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

July 21, 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-10213

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] "MHI's Responses to NRC's DRAFT Comments on MHI's Responses to RAIs on US-APWR TOP MUAP-07001" dated July 14, 2010

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

Enclosed are the responses to No. 41-1 (Item 2.3) that is contained within Enclosure 2 and 3. The other responses have been submitted in Reference [2].

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.

D081
NRO

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-10213

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 21st day of July, 2010.

Y. Ogata

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

Enclosure 3

UAP-HF-10213
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)

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

Q1
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)?

Response to Q1

The dispersion errors from the characteristic equation for the 1/2 scale CFD results are shown in Table 41-1-a for Case3 and Case6, which are the same test cases described in the CFD technical report (MUAP-09025, Rev. 0). The comparison between the test results and CFD results (both 1/2 and 1/1 scale) is discussed in Q3.

The initial CFD technical report calculated results at three time periods for the large flow phase, but only at two time periods for the small flow phase. As part of the response to Q2 below, an additional CFD calculation was performed for both test cases during the small flow phase (Case 3 at [ ]-sec and Case 6 at [ ] sec) to evaluate the dispersion error and its time dependency. These additional calculations are also included in Table 41-1-a below.

Table 41-1-a (1/2) Standard Deviation of Characteristic Equation and 1/2 Scale CFD Results (Large Flow)

Table 41-1-a (2/2) Standard Deviation of Characteristic Equation and 1/2 Scale CFD Results (Small Flow)

Q2

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)?

Response to Q2

The tendency is shown in Table 41-1-b which is same as Tables 2.3-1, 2.3-2(UAP-HF-10023-P). MHI believes that the tendency NRC pointed out normally should be evaluated by the comparison with the test results and 1/2 scaled CFD result shown in Table 41-1-c rather than the comparison characteristic equation and 1/2 scaled CFD result because calculation conditions of CFD are based on test result and are not based on characteristic equation (mean value).

1) Large Flow

As shown in Table 41-1-c, the 1/2 scale test data for Case 6 shows that Cv increases from [ ] at [ ] to [ ] at [ ]. The Cv values at [ ] and [ ] should be the same because cavitation does not occur at either time, as shown in the response to RAI 55 f) in UAP-HF-10201 (i.e., the CFD results show nearly identical values at both times). However, measurement uncertainty during the last part of large flow injection for Case 6 is considerably large ([ ] per Table 5.2-2 of MUAP-07001, Rev. 2). From the above, it is very likely that the measured test result for Cv at [ ], which occurs during the last part of large flow injection, is overestimated. Therefore, it is likely that the dispersion errors would be positive in the beginning and negative later.

For Case 3, although the CFD results overestimate the Cv value at [ ], the difference is within the CFD validation uncertainty for large flow shown in Table A-3. Therefore, it is likely that this apparent trend is due only to random CFD uncertainty.

In addition, the tendency that the dispersion errors are positive in the beginning and negative later does not seem to be due to scale effects, because the trend does not depend on scale as shown in Table 41-1-a or Table 41-1-b. Table 41-1-a compares the characteristic equation and 1/2 scale CFD results, and Table 41-1-b compares the characteristic equation and 1/1 scale CFD results.

2) Small Flow

In order to evaluate the time dependence of dispersion errors, MHI calculated an additional time condition for each small flow test case at later times (Case 3 at [ ] and Case 6 at [ ]). There does not appear to be any time dependence for dispersion errors when the additional cases are considered, as shown in Table 41-1-a (2/2), and Table 41-1-b (2/2) and Table 41-1-c (2/2).

Table 41-1-b (1/2) Dispersion and Significant Difference for Characteristic Equation and 1/1 Scale CFD Results (Large Flow)

Table 41-1-b (2/2) Dispersion and Significant Difference for Characteristic Equation and 1/1 Scale CFD Results (Small Flow)

Table 41-1-c (1/2) Standard Deviation of 1/2 Scale Test Data and CFD Results (Large Flow)

Table 41-1-c (2/2) Standard Deviation of 1/2 Scale Test Data and CFD Results (Small Flow)

Table 41-1-d (1/2) Dispersion and Significant Difference for Characteristic Equation and 1/2 Scale CFD Results (Large Flow)

Table 41-1-d (2/2) Dispersion and Significant Difference for Characteristic Equation and 1/2 Scale CFD Results (Small Flow)

Q3

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

Response to Q3

Figure 41-1-b and Table 41-1-e show dispersion errors from the characteristic equation based on comparisons with CFD calculations for the 1/2 and 1/1 scale model. An outline of the comparison method shown in Figure 41-1-b and Table 41-1-e is given below, and the details of the comparison are discussed in Appendix-A.

