August 19, 2008

Mr. Yoshiki Ogata, General Manager
APWR Promoting Department
Mitsubishi Heavy Industries, Ltd.
16-05, Konan 2-Chome, Minato-Ku
Tokyo, 108-8215 Japan

SUBJECT: MITSUBISHI HEAVY INDUSTRIES, INC. - REQUEST FOR ADDITIONAL INFORMATION ON ADVANCED ACCUMULATOR FOR US-APWAR TOPICAL REPORT MUAP-07001-P, REVISION 1

Dear Mr. Ogata:

By letter dated January 31, 2007, Mitsubishi Heavy Industries, Inc. (MHI) submitted for Nuclear Regulatory Commission (NRC) staff review the Topical Report MUAP-07001-P, Revision 0, "Advanced Accumulator." Revision 1 to the Topical Report MUAP-07001-P was submitted on March 2, 2007. The NRC staff has reviewed the Topical Report MUAP-07001-P, Revision 1 and has determined that additional information is needed for the NRC staff to complete its review.

Subsequently, the NRC staff sent a draft request for additional information (RAI) electronically on June 2, 2008, and held a conference call with MHI on June 12, 2008 to clarify the draft RAI. Furthermore, MHI has confirmed that the draft RAI did not contain any proprietary information.

MHI is requested to provide a response within 30 days of the date of this letter. MHI's responses to the NRC RAI will be addressed in the NRC staff's safety evaluation report for the Topical Report MUAP-07001-P. The RAI list is enclosed.

Sincerely,
***/RA/***

Ruth Reyes
Project Manager
USAPWR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-021

Enclosure: As stated

cc: See next page

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# REQUEST FOR ADDITIONAL INFORMATION NO. 2
# US-APWR TOPICAL REPORT MUAP-07001-P (R1)
# ADVANCED ACCUMULATOR

1. During early large flow injection period, the angular momentum of the flows from the standpipe and the small pipe cancel in the vortex chamber (See response to NRC question 2, and Eq. 2.1). These flows will decrease as the accumulator depressurizes and the level decreases. Does this angular momentum cancellation happen for all flows? Can there be some vortex during this time period?

2. Cavitation will occur at the lowest pressure location. In the preliminary computational fluid dynamic (CFD) analysis (see Fig. 1) that NRC performed, cavitation occurred during large flow rate conditions just downstream the throat of the nozzle.

    a. Can you quantify this cavitation occurrence?

    b. Can there be cavitation at the center of vortex where pressure will be low? Is the cavitation in the vortex center scale-dependent?

3. Will there be any choked flow at the throat of the outlet pipe?

4. The dissolved gas will come out of the coolant as the pressure decreases. How does that affect the pressure drop?

5. According to the topical report, there is no Nitrogen coming out of the tank.

    c. How was this measured?

    d. What will be the nitrogen solubility in the actual accumulator? Will it be in equilibrium? Do all the tests have equilibrium nitrogen solubility? How much nitrogen will come out of the solution in the vortex chamber and at the throat?

6. Section 3.3 of the topical report mentions Zobel Diode and the response to NRC Question 5 also refers to a web site. This reference does not provide any quantitative information. Is there any other reference that guides the design of vortex flow damper?

7. Table 3.3-1 of the topical report mentions the rationale for the shape and size of stand pipe, and the injection pipe throat area. Please provide quantitative arguments or references for the statements made in this table.

8. Figure 4.3-1 of the topical report shows the results for the 1/2 and 1/5 scale facilities. For the low flow injection case the flow rate coefficient seems to be almost independent of the cavitation factor. Does this mean that there is no gas phase in the flow path?

9. Section 4.3 of the topical report has alluded to Froude number and Reynolds number.

    a. Please show analytically (through balance equations) the relevant non-dimensional groups with justification for the reference quantities.

ENCLOSURE

    b. Provide a dimensional analysis using Pi groups to demonstrate that $C_v$ is a function of $\sigma_v$ only in this process. As the water level changes so do the velocity values thus, Reynolds Number or any dimensionless number involving velocity and probably shear stress should be part of the analysis.

    c. Using preliminary CFD analysis, Nitrogen was observed at the exit of the injection pipe. If this is the case, the presence of Nitrogen should be accounted for in the dimensionless analysis.

10. Please show how non-dimensional groups are preserved in the different scaled facilities and the full scale accumulator. If there are any distortions, will they affect the flow and by how much? What will be the uncertainty in the flow rate coefficient and the cavitation parameter for the full scale application? Can the correlation developed between the flow rate coefficient and the cavitation parameters based on ½ scale test data predict the performance at lower scale (1/3.5 and 1/5) tests?

