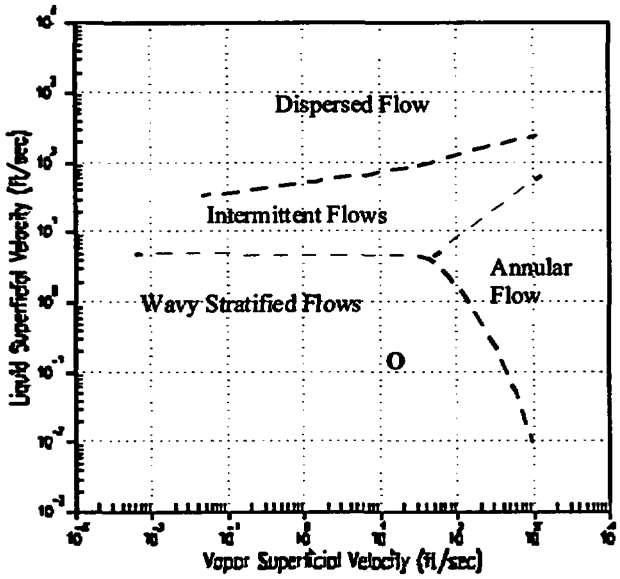


The expected operating point in the ADS4 pipe at 14days and 30days after SBLOCA are compared with the Taitel-Dukler vertical flow regime map. This comparison and the Kutateladze number for these conditions shown in Table 3 and 4 indicate that ADS4 is in annular/dispersed drop flows.

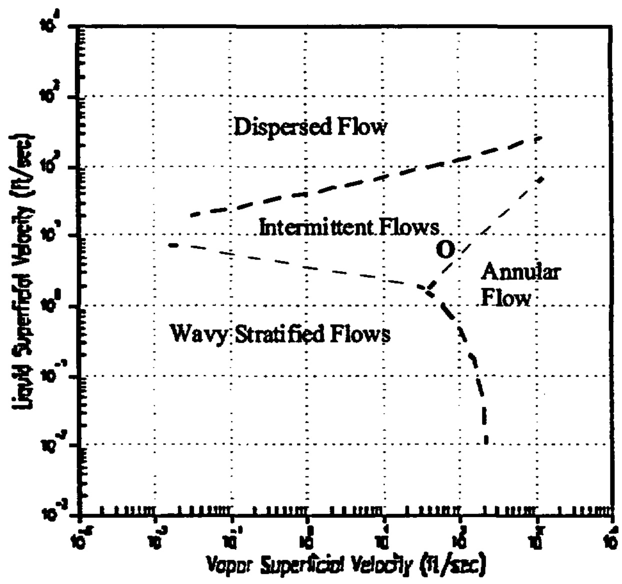
Horizontal Flow Regime in Hot Leg and ADS4 Horizontal Section

Similarly, the expected operating points are shown for Hot Leg pipe and ADS4's horizontal run below. As discussed below, on the average the Hot Leg is in the wavy stratified regime while going through a cyclic change between the stratified flow and the intermittent (slugging) flow to achieve the quasi-steady state transient.

Horizontal Flow Regime Map by Taitel-Dukler
at Pressure = 40 psia and DH = 31 in
Ref: Vol. 22. No. 1. AIChE Journal. 1976
O - Operating point at 14 days and 30 days



Horizontal Flow Regime Map by Taitel-Dukler
at Pressure = 40 psia and DH = 145 in
Ref: Vol. 22. No. 1. AIChE Journal. 1976
O - Operating point at 14 days and 30 days



Conclusions on the simplified modeling assumptions

A. One-dimensional flow model is considered to be adequate for calculating the boron concentration build-up in the core, given that the oscillatory behavior at the ADS4/Hot Leg interface and the stratification/slugging in the Hot Leg ultimately result in a quasi-steady state during the long term cooling. In this mode, the bulk liquid movement takes place from the core to the ADS4 valves in an average sense and may be treated as one-dimensional flow.

B. Homogeneous flow assumption is adequate for calculating the boron concentration build-up in the core, because the ADS4 flow path is intermittent or annular flow even at 30 days. Hot leg is either stratified or slugging. The intermittent flow in ADS4 means that the high interfacial drag in this flow regime would move the liquid along the vent path and out the ADS4 valves. The slugging in Hot Leg would promote the fluid mixing in Hot Leg such that the assumption of constant boron concentration in the liquid above the core is valid.

C. The boric acid will be concentrated in the core region where the heat input from the fuel boils off water. In the AP1000, the maximum core boron concentration is calculated to be less than 7400 ppm based on the ADS 4 vent quality from the WCOBRA-TRAC LTC analysis.

   After the slightly concentrated boric acid leaves the core region, there is no heat source available to boil off more water and so the boron concentration in the hot leg region will not change. Sensible heat from reactor structures in the upper plenum and hot legs is not significant with respect to the integrated decay heat over the hours important to this analysis. In addition, as discussed in item F, the specific gravity of slightly concentrated boric acid is equal to water. As a result, even if there were some small variations in boric acid concentrations it would have no impact on the thermal hydraulic analysis.

D. The instantaneous quality at the ADS4 valves can not be calculated exactly even with the best available system codes. However, knowing the quasi-steady state is reached during this time period (the long term cooling period), one may assume the mass, energy and momentum balance in a steady state sense. The simplified model is constructed assuming just such condition prevailed during the long term cooling period where the boron concentration build-up is an issue.

