MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

July 14, 2010

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-10204

Subject: MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001

Reference: [1] "DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001" dated April 5, 2010.
[2] MUAP-07001-P, Rev. 2, THE ADVANCED ACCUMULATOR, September, 2008.

With this letter, Mitsubishi Heavy Industries, LTD. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") MHI's responses to the NRC's "DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001" dated April 5, 2010.

Enclosed are the responses to No. 30, 31, 32, 36, 37, 38, 39, 50, 34-1 (Item 1.1 and 1.2) and 41-1 (Item 2.2) that are contained within Enclosure 2 and 3. The responses were previously explained to the NRC staff by MHI.

With regard to the NRC's comment on No. 34-1 (Item 1.2), MHI's response has not been changed in Enclosure 2 and 3. However, MHI understands further discussion is needed to have a common understanding and resolution to the NRC's question. Therefore, MHI is proposing a meeting with the NRC to address the effect of dissolved nitrogen in further. With respect to the NRC's comment on No 41-1 (Item 2.3), the response will be submitted later.

MHI understands that it is very important to finalize the Topical Report, MUAP-07001-P, "THE ADVANCED ACCUMULATOR," and would like to continue to facilitate the discussion on this report with the NRC staff.

As indicated in the enclosed materials, this document contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential. A non-proprietary version of the document is also being submitted with the information identified as proprietary redacted and replaced by the designation "[ ]".

This letter includes a copy of the proprietary version (Enclosure 2), a copy of the non-proprietary version (Enclosure 3), and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all materials designated as "Proprietary" in Enclosure 2 be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittal. His contact information is below.

D081
NRO

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosures:

1 - Affidavit of Yoshiki Ogata

2 - MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001 (proprietary)

3 - MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001 (non-proprietary)

CC: J. A. Ciocco
C. K. Paulson

Contact Information
C. Keith Paulson, Senior Technical Manager
Mitsubishi Nuclear Energy Systems, Inc.
300 Oxford Drive, Suite 301
Monroeville, PA 15146
E-mail: ckpaulson@mnes-us.com
Telephone: (412) 373-6466

ENCLOSURE 1

Docket No. 52-021
MHI Ref: UAP-HF-10204

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Yoshiki Ogata, state as follows:

1. I am General Manager, APWR Promoting Department, of Mitsubishi Heavy Industries, LTD ("MHI"), and have been delegated the function of reviewing MHI's US-APWR documentation to determine whether it contains information that should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001" dated July 2010, and have determined that portions of the document contain proprietary information that should be withheld from public disclosure. Those pages containing proprietary information are identified with the label "Proprietary" on the top of the page and the proprietary information has been bracketed with an open and closed bracket as shown here "[ ]". The first page of the document indicates that all information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The information identified as proprietary in the enclosed document has in the past been, and will continue to be, held in confidence by MHI and its disclosure outside the company is limited to regulatory bodies, customers and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and is always subject to suitable measures to protect it from unauthorized use or disclosure.

4. The basis for holding the referenced information confidential is that it describes the unique design of the Advanced Accumulator developed by MHI and not used in the exact form by any of MHI's competitors. This information was developed at significant cost to MHI, since it required the performance of Research and Development and detailed design for its software and hardware extending over several years.

5. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of information to the NRC staff.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information. Other than through the provisions in paragraph 3 above, MHI knows of no way the information could be lawfully acquired by organizations or individuals outside of MHI.

7. Public disclosure of the referenced information would assist competitors of MH in their design of new nuclear power plants without incurring the costs or risks associated with the design and testing of the subject systems. Therefore, disclosure of the information contained in the referenced document would have the following negative impacts on the competitive position of MH in the U.S. nuclear plant market:

A. Loss of competitive advantage due to the costs associated with development and testing of the Advanced Accumulator. Providing public access to such information permits competitors to duplicate or mimic the Advanced Accumulator design without incurring the associated costs.

B. Loss of competitive advantage of the US-APWR created by benefits of enhanced plant safety, and reduced operation and maintenance costs associated with the Advanced Accumulator.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information and belief.

