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Oct 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-10285

Subject: MHI's Responses to US-APWR DCD RAI No. 637-4988 Revision 2

Reference: [1] "Request for Additional Information No. 637-4988 Revision 2, SRP Section: 06.02.02 – Containment Heat Removal System - Design Certification and New License Applicants, Application Section: 6.2." dated Sep 23, 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. 637-4988 Revision 2".

Enclosed are the responses to 3 questions that are contained within Reference [1].

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.

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NRO

Enclosures:

1. Responses to Request for Additional Information No. 637-4988 Revision 2

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-10285
Docket No. 52-021

Responses to Request for Additional Information No. 637-4988 Revision 2

October 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/21/2010

US-APWR Design Certification

Mitsubishi Heavy Industries, Ltd.

Docket No. 52-021

RAI NO.: **NO. 637-4988 REVISION 2**

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

APPLICATION SECTION: **6.2.2**

DATE OF RAI ISSUE: **09/23/2010**

QUESTION NO.: 06.02.02-58

From June 7-9, 2010 the staff conducted an audit of the US-APWR suction strainer. The strainer head loss testing for US APWR was designed to accumulate debris on the strainer with minimal debris settlement. During the test, after all the non-chemical particulate was added, the staff noted a floating, foamy layer of debris, ranging from a thin layer to several inches thick, covering a significant portion of the test tanks water surface. After completing the fiber debris additions, the staff also noted some fiber debris held up on the surface of the water in the test tank and where piping and other components penetrated the water surface. Based on observation, it appears that air ingestion (bubbles) occurred during debris introduction and was interacting directly with the debris creating the floating masses. Just as debris settlement prevents debris from contributing to strainer head loss, so too does floating debris. The staff considers floating debris in the test to be inconsistent with the test intent to address debris accumulation on the strainer. Therefore the staff requests MHI to evaluate the impact on strainer head loss if the floating debris had transported/accumulated on the strainer and address the following questions: What amounts and types of debris were floating?

What are the principal phenomena that would contribute to debris floating? Was the phenomena modeled conservatively or prototypically in the test? Explain why it is acceptable for the test to permit floating as a debris removal mechanism given how the principal phenomena were scaled.

ANSWER:

The Staff has three (3) primary questions regarding the floating debris associated with the US-APWR and the possible affect on the test. The three (3) questions are as follows:

1. What are the principal phenomena that would contribute to debris floating?
2. Was the phenomena modeled conservatively or prototypically in the test? Explain why it is acceptable for the test to permit floating as a debris removal mechanism given how the principal phenomena were scaled.
3. What amounts and types of debris were floating?

Each question will be answered separately even though they are related in order to provide specific responses in a coherent manner.

Question 1: What are the principal phenomena that would contribute to debris floating?

Subsequent testing since the completion of the US-APWR head loss testing performed at the Alden Research Laboratory, has determined with certainty that the debris floatation is directly related to the Tank Test Flume Protocol and debris introduction method. The combination of the improved conservative mixing methodology to preclude fibrous debris agglomeration, the conservative high and low levels of agitation to preclude fibrous debris settlement, and the utilization of prototypical warm (i.e., ~120ºF) test flume water, caused air to be 'added' to the test flume. This entrained air then easily came out of solution, resulting in the suspension and floating of some debris within the test flume.

Specifically, a small amount of air was entrained into the debris mixing tank flow as the debris and water fell over the edge of the mixing tank inner weir overflow and down into the main debris receptacle. From there, the debris and water are pumped into the test tank flume where it is injected below the water column surface. This mixed debris injection water has a slightly lower temperature due to the cooling effect of the mixing action and, therefore, has the capability to have more dissolved air. The debris flow then heats up as it mixes with the rest of the recirculation flow causing the dissolved air to come out of solution. As the air comes out of solution, it 'attaches' itself to the debris which causes it to be easily suspended in the water column and float. One of the leading indicators of this process is the fact that some debris did not begin to float until after passing under several submerged skimmers that were intended to keep any floating debris in the high agitation region. The mixed air/debris combination proved extremely stable over the entire test duration, especially debris downstream near the strainer. This debris in particular showed no signs of settlement, even though the test was run overnight.

Question 2: Was the phenomena modeled conservatively or prototypically in the test? Explain why it is acceptable for the test to permit floating as a debris removal mechanism given how the principal phenomena were scaled.

The amount and composition of the floating debris was evaluated and shown to be prototypically representative of the debris which would not be captured by the fiber bed in the actual US-APWR prototype, and therefore have no significant effect on head loss. Because the test conditions did not allow debris settling, floatation was the only removal mechanism possible. In the prototype, the exact proportions of debris removed by floatation, settling, or other mechanisms may be different. However, the fiber bed and amount of debris captured by the fiber bed (and therefore, effect on head loss) was prototypically modeled.

