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TOKYO, JAPAN

February 2, 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-10023

Subject: **MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2**

Reference: [1] "Request for Additional Information Topical Report The Advanced Accumulator MUAP-07001-P Rev. 2" dated December 15, 2009.

With this letter, Mitsubishi Heavy Industries, LTD. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") the document entitled "MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2" a document package that responds to the NRC's Requests for Additional Information dated December 15, 2009.

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.

Sincerely,

Y. Ogata

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

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Enclosures:
1 - Affidavit of Yoshiki Ogata

2 - MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2 (proprietary)

3 - MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2 (non-proprietary)

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

<u>Contact Information</u>

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ENCLOSURE 1

Docket No. 52-021
MHI Ref: UAP-HF-10023

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 Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2" dated February 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 2nd day of February, 2010.

Y. Ogata

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

Enclosure 3

UAP-HF-10023
Docket No. 52-021

MHI's Responses to NRC's Requests
for Additional Information

on

Advanced Accumulator for US-APWAR Topical Report MUAP-07001-P,
Revision 2

February 2010
(Non-Proprietary)

RAI 34-1 Effect of dissolve nitrogen (RAI 34, UAP-HF-09450)

The response to RAI 34 addressed the effect of nitrogen on large flow phase and will accommodate it through the accumulator line resistance. The sensitivity study (Figure 34-1) on ACC line resistance (±10%) indicated that the increase in the line resistance (+10%) delayed the switch from the reduced (-10%) line resistance by 2.4 seconds. [

] A comparison of the Full-height 1/2 –scale tests 1 and 5 indicated a delay of 2 seconds in switching time and uncertainty of ±10% indicated a delay of 2.4 seconds in switching, so a range between 0 and 20% will capture nitrogen effect in large flow phase. It should be noted that nitrogen effect only increases resistance and, therefore, the effect will be only one sided.

Section 3.7.2 (LBLOCA Methodology, MUAP-07011) stated that for almost all parameters the uncertainty is same as Westinghouse 3- and 4-loops plants. [

] which is expected to include the equivalent line resistance uncertainty to account for flow switching delay caused by the dissolved nitrogen effect.

1.1 Both Section 3.5.1.2 and Appendix B in MUAP-07011 (LBLOCA Methodology) indicate that there are two components of resistance (Eq. 3.5.1-5, B-7 and B-8), i.e., damper resistance and injection piping resistance. However, Table 3.7.1 (MUAP-07011) only indicates accumulator line flow resistance. It is not clear if this line resistance is for the injection pipe only, or it also includes the flow damper resistance. Please explain what this line resistance includes. If the line resistance is only the piping resistance, then where is the damper resistance shown? How will the effect of dissolved nitrogen be considered in the damper resistance for large flow and small phases during LOCA analyses?

Response

"i) Accumulator Line Flow Resistance" in Ref 34-1-1 Table 3.7.1(2/2) is the parameter to take the increased amount of piping resistance due to the effect of nitrogen in water into the LBLOCA analysis and does not include damper resistance. The uncertainty of the damper resistance is not shown, but it is considered in the LBLOCA analysis as a statistical parameter other than the Line Flow Resistance.

As stated in the response to RAI 33 and 34 in Ref.34-1-2, the delay of flow switching in Test 5 is due to the large amount of tiny bubbles generated by bubbling and showering operation. It is not caused by the diffusion of nitrogen in water. Bubbling and showering are not conducted in the actual ACC tank and the probability of the occurrence of the flow switching delay shown in Test 5 is very small. However, it is very difficult to assume the number and scale of tiny bubbles expected in the actual ACC tank. Therefore, 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 the LOCA analysis. The expansion of tiny bubbles in ACC due to depressurization increases the pressure loss in the damper and injection piping, and is represented by the uncertainty of injection piping in the LOCA analysis.

1.2 How will the delay in switching in ACC flow due to dissolved nitrogen be accounted in the safety analysis for LBLOCA? Provide justification on how the use of the ACC line resistance uncertainty, which is treated randomly in the ASTRUM methodology in the LBLOCA analysis, can properly account for the effect of nitrogen that only has the one sided effect on the flow resistance.

