December 2, 2008

Mr. Yoshiki Ogata, General Manager
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16-5, Konan 2-Chome, Minato-Ku
Tokyo, 108-8215 JAPAN

SUBJECT: MITSUBISHI NUCLEAR ENERGY SYSTEMS, INC. - REQUEST FOR ADDITIONAL INFORMATION ON TOPICAL REPORT MUAP-07013-P, “SMALL BREAK LOCA METHODOLOGY FOR US-APWR”.

Dear Mr. Ogata:

On November 5, 2008, Mitsubishi Heavy Industries, LTD (MHI) participated in a conference call with the U.S. Nuclear Regulatory Commission (NRC) staff regarding the draft Request for Additional Information (RAI) for Topical Report MUAP-07013-P, “Small Break LOCA Methodology for US-APWR”. Enclosure 1 is the public version of final RAIs, which has the proprietary information removed and replaced by brackets. Enclosure 2 is the non-public version of final RAIs. Although the expected response time for RAIs is 30 days to the NRC Document Control Desk, there are 14 RAIs that have been given response times of 75 days from the date of this letter. These particular RAI numbers are marked with an asterisk. If you have any questions or comments concerning this matter, you may contact me at 301-415-7871, or via email at Michael.Takacs@nrc.gov.

Sincerely,

/RA/

Mike Takacs, Project Manager
US-APWR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-021

Enclosures:
As stated

cc: See next page

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REQUEST FOR ADDITIONAL INFORMATION

US-APWR TOPICAL REPORT MUAP-07013-P(R0)
Mitsubishi Heavy Industries, Inc.
Docket No. 52-021
SRSB Branch

The following RAIs are necessary to help determine if the requirements of 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors", and Appendix K of 10 CFR 50, "ECCS Evaluation Models" have been satisfied.

RAI Number	Reviewer	Statement of RAI
1-1		Table 1.1-1 The table attempts to present the correspondence between the organization of the SBLOCA methodology topical report (MUAP-07013-P(R0)) and the roadmap identified in Regulatory Guide 1.203 for the development and assessment of the evaluation methodology. Different sections of the topical report are associated with the 20 steps identified in the Regulatory Guide. Provide a more refined association of sub-sections of the topical report to the 20 steps. For example, Section 8 is identified to address Step 15: Assess Scalability of Models. However there is no specific section title in Section 8 that addresses the task identified in Step 15.
5-1		Section 5.2 The prototype plant in the scaling analysis of the test facilities is a reference PWR and not the US-APWR. Though the reference PWR is a 4-loop plant with 17x17 fuel assemblies there are significant differences between the reference PWR and the US-APWR, e.g. active fuel height (12 ft. for the reference and 14 ft. for the US-APWR) and number of grid spacers (9 for the reference PWR and 11 for the US-APWR). Provide an evaluation of the impact of not using US-APWR design parameters in the scaling analysis.
*6-1		Section 6.1.2 The M-RELAP5 documentation must be reasonably self-contained. The existing references for M-RELAP5 in the topical report refer to documentation for RELAP5-3D and RELAP5Mod3.3 extensively. There are no stand-alone M-RELAP5 code manuals. Provide stand-alone M-RELAP5 code manuals and in particular a user manual on how to call for the EM models in M-RELAP5.

REQUEST FOR ADDITIONAL INFORMATION

*6-2		Section 6.1.2 Table 6.1-1 summarizes independent assessments of RELAP5/MOD3 performed by the CAMP members specifically for SBLOCA. M-RELAP5 has not been assessed for all the integral effects tests and separate effects tests listed in the table. Has there been any systematic comparison of RELAP5/MOD3 and M-RELAP5 simulations of the assessment matrix in Table 6.1-1 to identify the effects of implementing the EM methodology? Do the EM models in M-RELAP5 predict more conservative results for the assessment tests when compared with RELAP5/MOD3?
6-3		Section 6.2.1.3 In Table 6.2.1-4a why does the separator component not apply for the secondary side of SG?