The US-APWR strainer module design employs 'standard' PCI patented Sure-Flow® strainer technology and design principles. Each strainer module consists of a core-tube, strainer disks fabricated from perforate plate, gap rings, and various ancillary components required to support and maintain the operability of the strainer for all Design Basis phenomena.

The gap between adjacent strainer module disks is 1". Due to the patented Sure-Flow® strainer core-tube technology, the debris will load on the strainer in a uniform manner. This has been documented during a significant number of Sure-Flow® strainer prototype development, and Licensee and foreign utility testing programs. The gap between adjacent strainer module disks is 1". Since the debris loading is on the strainer disks is uniform, that means that each adjacent disk 'face' separated by the 1" gap could each have 0.5" of debris deposited on each disk 'face' before the 1" gap is completely filled with debris.

The discussion is true for high fiber plants where all of the fiber would fill or exceed the 1" gap between disks 'faces'. In the case of the US-APWR, there is significantly less fibrous debris, and the 1" gap would not be filled.

It has been documented during previous Sure-Flow® strainer prototype development, and

Licensee and foreign utility testing programs that low fiber plants simply don't have enough fibrous debris to capture all of the particulate in circulation. The particulate will simply be transported to the strainer, but since there is not enough fibrous debris, the particulate simply 'floats' around the strainer and does not affect head loss. Upon drain down, the excess particulate settles to the floor of the flume once the flow to the strainer has stopped.

The US-APWR test strainer has a surface area of 303.414 ft^2. Based on the subject strainer surface area, the theoretical thin bed of 0.125" would require 3.16 ft^3 of fibrous debris which is equivalent to 7.59 lbm of NUKON®. The revised US-APWR Design Basis debris loading consists of the following:

- 6.2 ft^3 (14.88 lbm) of NUKON® fines
- 5.0 ft^3 (12.00 lbm) of NUKON® smalls
- 8.8 ft^3 (21.12 lbm) of latent fiber as NUKON®
- 119 lbm of latent particulate (PWR2 dirt & dust mixture)
- 13 ft^3 (1222.00 lbm) of epoxy coatings as acrylic coating powder
- 213.5 lbm of chemical precipitate as aluminum oxyhydroxide

Including the sacrificial area of 200 ft^2 for unidentified tags, labels, and other debris results in a reduced theoretical strainer surface area and an increase in the scaled quantity of debris utilized for the US-APWR test program. Not accounting for the sacrificial area would result in a debris scaling factor of 11.11%. However, including the sacrificial area would result in a scaling factor of 11.880%.

Therefore, the actual scaled quantities of debris utilized for the US-APWR test program were as follows:

- 1.80 lbm of NUKON® fines
- 1.50 lbm of NUKON® smalls
- 2.50 lbm of latent fiber as NUKON®
- 14.2 lbm of latent particulate (PWR2 dirt & dust mixture)
- 140.80 lbm of epoxy coatings as acrylic coating powder
- 25.41 lbm of chemical precipitate as Aluminum Oxyhydroxide

The total amount of fibrous debris utilized for the US-APWR test was 5.80 lbm. As previously noted, 7.59 lbm of fibrous debris is required to achieve the theoretical 0.125" thin bed. Based on the available scaled quantity of fibrous debris which also includes small fibrous debris, the US-APWR test strainer fibrous debris bed would only be 0.0955" thick. The actual US-APWR fibrous debris bed is approximately 23% less than the theoretical thin bed, and approximately 80% less than the maximum theoretical gap thickness of 0.5".

Based on the US-APWR Design Basis debris loading and strainer area, each one cubic foot (1ft^3) of strainer debris bed will consist of 0.01509 ft^3 of fibrous debris and 0.98491 ft^3 of particulate debris.

The US-APWR test strainer has an area of 303.414 ft^2. Applying the fibrous debris bed thickness of 0.0955" conservatively assumed to be 'spread' over the entire strainer surface results in a total fibrous debris bed volume of 2.4147 ft^3. This fibrous debris bed volume is based on the fibrous debris in the 'bulk form', that is the as-fabricated fibrous insulation which includes the interstitial area within the fiber matrix. The fibrous debris theoretically could 'capture' particulate within the interstitial spaces up to 0.5" in thickness. The gap space between the US-APWR strainer module disks is 1". Therefore, each disk could theoretically 'capture' 0.5" of fibrous and particulate debris.

However, the fibrous debris bed for the US-APWR is theoretically only 0.0955" thick or 2.4147 ft^3.

Based on the US-APWR Module Debris Weight calculation, the fibrous debris portion of the total debris bed volume is 0.0364 ft^3 (i.e., 2.4147 x 0.01509) and the total particulate debris bed volume portion is 2.3783 ft^3.