- Dispersion errors of test data from characteristic equation:
  Based on maximum dispersion from Case 3 or 6
  (See Table A-1)
- Dispersion errors of CFD result from characteristic equation:
  Based on total dispersion for Case 3 and Case 6
  (See Table 41-1-a for 1/2 scale and Table 41-1-b for 1/1 scale)
- Measurement uncertainty:
  Maximum instrument uncertainty from Case 3 or 6
  (See Table A-2)
- CFD validation uncertainty:
  Calculated based on GCI (Grid Convergence Index) and dispersion between test and CFD result for 1/2 scaled model in Case 3 and 6, per the guidance of ASME V&V 20-2009 and NEA Best Practice Guideline
  (See Table A-3)

1) Large Flow

a) Comparison between test and 1/2 scaled CFD

The dispersion error of the 1/2 scale CFD (Pink) is larger than that of the test (Black) because it is considered that the uncertainty of CFD for 1/2 scaled model is larger than that of measurement on the test as shown Table A-2 and A-3. That is to say, that is because prediction precision by CFD is slightly low. Thus, when CFD predicts the dispersion error from characteristic equation, it must be considered that the CFD overestimate the width of dispersion errors then the test.

b) Comparison between test and 1/2 and 1/1 scaled CFD

The dispersion error of the 1/1 scale CFD (Blue) is slightly larger than that for 1/2 scaled model (Pink) because the CFD validation uncertainty for the 1/1 scale CFD model may also be slightly larger than that for 1/2 scaled model (given in Table A-3). That is, from the evaluation of scale effect using CFD, the dispersion error for the 1/1 scale CFD model is not considered to be larger than that for 1/2 scale CFD model due to physical phenomena.

2) Small Flow

a) Comparison between test and 1/2 scaled CFD

The dispersion error of the 1/2 scale CFD (Pink) is almost the same as that of the test data (Black). That is because the width of CFD dispersion error for 1/2 scaled model is comparatively small and has good agreement with the test error which leads to small dispersion error (Pink). Overall, it appears that there is a correlation between width of dispersion error from characteristic equation (Pink) and width of CFD validation uncertainty (Green) between the large and small flow results for the 1/2 scale CFD. That is, there is a tendency that a small width of CFD validation uncertainty leads to small width of dispersion error and vice versa.

b) Comparison between 1/2 and 1/1 scaled CFD

The dispersion error of the 1/1 scale CFD (Blue) is slightly larger than that for 1/2 scaled model (Pink). This is considered to be due to the fact that the CFD validation uncertainty for 1/1 scaled model is slightly larger than that for 1/2 scaled model as shown in Table 41-1-e.

3) Evaluation of Scale effect by CFD

The dispersion error of the CFD results from the characteristic equation shows that the 1/1 scaled model is the same or slightly larger than that of 1/2 scaled model. This is considered to be due to the fact that the CFD uncertainty for the 1/1 scaled model is larger than that for 1/2 scaled model. Furthermore, scaling law analysis shown in Appendix-B describes that there is no scale effect between 1/2 and 1/1 scaled model. Therefore, it is concluded that there is no significant scale effect due to CFD prediction and scaling law analysis.

Figure 41-1-b 95% Confidence Intervals for Dispersion Error from Characteristic Equation

Table 41-1-e Range of Dispersion Error and Uncertainties for Figure 41-1-b

Appendix-A

A-1 Intervals for Dispersion Error

This section details the bases used for determining the dispersion intervals for the dispersion errors from the characteristic equation given in Figure 41-1-b and Table 41-1-e.

A-1.1 Dispersion Error between Test and Characteristic Equation

The standard deviations of the dispersion error of the test data from the characteristic equation (Table 5.2-1 of MUAP-07001, Rev. 2) are reproduced in Table A-1. Figure 41-1-b shows the error interval as twice the positive and negative standard deviation based on Table A-1. Specifically, the maximum standard deviation for either Case 3 or Case 6 (shown with a square "□" in Table A-1) was used for the interval in Figure 41-1-b.

Table A-1 Dispersion of the Data from the Experimental Equations

A-1.2 Dispersion Error between 1/2 Scale CFD and Characteristic Equation

The dispersion interval is taken as twice the standard deviation shown in Table 41-1-a, centered around the average of the dispersion for all cases given in Table 41-1-a.

A-1.3 Dispersion Error between 1/1 Scale CFD and Characteristic Equation

The dispersion interval is taken as twice the standard deviation (i.e., the square root of the unbiased variance given in Table 41-1-b), centered around the average of the dispersion for all cases given in Table 41-1-b.

A-2 Uncertainty Intervals

This section details the bases for the test instrument and CFD uncertainty intervals applied to the dispersion intervals in Figure 41-1-b and Table 41-1-e. For conservatism, the uncertainty intervals given below are algebraically combined with the upper and lower limits of the dispersion intervals calculated above.

A-2.1 Measurement Uncertainty

The test measurement uncertainty interval values for the early, middle, and late injection periods (Table 5.2-2 of MUAP-07001, Rev. 2) are reproduced in Table A-2 below. The maximum uncertainty (shown with a square "□" in Table A-2) is used in Figure 41-1-b.

Table A-2(1/2) Instrument Uncertainties at Large Flow

Table A-2(2/2) Instrument Uncertainties at Small Flow

A-2.2 CFD Validation Uncertainty

CFD validation uncertainty is calculated by following the guidance of References A-1 and A-2. The validation variable, Cv, is not measured directly. Rather, it is determined from a data reduction equation. Therefore, it is suitable to use the method from Section 5 of Reference A-1 ("Estimating u_{val} when the experimental value, D, of the validation variable is determined from a data reduction equation (Case 2)").