4-1	i	Section 4.2 Report identifies five phases of the SBLOCA transient. However, boundaries of these phases are not clearly defined. Provide parameters that indicate when one phase ends and other begins.
4-2		Section 4.2 Report (Page 4-4) indicated that relative pressure in the core increases. Explain what is relative pressure? How does it decrease liquid level in the core? (Loop Seal Clearance)
4-3		Section 4.2 What is mechanism of loop seal clearing? It is not clear from the description.
4-4		[[Proprietary information withheld under 10 CFR 2.390]]
4-5		[[Proprietary information withheld under 10 CFR 2.390]]
4-6		[[Proprietary information withheld under 10 CFR 2.390]]

* 75 day response time

4-7		Section 4.3.2.7 Pressurizer pressure is used as a parameter for reactor trip and safety injection signal. Vapor generation in the primary system will have strong influence on this pressure. Explain why interfacial mass transfer or flashing has not been identified as a phenomenon of interest.
4-8		Section 4.3.2.9 The report mentions that for smaller breaks the loop seal may not clear. During Loop Seal Clearing period, what is the status of safety injection (including accumulator flow) for various break sizes? (PIRT-45)
4-9		Section 4.3.2.9 There is some uncertainty as to whether loop seal clearing (PIRT #45) will occur first in the broken loop or the lumped intact loop (3 loops combined). The effect of loop dynamics (or asymmetric effects) was not included as one of the phenomenon for consideration in the PIRT process. Please explain.
4-10		[[Proprietary information withheld under 10 CFR 2.390]]
4-11		Section 4.4 How are medium ranked phenomena treated in the analyses? Are there any assessments of the medium ranked phenomena?
4-12		Section 4.4.2 What does confirmation mean? What are the criteria of confirmation?

7-1		Table 7.1.1-1(4/4) Appendix K requirement #15 ECC water bypass is taken as not applicable to SBLOCA. The bypass flow between upper head and downcomer could potentially provide a path for steam to enter the downcomer during the loop seal clearance period. Confirm that none of the SBLOCA analyses, including sensitivity cases, experience the effect of steam impeding ECC flow.
7-2		Table 7.1.1-1(4/4) Appendix K requirement #29 refill/reflood heat transfer is taken as not applicable to SBLOCA. However, there could be core uncovery during the loop seal clearance period resulting in cladding superheat. Confirm that all SBLOCA cases do not require refill/reflood heat transfer. If they do require refill/reflood heat transfer then explain why Appendix K requirement #29 is not for SBLOCA.
7-3		Section 7.1.2 The discussion of gap conductance model is in the form of one equation and one reference to the fuel design code FINE. Provide validation analysis of the gap conductance model as expressed in Equation (7.1.2-1). Provide verification of the implementation of the gap conductance model in M-RELAP5 and demonstrate the integration of the gap conductance model with the rest of the gap heat transfer model in RELAP5-3D, such as thermal radiation across the gap.
7-4		Section 7.1.3 Provide a reference or fuel cycle calculation to justify the claim that the default values of the ANSI/ANS 5.1-1979 standard are appropriate for the US-APWR and yield the highest decay heat from the actinide series.
7-5		Section 7.1.4.1 Provide verification of the implementation of the Metal Water Reaction Rate Model in M-RELAP5. Confirm that the hydrogen generation rate and the heat generation rate are consistent with the metal/water reaction rate.
7-6		Section 7.1.4.2 Verify the correctness of the exponential term in Equation (7.1.4-8). It appears a negative sign is missing.

7-8		[[Proprietary information withheld under 10 CFR 2.390]]
7-9		Section 7.1.6 It appears with non-condensable quality [illegible] the two-phase critical flow will be calculated by using the extended Henry-Fauske model instead of the Moody model. Explain this switch in two-phase critical flow model. The operation of the advanced accumulator may introduce non-condensable to the system. Did the SBLOCA analysis ever reach a state that required the use of the extended Henry-Fauske model?
*7-10		[[Proprietary information withheld under 10 CFR 2.390]]
*7-11		Section 7.1.7.2 The AECL look-up table for CHF has been under continuing improvement. The 1986 version implemented in M-RELAP5 is an older version, the latest being the 2006 version. Explain why in lieu of more recent development the 1986 version of the AECL look-up table still remains relevant or at least conservative.
7-12		Section 7.1.7.6 The logic to prevent return to nuclear boiling and transition boiling is only necessary (per Appendix K) during the blowdown phase of a LOCA. Provide the criteria used to define the blowdown phase when the prevention logic is applicable.
D-2		Appendix D also describes uncertainty in Cv. A set of questions were asked in Topical report on Adv Accumulator (MUAP-07001) and LBLOCA Methodology report (MUAP-07011), and will not be repeated here.

