Westinghouse

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

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

Direct tel: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP_NRC_002930

June 28, 2010

Subject: AP1000 Response to Request for Additional Information (SRP 6)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 6. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP6.2.2-SRSB-39 R2

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 Strategy

/Enclosure

1. Response to Request for Additional Information on SRP Section 6

D063

NRO

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	P. Donnelly	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Power	1E
	R. Kitchen	-	Progress Energy	1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	D. Lindgren	-	Westinghouse	1E
	D. Behnke	-	Westinghouse	1E

ENCLOSURE 1

Response to Request for Additional Information on SRP Section 6

RAI Response Number: RAI-SRP6.2.2-SRSB-39
Revision: 2

Question:

WCOBRA/TRAC was validated for long-term cooling analysis as described in WCAP-14776 and WCAP-15644. In the DVI break, the core flow is normally 152.2 lb/sec. For the DVI break that has significant debris clogging of the core inlet (e.g., Sensitivity case 10), the core flow reduces to 65 lb/sec.

a) Has WCOBRA/TRAC been validated against tests with such low flow rates and high steam qualities? Provide the validation report that documents the validation and verification of WCOBRA/TRAC at these low flow rates, low pressure and low liquid qualities. Identify specifically what tests and comparisons were used to validate WCOBRA/TRAC at these conditions.

b) Will the sensitivity study cases with high core flow resistance, which results in low core flow (e.g., Case 10), be outside the range of applicability of the WCOBRA/TRAC code for LTC analysis? Provide an evaluation to ensure that these new LTC cases are within the range of applicability.

Westinghouse Response, Revision 2:

The NRC staff requested additional information be included in the RAI response during a conference call on June 7th, 2010. Revision 2 to this RAI response provides the requested information.

The NRC staff performed an audit of the calculations supporting APP-PXS-GLR-001, "Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris," on March 22nd through March 24th of 2010. As a result of this audit the staff asked Westinghouse to describe the impact of changes made to WCOBRA/TRAC for error corrections and code updates between the code version used to perform the level swell validation calculations described in Reference 4 and the version used in the debris sensitivity calculations reported in Reference 1. During the audit it was also noted that the flow values on page 2-9 of Reference 4 for the G1 tests corresponded to units of ft/s not in/s as listed in the table. The Revision 1 response to this RAI addresses this question and error in Reference 4.

For AP1000 long term core cooling, the WCOBRA/TRAC modeling was validated against selected G1 (Reference 2) and G2 (Reference 3) boiloff tests as discussed in Reference 4 Section 2.3.3. The selected G1 test runs were 28, 35, 38, 58, and 61; and G2 test runs 728, 729, 730, 732, 733 and 734. The WCOBRA/TRAC validation of the selected G1 and G2 test results for AP1000 long term core cooling compared the calculated and measured core level swell, which is a measure of the average core void fraction and an integral assessment of the interfacial drag model. Reference 4 page 2-10 shows the relationship between the level swell and the average void fraction. The adequacy of the code prediction was shown in the Reference 4 Figure 2-6 and Figure 2-7 results. Applying a multiplier (YDRAG=0.8), WCOBRA/TRAC predicts the core level swell to within ± 20% of the measured test data. In the AP1000 debris sensitivity cases, YDRAG was set to 0.8. The

WCOBRA/TRAC AP1000 sensitivity study cases are performed with modeling consistent with the validation calculations of the low pressure, low flow G1 and G2 tests.

Reference 4 page 2-9 provides the range of test conditions of interest in these selected G1 and G2 tests. It should be noted that the Assembly Flow presented for the G1 test data range in Reference 4 page 2-9 is in units of ft/s, not units of in/s as noted in the table. The AP1000 and G2 flow ranges are correctly reported in in/s. Table 1 summarizes the corresponding ranges from the AP1000 debris sensitivity cases (Reference 1). Comparing Table 1 and Reference 4 page 2-9 shows that the conditions from the AP1000 debris sensitivity cases are within the range of the G1 and G2 test data validation and/or non-debris AP1000 long term core cooling calculations. As discussed in Reference 4 page 2-8, 2-9, since the G1 and G2 series were boiloff tests with core exit steam quality approximately 1.0, they represent more limiting conditions with respect to core cooling than the long term core cooling sensitivity calculations where the maximum exit quality was approximately 50% (case 10).