CFD Validation Uncertainty:

$u_{val} = E \pm (u^2_{input+D} + u^2_{num})^{0.5}$

where,

u_{val}: CFD validation uncertainty (Fig 5-3-2 in Reference A-1)

$u_{input+D}$: Dispersion error interval between test data and CFD result

u_{num}: Uncertainty from numerical solutions of equations

(GCI (Grid Convergence Index) is used as discussed in RAI 56 f) of UAP-HF-10201. GCI is defined as twice the standard deviation as discussed in Section 2 of Reference A-1)

E: Average difference between test data and CFD result

Table A-3 CFD Validation Uncertainty

Note 1: GCI for 1/1 scale CFD results is assumed to be equal to GCI for 1/2 scale CFD because the mesh is basically same for each scale model. (This value will be revised later based on calculations for 1/1 scale model.)

Note 2: $u_{input+D}$ is calculated based on the CFD result for 1/1 scaled model and postulated 1/1 test data, which would be the same as the 1/2 scale test because of no scale effect as discussed in Appendix-B

Reference:

A-1) "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer", ASME V&V 20-2009 (Nov. 2009).

A-2) "Best Practice Guidelines for the use of CFD in Nuclear Reactor Safety Applications", NEA/CSNI/R (2007)5, (May 2007).

Appendix-B
Scaling Law Analysis

CFD analyses are suitable to understand overall flow pattern and cavitation phenomenon. However, CFD analyses are not suitable to evaluate scale effects by comparing dispersion errors because of the CFD validation uncertainty. Therefore, MHI will employ the following scaling law analysis to evaluate scale effects.

$$\Delta \mathrm{P} = \mathrm{K}\frac{\rho V_D}{2}$$

where,

$$\mathrm{K} = \mathrm{K}(\sigma_v, \mathrm{Re})$$

$$\sigma_v = \frac{P_D - P_v}{(P_A - P_D) - \frac{\rho V_D^2}{2} + \rho g H}$$

ΔP:	Pressure loss of flow damper
K:	Pressure loss coefficient of flow damper
P:	Liquid density
Re:	Reynolds number
V_D:	Velocity of injection pipe
H:	Level difference
g:	Gravity acceleration
σ_v:	Cavitation factor

There is no scale effect on form loss coefficient because the flow damper in the test facility is geometrically similar to the 1/1 scale model. Therefore, pressure loss coefficient, K, is expressed as a function of the cavitation factor and Reynolds number.

$$(\Delta \mathrm{P})_\mathrm{R} = (\mathrm{K})_\mathrm{R}(\rho)_\mathrm{R}(V^2{}_D)_\mathrm{R}$$

where,
( )$_\mathrm{R}$: Ratio between 1/1 and 1/2 scale

Since the test conditions of the 1/2 scaled test are the same as the US-APWR, the ratio of liquid density and pressure loss is 1.

$$(\rho)_\mathrm{R} = 1$$

$$(\Delta \mathrm{P})_\mathrm{R} = 1$$

In addition, since form losses are dominant (rather than friction losses) for the pressure loss coefficient of the flow damper, the pressure loss does not depend on Re number. Then, the ratio of cavitation factor and velocity of injection pipe are shown as follows.

$$(\sigma_v)_\mathrm{R} = 1$$

$$(V_D)_R = 1$$

Then, the ratio of pressure loss coefficient of flow damper is given as follows.

$$(K)_R = 1$$

Thus, scaling law analysis shows that there is no scale effect, so that the characteristic equation and its uncertainty for the 1/2 scaled test data can be applied to the 1/1 scale model.

Q4

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?

Response to Q4

Figure 41-1-c reproduces Figure 2.3-1 of UAP-HF-10023-P with the additional two small flow CFD calculations included. The reason for the difference of the CFD results between the 1/2 and 1/1 scale model is discussed in this section.

For small flow, the Cv value does not depend on cavitation factor as shown by the characteristic equation. However, there are dispersion errors from the characteristic equation for the CFD result for 1/2 and 1/1 scaled models. These are due to scatter from the measurement uncertainty and the CFD validation uncertainty.

In addition, there is no significant scale effect as indicated by the significant difference test in the technical report "CFD Analysis for Advanced Accumulator (MUAP-09025-P)". This conclusion remains even if the additional two conditions are included in the significant difference test as shown in Table 41-1-f.

Thus, for small flow, it is expected that differences would exist between the 1/1 and 1/2 scale CFD results within the measurement and CFD uncertainty ranges. That is, there would not be a special reason for the differences except for the uncertainties.

Figure 41-1-c Comparisons between 1/2 and 1/1 Scale for CFD Result

Table 41-1-f (1/2) Result of Significant Difference Test for Large Flow

Table 41-1-f (2/2) Result of Significant Difference Test for Small Flow

Q5

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

Response to Q5

MHI will not use these larger dispersion errors since these are within the expected CFD uncertainty as discussed in Q3 above. MHI will keep using the original uncertainties described in the LBLOCA topical report (MUAP07011-P).