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November 10, 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-10306

**Subject:** **MHI's Responses to US-APWR DCD RAI No. 645-4375 Revision 0 (SRP Section 06.02.02)**

**Reference:** [1] "Request for Additional Information No. 645-4375 Revision 0, SRP Section: 06.02.02 – Containment Heat Removal System - Design Certification and New License Applicants, Application Section: 6.2 and 6.3." dated October 4, 2010.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Response to Request for Additional Information No. 645-4375 Revision 0".

Enclosed is the response to 1 question that is contained within Reference [1]. This response include changes from MHI's previous responses to the RAI 466-3715 Question 06.02.02-53 and RAI 354-2585 Question 06.02.02-23. Refer the enclosed response to "Question 5" for those changes.

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

Sincerely,

Y. Ogata

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

**Enclosures:**

1. Responses to Request for Additional Information No. 645-4375 Revision 0

D081
NRO

CC: J. A. Ciocco
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Contact Information


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Enclosure 1

UAP-HF-10306
Docket No. 52-021

Responses to Request for Additional Information
No. 645-4375 Revision 0

November 2010

# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**11/10/2010**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries, Ltd.**

**Docket No. 52-021**

**RAI NO.:** **NO. 645-4375 REVISION 0**

**SRP SECTION:** **06.02.02 – Containment Heat Removal System**

**APPLICATION SECTION:** **6.2 & 6.3**

**DATE OF RAI ISSUE:** **10/4/2010**

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**QUESTION NO.: 06.02.02-61**

The following are requests for additional information regarding US-APWR strainer qualification testing:

1. Describe the scaling approach and methodology.
   a. What similarities between test and plant conditions are preserved?
   b. Identify any assumptions in the scaling analysis.
2. List the design parameters, scaling factor(s), and calculated scaled values used for testing. Explain how each scaled value is prototypical or conservative for strainer head loss determination. Include values for non-chemical and chemical debris.
3. Identify important control parameters which must be considered in the design and operation of the test facility and explain the effects of the test facility design and operation on these important parameters.
4. Discuss how MHIs approach to the number of design basis tests conducted provides results that are bounding.
5. The strainer qualification testing conducted in June 2010 used debris amounts, size and size distributions (e.g., fiber fines and smalls) different from what was communicated in docketed correspondence. See RAI 466-3715 Question 06.02.02-53. Request MHI update or revise previously docketed correspondence to address design basis changes related to strainer qualification.

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**ANSWER:**

Each question will be answered separately as follows:

<u>Question 1: Describe the scaling approach and methodology</u>

<u>a. What similarities between test and plant conditions are preserved?</u>

The US-APWR strainer head loss test program utilized the mixing tank test protocol and facility that does not take credit for debris settlement upstream of the strainer. This is intended to conservatively bound plant conditions and is not intended to be prototypical nor similar to the near-field strainer flow dynamics of the plant. The intent of this protocol and facility are to keep debris suspended and prevent debris from settling during the tests. This was discussed with the NRC staff and it was their preference based on the February 2010 test plan discussion.

Other than as previously discussed, the test facility is specifically set-up for the US-APWR parameters. There are nine (9) strainer modules per sump in the plant. The test facility utilizes one (1) actual full scale strainer module which has the same configuration and design as the plant module (i.e., disk size, perforated plate hole size, disk gap height, strainer surface area, and submergence depth).

The US-APWR strainer module-to-module spacing gap is replicated in the test tank by confining the test module on three sides with a 3" spacing to the surrounding walls. This is equivalent to one half of the full gap between adjacent modules in the actual plant array design.

All debris is prepared and is consistent with the design basis debris characteristics discussed in MUAP-08001 Section 3.3 and Table 3-5, and Appendix-C.

The following are the US-APWR design basis non-chemical debris types and their surrogates, if applicable:

- Fiber Insulation (NUKON)
- Latent Fiber (NUKON)
- Latent Particle (Dirt and Dust)
- Coating (Acrylic Powder)

The following are the test debris characteristics which are the same and/or similar to the US-APWR design basis debris:

- NUKON insulation is used for the test fiber debris and latent fiber fines. The product has an average density of 2.4 lbm/ft$^3$, which is consistent with the design basis debris. The NUKON insulation is cut into pieces and then shredded into "fines" and "smalls".