The validation calculations summarized in Reference 4 page 2-9 were performed with the WCOBRA/TRAC M7AR4_SB03 code version. The current debris sensitivity calculations were performed with the WCOBRA/TRAC M7AR7_AP code version. The error corrections and code updates which are different between the two code versions were reviewed and all but one difference was classed into one of the following four categories judged to have no or negligible impact on the applicability of the G1, G2 validation calculations to the long term cooling debris sensitivity cases:

A. General code maintenance. These are discretionary changes to enhance code usability, including items such as modifying input variable definitions, units, and defaults; improved automation and diagnostics in the code; increased code dimensions; enhancing the code output for user convenience, modifications for code execution on different platforms, and general code cleanup. These changes do not impact the applicability of the G1, G2 validation calculations to the LTC debris sensitivity cases.
B. Addition of input options which are not used in the G1, G2 validation calculations or the LTC calculations. As these input options are not used, the changes do not impact the applicability of the G1, G2 validation calculations to the LTC debris sensitivity cases.
C. Error corrections which affect models or options which are not used in the G1, G2 validation calculations or the LTC debris sensitivity calculations. As these models or options are not used, the corrections do not impact the applicability of the G1, G2 validation calculations to the LTC debris sensitivity cases.
D. Change or error corrections which impact models or options which are used in the G1, G2 validation calculations or the LTC validation calculations but which are judged to not impact the applicability of the G1, G2 validation calculations to the LTC debris sensitivity calculations.

One code difference was identified which was judged to have impact on the level swell calculations: in the G1, G2 validation calculations the WC/T M7AR4_SB03 code version included a level sharpener applied to the heat transfer coefficient calculation for rods in the core region in the 3D VESSEL component. The level sharpener impacts the cladding heat up initiation time for a given fuel elevation, which is among the parameters used to calculate the level swell; with a level sharpener an earlier cladding heat up excursion time would be expected for a given elevation, at associated higher collapsed liquid level during the boil-off test.

In a boil-off mode scenario such as the G1 and G2 tests, the level swell calculated with the level sharpener is expected to be lower than the level swell calculated without a level sharpener. However, as discussed in Reference 4 and in response to DSER Open Item 21.5-3, for AP1000 long term cooling cases the two-phase mixture level is above the top of the active fuel and the two-phase mixture level is determined by the equilibrium between the injection flow and two-phase pressure drop for flow exiting the upper plenum into the hot leg and ADS Stage 4; the core power and degree of inlet subcooling control the total amount of vapor mass generated. Therefore, in this scenario, the two-phase mixture level is insensitive to the specific level swell model used within the core. The LTC DCD case and debris sensitivity cases show qualitatively similar behavior with the two-phase mixture level located in the upper plenum. The increased core inlet resistance in the sensitivity cases does not result in calculation of core dryout and heatup, consistent with the range of applicability for WCOBRA/TRAC established for AP1000 long term cooling analysis.

Based on this comparison of relevant input ranges, code version changes and behavior observed in the DCD and debris sensitivity cases, the sensitivity study cases with high core flow resistance which result in low core flow are within the range of applicability of the WCOBRA/TRAC code for AP1000 long term core cooling analysis.

Table 1. Range of Conditions of Interest from AP1000 WCOBRA/TRAC Debris Sensitivity Cases *

AP1000 Sensitivity Case	Upper Plenum Pressure (psia)	Power (kW/ft)	Core Flow (lbm/s)	Corresponding Core Velocity (in/s)	Core Inlet Subcooling (°F)
1	22	0.08	145.6	0.7	50
10	18	0.06	65.0	0.3	20

* Debris sensitivity cases 1 and 10 are selected as they bound the range of conditions observed in the debris sensitivity results presented in Reference 1.

Additional Response, Revision 2:

The following information is provided to clarify the effect of differences between the WCOBRA/TRAC (WC/T) M7AR4_SB03 and M7AR7_AP code versions on the G1 and G2 calculations as applicable to the AP1000 long term cooling (LTC) validation basis for the debris sensitivity calculations.

As discussed in Reference 4, selected G1 and G2 tests at low pressure, low flow and a range of power levels, prototypical of AP1000 LTC conditions, were modeled with WC/T in order to assess the code's prediction of the average core void distribution. The figure of merit from the integral assessment of the interfacial drag models was comparison of the calculated and measured values of level swell. Simulation of the G1 and G2 tests showed that the nominal interfacial drag models in WC/T tended to overpredict the level swell in the core during boiloff scenarios. The G1 and G2 calculations were repeated by applying a multiplier (YDRAG=0.8) to the interfacial drag coefficient computed from the vertical flow regime models in WC/T; as shown in Reference 4, the calculations with WC/T M7AR4_SB03 generally predicted the level swell to within +/- 20% of the measured value. Therefore, the YDRAG=0.8 multiplier was selected for use in the WC/T model for AP1000 LTC analysis.