It was conservatively assumed that all of the fibrous debris is deposited on the US-APWR test strainer due to the continuous Tank Test Flume agitation. However, since the theoretical fibrous debris bed for the US-APWR test strainer is minimal (0.0955"), it is difficult if not impossible to capture all of the particulate debris within the fibrous debris bed interstitial spaces. Simply stated, the interstitial spaces within the fibrous debris bed matrix are 'filled' before the remainder of the excessive particulate debris can be 'captured' by the bed. Based on the previous discussion, 2.3783 ft^3 of particulate or 223.56 lbm (conservatively assuming that all of the particulate is epoxy coating particulate at a density of 94 lbs/ ft^3) could theoretically be captured within the interstitial space matrix of the fibrous debris bed on the US-APWR strainer. It should be noted that even though the chemical precipitate is treated as particulate for debris purposes, it is actually a chemical surrogate material that is suspended in water. Therefore the chemical precipitate was not included in the total particulate debris mass since it was conservatively assumed that the majority of the chemical precipitate debris would remain suspended in the Tank Test Flume and would not affect the US-APWR strainer debris bed. The actual US-APWR strainer head loss tests support this conservative conclusion. That is, the head loss only minimally increased following the addition of the entire scaled quantity of chemical precipitate debris.

The total weight of particulate debris utilized in the US-APWR test was 259 lbm. However, based on the conservative assumption that all of the particulate debris is epoxy coating particulate with a density of 94 lbs/ft^3, only 223.56 lbm of particulate can be absorbed by the fibrous debris bed. Theoretically, 35.44 lbm of particulate would not be captured by the fibrous debris bed for the US-APWR. In reality, significantly less particulate debris would be captured if the latent dust & dirt particulate density of approximately 170 lbs/ft^3 were utilized.

Following the completion of the US-APWR thin bed test and prior to flume drain down, the debris floating on the flume surface was collected for analysis. After extensive drying of the floating debris to remove moisture, there was approximately 36.6 lbs of dried material. The amount of dried floating debris (i.e., 36.6 lbm) compares very favorably with the theoretical expected amount of debris that would not be captured by the fibrous debris bed (i.e., 35.44 lbm). The slight difference in weight could be attributed to moisture 'locked-in' the matrix of the dried debris.

The dried material is very hard, almost like a 'brick' or stone (Alden indicated that even using a hammer and chisel on the 'brick' still makes it difficult to break the 'brick' open to enhance further examination). However, the limited examination of the dried material does indicate the presence of fibrous debris, but in a limited quantity. It could logically be surmised that the fibrous debris within the dried 'brick' is most likely the NUKON® 'smalls' fibrous debris which are larger than the NUKON® 'fines'. The NUKON® smalls would have a tendency to 'trap' air due to the debris mixing and flume agitation processes, and would therefore 'float'. This air trapping phenomena was previously discussed in the response to Question 1 of this RAI. However, it can be concluded from the visual observations that the majority of the dried debris contained within the 'brick' is coating particulate (i.e., acrylic powder).

The quantity of floating debris (i.e., 36.6 lbm) compares very favorably (i.e, ~3.3%) with the estimated theoretical quantity (i.e., 35.44 lbm) of particulate debris not expected to be captured by the US-APWR strainer fibrous debris bed. Since the US-APWR strainer resulted in a head loss that could be considered to be based on the thin bed effect, the presence of floating debris can be reasonably concluded to not have affected the US-APWR strainer head loss test. This conclusion is further supported by the presence of a uniform and relatively thin combined fibrous and particulate debris bed that covered the entire strainer surface. The thin uniform debris bed was observed and photographically documented following the completion of the US-APWR head loss test and subsequent drain-down of the Tank Test Flume.

Since the US-APWR utilizes fully submerged strainers, floating (buoyant) debris is not considered a problem as discussed in NEI 04-07 GR Section 3.7.2.3.2.5.

Question 3: What amounts and types of debris were floating?

The types and estimated amounts of floating debris associated with the US-APWR test program were previously discussed in the response to Question 2 of this RAI. In summary, there was approximately 36.6 lbm of floating debris. Based on visual observation, this consisted primarily of epoxy coating (i.e., acrylic powder) and a minimal amount of fibrous debris. Only the total overall dried weight of the combined floating debris could be measured; the specific amounts of epoxy coating (i.e., acrylic powder) and fibrous debris could not be individually measured.

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.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/21/2010

US-APWR Design Certification

Mitsubishi Heavy Industries, Ltd.

Docket No. 52-021

RAI NO.: **NO. 637-4988 REVISION 2**

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

APPLICATION SECTION: **6.2.2**

DATE OF RAI ISSUE: **09/23/2010**

QUESTION NO.: 06.02.02-59

Near the conclusion of the thin bed testing on June 9, 2010, MHI and its contractors realized that the sensing lines of the differential pressure (dP) transmitters contained air. The air was cleared from the lines upon realizing this, and immediately the head loss rose approximately 2 ft. The staff's concern is that the air introduced uncertainty in the test data. The staff requests MHI to explain the causes for the air in the sensing line and the impact of this air on test results.