- Acrylic powder is used for the test as the coating debris surrogate since it has similar density, particle size and shape characteristics as those of the US-APWR as defined in MUAP-08001 Table 3-5

- Latent debris for the test (i.e., dust and dirt) is in accordance with the recommendations of NUREG/CR-6877 (Table 16, Section 4.3, Reference 1).

As discussed in MUAP-08001 Appendix-C, the US-APWR defines two chemical precipitates that form post-LOCA: aluminum oxy-hydroxide (AlOOH) and sodium aluminum silicate. For the head loss test, only AlOOH is used due to the hazardous nature of sodium aluminum silicate. Acceptance of the use of AlOOH for the sodium aluminum silicate is documented in the NRC SE for WCAP-16530-NP-A (Reference 2).

The test chemical precipitate, AlOOH is generated and evaluated to satisfy the settling rate acceptance criterion documented in the NRC SE for WCAP-16530-NP-A. (Reference 2)

Further details regarding test debris for both non-chemical and chemical debris will be provided in MUAP-08001, Appendix-B re-titled as "Sump Strainer Head Loss Tests".

b. Identify any assumptions in the scaling analysis.

There were no assumptions made for the scaling analysis. The scaling analysis is further discussed in the response to RAI Question 2.

Question 2. List the design parameters, scaling factor(s), and calculated scaled values used for testing. Explain how each scaled value is prototypical or conservative for strainer head loss determination. Include values for non-chemical and chemical debris.

The test parameters were scaled based on the conservative effective surface area in the prototype. The US-APWR utilizes nine (9) strainer modules per sump with an effective surface area of 2,554.067 $ft^2$. The effective strainer surface area includes reductions for manufacturing tolerances and sacrificial area due to miscellaneous items. (Refer to the response for Question 06.02.02-57 that addresses consideration of manufacturing tolerances and sacrificial area used to determine the effective strainer surface area.) In summary, one (1) prototypical strainer module with a surface area of 303.414 $ft^2$ was used for the US-APWR test program. A scaling factor (i.e., 0.1188 = 303.414/2554.067) was applied to the debris quantities and pump flow rate.

The test strainer recirculation flow rate (i.e., 617.8 gpm) is appropriately scaled based on the plant volumetric design basis flow (i.e., 5,200 gpm per sump) for the emergency core cooling system (ECCS) and containment spray system (CS) pumps.

Non-chemical and chemical debris quantities for the test strainer module are in proportion to the test surface area defined by the design basis surface area. Non-chemical and chemical debris loadings are based on mass per unit area of the screen.

The principle test parameters including debris characteristics are summarized in Table-1. This response will be incorporated into MUAP-08001 Appendix-B re-titled as "Sump Strainer Head Loss Tests.

Question 3. Identify important control parameters which must be considered in the design and operation of the test facility and explain the effects of the test facility design and operation on these important parameters.

Flow rate, water temperature, differential pressure across the strainer, and measured debris quantities are important control test parameters. Where appropriate, these parameters were accurately measured and recorded to document the test results and to qualify the strainer design. These parameters were controlled within target ranges as follows:

- Flow rate is controlled by a control valve and/or a variable speed pump motor to +5% to -0% of the target flow rate value.
- Water temperature is initially targeted to 120 °F or less and is recorded with accuracy through the test program. A water viscosity correction can be applied to determine the head loss at designated design basis temperatures.
- Differential pressure (i.e., head loss) is corrected to account for test pipe and fitting losses, as well as the velocity head in the pipe, to determine the corrected strainer head loss. The differential pressure measurement accuracy is ±0.25 inches of water.
- Debris quantity is measured using a calibrated scale accurate to ±0.10 lbm.

This response will be incorporated into MUAP-08001 Appendix-B re-titled as "Sump Strainer Head Loss Tests.

