REQUEST FOR ADDITIONAL INFORMATION

06/11/2009

US-APWR Topical Report: Small Break LOCA Methodology, MUAP-07013-P (R0)

Mitsubishi Heavy Industries
Docket No. 52-021
SRSB Branch

The following are NRC requests for additional information (RAIs) based on the review of the Small Break LOCA Methodology Topical Report, including reference to previously issued RAIs from 12/5/2008 (ML083220033)

New RAI	Related RAI (previously issued)	Question
1-2	1-1	Scaling of the test facility relative to the US-APWR needs to be addressed. In compliance with Step 6 of the evaluation model development and assessment process (EMDAP), as identified in Regulatory Guide 1.203, provide quantitative scaling analysis to ensure that the data from separate effects tests (SET) and integral effects tests (IET), and the models based on those data, will be applicable to the analysis of the US-APWR. a) Identify non-dimensional groups that govern the physical phenomena to be examined by the test facilities and compare the similitude between the facilities and the US-APWR. b) Based on the US-APWR-specific scaling analysis, address Step 8 of the EMDAP (evaluate the effects of IET distortions and SET scale up capability). c) Assess scalability of models (Step 15 of the EMDAP) - this is to demonstrate that models and correlations implemented in M-RELAP5 for the PIRT high ranking phenomena are appropriate for the SBLOCA evaluation specific to the configuration and conditions of the US-APWR. Examples of quantitative scaling analysis are: a. Novak Zuber, Wolfgang Wulff, Upendra S. Rohatgi and Ivan Catton, "Application of Fractional Scaling Analysis (FSA) to Loss of Coolant Accidents (LOCA), Part 1: Methodology Development", Paper: 153, 11th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics (NURETH-11), Popes' Palace Conference Center, Avignon, France, October 2-6, 2005. b. Wolfgang Wulff, Novak Zuber, Upendra S. Rohatgi and Ivan Catton, "Application of Fractional Scaling Analysis (FSA) to Loss of Coolant Accidents (LOCA), Part 2. System Level Scaling for System Depressurization", Paper: 111, 11th International Topical

		Meeting on Nuclear Reactor Thermal-Hydraulics (NURETH-11), Popes' Palace Conference Center, Avignon, France, October 2-6, 2005. c. Ivan Catton, Wolfgang Wulff, Novak Zuber, and Upendra S. Rohatgi, "Application of Fractional Scaling Analysis (FSA) to Loss of Coolant Accidents (LOCA), Part 3. Component Level Scaling for Peak Clad Temperature", Paper: 055, 11th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics (NURETH-11), Popes' Palace Conference Center, Avignon, France, October 2-6, 2005. d. Wolfgang Wulff and Upendra S. Rohatgi, "System Scaling for the Westinghouse AP600 Pressurized Water Reactor and Related Test Facilities, Analysis and Results, NUREG/CR-5541, January 1998. e. J. N. Reyes, Jr., Qiao Wu and John B. King, Jr. "Scaling Assessment for the Design of the OSU APEX-1000 Test Facility", OSU-APEX-03001 (Rev. 0), May 12, 2003. f. Revision 1: R. E. Gamble, A. F. Fanning and V. Chandola, Revision 2: P. Saha, "ESBWR Scaling Report", NEDO-33082, Revision 1, December 2002, Revision 2, April 2008. g. S. Banerjee, M. G. Ortiz, T. K. Larson and D. L. Reeder, "Top Down Scaling Analyses Methodology for AP600 Integral Tests", INEL-96/0040, May 1997.
4-13	4-1	The heat transfer logic at the end of blowdown must be precisely defined in the documentation so that it can be verified against the code and the analysis.
4-14	4-7	[(Proprietary information withheld under 10 CFR 2.390)]
4-15	4-10	PIRT Tables have some rankings that are break size dependent. Is the ranking in PIRT Table (4.3.2-1, MUAP-07013-P) the highest value for all break sizes? If not, please revise the table and provide the highest ranking for each phenomenon. Also, is there a method (for example a sensitivity analyses) of confirming the ranking in the PIRT?
*****4-16	4-11	PIRT tables provide ranking of all phenomena as they impact the figure of merit. However, it is not clear how high and medium rank phenomena are treated. Why are some high ranked phenomena (Table 4.3.2-2) not validated (Table 4.4.2-1)? Are medium ranked phenomena validated? Are high and medium ranked phenomena, not covered by Appendix K, modeled with best estimate or conservative models in the SBLOCA analyses?

