Westinghouse

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U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002973

July 30, 2010

Subject: AP1000 Response to Request for Additional Information (SRP6.2.2)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 6.2.2. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

A response is provided herein for RAI SRP6.2.2-CIB1-28.

Pursuant to 10 CFR 50.30(b), proprietary and non-proprietary versions of the response to the request for additional information on SRP Section 6.2.2 are submitted as Enclosures 3 and 4. Also enclosed is one copy of the Application for Withholding, AW-10-2892 (non-proprietary) with Proprietary Information Notice, and one copy of the associated Affidavit (non-proprietary).

This submittal contains proprietary information of Westinghouse Electric Company LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-10-2892 and should be addressed to James A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P. 0. Box 355, Pittsburgh, Pennsylvania 15230-0355.

D063
NRO

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

Very truly yours,

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

/Enclosures

1. AW-10-2892 "Application for Withholding Proprietary Information from Disclosure," dated July 30, 2010
2. AW-10-2892, Affidavit, Proprietary Information Notice, Copyright Notice dated July 30, 2010
3. Response to Request for Additional Information on SRP Section 6.2.2, RAI SRP6.2.2-CIB1-28 (Proprietary)
4. Response to Request for Additional Information on SRP Section 6.2.2, RAI SRP6.2.2-CIB1-28 NP (Non-Proprietary)

cc:	D. Jaffe	-	U.S. NRC	4E
	E. McKenna	-	U.S. NRC	4E
	P. Donnelly	-	U.S. NRC	4E
	T. Spink	-	TVA	4E
	P. Hastings	-	Duke Power	4E
	R. Kitchen	-	Progress Energy	4E
	A. Monroe	-	SCANA	4E
	P. Jacobs	-	Florida Power & Light	4E
	C. Pierce	-	Southern Company	4E
	E. Schmiech	-	Westinghouse	4E
	G. Zinke	-	NuStart/Entergy	4E
	R. Grumbir	-	NuStart	4E
	D. Lindgren	-	Westinghouse	4E
	D. Behnke	-	Westinghouse	4E

ENCLOSURE 1

AW-10-2892

APPLICATION FOR WITHHOLDING
PROPRIETARY INFORMATION FROM DISCLOSURE

Westinghouse

Westinghouse Electric Company
Nuclear Services
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Pittsburgh, Pennsylvania 15230-0355
USA

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ATTENTION: Document Control Desk
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Your ref: Docket Number 52-006
Our ref: AW-10-2892

July 30, 2010

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Submittal of Proprietary and Non-Proprietary Technical Document Information, Response to Request for Additional Information (RAI) on SRP Section 6.2.2

The Application for Withholding is submitted by Westinghouse Electric Company LLC (Westinghouse), pursuant to the provisions of Paragraph (b) (1) of Section 2.390 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 RAI response. In conformance with 10 CFR Section 2.390, Affidavit AW-10-2892 accompanies this Application for Withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectively requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this Application for Withholding or the accompanying affidavit should reference AW-10-2892 and should be addressed to James A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Very truly yours,

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

ENCLOSURE 2

Affidavit

AW-10-2892
July 30, 2010

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared Robert Sisk, 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:

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

Sworn to and subscribed before me this 30 day of July 2010.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Josette Michelle Colantuono, Notary Public
Cranberry Twp., Butler County
My Commission Expires June 16, 2013
Member, Pennsylvania Association of Notaries

Notary Public

(1) I am Manager, Licensing and Customer Interface, 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 rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 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 Westinghouse 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 2.390 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 that 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 2.390, 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 RAI SRP6.2.2-CIB1-28, in support of the AP1000 Design Certification Amendment Application, being transmitted by Westinghouse letter (DCP_NRC_002973) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse for the AP1000 Design Certification Amendment application is expected to be applicable in all licensee submittals referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application in response to certain NRC requirements for justification of compliance of the safety system to regulations.

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

(a) Manufacture and deliver products to utilities based on proprietary designs.

(b) Advance the AP1000 Design and reduce the licensing risk for the application of the AP1000 Design Certification

(c) Determine compliance with regulations and standards

(d) Establish design requirements and specifications for the system.

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 plant construction and operation.

(b) Westinghouse can sell support and defense of safety systems based on the technology in the reports.

(c) The information requested to be withheld reveals the distinguishing aspects of an approach and schedule which was developed by Westinghouse.

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 digital technology safety systems 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.

Further the deponent sayeth not.

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 2.390 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 2.390(b)(1).

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ENCLOSURE 4

Response to Request for Additional Information on SRP Section 6.2.2

RAI SRP6.2.2-CIB1-28-NP

(Non-Proprietary)

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI SRP6.2.2-CIB1-28: Concrete as a Debris Source
Revision: 2

In a letter dated April 26, 2010, Westinghouse responded to RAI SRP6.2.2-CIB1-28 R1 regarding concrete as a potential source of particulate debris from a LOCA jet. The staff needs additional information related to the applicant's response to justify the applicant's position that a LOCA jet will not generate concrete particulate debris for the AP1000:

1. During its review, the staff found that NUREG-0897, Rev. 1, "Containment Emergency Sump Performance," March 1985, shows spalled concrete attributed to thermal shock. The damage occurred during a blowdown test in the German HDR facility. It's not clear how much of the debris was transportable, fine particles. The April 26, 2010, response, addressed jet temperature, but it was not clear that thermal shock was considered. Please discuss how you addressed the possibility of transportable debris generated by thermal shock.