Question 4. Discuss how MHIs approach to the number of design basis tests conducted provides results that are bounding.

The US-APWR strainer test program was planned to obtain test data that is used to demonstrate acceptable head loss across the sump strainer subject to design basis post-LOCA debris loading. The test protocol was developed to reflect the discussions between the staff and MHI; extensive review and evaluation of NRC public meeting documents associated with GL-2004-02, GSI-191, and RG 1.82, Rev. 3; licensee RAI responses; and publicly available NRC trip reports that documented licensee strainer head loss testing. In addition, particular attention was paid to the 2008 March Guidance document. The test protocol and test plan also utilized guidance provided in NEI 04-07 Volume 1 and 2.

The following US-APWR test program was implemented:

Test-1 - Clean Strainer Head Loss (CSHL) Test
Test-2 - Thin Bed Test
Test-3 - Design Basis Test

Each of the subject tests are described below. It should be noted that Test-2 (Thin Bed Test) bounded Test-3 (Design Basis Test) due to the limited Design Basis quantity of fibrous debris associated with the US-APWR design. Accordingly, Test-3 was not performed. In addition, a Fiber Only Bypass Test was conducted to determine the quantity of fibrous debris that by-passes the strainer's perforated plate during operation. Grab samples were taken and stored for future evaluation.

Test-1 - Clean Strainer Head Loss (CSHL)
The purpose of Test-1 was to establish the clean strainer head loss (CSHL) for the US-APWR full scale test strainer and to establish the system head loss prior to debris loading. For this test, non-chemical and chemical debris was not introduced. The test data results are subtracted from subsequent tests (i.e., Test-2 and Test-3) to determine the "debris loaded" head loss for the strainer.

Test-2 - Thin Bed
The purpose of Test-2 was to determine the potential for the formation of a thin bed that could increase head loss across the strainer through the formation of a fiber bed which could trap additional particulate debris.

Test-3 - Design Basis
The purpose of Test-3 was to determine the maximum head loss across the strainer with the design basis debris loading. As previously noted, Test-3 was not performed since Test-2 bounded Test-3.

Since Test-2 bounded Test-3, Test-2 was utilized to establish the design basis debris laden head loss. Again, the measured CSHL for Test-1 (i.e., "test" CSHL) is subtracted from the Test-2 result to calculate a "debris loaded" head loss. Then, the prototype clean strainer head loss (calculated separately) is added to determine the total design basis strainer head loss.

This response will be incorporated into MUAP-08001 Appendix-B re-titled as "Sump Strainer Head Loss Tests.

Question 5. The strainer qualification testing conducted in June 2010 used debris amounts, size and size distributions (e.g., fiber fines and smalls) different from what was communicated in docketed correspondence. See RAI 466-3715 Question 06.02.02-53. Request MHI update or revise previously docketed correspondence to address design basis changes related to strainer qualification.

The RAI 466-3715 Question 06.02.02-53 is a follow up to RAI 354-2585 Question 06.02.02-23. These questions were associated with an assumption of the design basis debris allocation applied to two (2) operable sumps and a debris distribution of 70% to one sump and 30% to the other.

MHI did not change any assumptions with regard to the determination of LOCA generated debris types, quantities, size, size distribution, or subsequent debris transport analysis utilized for the head loss test program. The debris allocation per sump (i.e., 70%) and erosion factor (i.e., 40%) remained the same.

The following provides clarification for the previous responses to Questions 06.02.02.53 and 06.02.02.23:

a. Re-examination of the debris source term to further reduce the fibrous insulation debris quantity. This change was made due to the application of the very conservative non-prototypical head loss test protocol using the mixing tank which takes no credit for debris transport or settlement. This resulted in reduction of the quantity of fibrous insulation debris necessary for testing from 46 $ft^3$ to 16 $ft^3$ (i.e., 11.2 $ft^3$ based on 70/30 debris allocation to the two (2) operating sumps).

b. Revised the justification for the evaluation assumptions applicable to determination of the design basis debris per sump, such as debris allocation (i.e., 70%) and erosion factor (i.e., 40%). These issues were discussed in responses to Questions 06.02.02-53 and 06.02.02-23. Instead, uncertainty or potential non-conservatisms associated with these assumptions are justified or bounded by “overall conservatisms” discussed in a subsequent portion of this RAI response.