Executed on this 14th day of July, 2010.

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure 3

UAP-HF-10204
Docket No. 52-021

MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001

July 2010
(Non-Proprietary)

RAI 30.

The questions in this RAI were about the existence of two phase region in the flow damper and injection pipe during the large and small accumulator flows. MHI has provided responses based on the CFD analyses (MUAP-09025-P). There is cavitation (vapor generation) in the injection pipe during the large flow phase and in the vortex chamber during the small flow phase. This is correctly identified.

The CFD analyses did show void region in the injection pipe during the small flow phase. MHI claims that the vapor region is due to cavitation in the flow damper and there is no additional vapor generation in the injection pipe due to reverse flow in the injection pipe. However, the CFD report does not provide evidence of reverse flow in the diffuser section of the injection pipe. Also, Fig 38-1 in the response to RAI 38 shows that the lowest pressure occurs at the throat and voiding should also occur there if it occurs in the vortex chamber for small flow phase.

1) Please provide a figure showing reverse flow as predicted in the CFD analyses.
2) Explain why there is no vapor generation at or near the injection pipe throat, where the pressure is the lowest (Fig 38-1).
3) Does the FLUENT code model the dissolved nitrogen and its emergence? How does the amount of nitrogen emerging from the solution compared to vapor generation?

Response

1) Fig. 30-a shows the reverse flow region in the outlet nozzle of the 1/2-scale model for Case 3, small flow injection at 43 sec. It is shown as red and is also shown overlapped with the calculated void fraction. It shows that reverse flow is present not only at the center of the throat but also in the reducer. The void regions occur within and at the periphery of the reverse flow region. Forward flow which determines the overall flow rate characteristics of the flow damper exists in the vicinity of the wall of the reducer.

Fig. 30-a Reverse flow region with void fraction in the outlet nozzle of the 1/2-scale model for Case 3, small flow injection at 43 sec.

2) Fig. 38-1 shows the static pressure distribution averaged over each cross section. Local pressures can be lower than the mean pressure at each cross section to form local void fractions as shown in Fig. 30-a, including at the center of the throat. The scale testing did not specifically test for and/or measure these regions of local voiding and reverse flow, since the testing was concerned with the overall flow resistance of the damper. However, as confirmed by the experiments, the regions of the reverse flow do not affect the overall flow rate characteristics of the flow damper.

3) There is no dissolved gas model among the standard physical models of the FLUENT code. It can take incondensable gas into consideration in the cavitation model, but the initial mass fraction of incondensable gas is kept through the calculation. The cavitation model is to calculate of vaporization or condensation of liquid, but not diffusion of incondensable gas in liquid. Dissolution or emergence of dissolved gas cannot be calculated in it.

   Please, refer to the Response for RAI 33 on the effect of the dissolved nitrogen which is negligible compared to cavitation.

RAI 31.

The MHI response implies that the flow damper losses are independent of the injection pipe exit conditions and vapor pressure, and are, therefore, independent of the cavitation parameter.

(1) What does the characteristic equation mean for the small flow phase?
(2) Since the flow damper region has the largest pressure drop during the small flow phase, please explain what does the damper pressure drop depend upon? Does the damper pressure drop depend on the size of the vortex chamber?

Response

(1) As mentioned in the Response for RAI 50, at the start of the development of the advanced accumulator, there was not enough information about the independence of the flow rate coefficient from cavitation factor for the small flow phase. Therefore, it was initially assumed that the small flow was a function of the cavitation factor. The scale tests confirmed that the flow rate coefficient is largely independent of cavitation factor for small flow injection.

(2) The damper pressure drop depends on the overall size of the vortex chamber for small Reynolds numbers (below those of the advanced accumulator). For larger Reynolds numbers (such as for the 1/5-scale and larger models), the pressure drop depends primarily on the ratio of chamber diameter to throat diameter and (to a lesser extent) on the ratio of chamber height to chamber diameter.