11. Please provide one table summarizing all the similar dimensions for different facilities including the actual accumulator.

12. During the low flow injection regime, is there a flow from the standpipe and what is the ratio between the two flows, from the standpipe and from the side pipe? If the standpipe flow is zero, the device is like a vortex diode instead of a vortex triode. In the case of a diode, the resistance is a function of the ratio of radii of outer wall and of the inlet of the injection pipe for the inviscid flow. Is this also applicable for a triode?

13. What is the effect of wall friction from different walls in the vortex chamber?

14. There are three flow regimes in the vortex chamber: near the outer wall, middle section, and near the entrance to injection pipe. It is shown (Kirshner and Katz book, Academic Press, 1975, Pages 280-283) that there is a recirculation in the middle region between two horizontal surfaces where most of the losses will occur. How is the scaling done for the vortex chamber so that the loss coefficient is the same for the ½ scale and full scale facility. Also, what is the effect of the height (vertical dimension) of this chamber on the flow?

15. Equation 4.2 in the topical report defines Froude number. What is typical velocity? Why is the standpipe diameter a right length scale?

16. Tables 4.2.3-1 and 4.2.3-2 summarize the conditions for different tests for the 1/5 scale facility. What is the difference between Tests 1/5-1-1 and 1/5-2-1?

17. The figures for the 1/5 scale facility (Section 4.2.3) have data for different tank pressures. However, there is no trend of pressure dependencies on cavitation factor. Why?

18. For the ½ scale facility (Figures 4.2.4), what controls the standpipe water level? It varies from case to case right after the switch from large flow to small flow.

19. For the ½ scale facility (Figures 4.2.4), the peak flow rates vary in magnitude and timing from case to case. Why?

20. For the ½ scale facility (Figure 4.2.4-11), why does Case 1 have lower cavitation factors than Case 7 when Case 1 is for higher pressure?

21. In the response to NRC question 13-B, the threshold cavitation factor, $\sigma_{th}$, below which cavitation can occur, is derived based on the one dimensional momentum equation (the fourth equation).

    Please show how the one dimension momentum equation is obtained and used.

22. The response to NRC question 17-A is not clear. Please provide the numerical values of the time periods suggested in this question, such as early, middle and late injection during large flow period.

23. In the response to NRC question17-B, why are there two separate diameters in Eq. 17.2? Eq. 4.7 in main report does not show this.

24. In the response to NRC question 17, what do the relative influence coefficient and degree of freedom mean in Tables 17-1 and 17-2?

25. The response to NRC question 18 is related to the manufacturing errors. However, in all estimates of corresponding biases in the flow coefficient, it is assumed that the velocity is not affected. Is there an effect of the manufacturing errors on loss coefficients? For large flow conditions, the facing angle error contribution to the bias is 1.2%. How is this estimated? Any off design condition (such as facing angle error) will lead to vortex formation and increase in losses. Please explain.

26. Section 4.2.4 of the topical report, regarding the full-height ½ scale tests, states that pressure, water level, and temperature were measured by the instruments shown in Figure 4.2.4-1 for all test cases and used to calculate the cavitation factor and the flow rate coefficient.

    a. How is the flow rate in the injection pipe in the scaled tests measured or calculated, and where is that data shown in the topical report (In Figures 4.2.4..)?

    b. Once a flow establishes due to a difference in pressure between the ACC tank and the external system pressure, what happens to the mass flow rate versus time curves shown in Section 4.2.4 figures when the external system pressure varies during the transient (this could be due to various feedbacks from the break)?

27. The level of water in the accumulator tank is used to quantify the exit mass flow rate but, as our preliminary CFD shows, the level of the water is not uniform across the tank.