In order to incorporate the above changes, MUAP-08001 Section 3.3 titled “Debris Characteristics” and Section 3.4 titled “Debris Transport” will be revised to reflect and/or include the following:

In Table 3-5 Debris Generation, the quantity of Fibrous Insulation (Nukon) debris (i.e., 46 $ft^3$) has been reduced to 16 $ft^3$ (i.e., 11.2 $ft^3$ based on 70/30 debris allocation to the two (2) operating sumps).

The US-APWR design assumes that all fibrous insulation debris within the ZOI is small. The term “small” refers to small fines as discussed in NEI 04-07 (GR). The NEI GR classified fibrous debris into four (4) groups as follows:

1. fines that remain suspended
2. small pieces of debris that are transported along the floor
3. large pieces of debris with the insulation exposed to potential erosion
4. large pieces of debris with the insulation undamaged and/or still protected by a covering, thereby preventing erosion

Therefore, fine fibrous (insulation) debris is considered to be suspended, and smalls are considered as non-suspended, but subject to transport along the floor. Based on the SE Appendix II of NEI GR (Volume 2), specifically section II.3.1.2, it is assumed that 15% - 25% of the design basis total fibrous debris small fines is in the form of fines which will transport. The other remaining 75% percent is in the form of smalls which may or may not transport following the LOCA, but which may erode. It has been very conservatively assumed for head loss testing purposes that a minimum of 25% of the total fibrous debris is fines.

The 30 day post-LOCA period for the potential erosion of small fiber insulation debris in the containment was considered. Application of the erosion factor eventually results in debris characteristics, in particular for determination of the debris size, which is similar to fine fibrous debris.

It is assumed that all fibrous debris (smalls) erode into fines at an erosion rate of 40%, which provides a safety factor of 4 based on the 10% erosion factor acknowledged by the NRC as supported by 30-day erosion tests (Reference 3). The letter (Reference 3) concludes that 10% erosion factor for small NUKON fiber is acceptable as long as its applicability for plant specific conditions is justified. While the US-APWR does not provide quantitative justification for this, this assumption applies because of the following alternative justification:

(1) The US-APWR design utilizes NUKON fiber insulation that is the same type of insulation used for the industry 30-day erosion test.

(2) The small debris subject to erosion is non-transportable, settles in the post-LOCA containment, or is trapped at curbs, interceptors, or various structures and components. The erosion factor is based on the fluid flow velocity through the post-LOCA containment to the strainers and the turbulent energy levels associated with areas containing trapped fibrous debris. However, the US-APWR assumes that all of the debris is transportable to 2 of 4 operable sumps, and there is no credit taken for a reduction in the quantity of debris reaching the strainers based on the debris transport analysis. The safety factor (i.e., 4) based on the actual 10% erosion factor and taking no credit for debris trapping in the containment ensure that the overall US-APWR sump performance evaluations are conservative.

To summarize, it is assumed that the LOCA-generated fiber debris initially consists of 25% fines and 75% smalls. For the smalls, 40% are assumed to erode into fines during the recirculation period. For conservatism, the US-APWR test program utilized the final recirculation fiber size distribution (i.e., with the maximum number of fines). Therefore, the US-APWR test program consisted of 55% fines (25% initial fines + 75% initial smalls x 40% eroded = 55% fines) and 45% smalls (75% initial smalls x 60% non-eroded = 45% smalls).

The strainer debris allocation discussed in MUAP-08001 Section 3.4 titled "Debris Transport" indicates that the 70% debris allocation per sump is an "assumption" based on the debris transport scenario discussed in the subject document. This assumption is still valid and was applied to the current debris transport evaluation.