REQUEST FOR ADDITIONAL INFORMATION

C-1		[[Proprietary information withheld under 10 CFR 2.390]]
C-2		Appendix C What is the impact of the discontinuity exhibited by the right end points of the curves in Figure C-4?

8-1		Section 8.0 M-RELAP5 was created by modifying RELAP5-3D. Does any of the change have a direct impact on the result of the M-RELAP5 assessment? Are the differences in the results produced by using M-RELAP5 and RELAP5-3D consistent with the differences in the two codes?
8-2		Section 8.0 Was a single frozen version of M-RELAP5 used in all the assessments presented in this section? If yes, was the same version of M-RELAP5 used in the SBLOCA analysis?
8.1-1		Discuss the scaling of each test in Sections 8.1.1 (ROSA-IV LSTF) and 8.1.2 (ORNL/THTF) vs. US-APWR (in terms of vessel and rod heights, volume, flow areas, rod diameter, power/heat flux ratio, grid spacers, ratio of heated and unheated rods, and SG elevation, tube diameter and tube length, etc.), and justify the scaling (i.e., why the differences in these scales, if any, are not an issue) in using these tests for the US-APWR assessment.
8.1-2		For each of the tests discussed in Sections 8.1.1, 8.1.2 and 8.1.3 scale the testing power in comparison with the timing of the US-PWR decay power (120% of ANS curve)
8.1-3		Sections 8.1.1, 8.1.2 and 8.1.3 The submittal concluded that M-RELAP5 was conservative based on the results of test simulations which used only one nodalization for each test. However, sometimes results can vary depending on nodalization. Discuss if any nodalization sensitivity studies were performed to make sure the results were conservative regardless of the nodalization for each test simulation.
8.1.1-1		ROSA is an integral test facility including pressurizer and steam generators (SGs). But the simulations were performed only for the vessel. Are the selected tests vessel only tests, or is the vessel isolated for the simulations?
*8.1.1-2		[[Proprietary information withheld under 10 CFR 2.390]]

8.1.1-3		[[Proprietary information withheld under 10 CFR 2.390]]
8.1.1-4		[[Proprietary information withheld under 10 CFR 2.390]]
8.1.1-5		Compare how the grid spacers are modeled in the test and in plant simulations (e.g., flow areas, friction factors), and discuss the impact of these modeling differences, if any, on the void fraction distributions.

8.1.2-1		Figure 8.1.2-2 shows a "shroud plenum annulus". Is this space filled with water? Is there any water flowing through this space? How is this space handled in the test and the simulation?
8.1.2-2		[[Proprietary information withheld under 10 CFR 2.390]]
8.1.2-3		[[Proprietary information withheld under 10 CFR 2.390]]
8.1.2-4		How is the "measured mixture level" (in Figures 8.1.2-7 and 8.1.2-30) determined in the tests? How is the predicted mixture level (in Figure 8.1.2-30) defined and calculated?
8.1.2-5		Section 8.1.2.3 states that "Eventually, the THTF settled into a quasi-steady state with the bundle partially uncovered and inlet flow just sufficient to make up for the liquid being vaporized." Then, please explain why the mass fluxes of Tests K and CC in Table 8.1.2-1 are widely different (2.22 vs. 7.22) for the similar pressure, inlet subcooling and linear heat power. (Comparison of J and AA also.) (Also test FF, which has a higher pressure and higher subcooling, has a higher mass flux, i.e. higher vapor production, than test K for the same power, which is an anomaly). Did all tests result in vaporizing 100% of the incoming liquid? Please provide a table showing the SS energy balance for each test (i.e., Outlet enthalpy- Inlet enthalpy= Heat Input - loss).
8.1.2-6		How was the fractional heat loss in Table 8.1.2-1 determined (measured, or calculated to match the energy balance)? Why are they widely different from less than 2% to 17%?
*8.1.2.7		It is observed in Section 8.1.2.5 that "in most cases the calculated void fractions are slightly larger than the experimental values." Please discuss the implication of this observation, particularly in relation to the mixture level. Is this systematic deviation, an indication of the code deficiency?
*8.1.2.8		The calculated vapor temperature is higher than measured (by about 20K) in Figure 8.1.2-9. Based on the energy balance shouldn't they be the same? Please explain (Note that boundary conditions, i.e., inlet temp, flow rate, vapor pressure and heat generation, are the same.) Is this due to entrainment?