Response

The nitrogen (existing as tiny bubbles) in water contributes to the increase of the line resistance leads to the delay of ACC water level drop. The water level drop delay causes the delay of flow switching. Therefore, the flow switching delay due to the effect of nitrogen in water is accounted for by considering the uncertainty of the line resistance as a statistical parameter in the analysis. The uncertainty range has been described as [ ] % in the response to RAI 34(c) in Ref.34-1-3, but on the point of view of the design resistance value, the uncertainty range of piping resistance covers from the design value to the maximum effect value of nitrogen in water. Consequently, only the positive contribution corresponding to approximately [ ] % of design resistance is considered in the LBLOCA analysis.

1.3 What is the ACC line resistance uncertainty in ASTRUM application for LBLOCA for US-APWR? Please provide reference and justification for this range [

] What will this range be without nitrogen effect? What will this range be if dissolved nitrogen effect is accounted for? Does the dissolve nitrogen effect provide additional uncertainty and if not, why not? Is the effect of dissolved nitrogen taken only as positive contribution to uncertainty range?

Response

As described in the response to RAI 34-1.1, the uncertainty range of line resistance is the increment of line resistance due to the effect of nitrogen in water. US-APWR is different from the conventional PWR plants and is designed to provide flow adjustment capability by the orifice in the injection line (injection line resistance is modified after in field test by replacing orifice plate if necessary), does not have any uncertainties other than the effect of nitrogen in water. Therefore, only the positive contribution due to the effect of nitrogen in water is taken to design line resistance value, as stated in the response to RAI 34-1.2.

1.4 How will the dissolved nitrogen affect be considered during small flow phase in the LOCA analyses? Please also provide justification.

Response

The effect of nitrogen in water is considered in the uncertainty of line resistance during small flow phase as well as large flow phase, as described in the response to 34-1.1.

1.5 Will the same uncertainty range and distribution in ACC line flow resistance and the flow damper resistance be used for small flow phase as for large flow phase? If it is same, please provide justification.

Response

The accumulator line resistance uncertainty is the uncertainty due to the effect of nitrogen in water, and larger range is applied for both of large and small flow phases. The uncertainty range of ([ ] %) is accounted to cover the result of experiment with consistently forced saturated condition by bubbling and showering. However, such forced saturated condition does not occur in normal operation condition and very conservative assumption. Therefore, the uncertainty range ([ ] %) is sufficient for the both of large and small flow phases. In addition, uniform distribution is used in the LBLOCA analysis with the assumption that every nitrogen existing condition in water occurs in the same probability.
As shown in MUAP-07001(R2), Figure 5.1-1, damper resistance is evaluated by individual empirical correlations for large and small flow phases, and the uncertainty range for each correlation is accounted. As shown in Table 3.5-6 of Ref. 34-1-1, the uncertainty range indicated by boldface is applied to the LBLOCA analysis. Damper resistance uncertainty consists of instrument uncertainty, dispersion deviation, and manufacturing error, and each of which shows normal distribution. Therefore, normal distribution is used for the damper resistance uncertainty in the LBLOCA analysis.

1.6 A comparison of small flow rates from the full-height 1/2 –scale Test 1 and Test 5 indicated larger flow for Test 5. Please explain this.

Response

Pressure transients of test tanks during small flow phase in Test case 1 and 5 are shown in Figure 34.1.6-1. In this figure, the test tank pressure of Test case 5 is higher than that of Test case 1 in small flow phase, which is considered the reason for the flow rate of Test case 5 was larger than that of Test case 1. In Test case 5, nitrogen in the test tank water came out of water into air space and restrained the pressure reduction of gas space, and this is considered the reason for the pressure of test tank in Test case 5 exceeding that of test tank in Test case 1.

Figure 34.1.6-1 Test Tank Pressure Transients

Reference

34-1-1 "Large Break LOCA Code Applicability Report for US-APWR", MUAP-07011-P(R0), Mitsubishi Heavy Industries Ltd., July 2007.

34-1-2 "MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2", UAP-HF-09239, May 2009, May 20, 2009

34-1-3 "Amended MHI's Responses to NRC's Requests for Additional Information on Advanced Accumulator for US-APWR Topical Report MUAP-07001-P, Revision 2", UAP-HF-09450, September 16, 2009

41-1 Scaling effect on Characteristic Equation (RAI 41, UAP-HF-09450)

The response to RAI 41 is incomplete. The characteristic equations for the large and the small flows were developed from the data from 5 tests from the full height/half diameter test facility. There is still a concern that there is some additional uncertainty due to differences in test facility and the actual plant. The characteristic equations, developed in the program, will predict the tests facility performance but there is still no convincing argument that this equation will represent full scale plant. There is no parameter representing the diameter of damper. While uncertainties due to measurement and manufacturing may be scale-independent, the dispersion error will be different as it will be based on actual data (if available for actual facility). This difference between two data sets will be additional uncertainty if the characteristic equation is based on reduced size facility.