A realistic assumption is that the debris will eventually be allocated equally between each sump during long term recirculation. However, this approach is less conservative. On the other hand, it is also too conservative and unrealistic to assume that 100% of transported debris is allocated to only one sump, and that the other sump remains free of debris. The assumption of 70% debris allocation to one sump includes some uncertainty. However, the assumption is bounded by "overall conservatisms" as discussed below:

(1) The US-APWR applies ZOIs recommended in the SER of NEI 04-07 GR in the debris generation analysis to maximize the amount of debris. A reduced ZOI(s), which has been proposed by the industry, is not applied.

(2) The US-APWR assumes no credit for capturing debris on gratings or other structures and equipment in the upper containment. Although a significant fraction of debris captured in upper containment could eventually be washed back down to the containment pool, taking no credit for debris capture in upper containment is conservative with respect to the sump strainer performance evaluation.

(3) The US-APWR did not credit debris holdup in the reactor cavity or the ineffective pools in the lower containment drain sump region. As discussed in MUAP-08001 Section 3.7.1 and defined in Table 3-11, the volume of these ineffective pools is approximately 45% of

the initial RWSP water volume, however none of the debris is assumed nor credited as captured debris in the transport evaluation.

(4) The US-APWR assumes that none of the fibrous debris is generated as intact pieces, which maximizes the quantity of debris available for erosion over a 30 day period in the post-LOCA containment pool. The 40% erosion factor is conservatively applied for erosion of smalls into fines, which is based on a safety factor of 4 (i.e., actual value is 10% erosion factor as acknowledged by the staff and supported by industry erosion testing).

Although the effect of these conservatisms is difficult to quantify, the overall conservatisms included in the evaluation provides a confident compensation for the uncertainties and potential non-conservatisms associated with the assumption regarding debris allocation per sump.

Reference


1. NUREG/CR-6877 (LA-UR-04-3970), Characterization and Head Loss Testing of Latent Debris from Pressurized Water Reactor Containment Buildings, July 2005 USNRC (ADAMS Accession No. ML052430751).
2. Letter from Ho K. Nieh (NRR) to Gordon Bischoff (PWROG) , dated December 21, 2007, Final Safety Evaluation for Pressurized Water Reactor Owners Group (PWROG) Topical Report (TR) WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" (TAC No. MD1119) (ADAMS Accession No. ML073521072), and Final Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report WCAP-16530-NP "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191" Pressurized Water Reactor Owners Group Project No. 694 (ADAMS Accession No. ML073520891)
3. Letter from William H. Ruland, NRR to Alion Science & Technology, dated June 30, 2010, Subject: Proprietary Erosion Testing of Submerged Nukon Low-Density Fiberglass Insulation in Support of Generic Safety Issue 191 Strainer Performance Analyses (ADAMS Accession No. ML101540221).

**Table 1 Principle Plant/Test Parameters**

| Parameter(s) | Unit | Plant | Actual Test |
|---|---|---|---|
| 1. Strainer Surface Area | $ft^2$/sump | 2,554.1 (9 modules) | 303.4 (1 module) |
| 2. Flow Rate | gpm/sump | 5,200 | 617.8 (2) |
| 3. Submergence | in | 12 | 11 |
| 4. Fluid Temperature | °F | variable | 120°F |
| 5. Debris | | | |
| a. NUKON Fine & Erosion Fiber | lbm | 14.88 (1) | 1.80 (2) |
| b. NUKON Small Fiber | lbm | 12.0 (1) | 1.50 (2) |
| c. Epoxy coating | lbm | 1184.4 (1) | 140.8 (2) |
| d. Latent Fiber (NUKON) | lbm | 21.1 (1) | 2.5 (2) |
| e. Latent Dirt & Dust | lbm | 119 (1) | 14.2 (2) |
| f. Chemical | lbm | 213.5 (1) | 25.4 (2) |

Note:
(1) Accounts for debris allocation per sump (i.e., 70%).
(2) Plant parameter multiplied by 0.1188 (scaling factor).

**Impact on DCD**

There is no impact on the DCD.

**Impact on COLA**

There is no impact on the COLA.

**Impact on PRA**

There is no impact on the PRA.