Please refer to the Response for RAI 41-1 Item 2.2, for a discussion on the effect of the chamber diameter to throat diameter ratio. Please refer to the Response for RAI 38 Item b for a discussion on the effect of the chamber height to chamber diameter ratio.

The primary parameter is the ratio of the radii of the vortex chamber to the throat. A strong vortex in the vortex chamber converts static pressure of the flow into dynamic pressure, and strong shear stresses at the center of the chamber and in the reducer transform the dynamic pressure into energy loss. The total amount of the pressure drop is, hence, determined by the strength of the vortex in the vortex chamber, and its energy loss occurs at the center of the vortex chamber and in the outlet nozzle. The strong vortex also controls the flow velocity in the outlet nozzle.

The chamber height to chamber diameter of the flow damper is [ ].

RAI 32.

The response to RAI 32 is incomplete. MHI states that the flow near the throat will be single phase for the small flow phase, which is inconsistent with the CFD results, e.g., Case 3, ½ scale case, (Fig 3.5-9(b), MUAP-09025-P).

Why do the phases separate, and what is the effect of voiding on flow rate coefficient, Cv and why?

Response

The void separation at the throat (as shown in Fig. 3.5-9(b), MUAP-09026-P) was not observed in the scaled tests to have any effect on the overall small flow phase flow rate coefficient. Fig. 30-a shows that the voided regions occur in and around the reverse flow. Fig. 32-a shows the void fraction and axial velocity distributions at the throat. These are given by an unsteady calculation performed as a follow-up to Fig. 30-a, (or Case 3, 1/2 scale case, Fig.3.5-9(b), MUAP-09025-P). The following results are indicated in the calculated results.

1) There always exists a reverse flow at the center of the throat,

2) Void region is in the reverse flow or in its periphery where axial velocity is relatively small,

3) High axial velocity always exists in the neighborhood of the wall of the throat with little void.

These calculated results suggest that the void is formed by a strong swirl flow at the center of the throat and the reducer, and the reverse flow is induced by the positive pressure gradient along the axis of the outlet nozzle (which includes the throat). The reverse flow prevents flow choking at the throat, but cannot prevent void generation at the center of the swirl flow. The high axial velocity with little void near the wall of the throat is controlled by the vortex in the vortex chamber and determines the overall characteristics of the flow damper.

Fig. 32-a shows tangential velocity distributions at the throat. It can be seen that that the tangential velocity is almost zero in the reverse flow region.

Fig. 32-a Axial Velocity Distributions along the Lines 1 and 2 at the Throat at 43sec in Case 3

Fig. 32-b Tangential Velocity Distributions along the Lines 1 and 2 at the Throat at 43sec in Case 3

RAI 36.

The explanation about the gravity and viscous terms is reasonable. However, the characteristic equation for the small flow phase does not account for the parameters that control the vortex region. There is no dimensionless group that accounts for size of the vortex chamber. Table 3.5-2 of CFD Study (MUAP-09025-P) indicates that the flow rate coefficient, Cv, is not a constant for the small flow phase, and is different for the ½ and 1/1 scale models. In addition, the Cv increases with time for ½ scale model and decreases for 1/1 scale facility. For free vortex regime, the velocity will increase with decrease in radial position. As the velocity at the entrance to vortex chamber are matched between ½ and 1/1 scale models, the velocity at the center or near the center will be different.

How is the effect of vortex chamber dimensions considered in the characteristic equations? Is the flow rate coefficient a constant for all facilities for all flows, if there is no cavitation? What is the basis of MHI statement that flow rate coefficient is constant for the flow damper of given configuration with different sizes?

Response

The difference between the 1/2 scale and 1/1 scale CFD results shown in Table 3.5-2 of MUAP-09025-P is not due to "Scaling Error" as described in RAI 41-1 Item 2.3. Therefore, the effect of vortex chamber dimensions and flow damper of a given configuration with different sizes is described as follows.