* 75 day response time

*8.1.2.9		The large difference and a sudden jump of void fractions in Figure 8.1.2-11 for Test K was explained by heat loss at boundary (Section 8.1.2.5). But this was observed only in this test and not in Test N where the heat rate and mass flux were similarly low, and heat loss was similarly high. Explain this anomaly.
*8.1.2-10		1) The measured heat transfer coefficients in the vapor region generally increases rapidly with temp increase while the calculated coefficients generally unchanged, indicating the M-RELAP5 model may be deficient. Explain this discrepancy between data and model prediction . 2) In three (J, M, N) of the four tests, the measured heat transfer coefficients show sudden drops after peaking in the vapor region. Are these considered real? Is there any concern that these are not shown in the simulations, and thus the M-RELAP5 model may be deficient. Explain.
8.1.2-11		Provide more detailed explanations of sensitivity study 1. Are these simulations only or also tests? (It appears the measured levels of tests are unchanged. What is the significance of comparing cases of different power level?)
8.1.2-12		[[Proprietary information withheld under 10 CFR 2.390]]

8.1.3-1		Scale the inlet mass flux in Table 8.1.3-1 in terms of the US-APWR scaling and compare them with the appropriate/typical core inlet flow rate during the reflood period of US-APWR SBLOCA
8.1.3-2		The flow in Table 8.1.3-1 is given in inlet mass flux (kg/s.m^2), while the flow in Figure 8.1.3-2 is given in m^3/s. Revise either so that the units are consistent.
8.1.3-3		The inlet mass flux in Table 8.1.3-1 is not consistent with the flooding velocity of Table 5.2.1.4-4, or Figures 8.1.3-2 and -5. (e.g., Table 8.1.3-1 show similar inlet mass flux for Tests P and Q, but Figure 8.1.3-2 for Test P and Figure 8.1.3-5 for Test Q show substantially different flow rates). Clarify the discrepancy (the same applies to tests R and S).
8.1.3-4		Explain how the inlet temperatures of Figure 8.1.3-3 and 8.1.3-6 were selected and compare them with the inlet temperature to the core during the reflood period in a typical SBLOCA transient.
8.1.3-5		The inlet temperature profiles for Test P (Figure 8.1.3-3) and Test Q (Figure 8.1.3-6) are substantially different. Explain.
8.1.3-6		Explain how the pressures (boundary condition) in Figures 8.1.3-4 and -7 were selected.
*8.1.3-7		Explain the saw-tooth behavior of the collapsed liquid level for the M-RELAP5 results in Figures 8.1.3-10 and 14. Explain why the calculated collapsed liquid level at time=0 for test Q (Figure 8.1.3-14) does not match the measured level.
8.1.3-8		The quench velocities for test P (Figure 8.1.3-11) and test Q (Figure 8.1.3.15) are similar for the tests (about 3 cm/sec for P and 2.8 cm/sec for Q), but they are substantially different for the simulations (about 2.4 for P and 1.3 for Q). This may imply that the quench velocities for the simulation could be higher than the test for some parameter ranges, and thus the simulation may not be conservative. Please explain.