2. Clarify the relevance of Figure A7 in the April 26, 2010, response, which shows the side view of an expanding subcooled jet parallel to the top surface of a concrete pad. Based on the staff's calculations, the L/D ratio for this geometry is approximately 9.9, which is much larger (and presumably less damaging) than most of the L/D values for concrete surfaces in the AP1000 design, as given in Table A2 of the RAI response. How does the testing represented in Figure A7 indicate a lack of destructive power for LOCA jets from pipes parallel to the concrete surfaces in the AP1000 design?

3. Please make available to the staff a copy of WCAP-7391, which was referenced in the April 26, 2010, response. According to the description in the RAI response, this report appears to be a useful source of information on impingement from two-phase, perpendicular jets, but the staff was not able to locate a copy.

Westinghouse Response:

(This response is separate from and in addition to the Revision 0 and Revision 1 response.)

1. Under design basis conditions of a postulated loss of coolant accident (LOCA) associated with the reactor coolant system (RCS), a high pressure jet of flashing water could be discharged onto structural surfaces within the containment such as the containment floor, walls, biological shield, etc. Of interest in this regard is the potential for attack of the walls and floors as a result of thermal stress. A review of the technical literature for the HDR, Marviken, Battelle Frankfurt, etc. large scale experiments provided little insight into the observations directly from these tests in terms of possible spallation of concrete due to thermal stresses. There is a comment in Appendix C of NUREG-0897 Rev. 1 which states that "Blowdown tests conducted in the HDR facility showed that there were high dynamic loads in the vicinity of the immediate break area. Inspections following these blowdown tests revealed: spalled concrete (attributed to thermal shock), . . ."

While this observation is valid for the total of HDR containment experiments, several features need to be considered when attempting to relate this observation to current reactor containment buildings, as well as those new plants that are being built today. It is noted that numerous HDR tests were performed over a number of years. The information available for concrete performance in the HDR tests is sparse and does not support the evaluation of the net results of a single test, especially the first blowdown test that was performed. Thus, the applicability of the HDR observation to concrete damage due to initial exposure to a single LOCA jet cannot be assessed from the data available from HDR. Thus, the applicability of the observation from the HDR testing to a single exposure to a subcooled jet, such as a jet resulting from a postulated LOCA, is at best suspect.

As noted in the response to Revision 1 of this RAI, results from testing performed at PWR conditions as reported in WCAP-7391 (Reference 1) that were obtained using six single-use concrete targets showed [ ]^{a,c} These single-use concrete targets were not coated with an epoxy coating and provided for the exposure of bare concrete surface to the jet flow. The use of a supply fluid at [ ]^{a,c} provided for thermal conditions, including thermal shock, on the six concrete targets for this test to be similar to those of a postulated cold leg LOCA. As no spalling was observed, this data demonstrates that thermal shock from a jet impingement at PWR primary loop condition does not result in spalling.

In addition to the information provided in Reference 1, results from jet impingement testing at PWR conditions with 12" x 12" x 2" concrete coupons coated with Design Basis Accident (DBA) Qualified epoxy coatings (Reference 2) showed no loss of coatings material and therefore no spalling or loss of concrete from the surface of the concrete substrate test target. The AP1000 plant cannot credit this testing. The AP1000 Service Level 2 epoxy coatings are purchased as DBA-Qualified coatings and a program will be used to control their application, inspection and monitoring. Therefore, these coatings as applied inside the AP1000 reactor containment building are expected to perform similar to Service Level 1 coatings although they are not treated as DBA-Qualified or Service Level 1 coatings for the purposes of analyses or evaluations.

Included in Appendix E of Reference 2 are evaluations by three manufacturers of DBA-Qualified coatings, two coatings consultants, and one engineer knowledgeable in the area of safety related protective coatings and the applicability of DBA Qualified/Acceptable test data to the family of DBA Qualified/Acceptable epoxy coatings. The consensus opinion expressed is that epoxy coatings that have been demonstrated to be DBA-Qualified or acceptable will perform similarly when applied in the manner in which they were qualified regardless of the manufacturer of the coating system. Considering that the Service Level 2 epoxy coatings within the AP1000 plant reactor containment building are expected to perform similar to those for DBA qualified coatings and the robust performance of epoxy coatings in general, it is expected that jet impingement testing of epoxy coatings applied to exposed concrete surfaces in the AP1000 plant's reactor containment building would yield similar results as the testing in Reference 2.

In summary, there is limited information that shows that some spallation can occur after repeated tests under high temperature blowdown conditions (HDR). However, the available information from the HDR tests is sparse and does not support the evaluation of the net results of a single test, especially the first blowdown test that was performed. Therefore, the applicability of the HDR test observations to the initial single exposure of a concrete surface to LOCA jet flows cannot be demonstrated. Additionally, thermally induced spalling of concrete was not observed in jet impingement testing of single-use concrete beams with subcooled water at PWR cold leg conditions (Reference 2). Rather, this testing demonstrated that only minor surface erosion of the concrete beam will occur with the concrete surface area located in close proximity of the jet.

Additional discussion of the application of the test data reported in Reference 1 to exposed concrete surfaces in the AP1000 plant design is discussed in Appendix A of this RAI response entitled, "Comprehensive Assessment of Margin."