For the small flow phase, the flow coefficient depends on the ratio of chamber to throat diameter and also on the ratio of chamber diameter to height, as discussed in the response to RAI 31 above. Please refer to the Response for RAI 41-1 Item 2.2, for a discussion on the effect of the chamber diameter to throat diameter ratio. Please refer to the Response for RAI 38 Item b for a discussion on the effect of the chamber diameter to chamber height ratio.

The 1/2 and 1/1 scale vortex chambers have similar geometry, meaning the above two ratios are equal. The characteristic equation is applicable to all vortex chambers for which these two ratios are equal and for which the Reynolds number is large (i.e., where boundary layer and viscous effects do not govern the flow).

RAI 37.

The response to this RAI states that pressure drop for the test and the prototype is specified to be same. The frictional pressure drop is not significant and form losses are the dominant part of the pressure loss. This conclusion is reasonable.

i) The form loss is a function of form loss coefficient and velocity. Please explain why form loss coefficient or velocity will be the same for the test and the prototype damper?

ii) The flow rate coefficients for the 1/5 and ½ scale facilities are similar for the same cavitation parameter. How can this conclusion be extrapolated to full size damper? Please show the effect of damper dimensions on the flow rate coefficient.

Response

i) Form loss coefficient is determined only by the configuration of the flow damper.
Form loss, or pressure drop, Δp, is given by the following equation:

$$\Delta p = \zeta \frac{\rho}{2} V^2 \tag{1}$$

where ζ is the form loss coefficient, ρ is the density of fluid, and V a characteristic velocity. Since the configuration of the 1/2 scale damper is similar to that of the prototype, the form loss coefficient of the 1/2 scale damper is the same as that of the prototype. In other words, the geometric dimensions of the 1/2 scale model are scaled to those of the prototype down for large flow, which also implies equal chamber diameter / throat diameter / chamber height ratios for small flow. The pressure across the 1/2 scale damper is identical to that across the prototype damper so that the velocity must be the same for the test and prototype dampers.

ii) Effect of friction is represented by a Reynolds number. The larger a Reynolds number is, the less friction affects flow. It is experimentally confirmed that friction has little influence on the flow rate coefficient by the 1/5 and 1/2 scale facilities. Since the Reynolds number of the prototype is larger than those of the scale models, effect of friction for the prototype is much smaller than those for the 1/5 and 1/2 scale models, and negligible.

Generally speaking, flow is a boundary value problem and determined by the following three items both for a scale model and a prototype.

(1) Governing Equations: Equation of continuity and Equation of motion
(2) Boundary Conditions: Configuration of the flow path, inlet conditions and outlet conditions
(3) Initial Conditions: Initial state of flow

Neglecting friction losses in the flow damper, we can get dimensionless forms of the governing equations to yield the unconditional similarity of the flow in the flow damper as:

Equation of Continuity: $\left(\nabla^* \cdot \mathbf{u}^*\right) = 0$, and

Equation of Motion: $\dfrac{\partial \mathbf{u}^*}{\partial t^*} + \left(\mathbf{u}^* \cdot \nabla^*\right)\mathbf{u}^* = -\nabla^* p^*$,

Where the density of fluid, ρ , is constant, L the characteristic length, U the characteristic velocity, $\mathbf{u}$ velocity vector, t time, p pressure, g the gravitational acceleration, z coordinate of the vertical axis, and the dimensionless quantities defined as:

$$\mathbf{u}^* \equiv \frac{\mathbf{u}}{U}, \quad t^* \equiv \frac{Ut}{L}, \quad \nabla^* \equiv L\nabla, \quad p^* \equiv \frac{p}{\rho U^2} - gz .$$

Hence, the similarity of the governing equations are satisfied both for the test and the prototype dampers, providing these dimensionless quantities are taken to be common to them.

The configuration of the 1/2 scale damper is similar to that of the prototype, and the pressure at the inlet and outlet boundaries are identical. Therefore, the similarity of the boundary conditions are satisfied between the 1/2 scale and prototype dampers.

Initial sate of flow in the damper is at rest both for the 1/2 scale and prototype dampers.