Appropriate CFD calculations may show the scale effect. In addition, in response to RAI-1B, (July 2007), MHI stated that the performance of the actual accumulator will be confirmed in a pre-operational test.

2.1 MHI is requested to describe how the pre-operational test will be performed to confirm the accumulator performance and appropriateness of the accumulator characteristic equations for full scale application.

Response

Accumulator injection test is conducted and the resistance coefficient obtained from measured data is confirmed to meet the requirement, and then, accumulator system is determined that it has appropriate designed performance.

Accumulator is pressurized, the injection test is initiated with opening of the accumulator discharge valve, and parameters such as tank pressure are measured. Initial test pressure and water level are set to allow to obtain the resistance coefficient at from large to small flow injection phases. Resistance coefficient and cavitation factor are calculated from measured data. The summary of injection test is shown in Table 2.1-1.

Accumulator injection test is an ITAAC item shown in item 7.b, Table 2.4.4-5 of Tier 1, and acceptance criteria are also described in Table 2.4.4-6 of Tier 1.

Table 2.1-1 Outline of Accumulator Injection Test

Initial Condition		
Initial Pressure	213 psig	Pressured by Nitrogen
Initial Water Level	Normal Water Level	
Reactor Vessel	Vessel Head and Core Internal are removed	
Refueling Cavity	Filled with water	
Measured Parameters		
Parameters	Accumulator water level, Accumulator pressure, Accumulator outlet pressure Water temperature	
Procedure		
- Initiate the test to open the accumulator discharge valve - Inject water to the reactor vessel - Measure the parameters during the test - Calculate cavitation factor and resistance coefficient		
Acceptance Criteria		
The injection performance is as specified in Table 2.4.4-6 of Tier 1		

2.2 Explain the effect of diameter on the flow field and on the losses in the vortex chamber during small flow phase.

Response

For small flow phase, a strong and steady vortex is formed in the vortex chamber. Figure 2.2.1 shows the one-dimensional model of a vortex for small flow injection. The tangential velocity, *v*, at a radius, *r*, is expressed as;

$$v = V\left(\frac{r}{R}\right)^n \qquad (2.2.1)$$

where *R* is the radius of the vortex chamber, and *V* the velocity at *r*=*R*. If the exponent *n*=1, Equation (2.2.1) expresses a forced vortex, while if *n*=-1, Equation (2.2.1) expresses a free vortex. Practically, n is between -1 and 1, and depends on the configuration and the size of the vortex chamber and the property of water. The diameter, 2*R*, will, thus, affect the flow field through its ratio with respect to an arbitrary diameter, 2*r*, in the vortex chamber.

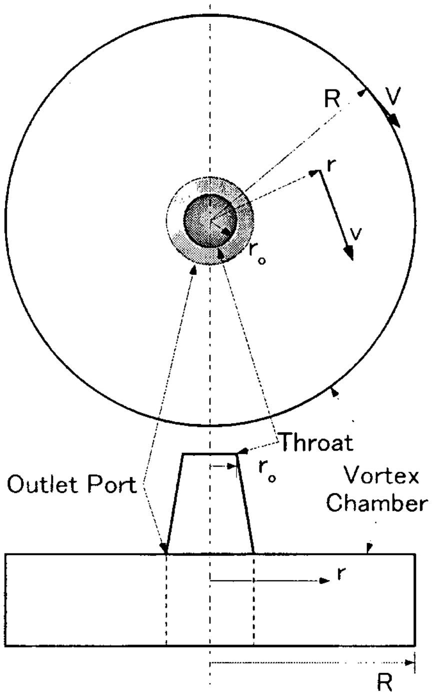

Fig. 2.2.1 One-dimensional model of a vortex in a vortex chamber

The equation of motion yields the pressure drop, Δ*p*, from the radius, *R*, to an arbitrary radius, *r*, using Equation (2.2.1) as:

$$\Delta p = \frac{1}{n}\frac{\rho}{2}V^2\left\{1-\left(\frac{R}{r}\right)^{2n}\right\}. \qquad (2.2.2)$$