***4-17**	4-12	Section 4.4.2 refers to confirmation plan for high ranking phenomena. What are the acceptance criteria for confirming the model of a given phenomenon? How is it established that the code model will accurately represent the phenomenon (e.g., percentage difference)? How is it determined that the code prediction is conservative? How is the uncertainty of measurement accounted for? Is there any sensitivity study?
5-2	5-1	The MHI response does not provide quantitative scaling analysis that supports their claim that the differences between the US-APWR and a conventional PWR in active core height and number of grid spacers is negligible. Provide M-RELAP5 validation runs for the prediction of CHF and PCT in a 12-ft fuel assembly and the scaling analysis that demonstrates the validity of extending the M-RELAP5 capability to predict CHF and PCT in a 14-ft fuel assembly typical of the US-APWR core.
***6-4**	6-1	Provide documentation of the changes made to RELAP5-3D that created M-RELAP5. The level of documentation detail should be the same as the RELAP5-3D manual. Either the changes can be added to the RELAP5-3D documentation and a complete code manual provided, or an Addendum can be issued. The documentation needs to identify any RELAP5-3D features that are not relevant for M-RELAP5.
6-5	6-2	To satisfy TMI action plan requirements in NUREG-0737 requires assessing against Semiscale and LOFT data. MHI is requested to include Semiscale test S-UT-8 and LOFT test L3-1 in their assessment matrix.
6-6	6-2	Based on the information provided in UAP-HF-09041-P, "MHI's 2nd Part Responses to the NRC's Requests for Additional Information on Topical Report MUAP-07013-P (RO) "Small Break LOCA Methodology for US-APWR", February 2009, in response to Request 6.2, in Table 5, "Summary of Validation Status for M-RELAP5-Specific Models," it is not clear how the assessments were performed. Provide a table that lists all Appendix K features that were used for each of the assessment cases
7-13	7-1	Does the M-RELAP5 model of the US-APWR include a bypass flow path between the upper head and the downcomer that could potentially allow steam to leak from the core region? If this bypass flow path is present in the model evaluate its effect on the progression of the SBLOCA and the potential for the bypassed steam to sweep some of the ECC water out the break.

<table>
<tr><td>7-14</td><td>7-2</td><td>The break size spectrum for the APWR is different than previously considered by the NRC for SBLOCA, since the limiting case is at the high end of the range (1.0 ft^2). For PWRs limiting breaks have historically been in the range of 2 to 4 inches. It is not certain that the APWR break size range can be characterized fully by SBLOCA phenomena. To assist the NRC in determining whether the governing phenomena are more like a SBLOCA or LBOCA (e.g. to resolve end of bypass, FLECHT heat transfer applicability, amount of dissolved Nitrogen in RCS from accumulator based on accumulator water level) the following information is requested:

For the limiting 1.0 ft^2 break and the 7.5 in^2 break, provide plots of the following parameters:

a. the cold leg to downcomer mass rate for each loop,
b. the downcomer to lower plenum mass flow rate,
c. the mass flow rate into and exiting the average and hot channel (vapor and liquid components as appropriate),
d. the core bypass inlet mass flow rate,
e. the neutron reflector inlet mass flow rate,
f. the accumulator water levels as functions of time,
g. the equivalent two-phase levels in the average and hot channel as functions of time,
h. the peak cladding temperature as a function of time and identify the SBLOCA phase (i.e., blowdown, loop-seal clearing, natural circulation, etc.) time spans on the plots.
i. the heat transfer coefficient at the peak clad temperature location and the heat transfer correlation identifier and annotate the plot to indicate the time when an Appendix K heat transfer lockout occurs.</td></tr>
<tr><td>7-15</td><td>7-2</td><td>Based on Section 4.4, “Reflood Model,” in Volume IV of the RELAP-3D code description, “Paul Scherrer Institute (PSI) in Switzerland developed updates to improve the quench front behavior during the reactor core reflood process. A modified version of these updates was incorporated into RELAP5-3D along with a new quench front plotting capability.” A literature search suggests a multiplier of 0.6 should be applied to the heat transfer coefficient for flooding rate greater than 1 inch/sec to meet Appendix K requirements, based on an assessment against FLECHT-SEASET tests.

Is the 0.6 multiplier used for SBLOCA reflood rates greater than 1 inch/second? If not, why? Are any other modifications used in M-RELAP5, such as a multiplier, to meet the Appendix K requirements?</td></tr>
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*7-16	7-2	Comparisons to FLECHT heat transfer correlation for reflood rates greater than 1" per second. MHI previously stated that this did not apply to SBLOCA based on NOTRUMP SER, but the APWR limiting break size is much larger than typical PWRs (3-4 inches). Please provide a discussion addressing the larger limiting break size for the APWR which justifies the MHI position of not comparing to FLECHT data.
7-17	7-2	During refill and during reflood when reflood rates are less than one inch per second, heat transfer calculations shall be based on the assumption that cooling is only by steam. The M-RELAP reflood model uses the Forsland-Rohsenow correlation which includes heat transfer to droplets and does not comply with the Appendix K requirement for steam cooling only. Please explain how using the heat transfer coefficient model, which includes the Forsland-Rohsenow correlation, satisfies the Appendix K steam cooling only requirement. In M-RELAP5, radiation to droplets is then added to the final film boiling coefficient. Please explain how this term satisfies the Appendix K steam only criterion.
7-18	7-2, 7-10	[(Proprietary information withheld under 10 CFR 2.390)