Consequently, all the requirements for the similarity of the flow are satisfied both for the test and prototype dampers. The damper dimension does not affect the flow rate coefficient at least for the damper equal to or larger than the 1/5 scale model.

RAI 38.

a) The vortex chamber has three important dimensions, height, diameter and the diameter of the connection to the entrance to injection pipe. What does similar dimension means in term of these three dimensions? How does this similarity assure similar flow structure?

b) MHI's description of flow structure and effect of height is reasonable. However, the response did not address the question of height to diameter ratio and its effect on the flow rate coefficient.

Response

a) The similar dimension requires that the ratios, D/d and H/d, are identical for the test and prototype dampers, where D and H are the diameter and the height of the vortex chamber, respectively, and d the diameter of the throat. As mentioned in the Response to RAI 38 ii, it is essential for the similarity of boundary conditions to ensure the similarity of flow.

b) As discussed in the original response to RAI 38 Item b, the total flow can be classified into two categories – the main vortex flow and the boundary layer flow. The main vortex flow results in higher pressure losses, while the boundary layer results in lower-loss "bypass" flow. The chamber height to diameter ratio affects the distribution of the total flow into each of these categories. For a given flow and chamber diameter, a smaller height will result in a lower fraction of main vortex flow and higher fraction of "bypass" flow. This will reduce the overall pressure drop and increase the overall flow coefficient.

<u>RAI 39.</u>

b) Though referenced by the response to RAI 39, the response in RAI 53 (CFD Analyses Report) does not provide the breakdown of pressure drop in the vortex chamber and injection pipe.

c) The use of the boundary layer coefficient (BLC) of dimensionless groups as one criterion of flow structure in vortex chamber is reasonable. BLCs for the test and prototype are close so the flow structure is likely to be close. Equality of BLC could provide another method of specifying dimensions.

Please show if current dimensions and equality of velocity will lead to the same BLC for the test and the prototype. What is the impact of difference in BLC on the form loss in the damper?

<u>Response</u>

b) The breakdown of pressure drop in the vortex chamber and injection pipe is shown in Fig. 39-a and Fig 39-b. Fig 39-a shows the pressure distribution of the 1/2 scale model at [ ] seconds in Case 3. Fig 39-b shows the pressure distribution of the 1/2 scale model at [ ] seconds in Case 6. The origin of the distance is at the radius equals to [ ] mm in the vortex chamber, while the radius of the outlet port is [ ] mm. The pressures are mean value in every cross sectional area.

Fig. 39-a Pressure distribution in the flow damper and the outlet nozzle of the 1/2 scale model at [ ] seconds in Case 3.

Fig. 39-a Pressure distribution in the flow damper and the outlet nozzle of the 1/2 scale model at [ ] seconds in Case 3.

c) Assumption of equalities of BLC* and velocity yields the following relationship between the dimensions of the model and prototype dampers:

$$\frac{b_m}{b_p} = \left(\frac{R_m}{R_p}\right)^2 \left(\frac{h_p}{h_m}\right)^{1.25},$$

where b is the width of the small flow pipe, R and h the radius and the height of the vortex chamber respectively, and suffixes m and p indicate quantities of the model and the prototype respectively. The vortex chamber of the 1/2 scale model requires the width of the small flow pipe of the model be [ ] instead of [ ] that of the prototype. But such a modification may result in dissatisfaction of the similarity of the changeover of flow rate, and is not suitable for confirmation tests of the flow damper characteristics.