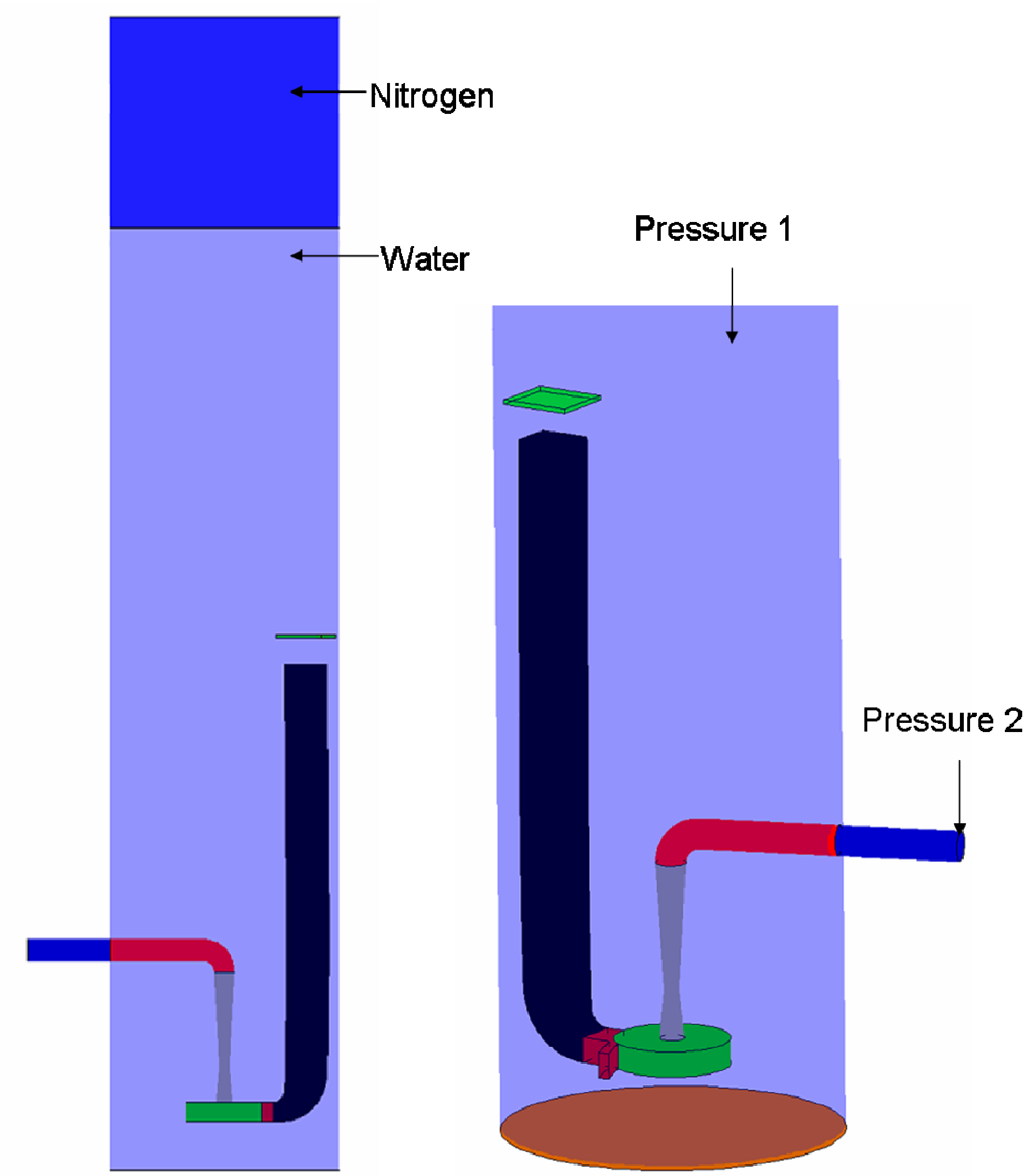
    How is this discrepancy accounted for during level calculations?

28. The NRC staff is conducting an in-depth study of the advanced accumulator (ACC) using computational fluid dynamics (CFD) calculations. Please provide detailed dimensional drawings of the1/2 scale test ACC model and the actual full scale ACC, and in particular. The dimensions of the anti-vortex caps and their connections to the standpipe and small flow pipe.

29. Explain under what conditions and at what liquid level in the accumulator, there will be entrainment of nitrogen from the gas space, and injection to the reactor vessel? What will the flow rate for this nitrogen be? Are there any data on this type of nitrogen injection?

Figure 1 In reference to RAI questions 2, and 27

Our preliminary model consist of a cylindrical accumulator tank housing features seen in the Advanced Accumulator such as the large flow pipe, small flow pipe, vortex chamber, throat, and injection pipe. Fluent 6.3.26 was used for the analysis and due to the multiphase flow nature of the problem the Mixture Model and Cavitation Model were involved. The initial tank pressure was set at 4.04 MPa (gage), pressure at the injection outlet pipe decreases linearly from the initial tank pressure to 0.098 MPa (gage).



Side 1 (2-D) Side 2 (3-D)