1.1 References

1. WCAP-7391, "Pressurized Water and Steam Jet Effects on Concrete," Westinghouse Proprietary, (1969)

2. WCAP-16568-P, "Jet Impingement Testing to Determine the Zone of Influence (ZOI) for DBA-Qualified/Acceptable Coatings", Westinghouse Proprietary, (2006)

2. The photograph shown in Figure A-7 of the response to Revision 1 of RAI SRP6.2.2-CIB1-28 is of a jet impingement test conducted at Wyle Labs at their Huntsville, AL facility. Based on the two jet impingement tests performed by Westinghouse using the Wyle facility, as well as other high energy line testing performed using the same facility over the past decade, it is anticipated that if erosion or ablation of concrete were to occur, it would have been observed by now.

   Calculations were performed to evaluate the pressure that would impinge on a concrete surface for a limiting pipe running parallel to a concrete surface. The calculations were performed with the ANSI/ANS 58.2-1988 jet expansion model to simulate a double-ended guillotine break in the PRHR pipe (ID = 11.19 inches) (see Figure A-3 of the response to Revision 1 of RAI SRP6.2.2-CIB1-28). The pressure of the fluid upstream of the break was set as 2250 psia. The calculations were repeated for fluid temperatures of 550°F (cold leg) and 620°F (hot leg). The output of the calculations was the isobars and their corresponding temperatures for the expanding jet. A range of isobars that were calculated for the expanding jet are shown in Figure 1 and Figure 2.

   The distance from the centerline of the PRHR pipe to the surface of the floor is taken to be 1.33 ft. From Figure 1, for the cold leg conditions (550°F), the maximum pressure isobar at the surface of the concrete is calculated to be about 120 psig with a temperature of 350°F. From Figure 2, for hot leg conditions (620°F), the maximum pressure isobar at the surface of the concrete is calculated to be about 140 psig with a corresponding temperature of 361°F.

For a PWR, it is noted that the plots of Figure 1 and Figure 2 are based on choked flow at initial pressure and temperature conditions. As the reactor coolant system fluid inventory is depleted, the back pressure, and hence the mass flow rate, decreases, resulting in the isobars collapsing towards the jet centerline. Thus, the pressure and temperature of the flow passing over the concrete surface would also decrease over the blowdown duration.

For a 30-second duration, typical of the blowdown time for a large-break LOCA, subjecting concrete to the pressures and temperatures shown in either Figure 1 or Figure 2 will not cause concrete to spall.

Refer to Section A.3 for the results of the evaluation of jet impingement from double-ended breaks for all the lines located near concrete surfaces.

3. Westinghouse placed a copy of WCAP-7391 in the Westinghouse Washington Operations Office in Rockville, MD for audit by the NRC staff on May 28th, 2010.

a,c

Figure 1: Calculated Isobars for Jet Parallel to Concrete Surface; PWR Cold-Leg Conditions

a,c

Figure 2: Calculated Isobars for Jet Parallel to Concrete Surface; PWR Hot-Leg Conditions

APPENDIX A: Comprehensive Assessment of Margin

The following discussion in this Appendix provides a holistic assessment which demonstrates that concrete debris is not expected to be generated. However, even if it were conservatively assumed that concrete debris were generated, that debris will not adversely affect long-term core cooling.

The only concrete surfaces that could potentially be impacted by LOCA jets are concrete floors. There are a minimal number of locations inside containment that could be subjected to a direct jet impingement from a double-ended guillotine break or a side/split break. Test data has shown that at a LOCA jet impingement stagnation pressure of [ ]a,c there will be no concrete damage. Evaluations of double-ended guillotine breaks show that the LOCA jet stagnation pressures on the concrete surfaces would not be sufficient to cause damage.

Some locations of potential split breaks were evaluated to have LOCA jet impingement stagnation pressures greater than [ ]a,c and were conservatively assumed to create some concrete debris. The estimation of the potential mass, particle size distribution, and surface area of this concrete debris does not exceed the design basis particulate debris loading or the post-LOCA chemical precipitate loading.

A.1 Minimal Exposed Concrete Surface Area inside the AP1000 Plant Containment Building

The AP1000 design calls for the containment module walls and ceiling to be steel plated. Therefore, the only surface area of concrete inside containment that might be exposed to jet impingement loads is the floor areas. Figure A-4 through Figure A-9 show the concrete floor surface areas inside the AP1000 containment that might be subjected to direct jet impingement.

A.2 Acceptance Basis for Impingement of a Subcooled Liquid Jet on Concrete

Westinghouse performed testing with subcooled jets impinging on concrete beams (Reference A-1). The purpose of the tests was to evaluate erosion of concrete structures inside the reactor containment building under jet impingement loads that would result from a postulated break in the reactor coolant system primary piping.

The concrete beams used in the test were [ ]a,c The beams were constructed of [ ]a,c The concrete beams did not have a protective coating applied to them.

Three (3) nozzle sizes were used in the testing; [ ]a,c The beams were placed perpendicular to the nozzle at two (2) different distances from the nozzle; [ ] a,c Thus, six (6) jet impingement tests were performed at the following six (6) $\frac{L}{D}$ ratios;

[ ] a,c

For these tests, the supply vessel fluid conditions were subcooled water at [ ] a,c These fluid pressures and temperatures are typical of primary coolant conditions in the cold leg for a Westinghouse pressurized water reactor.