J.W. Stairmand addressed that the flow within the chamber conserves circulation for BLC* equal to or less than 0.25, and, as BLC* is increased, so the extent of the central forced vortex increases until when BLC*=2 it occupies most of the chamber. (J.W. Stairmand: Flow Patterns in vortex chambers for nuclear duties, Nucl. Energy, 1990, 29, No. 6, Dec., 413-418) BLC*s for the 1/5- and 1/2-scale dampers and the actual flow damper are [ ] respectively, which are close to the critical value of 0.25. The circulations of these dampers are, therefore, conserved along the radii of the vortex chambers except the centers of the chambers. If the differences in BLC* affect to the flow rate coefficients, the circulation at the center of the chamber of the 1/5 model may be a little bit smaller than that of the 1/2-scale model. According to the experimental results of the 1/5- and 1/2-scale models, their flow rate characteristics agreed well to each other. Since the difference of BLC* between the 1/2 scale model and the prototype is smaller than that between the 1/5- and 1/2-scale models, the flow rate characteristics of the prototype must agree better with that of the 1/2-scale model.

RAI 50.

MHI's response about insensitivity of flow rate coefficient to cavitation factor for small flow phase is reasonable. There will be some effect of cavitation on pressure losses (therefore, on Cv) due to additional losses in the injection pipe. As the dominant effect is in the vortex chamber, the effect of loses in the injection pipe will have small effect on overall loss coefficient.

Response

No response required.

RAI 53.
However, the CFD calculation report does not provide all the information requested. The staff has prepared RAIs.

Response
No response required.

Comments on RAI Response (UAP-HF-10023-P, dated February 2, 2010)

RAI 34-1 Effect of dissolved nitrogen

Item 1.1:
The effect of nitrogen on damper resistance is not included in the characteristic equations as Test 5 was not part of the data used to develop characteristic equations. The approach stated in your response that "the increase of resistance in ACC system which causes flow switching delay as shown in Test 5 is considered in the maximum uncertainty range of the injection line resistance in LOCA analysis" is an acceptable approach.

Appendix B of LBLOCA Methodology (MUAP-07011-P) shows the inclusion of uncertainty in the equation on the top of page B-3. The corrected flow rate coefficient is represented by Cv*. However, the uncertainty, UC, is not defined. The equation will increase Cv and therefore reduce the damper resistance. This is not conservative as it will lead to higher flows. In addition, this corrected parameter, Cv*, is not used in calculating the damper resistance (Eq. B-6).

Please (1) explain why the uncertainty in Cv is not used in computing the damper resistance (Eq. B-6); (2) provide a revised list of parameters (Table 3.7-1, MUAP-07011-P) that includes the damper resistance coefficient uncertainty; and (3) provide the injection line resistance range without nitrogen and with nitrogen effect with reference.

Response

The uncertainty UC is defined as the total uncertainty for the damper resistance. The uncertainty UC is not defined as the total uncertainty for line resistance. The value for UC is randomly sampled from the ranges in table 3.5.6 of MUAP-07011-P. As summarized in table 3.5.6, the value from the range has both positive and negative sides. When the negative value is sampled, Cv* becomes smaller than Cv, and increases the damper resistance KD. So, the treatment of Cv, Cv* and UC does not always lead to a higher flow.

(1) Cv in Equation B-6 is typo. It should be Cv*. The uncertainty UC is used in computing the damper resistance for LBLOCA safety analysis.

(2) The numerical values for the damper resistance and line resistance used in the US-APWR LBLOCA analysis are listed in Table 34 -1. As for other parameters in table 3.5.6 of MUAP-07011-P, please refer to Response for Question 30 in Reference 34-1.

Table 34 -1 Uncertainties for Accumulator resistances

(3) The range of ACC line resistance uncertainty that used for large break LOCA analysis does not include the additional range for an effect of dissolved nitrogen. Please refer to the related response to Item 1.2 for the detail explanation.

Reference

34-1 MHI's Responses to the NRC's Requests for 2nd Set Additional Information on US-APWR Topical Report "LARGE BREAK LOCA CODE APPLICABILITY REPORT, MUAP- 07011-P (R0)", UAP-HF-10130-P (May 24, 2010)

Item 1.2.

The response to Item 1.2 does recognize the effect of dissolved nitrogen in the line resistance. It is stated that "only the positive contribution corresponding to approximately [ ]% of design resistance is considered in the LOCA analysis." However, no reference, table number etc is provided.