E. As stated earlier, and in response to DSER Open Item 21.5-3, we believe that the system reaches a quasi-steady state despite the presence of some phenomena which are not very well understood such as the upper plenum and ADS4 off-take entrainment. This view is supported by OSU APEX tests and by system code predictions with NOTRUMP, RELAP5 and WCOBRA/TRAC. The uncertainties in these specific models contribute in a way which may shift the quasi-steady state such as the exact hot leg and Upper Plenum levels and the pressure drops, however, variations due to these uncertainties do not preclude the fact that the system reaches a quasi-steady state. The mass conservation equation cannot be satisfied without liquid flow in the ADS4 line and this is supported by the average response predicted by the system codes. The simplified model is built on this knowledge and used those knowledge as simplifying assumptions which are necessary to focus on the system wide behavior.

F. This issue was addressed in our revised response to DSER OI 15.2.7. That discussion is repeated as follows.

"No buildup of boron is expected in the RCS hot legs and ADS 4 vent paths because these areas always see a flow of hot water and steam. Note that although the hot water contains boron, its concentration is far below the solubility limit; when the core is at its maximum boron concentration of 7400 ppm the water is capable of holding about 80,000 ppm boron (at 240 F). Even assuming that the inside surface of the ADS 4 piping is at the containment temperature of 176 F, the water could still hold 33,000 ppm boron. Boron in the steam will be at a much lower concentration (about 1% of that in the water, or about 74 ppm in this case). The only way that the boron in the steam could plate out would be for the steam to be condensed and then have the water evaporate. Such a process could not happen inside the ADS piping with the continued high flow of hot water. "

In addition, the horizontal section of the ADS 4 lines are located above the containment floodup level, such that cooler containment water will not be able to effectively condense steam inside the ADS 4 lines. Note that the ADS 4 lines are well insulated from the hot leg out to but not including the ADS 4 squib valves in order to limit heat losses during normal operation. There will not be significant condensation of steam inside the ADS 4 lines because of this insulation and because the steam-air mixture outside the lines is only slightly cooler than the steam-water mixture inside the lines.
Also note that condensation of steam inside the ADS 4 lines will not result in any crystallization of boric acid inside the lines as discussed in our response to 15.2.7, revision 1, shown above.

Table 1: Key Elevation Data for AP1000

Key Location	Elevation Relative to Bottom of Core
ADS4 Discharge	30.4 ft
Containment Water Level	21.6 ft (1)
Top of Hot Leg	20.9 ft
DVI Injection Port	17.9 ft
Top of Core	14 ft
Bottom of Core	0

Note 1 – Minimum level for very long-term (> 14 days) with wall-to-wall flooding. Initial recirculation level is 26.2 ft and maximum level is 28.5 ft.

Table 2: Flow Area Data

Flow Path	Flow Area (ft2)	Relative to Core Flow Area
Core Exit	41.55	1
Core Top Nozzle	31.95	0.769
Upper Plenum	68.56	1.650
Hot Legs (2 combined)	10.49	0.252
ADS4 Pipes (2 combined)	2.27	0.055
ADS4 Valves (3 operational)	1.4	0.0336

Table 3: Vapour Superficial Velocity at 14 days

Location	Flow Area (ft2)	Jg (ft/s)	Ku
Top of the Core	41.55	4.6	0.26
Core Top Nozzle	31.95	6.0	
Upper Plenum	68.56	2.8	
Hot Leg	10.49	18.2	
ADS4 Pipe	2.27	84.2	4.8
ADS4 Valve	1.4	136.4	

Table 4: Vapour Superficial Velocity at 30 days

Location	Flow Area (ft2)	Jg (ft/s)	Ku
Top of the Core	41.55	3.5	0.20
Core Top Nozzle	31.95	4.6	
Upper Plenum	68.56	2.1	
Hot Leg	10.49	13.8	
ADS4 Pipe	2.27	64.0	3.65
ADS4 Valve	1.4	103.8	

References:

[1] K. B. Welter, S. M. Bajorek, J. Han, Q. Wu, Y. You, J. N. Reyes, Jr.,"Experimental Investigation of Liquid Entrainment in a Horizontal TEE with a vertical Branch," to be issued in International journal of Multiphase Flows.

[2] Y. M. Moon and H. C. No, "Off-take and Slug Transition at T-junction of Vertical-up Branch in the Horizontal Pipe," Journal of Nuclear Science and Technology, Vol. 40, No. 5, pg. 317-324.

[3] C. Smoglie, "Two-phase Flow through Small Branches in a Horizontal Pipe with Stratified Flow, KfK-3861, Kernchungszentrum Karlsruhe, (1984).

Design Control Document (DCD) Revision:

None

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 21.5-2 Item 19 Revision 1

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.

Westinghouse Response:

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

$\rho_{f,\,ref}$ = 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.

Numerical Evaluation of Scaling Parameters

The downcomer volume scaling ratio of APEX-1000 relative to AP1000 is about 1/112 as shown in Table 1 below. The scaling of the downcomer in APEX results in a larger scaled volume relative to other reactor vessel volumes.

It can be seen from Table 1 that the core mass-flow ratio of APEX-1000 relative to AP1000 is about 1/58. This results in a larger scaled mass-flow rate in APEX-1000 relative to AP1000 and was obtained by applying the Simple Model (see Open Item Response 21.5-3) to APEX-1000 and AP1000 at scaled power and downcomer level for a DEDVI event. It can be seen from Table 2 that the primary difference in inputs to the Simple Model was core inlet temperature (about 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.

Applying these volume and massflow ratios (as 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

Thus the APEX test 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 core cooling.

Table 1: 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

Table 2: 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

Design Control Document (DCD) Revision:

None

PRA Revision:

None