To summarize, jet impingement tests have been performed on concrete targets over the range of $\frac{L}{D}$ ratios of;

[ ] a,c

Table A-1 lists the conditions for the tests in which concrete beams were subjected to subcooled jet impingement.

For the uncoated concrete beam jet impingement tests,

[ ] a,c, the results showed that the erosion for all tests was observed to be [ ] a,c It is therefore concluded that short-term erosion of concrete surfaces as a result of a loss-of-coolant accident generates a [ ] a,c inside the reactor containment building.

The maximum stagnation pressure would occur immediately upon initiation of the postulated break at the closest positioning of the concrete beam to the jet nozzle. The stagnation pressure would then decay as the primary coolant inventory is expelled through the postulated break. Using the ANSI/ANS 58.2-1988 jet expansion model (Reference A-2), the initial maximum stagnation pressure at the most limiting positioning of the beam is calculated to be [ ] a,c This was the test with a nozzle to beam distance equal to [ ] a,c and an orifice diameter equal to [ ] a,c resulting in an L/D equal to [ ] a,c As noted above, the visual observations from this test were [ ] a,c

Thus, the testing reported in Reference A-1 demonstrates that for jet flows driven by conditions representative of PWR cold leg break, damage to concrete will not occur at a stagnation pressure of [ ] a,c This value of stagnation pressure represents cold leg conditions when the ratio of the distance of the target along the jet centerline, L, to the jet diameter, D, is [ ] a,c (see Figure A-10).

Performing a similar ANSI/ANS 58.2-1988 jet expansion model calculation for hot leg conditions and at a stagnation pressure of [ ]a,c, the resulting ratio of distance along the jet centerline to jet diameter is calculated to be [ ]a,c (see Figure A-11).

The jet stagnation pressure at which no concrete damage will occur is [ ]a,c. Based upon this value, an acceptance criterion of a jet stagnation pressure of [ ] a,c will be used to evaluate the potential for damage to concrete surfaces exposed to LOCA jets. The distance that this pressure will be assumed to occur at is [ ] a,c for a cold leg break, and [ ]a,c for a hot leg break.

Using the acceptance criterion of [ ]a,c in the AP1000 evaluations, if the ratio of distance between the impingement surface and the jet diameter is greater than [ ]a,c for a cold leg break, and [ ]a,c for a hot leg break, no damage to concrete will occur. If the distance to diameter ratio is smaller than these values, then it is assumed that there is a potential for concrete damage to occur and for concrete debris to be generated.

The method of evaluation and the acceptance criterion to determine if the concrete surface in the AP1000 containment will be damaged by jet impingement has been defined. Section A.3 and Section A.4 of this RAI response contain the details of the evaluations.

A.3 <u>Analysis of double-ended pipe breaks in these AP1000 lines</u>

The AP1000 lines listed in Table A-2 have been evaluated for double ended ruptures. This evaluation included consideration for discharges that were perpendicular to the floor as well as parallel discharges. The jet impingement pressures on the concrete surfaces that are listed in Table A-2 were developed consistent with the discussions in Section A.2 of this RAI response. As shown in

Table A-2, these pressures are all less than the pressures that would potentially result in concrete debris generation.

Evaluations have been performed of the potential for breaks to result in the generation of concrete debris. Table A-2 shows the resulting pressures on the concrete surface from double-ended ruptures of these pipes. All of the pressures listed are below the [ ]^{a,c} stagnation pressure of a LOCA jet that has been demonstrated by test results (Reference A-1) to not cause concrete debris generation.

A.4 Analysis of split or side breaks in these AP1000 lines

Complete (double-ended guillotine) breaks were considered in Section A.3 of this RAI response. Breaks that are in the side wall of the piping, sometimes called "split" or "fish-mouth" breaks, are also evaluated for potential to generate concrete debris in the AP1000 containment.

The sizing of a side wall break for evaluation under NRC's Standard Review Plan is included in Section B.C.(ii)(4) of NRC Branch Technical Position (BTP) 3-4 for split breaks. This section of NRC BTP 3-4 identifies the break size for evaluation to have a width of ½ of the inside diameter of the pipe of interest and a length of 2 times the inside diameter of the same pipe. For the purposes of evaluating the potential for this break to damage concrete in the AP1000 containment, this definition of side or split breaks is adopted with the additional assumption that the break runs along the bottom of the pipe parallel to the floor. This latter assumption maximizes the area of concrete exposed to jetting flow.

For the purposes of assessing the pressure on the concrete surface for evaluation, a circular break having a diameter of ½ of the inside diameter of the pipe of interest will be used. This approximation allows for the ANSI/ANS 58.2-1988 model to be used to calculate stagnation pressure on a jet centerline.

All locations within the AP1000 plant where a split break may allow for jet impingement from a potential split or side break are leak-before-break (LBB) qualified lines. The stagnation pressure at these locations is less than [ ]^{a,c} with the exception of five locations shown in Table A-3. For the locations that do not meet the [ ]^{a,c} criterion, the maximum side break diameter that meets the acceptance criteria of [ ]^{a,c} at the concrete surface would be somewhat smaller than ½ of the inside pipe diameter.