ANSWER:

The issue of air in the dP sensing lines was observed during the test, but prior to the termination of the test.

Investigation of the cause of the air in the dP sensing lines was performed. The primary cause of the source of the air was discussed in the response to RAI 06.02.02-58. In summary, the combination of the improved conservative mixing methodology to preclude fibrous debris agglomeration, the conservative high and low levels of agitation to preclude fibrous debris settlement, and the utilization of prototypical warm (i.e., ~120ºF) test flume water, caused air to be 'added' to the test flume and to easily come out of solution. Because the mixed debris injection water has a slightly lower temperature due to the cooling effect of the mixing action, it has the capability to have more dissolved air dissolved. The debris flow then heats up as it mixes with the rest of the recirculation flow. This causes the dissolved air to come out of solution both in the Tank Test Flume and subsequently due to the additional pressure drop that the flowing fluid experiences as it passes through the US-APWR strainer debris bed. As the air comes out of solution, it enters the sensing lines of the dP instruments. It was further determined that the routing and orientation of the lines (i.e., high points over various components/interferences) lead to the accumulation of the air released from solution within the subject lines.

Re-routing of the lines while the test was in progress, in conjunction with the bleeding of the air from the subject lines, resulted in accurate dP (i.e., head loss) measurements for the US-APWR Design Basis strainer test. Alden bled the air from the lines and the head loss increased accordingly. Alden continued to monitor the sensing lines to ensure that there was no further air in the lines. The test data and head loss plots support this fact. The head loss measured during the US-APWR test for the CSHL, non-chemical debris head loss, and total head loss (i.e., non-chemical and chemical debris) at the end of the test when the termination criteria was met, is a true and accurate presentation of the US-APWR head loss.

The air in the sensing lines did not affect the intermediate or final head loss results for the US-APWR. Alden has taken specific corrective action to ensure that this issue will not occur in the future.

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.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/21/2010

US-APWR Design Certification

Mitsubishi Heavy Industries, Ltd.

Docket No. 52-021

RAI NO.: **NO. 637-4988 REVISION 2**

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

APPLICATION SECTION: **6.2.2**

DATE OF RAI ISSUE: **09/23/2010**

QUESTION NO.: 06.02.02-60

During chemical effects testing on June 9, 2010 the staff was informed by the applicant that an unexpected test result occurred and that other options would be explored to meet the design basis of the strainer. The staff noted a head loss of 4.7 ft at 120°F at the time of the unexpected test result. The applicant should describe how the unexpected test result will be evaluated in order to meet the acceptance criteria described in Technical Report MUAP-08001-P, Revision 2, US-APWR Sump Strainer Performance.

ANSWER:

The measured maximum head loss at the test exceeded the maximum head loss criterion based on the conservative methodology described in Section 3.6 of the technical report MUAP-08001 Revision 2. The measured head loss (i.e., 4.766 ft at 120F) will exceed the current acceptance limit of 4.7 ft at 70F when it is converted by water viscosity corresponding to the fluid temperature.

The past methodology conservatively neglected the minimum initial containment pressure which exists prior to accident by assuming that the containment pressure was equal to the sump fluid vapor pressure at low temperatures. This approach is more conservative than the methodology required by RG 1.82, Revision 3. MHI will change the methodology to be consistent with RG 1.82, Revision 3, at low temperatures. The revised methodology will account for the initial containment pressure prior to accident when the sump temperature is low and will assume that the containment pressure is equal to the fluid vapor pressure when the sump temperature is high (above the saturation temperature corresponding to the minimum initial containment pressure). For reference, the methodology at high sump fluid temperatures is discussed in further detail in the response to RAI 626-4750 Question #06.03-87 in MHI Letter UAP-HF-10276 dated 10/14/2010.

Detailed discussions have occurred with the NRC staff over a number of conference calls from July to October, 2010, using a white paper titled "ECCS Pump NPSH Calculation Methodology" to describe the new approach. This information describing the updated methodology will be incorporated into Section 3.6 in the Technical Report MUAP-08001 Revision 3 which is scheduled for submission to the NRC by end of October, 2010.

Impact on DCD

The DCD Section 6.2.2.3 “Design Evaluation” and Table 6.2.2-1 will be revised and/or replaced with additional information provided in the cited white paper (which will be incorporated into the revised Technical Report). Detailed changes on the DCD will be proposed to the staff by November 19, 2010 as a DCD tracking report.

Impact on COLA

There is no impact on the COLA

Impact on PRA

There is no impact on the PRA.