From Equation (2.2.2), the pressure drop coefficient from the radius, *R*, to the radius of the throat, r_o, is defined as

$$\zeta_s \equiv -\frac{\Delta p}{\rho V^2/2} = \frac{1}{n}\left\{\left(\frac{R}{r_o}\right)^{2n} - 1\right\}. \qquad (2.2.3)$$

Figure 2.2.2 shows the pressure drop coefficient with respect to the vortex radius ratio. The larger the vortex radius ratio is, the larger the pressure drop coefficient of the vortex damper is. Moreover a free vortex, or *n*=-1, yields the largest pressure drop among the exponent *n*=-1 to 1. Practically, the size of the vortex chamber is limited by the space available for it.

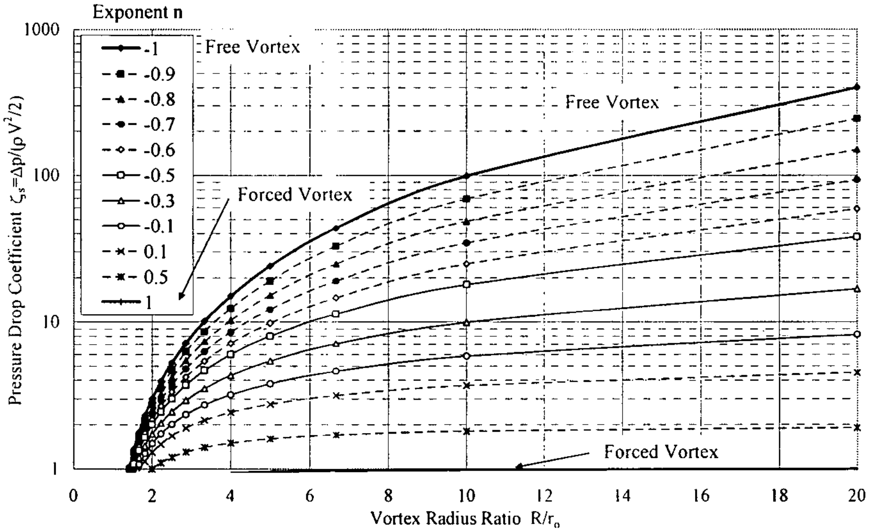

Fig. 2.2.2 Pressure drop coefficient with respect to vortex radius ratio

Consequently, the diameter, 2*R*, will affect the pressure drop in the vortex chamber through its ratio with respect to the diameter of the throat, $2r_o$.

2.3 The results of the expected CFD analyses, which MHI will submit for NRC review as per conference call of July 9, 2009, will be compared with existing data for large and small flow phases for validation of approach and then used to predict performance of full scale accumulator with appropriate boundary and initial conditions. Please provide a comparison of predicted results for full scale and ½ diameter facilities. In addition, please provide dispersion errors for both the current characteristic equations and full scale predicted results.

Response

A comparison of predicted results for full scale and ½ diameter facilities is described in the technical report, "CFD Analysis for Advanced Accumulator, MUAP-09025-P (R0), section 3.5.2 Evaluation of Scale Effect Due to CFD" and Figure 2.3-1. These CFD results have good agreement each other. The technical report also shows that there is no significant difference between 1/2 and 1/1 CFD results for flow rate coefficient due to significant difference test with [ ] of significant level. Thus, the technical report say that the validity of the current evaluation approach for the ACC performance, i.e. an extrapolation from the scaled model experiment and the characteristic equations, is uncontradicted due to comparison of the calculated data in 1/2 scaled model and 1/1 scaled one.

The evaluation results of dispersion errors for both the current characteristic equations and full scale predicted results are shown in Table 2.3-1 and Table 2.3-2. While there are some differences and dispersion between CFD results of full scale and characteristic equation for large and small flow, it is shown that the differences are insignificant due to significant difference test with [ ] of significant level which is same method shown the technical report (MUAP-09025-P (R0), section 3.5.3). Therefore, to use the characteristic equation based on 1/2 scaled facility test is acceptable to evaluate the full scale ACC.

Figure 2.3-1 Comparison between 1/2 and 1/1 Scale of CFD Result

Table 2.3-1 Comparison of dispersion and significant difference for both the current characteristic equations and full scale predicted results (Large Flow)

Table 2.3-2 Comparison of dispersion and significant difference for both the current characteristic equations and full scale predicted results (Small Flow)