* 75 day response time

8.1.4-1		The UPTF test description mentions steam injection and air injection (Section 8.1.4.2). Is it correct? Was the test steam only?
8.1.4-2		[[Proprietary information withheld under 10 CFR 2.390]]
8.1.4-3		RELAP5 uses CCFL correlation with three input specified parameters that indicates the effect of surface tension and gas flow rate for hold up. It correctly indicates that for large pipes surface tension is important (Kutateladze correlation) and for small pipes the length scale does not depend on surface tension. However, there is no statement on size of the pipe where the transition occurs. Explain the criteria for selecting the use of either the “big” pipe or “small” pipe form of the CCFL correlation.
8.1.4-4		The large pipe CCFL correlation was obtained by regression analyses of the actual UPTF data. The coefficients (m, c, β), obtained from these analyses, are used to model these tests with RELAP5 as part of validation. However, this is not a validation but verification of implementation of the model. What set of coefficients will be used in plant simulation?
*8.1.4-5		Figure 8.1.4-3 shows nodalization diagram for UFT test. Please explain the rationale for number of nodes in the different sections. How does this nodalization compare to nodalization of similar sections for the US-APWR?
8.1.4-6		Figure 8.1.4-4 indicates a comparison of code prediction and the test results. Are there code results for actual test conditions? How do they compare? For 3 bar case, there are three steam flow rates with liquid upward flow but none in the data. Please explain.

8.1.5-1		Section 8.1.5 Discuss the scaling of the Duckler Air-Water Flooding test facility in comparison with the US-APWR steam generator tubes (diameter, length, friction factor, etc.),
8.1.5-2		Section 8.1.5 Compare the test pressure, temperature and flow rates (both water and air) with those of the expected conditions at the SG U-tube uphill side during the loop seal clearing period, and discuss why these tests are applicable to the loop seal period of a SBLOCA.
8.1.5-3		Section 8.1.5 The test sections are made of Plexiglas/flexible tygon tubing while the SG tubes are made of inconel. Discuss the impact of the pipe material difference in assessing the applicability of the test results, since the surface property (friction factor and surface tension) of the pipes may influence the results. Smooth surface may be more inductive to more water going down, which the results indicate.
8.1.5-4		Section 8.1.5 The test was performed with water and non-condensable gas (air), while the fluid in the SG tubes is condensable water/steam mixture during SBLOCA. Discuss the applicability of this test in spite of this difference.
8.1.5-5		Section 8.1.5 Discuss if the test cover all flow regimes since reflood/reflux flow would be affected by the flow regime.
8.1.5-6		Is the CCFL correlation described in Section 8.1.5.3.b, namely the three parameters in the Hewitt & Wallis correlation, the same one used in all SBLOCA simulations?
*8.1.5-7		[[Proprietary information withheld under 10 CFR 2.390]]

8.2.1-1		The assessment of M-RELAP5 against the ROSA-IV/LSTF tests was for application to the US-APWR. Table 8.2.1-1 showed the scaling of the major design characteristics of the test facility against a PWR. Provide a similar table for the US-APWR.

* 75 day response time

8.2.1-2		In Section 8.2.1.3 (a), it was stated that “the hot and cold legs were sized to conserve the volume scaling and ratio of the length to the square root of pipe diameter, L/sqrt(D), for the reference PWR.” Does this still hold for the US-APWR? If not, discuss the implication or why this doe not matter
*8.2.1-3		Test SB-CL-18 (5% break) was selected for analysis which is equivalent to a 6-inch break, because “both loop seal phenomena and boil off phenomena considered important for SBLOCA were observed in the experiment.” However, the SBLOCA spans from 2” to 12”, and it may be also important to know what phenomena occurs or does not occur at certain size breaks (and the code can simulate the non-occurrence of them at those sizes). Are there any plans to do additional assessment for other break sizes. Discuss the applicability of M-RELAP5 to break sizes other than the 6-inch break that has been assessed against data.
8.2.1-4		What is the timing of 10 MW in the decay heat curve (120% of ANS curve) in terms of scaling with respect to the US-APWR?
8.2.1-5		[[Proprietary information withheld under 10 CFR 2.390]]
*8.2.1-6		Figure 8.2.1-17 shows that M-RELAP5 core water level drops earlier than test (300 sec for the analysis vs. 400 sec for the test.) during the boil off period. Section 8.2.1.5 (d) (1) attributes it to more liquid remaining in the cross-over legs for the analysis (Figures 8.2.1-32 and -33). However, the figures show that water holdup is larger during the period preceding this difference, and the difference is decreasing at 300 seconds. This observation seems contradictory to the above explanation. Provide an explanation for the observed inconsistency.

* 75 day response time