The G1 and G2 calculations with M7AR4_SB03 show that applying a multiplier of YDRAG=0.8 to the WC/T interfacial drag models is reasonable for the prediction of the average core void fraction. As shown in Reference 4 Figure 2-6 and Figure 2-7 this multiplier is not determined to a high level of precision and the uncertainties in its value are not quantified. Reference 4 Figure 2-6 and Figure 2-7 show that there is scatter in the prediction of the G1 and G2 level swell and reducing the interfacial drag coefficient from its nominal value to 80% of the nominal value did not uniformly affect the predicted level swell. Considering the following factors, application of a reasonable nominal YDRAG value, without detailed treatment of its uncertainties, is acceptable:

- The insensitivity of the AP1000 LTC response to variation in YDRAG, as discussed in Revision 1 of the RAI response.
- Appendix K features of the AP1000 LTC model, particularly the use of Appendix K decay heat.

For preparation of Revision 1 to the RAI response, relevant calculation notes were reviewed to identify differences between WC/T M7AR4_SB03 used in the G1, G2 validation cases and WC/T M7AR7_AP used in the debris sensitivity cases. The M7AR4_SB03 code version is documented within the Westinghouse Configuration Control system, as are subsequent WC/T code versions that include specific AP modeling features as described in Reference 4 that were employed in the DCD Revision 15 LTC analysis and in the recent debris sensitivity calculations. It is noted that although the M7AR4_SB03 and M7AR7_AP WC/T code versions incorporated some different options available to the user, these different options were not used in the G1, G2 tests or AP1000 LTC calculations, and therefore are considered Category B differences as described in the Revision 1 response to this RAI. The YDRAG multiplier option is the only AP modeling feature necessary for simulation of the low pressure G1, G2 boiloff tests in support of the WC/T validation basis for AP1000 LTC. Both the M7AR4_SB03 and M7AR7_AP code versions use the same code logic to apply the user-input YDRAG multiplier to the core interfacial drag coefficient calculated from the same vertical flow regime models.

As discussed in Revision 1 of the RAI response, review of the differences between the M7AR4_SB03 and M7AR7_AP code versions identified that the M7AR4_SB03 contained level sharpener logic which may potentially affect the level swell assessment. It is noted that the WC/T version used in the DCD Revision 15 LTC analysis, as described in Reference 4, does not include the level sharpener logic.

M7AR4_SB03 was originally developed for application in best estimate small break LOCA analysis. The level sharpener was incorporated in order to better track the mixture level within a hydraulic cell in a high pressure boiloff scenario where an accurate assessment of the mixture level is important to the prediction of the peak cladding temperature. The level sharpener logic for heat transfer calculations used in M7AR4_SB03 is described in Reference 5 Section 11-2-4. The level sharpener logic in M7AR4_SB03 is only applied to the void fraction used in fuel rod heat transfer calculations for heat transfer nodes in hydraulic cells where a sharp void fraction gradient is detected, in the vicinity of the two-phase mixture level; the level sharpener does not directly affect the global distribution of liquid across different hydraulic cells.

In the G1, G2 validation calculations described in Reference 4, the predicted level swell is compared to the measured level swell. The level sharpener may affect the heatup time at a given elevation which in turn may influence the calculation of the predicted level swell to a small extent; the effect of the level sharpener is limited by the size of the hydraulic node.

Considering the restricted application of the level sharpener logic to the heat transfer calculation, the scatter shown in the prediction of the G1 and G2 level swell behavior with WC/T M7AR4_SB03, and the conclusion that all other code differences between M7AR4_SB03 and M7AR7_AP have no or negligible effect on the G1 and G2 simulations, it is concluded that the impact of the level sharpener logic on the G1 and G2 simulations is small. Therefore, a similar conclusion on the reasonable nominal value of the interfacial drag multiplier for AP1000 LTC analysis is expected with or without the level sharpener logic, and the G1 and G2 simulations presented in Reference 4 are applicable for the purpose of demonstrating the adequacy of the interfacial drag prediction of WC/T M7AR7_AP for AP1000 LTC. In the context of identifying a reasonable interfacial drag multiplier for use in the AP1000 plant analysis LTC cases, the existing validation is sufficient to support the use of M7AR7_AP for the LTC debris sensitivity cases, in which low pressure, low flow conditions are predicted (e.g. Sensitivity Case 10).

References:

1. APP-PXS-GLR-001 Revision 4, "Impact on AP1000 Post-LOCA Long-Term Cooling of Postulated Containment Sump Debris," February 2010.
2. WCAP-9764, "Documentation of the Westinghouse Core Uncovery Tests and the Small Break Evaluation Model Core Mixture Level Model," July 1980.
3. Andreychek, T. S., "Heat Transfer above the Two-Phase Mixture Level under Core Uncovery Conditions in a 336 Rod Bundle," Volumes 1 and 2, EPRI Report NP-1692, January 1981.
4. WCAP-15644-P Revision 2, "AP1000 Code Applicability Report," March 2004.
5. WCAP-14936, "Code Qualification Document for Best Estimate Small Break LOCA Analysis," August 2001.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None