The fact that the pressure may exceed [ ]^{a,c} and may cause concrete debris generation is acceptable because:

1) These lines are LBB qualified, therefore these split breaks would develop over protracted period of time (days) from cracks. The AP1000 plant

provides a very reliable leak detection system that is capable of detecting leaks less than or equal to 0.5 gpm as discussed in Section A.5. The AP1000 leak detection system will allow the operators to shut down the plant before the crack propagates to a split break sufficiently large to challenge concrete integrity.

2) Although the AP1000 plant leak detection system will preclude concrete damage from crack propagation, an evaluation was performed that conservatively assumed that concrete debris was generated for these five break locations. This evaluation is discussed in Section A.6 and the results of the evaluation are summarized in Table A-3. The calculated amounts of concrete debris are acceptable with respect to the AP1000 GSI-191 evaluations.

A.5 Redundant leakage detection systems

The AP1000 plant incorporates very reliable and effective means of reactor coolant pressure boundary (RCPB) leak detection capability. As discussed in DCD Section 5.2.5, this capability is redundant and diverse. The Technical Specifications require that the system be operable. Technical Specification 3.4.9 defines the requirements for leakage detection. The AP1000 RCPB leakage detection systems have the capability to detect RCPB degradation early, which minimizes the potential for propagation to a gross failure.

One method of protecting against large RCS leakage derives from the ability of instruments to rapidly detect extremely small leaks. This requires instruments of diverse monitoring principles to be operable to provide a high degree of confidence that small leaks are detected in time to allow actions to place the plant in a safe condition, when RCS leakage indicates possible RCPB degradation.

For the AP1000 plant, this is satisfied when monitors of diverse measurement means are available. Thus, the containment sump level monitor, in combination with a containment atmosphere activity (^{18}F particulate) monitor, provides an acceptable design.

The AP1000 plant containment sump collects unidentified leakage, and is equipped with three redundant, seismically-qualified level instruments. Any of these instruments allow detection leakage rates of 0.5 gpm or less. This sensitivity is acceptable for detecting increases in unidentified leakage. The containment water level sensors provide a diverse backup method that can detect a 0.5 gpm leak within 3.5 days.

Leakage through the AP1000 RCPB will also be detected by the containment atmosphere ^{18}F particulate monitor, as discussed in DCD Section 5.2.5 and Revision 1 of the Westinghouse response to RAI-SRP11 5-CHPB-05. This monitor provides detection of RCPB leakage of 0.5 gpm or less, is seismically designed, and is required to be operable by Technical Specification 3.4.9.

Note that the RCPB leakage is detectable at flowrates several orders of magnitude less than the flowrate required to create a risk of concrete debris generation from jet impingement due to side/split breaks.

This redundant leakage detection capability for the AP1000 plant supports the leak-before-break design and minimizes the potential for a high-energy pipe break to propagate from an initial small leak. Successful leak-before-break would eliminate the potential for concrete debris generation.

A.6 <u>Analysis of potential concrete debris generation resulting from split or side breaks in these AP1000 lines</u>

As shown in Table A-3 only five of the AP1000 break locations could potentially result in debris generation. This section discusses the amount of debris that might be generated and the consequences of that debris generation.

Table A-3 shows the results of a conservative estimate of the amount of concrete debris that might be generated by a split break. The key assumptions include:

1) The largest split break is one that is ½ pipe ID wide and 2 pipe ID long. This break is based on NRC Branch Technical Position paper 3-4, as discussed previously.

2) The jet impingement model is used to determine the distance to where concrete would no longer be damaged, i.e. the pressure on the concrete is [ ][a,c]. This is also discussed above.

3) It is assumed that all of the concrete that is located where the jet impingement pressure is [ ][a,c] becomes debris. The formula for the volume of a spherical cap is used to calculate the volume of this debris:

$$\text{Volume of concrete debris} = \Pi/3 * (h^2) * (3r-h),$$

where h is the distance between the concrete surface and the distance where the pressure drops to [ ][a,c] and r, the radius of the sphere, is the distance from the break to where the pressure drops to [ ][a,c].

4) To account for the split shape the amount of debris determined by item 3 is multiplied by a factor of 0.5. This factor was derived by comparing the volume of a sphere to the volume of an ellipsoid. The calculated ratio of the volume of an ellipsoid to the volume of a sphere (centered within the ellipsoid) is [ ][a,c] The volume of that ellipsoid is smaller than the volume of that one

sphere. Therefore using the equation for the volume of a spherical cap and multiplying by a factor of 0.5 bounds the ellipsoid volume and conservatively estimates the volume of concrete affected by the postulated LOCA jet. In Table A-3, the values in the column entitled "Vol Concrete [ft^3]" are calculated using the equation for the volume of a spherical cap multiplied by a factor of 0.5.

The details of the method and calculations for determining this factor are provided in the following paragraphs. Figure A-12 depicts the assumed spherical and ellipsoidal shapes used in the calculations.

Ellipsoid Height

[

]a,c

Ellipsoid Width

[

]a,c

Ellipsoid Length

[

]a,c

This estimation of the volume of concrete affected by the LOCA jet is conservative because there is an extensive interconnected network of steel rebar located 4 inches under the concrete floor surface in the AP1000 containment. The presence of the rebar will reduce the amount of concrete debris that can be generated because the steel rebar takes up the space of concrete that would otherwise be present. The steel rebar will also shield parts of the concrete underneath the rebar.