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7-19	7-8	[(Proprietary information withheld under 10 CFR 2.390)]
*7-20	7-8	M-RELAP5 has implemented its own model for the transition from subcooled single-phase critical flow to two-phase critical flow. From the original response to RAI 7-8 it appears that MHI is taking credit for a lower critical flow rate when vapor phase exists with subcooled liquid in the volume upstream of the break. Also a special numerical scheme was implemented to smooth out the prediction of critical flow when the transition occurs. Provide validation analyses against critical flow tests that span conditions of subcooled liquid with vapor and also transition from single-phase liquid to two-phase critical flow. Is the under-relaxation method part of the Appendix K modification or part of the M-RELAP5 base code (i.e. the under-relaxation method is in operation even if none of the Appendix K model is activated)?
7-21	7-8	[(Proprietary information withheld under 10 CFR 2.390)]

* 60 day response time

*7-22	7-10	[(Proprietary information withheld under 10 CFR 2.390)]
8-3		The 1/2 scale test will be simulated with RELAP5/MOD3.3 as part of the confirmatory calculations. The purpose is to benchmark the advanced accumulator modeling approach used in RELAP5/MOD3.3 (uses control systems) against experimental data. Please provide the M-RELAP5 input file that was used for the 1/2 scale advanced accumulator tests
*8-4		[(Proprietary information withheld under 10 CFR 2.390)]
*8-5		[(Proprietary information withheld under 10 CFR 2.390)

* 60 day response time

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***8.1-4**	8.1-2	The timings of PCT in the RAI response of 8.1-2 cover 7.5-inch and 1 ft^2 break. Discuss whether the LHGR of the tests cover the range of PCT timing of other break sizes. Also discuss if the mass flux of these simulations cover the range of mass flux of entire SBLOCA spectrum of break sizes.
***8.1-5**	8.1-3	Sensitivity study in the nodalization of the plant model is not a substitute for sensitivity study for the test simulation. Demonstrate that conclusions derived from the simulation do not depend on the nodalization of the test facilities (especially for the nodalization of the ROSA/LSTF cross-over legs, which are substantially different from the plant model).
8.1.2-13	8.1.2-5	The mass fluxes for Tests K and N in Table RAI-8.1.2-5.1 are not the same as those in Table 8.1.2-1. This should be clarified. Also, note there is substantial energy imbalance, especially for tests J, BB and CC (Some of them are more than 15%. They will be even larger when divided by (d)-(c) rather than (d).) Discuss the impact of these imbalance on the conclusion that the code prediction is reasonable and validates the code.
8.1.4-7	8.1.4-3	The CCFL correlation has three coefficients that are provided through input. Provide locations of all the places where CCFL correlation is applied, values of CCFL coefficients, and justification. What is the size of pipe when surface tension effect is not important? Does the set of coefficients change with a change in pressure (see Table RAI-8.1.4-3.1, January-2009 MHI response, page 93)?

***** 60 day response time

*8.1.4-8	8.1.4-4	[(Proprietary information withheld under 10 CFR 2.390)]
8.1.4-9	8.1.4-6	Why does the data for 3 bar in Figure 8.1.4-2 of MUAP-07013-P(R0) show less liquid down flow when compared to the 15 bar data at the same Hg? Is this an indication of pressure dependence of the coefficients (c and m) for the CCFL correlation? Figure 8.1.4-4 of MUAP-07013-P(R0) compares analytical results and test data at two pressures, 3 bar and 15 bar. The comparison at 3 bar shows that for a given steam mass flow, the analytical result predicts higher water mass flow than the test data. Is the set of coefficients for CCFL correlation obtained from the UPTF tests conservative for SBLOCA simulation for the US-APWR? Has the validation of the CCFL correlation been done with an independent set of data, i.e. other than the UPTF data that were used to develop the coefficients for the CCFL correlation? Also, there are CCFL models applied at the main coolant pump suction and discharge. Please describe the basis for selecting these models including the assessments that demonstrate applicability to the US-APWR application.
8-3	8-2	Have there been error fixes in M-RELAP5 since MUAP-07013-P (R0) was issued? What impact do these error fixes have on the SBLOCA methodology as presented in MUAP-07013-P (R0) and the technical report MUAP-07025-P (R0)?
D-2	D-1	Appendix D describes the model and uncertainty in the correlations. The model description is for regular accumulator and there is description of spherical accumulator that is not representative of the advanced accumulator in the US-APWR. The model does not explicitly provide expressions for calculating level in tank (“H”). Also, how does the code calculate L_{fL}? The definitions of A_g and A_f (top of page D-5) are not clear.

***** 60 day response time