Response

The response to RAI 34-1 item 1.2 in UAP-HF-10023 explains that the time delay for flow switching in Test-5 can be simulated by the [ ] % increase of the accumulator injection line resistance. Response to previous RAIs (UAP-HF-09239 RAI33, UAP-HF-09450 RAI-34(c)) explains that the condition of Test-5 is unrealistic. Accordingly, to take the condition of Test-5 into the LBLOCA analysis is impractical and unrealistic. It is expected that the effect of dissolved nitrogen on the switching delay is negligible for the actual accumulator; therefore, additional uncertainty for the dissolved nitrogen effect is unnecessary.

The [ ] % uncertainty of the line resistance used in the LBLOCA analysis is considered the range for the target line resistance including the manufacturing tolerance. Since the line resistances of actual accumulators are going to be adjusted to the target line resistance by replacing an orifice plate in the start-up test, the expected uncertainty has a prospect to be much smaller than [ ] % and to make a margin within the [ ] %. It may not deny the possibility of the very slight effect of dissolved Nitrogen. Nevertheless, the [ ] % uncertainty will cover its very slight effect sufficiently with the margin if the dissolved Nitrogen affects the switching delay.

Consequently, additional uncertainty due to dissolved nitrogen has not been used in the LBLOCA statistical analysis in DCD Chapter 15.

RAI 41-1 Scaling Effect on Characteristic Equation

Item 2.2:

The analysis provided in the response indicates that there are two possible flow regimes, free vortex and forced vortex. The forced vortex or solid body rotation regime occurs near the center and the free vortex flow field is generally towards the walls. There is transition between forced and free vortex flows. This transition is function of friction factor, radial and tangential velocities and different geometrical parameters. The pressure drop differs in these two regimes. (References: "Flow Patterns in Vortex Chambers for Nuclear Duties," Nuclear Energy, 1990, 29, No 6, pg 413-418; "CFD Simulation of Flow in Vortex Diodes," AICHE Journal, May 2008, Vol 54, No 5.)

Please show the flow regimes (forced and free vortex flows) for the ½ and 1/1 scale facilities.

Response

Fig. 41-1-a shows an example of the tangential velocity distributions on the middle height in the 1/2 scale and actual vortex chambers. The distributions agree with each other very well for radii larger than that of the outlet port because of free vortex flow. The maximum velocities occur at the outer radius of the throats for both cases. There is a small difference between the maximum velocities of the 1/2 scaled and actual vortex chambers, which may be attributed to the viscosity effects. In other words, the scale effect is small and restricted to the outlet port region.

Fig. 41-1-a Tangential Velocity Distributions in the Vortex Chambers for Case 3 at 100 sec.

Item 2.3:

This response shows the dispersion error when the CFD results are compared with the predicted values from the characteristic equations. The errors vary with time and the range is from +10.6% to -12.5% for the large flow phase, and from 5.3% to -11.9% for small flow phase. The highest errors are for the Case 6. If CFD calculations are to be used as surrogate to tests, all five tests should be simulated and dispersion error should be estimated. A comparison with Table 5.2-1 (Adv Accumulator report, MUAP-07001) indicates that the dispersion errors are smaller for ½ scale tests than for the CFD predicted values for full scale. There appears to be a scale effect.

How do the dispersion errors for the CFD results for the ½ scale facility compare to the results in Table 5.2-1 (MUAP-07001)?

Why are the dispersion errors positive in the beginning and negative later on for Case 3 and Case 6 (Tables 2.3-1, 2.3-2, UAP-HF-10023-P)?

How do the dispersion errors (based on CFD calculations) compare for the ½ and 1/1 scale facilities?

Why are there differences in the 1/1 and ½ scale facility plots in Figure 2.3-1 (UAP-HF-10023-P) for the small flow phase when the analytical relationships between the flow rate coefficients and cavitation factor have two independent parameters (discharge velocity and discharge pressures) that are equal?

Will these larger dispersion errors for the 1/1 scale accumulator be applied in LOCA analyses?

Response

This response will be submitted later.