5) The concrete debris generated is assumed to be [ ]a,c An explanation of this particle size distribution follows.

   a) Jet impingement testing performed by Westinghouse (Reference 1 in Section 1.1 of this RAI response) demonstrated that jet flows from a working fluid source at [ ]a,c did not damage concrete surfaces located at a ratio of distance from the jet nozzle, L, to the jet nozzle diameter, D, of [ ]a,c The test report stated that the erosion under all beam tests was observed to be [

]^{a,c} It was therefore concluded that short-term erosion of concrete surfaces as a result of either a loss-of-coolant accident or steam line break is definitely not a design consideration.

b) However, inspections performed following blowdown tests conducted in the HDR facility revealed damage to a variety of structures and components inside the containment structure including spalled concrete that was attributed to thermal shock. As noted previously in the response to Item 1 of this RAI, it cannot be determined from the test write-up in Revision 1 of NUREG/CR-0897 when the concrete damage occurred. However, information from these inspections can be used to provide a basis for conservatively setting the size of concrete debris that might be generated if concrete damage observed in the HDR test facility was assumed to occur during the blowdown associated with a postulated large-break LOCA in the AP1000 containment.

c) Figure A-1, Figure A-2, and Figure A-3 are photographs of the HDR facility inspections performed following the blowdown tests that identify damaged concrete. Figure A-1 shows limited surface damage to concrete structures within the blowdown compartment. Figure A-2 shows apparent damage at the corners of a concrete stairway in a compartment near the HDR blowdown chamber. Figure A-3 shows spalled concrete from the stairwell located near the blowdown compartment. Collectively, Figure A-2 and Figure A-3 show that the spalled concrete in HDR was in the form of large pieces several inches in length and width. From the size of the doorway shown in Figure A-3, the concrete debris in the HDR test facility is estimated to be several inches in size.

d) Considering debris size shown in Figure A-2, for the purposes of conservatively evaluating the consequences of debris generated by the potential spalling of concrete for the AP1000 design, the following relative size distribution will be assumed:

- [
-]^{a,c}

e) The dimensions used to characterize "small" concrete debris are not the same as the "fine debris" dimension of [ ]^{a,c} used for testing debris capture and head loss behavior of recirculation screens or fuel assemblies. The [ ]^{a,c} size distribution was used for head loss testing for the following reasons:

- The smaller debris was more readily transported in test flumes (loops) to the recirculation screens and fuel assemblies, assuring maximum particulate available for deposition on a fibrous debris bed, if it formed. Head loss testing of recirculation screens has demonstrated that even the [ ]^{a,c} debris tends to settle in long flumes.

- The smaller debris, if collected on a fiber bed, would collect in interstitial voids within the collected fibrous debris and form a tight, compact, mixed debris bed that would maximize pressure drop.

This margin assessment assumes that all of the small concrete debris that might be generated is transportable and compares it to the amount of particulate tested for the AP1000 design. Thus, the relative size of the "small" debris is inconsequential for this margin assessment.

f) One aspect of this margin assessment is to evaluate the amount of particulate debris generated and the resulting post-LOCA chemical precipitates. Concrete used in the AP1000 consists of a mix of sand, gravel, and cement. The gravel is unlikely to be chemically reactive in the post-LOCA recirculating coolant. Therefore, treating all of the concrete particulate debris as cement that could release calcium and silicon, without segregating out chemically inert constituents, conservatively estimates the potential chemical precipitate loading.

g) The debris distribution identified above conservatively limits the size of concrete debris to be less than the debris sizes shown in Figure A-2 from the HDR test facility. Therefore, this size distribution also conservatively maximizes both the amount of particulate and the surface area associated with that concrete debris to be considered in evaluating consequential effects of concrete debris and provides for the evaluation of a conservative chemical loading from the reaction between the potential concrete debris and the recirculating coolant pool post-LOCA.

Results of Concrete Debris Calculations

As shown in Table A-3, only five lines have the potential to produce any concrete debris from jet impingement loads. Three of these locations produce very little debris

[ ][a,c] The remaining two break locations produce more concrete debris. The maximum amount of concrete debris produced is for the [ ][a,c] With this conservative analysis, a split break in this line might produce as much as [ ][a,c] pounds of concrete debris with a surface area of approximately [ ][a,c] The next highest debris amount is for the [ ][a,c], which might produce [ ][a,c] pounds of concrete debris with a surface area of approximately [ ][a,c] However it is estimated that only the 10% of the debris that is small particles will be transported with the post-LOCA recirculating coolant. The potential impact of this debris on the pressure drop across the screens and the fuel assemblies (FAs) has been evaluated and found to not affect the AP1000 licensing basis. The potential impact on the post accident chemical debris production has also been evaluated and shows that the current AP1000 licensing basis is not affected.

One break location, the hot leg at the reactor cavity, will produce no concrete debris, [ ][a,c]

Effect on Total Particulate Debris Loading

Since HL LOCAs are not limiting for debris-induced head loss for the AP1000, the PRHR return line has been evaluated for the effects of additional particulate debris from concrete. For the screen test and FA test pressure drops, it has been determined that the total amount of particles that needs to be considered is not increased. The reason is that for CL breaks the total amount of particles is comprised of 130 lb of latent debris, less 6.6 lb of latent fiber, for 123.4 lb of latent particles. In addition, 70 lb of ZOI generated coating fines is considered. The 70 lb of ZOI coatings results from a CL loop pipe break at the RCP. For this PRHR return line break, the ZOI coatings debris has been estimated to be approximately 1 lb. This would allow for as much as 69 lb of concrete at this break location. Since this break location has been conservatively estimated to produce no more than [ ][a,c] of concrete debris, the licensing basis for particulate debris amount is not exceeded. Also, for the DVI A Upper and DVI B Upper split break locations, approximately 0.3 lb of coatings debris is estimated. These split break locations have been conservatively estimated to produce no more than [ ][a,c] of concrete debris.

Effect on Post-LOCA Chemical Precipitate Loading

The additional concrete debris particles created would not adversely affect the chemical effects and LOCADM evaluations for AP1000 GSI-191. The most limiting break location identified for creating concrete particulate debris was the pressurizer surge line. The concrete particles (large pieces and small particles) estimated at this location have a total surface area of approximately [ ]a,c The chemical effects analysis (APP-PXS-M3C-052, Rev. 1) currently contains a concrete surface area input of [ ]a,c This is the total surface area of submerged concrete in the AP1000 containment. This surface area value does not take credit for the protective function of coatings, which will be on the concrete, from preventing the chemical reactions between the coolant and the concrete. Adding the additional concrete debris surface area to the existing input value of [ ]a,c, the result is a new input value of [ ]a,c Summing the two values is conservative since the surface area of concrete in the location that is damaged is counted twice: once in the intact concrete surface area value and second time in the surface area of concrete particles.

[

]a,c For purposes of this RAI response, we can reduce conservatism in the chemical precipitation analysis and assume that [

]a,c

The new input value of [ ]a,c concrete debris to the chemical effects evaluation, combined with the assumption of [ ]a,c, has an insignificant effect. The total amount of chemical precipitates remains below the 57 lbm stated in the DCD (Tier 2, Section 6.3.2.2.7.1, Item 12). The total amount of chemical precipitates generated using [ ]a,c of concrete as an input is [ ]a,c This is understandable because the contribution of concrete to chemical debris is very small in the existing analysis; such that a [ ]a,c increase in concrete surface area results in an insignificant increase in total chemical precipitates.

The [ ]a,c increase in concrete surface area from concrete particulate debris would have an insignificant effect on the AP1000 LOCADM evaluation (APP-PXS-M3C-057, Rev. 2). The increase in post-LOCA chemical scale on the fuel rods is insignificant and does not challenge the LOCADM acceptance criteria.

Additional Margin Discussion

The margin that exists within the assessment presented in Appendix A of this RAI response could tolerate a concrete particle size distribution of [ ]^{a,c} distribution were incorporated with the data shown in Table A-3, then the results for the split break in the pressurizer surge line would be [ ]^{a,c}

For the PRHR return line, employing a [ ]^{a,c} concrete particle size distribution results in [ ]^{a,c}.

A.7 Conclusions

Based on this margin assessment, it has been shown that concrete debris is not expected to be generated. However, even if it were conservatively assumed that concrete debris were generated, that debris will not adversely affect long-term core cooling.

- By design, the AP1000 plant minimizes the potential for post-accident concrete debris generation.
- AP1000 utilizes very little concrete area, only on floors.
- Double-ended breaks do not result in concrete debris.
- Side/split breaks might generate some concrete debris in five locations.
    - In these five locations, it is highly likely that side breaks would be detected and the plant shut down before the break size propagated to a size large enough to generate debris.
    - In these five locations, if concrete debris is assumed to be generated using a conservative geometry and a range of particle size distributions, the results are acceptable with respect to the AP1000 GSI-191 evaluations.

A.8 Appendix A References

A-1 WCAP-7391, "Pressurized Water and Steam Jet Effects on Concrete," Westinghouse Electric Corporation, (Proprietary), January 1970.

A-2 ANSI/ANS 58.2-1988, "American National Standard Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture," 1988.

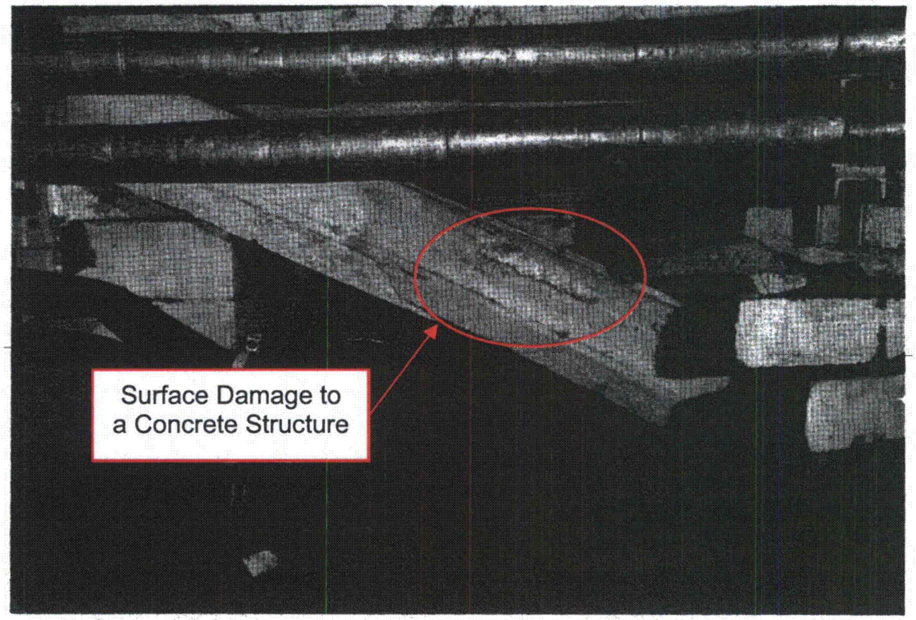

Figure A-1: DR post-blowdown damage to concrete structures within blowdown compartment (Figure C-3 of NUREG/CR-0897, Revision 1)

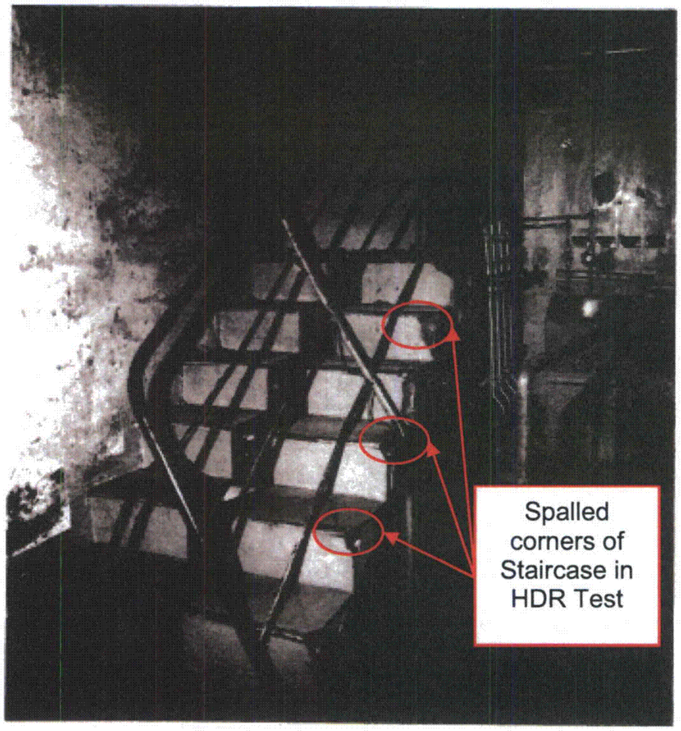

Figure A-2: HDR post-blowdown damage to railing structures in compartment near blowdown chamber (Figure C-4 of NUREG/CR-0897, Revision 1)

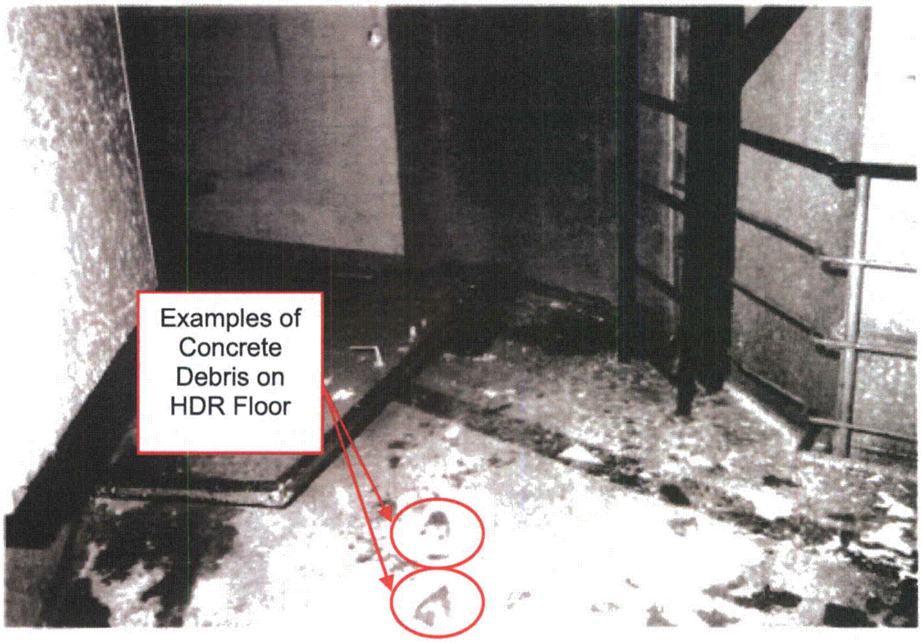

Figure A-3: HDR post-blowdown damage to compartment doors due to pressure wave. Debris shown is spalled concrete from stairwell located near blowdown compartment (Figure C-5 of NUREG/CR-0897, Revision 1)

a,c

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a,c

a,c

[ ]

Table A-1: Concrete Beam Jet Impingement Test Conditions (from Reference A-1)

a,c

Table A-2: Containment Piping with Possible Double-Ended Guillotine LOCA Jet and Concrete Surface Interaction with Calculated Jet Impingement Pressure at Concrete Surface

a.c

Table A-3: Evaluation of Split Breaks and Potential Damage to Concrete Surfaces in the AP1000 Containment

a,c

a,c

Figure A-4: Isobar Plot for Cold Leg Conditions

a,c

[ ]

Figure A-5: Isobar Plot for Hot Leg Conditions

a,c

Figure A-6: Development of Concrete Damage Ellipsoid for Split Break

a,c

Figure A-7: [ ] a,c Isobar With Bounding Sphere and Ellipse

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None