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February 1, 2013

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-13013

Subject: MHI's Response to US-APWR DCD RAI No. 979-6936 (SRP 05.04.07)

Reference: 1) "Request for Additional Information No. 979-6936, SRP Section 05.04.07 – Residual Heat Removal (RHR) System - Application Section: 5.4.7", dated December 10, 2012.

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. 979-6936."

Enclosed is the response to a question contained within Reference 1.

Please contact Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

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

Enclosure:

1. Response to Request for Additional Information No. 979-6936

D081
NRO

CC: J. A. Ciocco
J. Tapia

Contact Information

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Enclosure 1

UAP-HF-13013
Docket No. 52-021

Response to Request for Additional Information No. 979-6936

February 2013

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

2/1/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 979-6936**

SRP SECTION: **05.04.07 – RESIDUAL HEAT REMOVAL (RHR) SYSTEM**

APPLICATION SECTION: 5.4

DATE OF RAI ISSUE: **12/10/2012**

QUESTION NO.:05.04.07-15-1

Based on the air ingestion tests, the report indicated that other pipe choices such as 12Bx12B and 12BX10B (step nozzle) were superior to the chosen 10X10B design. Why was the 10BX10B design chosen instead of the other designs?

ANSWER:

The 12B x 12B and 12B x 10B (step) nozzles were shown to result in better air ingestion performance compared to the 10B nozzle. However, the testing indicated that the 10B nozzle had sufficient and acceptable air ingestion performance with less than the allowable air ingestion observed at an h/d value less than the Low-Low RCS water level in the US-APWR.

As discussed in response to Question #3 below, the RCS water levels in the US-APWR have a large amount of conservatism to the allowable air ingestion water level observed in testing. Additionally the amount of NPSHa and elevation head which were not taken into account during RHR nozzle testing will mitigate any air ingestion effects on the RHR pump (as discussed in Question #4 below).Therefore, the 10B nozzle is considered to provide acceptable and conservative air ingestion performance.

Furthermore, the 10B nozzle was considered to be superior to the 12B x 12B and 12B x 10B (step) nozzles in other aspects of the design. The use of smaller diameter 10B piping will reduce capital costs and increase flow velocities within the piping to prevent gas accumulation. The elimination of the additional weld at the 12B x 10B step will reduce operating costs and personnel dose over the lifetime of the plant. Therefore, the 10B nozzle was chosen based on superior cost and inspection performance while still providing sufficient and conservative air ingestion performance.

Impact on DCD

There is no additional impact on the DCD as a result of this RAI response.

Impact on R-COLA

There is no additional impact on the R-COLA as a result of this RAI response.

Impact on S-COLA

There is no additional impact on the S-COLA as a result of this RAI response.

Impact on PRA

There is no impact on the PRA.

Impact on Topical/Technical Reports

There is no new impact on any of the referenced technical reports as a result of this RAI response.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

2/1/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 979-6936

SRP SECTION: 05.04.07 – RESIDUAL HEAT REMOVAL (RHR) SYSTEM

APPLICATION SECTION:5.4

DATE OF RAI ISSUE: 12/10/2012

QUESTION NO.:05.04.07-15-2

What hot leg level is required to work/inspect on the reactor coolant pumps components (e.g. the RCP seals)? How does this level compare to the SG nozzle dam installation level?

ANSWER:

The hot leg water level throughout RCP seal inspection is nominally above the top of the hot leg pipe during most of the inspection process. The only times RCS water level will be lowered to the top of the hot leg are during inspection preparation when the seals are removed and seal caps are installed and after inspection is completed and the seals are reinstalled.

The exact water level height for installation of SG nozzle dams and MCP seals is still to be determined. However, the top of the MCPs will be located lower than the bottom of the SG nozzles. Therefore, the RCS water level during SG nozzle dam installation does not need to be lowered to the top of the MCPs.

Impact on DCD

There is no additional impact on the DCD as a result of this RAI response.

Impact on R-COLA

There is no additional impact on the R-COLA as a result of this RAI response.

Impact on S-COLA

There is no additional impact on the S-COLA as a result of this RAI response.

Impact on PRA

There is no impact on the PRA.

Impact on Topical/Technical Reports

There is no new impact on any of the referenced technical reports as a result of this RAI response.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

2/1/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 979-6936

SRP SECTION: 05.04.07 – RESIDUAL HEAT REMOVAL (RHR) SYSTEM

APPLICATION SECTION: 5.4

DATE OF RAI ISSUE: 12/10/2012

QUESTION NO.:05.04.07-15-3

What is the basis for the nominal 0.47ft above the main coolant pipe (MCP) centerline water level? Can the mid-loop water level be raised higher than the 0.47 ft above MCP centerline? If not, explain in detail why the nominal water value cannot be raised (increased).

ANSWER:

The 0.47 feet water level above MCP centerline is not the nominal RCS water level for mid-loop operation. 0.47 feet is the "LOW" alarm set point and the minimum design-basis water level for RHR pump operation during mid-loop conditions. This water level is specified to provide margin to both the required level for SG draining and the allowable air ingestion level obtained from scaled testing.

The starting point for specifying the RCS water levels is the height of the SG nozzles. The alarm set points are then specified as follows:

- The Low alarm is specified based on the SG nozzle height and Japanese operating experience for required water level to perform steam generator tube draining, plus margin. This alarm notifies that operator actions are required to increase RCS level.
- The difference between Low and Low-Low level is based on operating experience (plus margin) for the operators to recognize the Low level alarm and manually close the letdown isolation valve. Margin is provided to allow operators to identify that this action was not successful and give time for further action.
- The Low-Low alarm is specified to be greater than, and provide margin to, the RCS water level resulting in allowable air ingestion from scaled testing. This alarm notifies operators that initial recovery actions were not successful and that SFP gravity injection should be initiated.

The basis for the LOW water level comes from Japanese operating experience during steam generator tube draining. During this time, the water level in the MCP may fluctuate as the water level declines in the hot leg pipe and air is mixed into the steam generator tubes causing water to discharge into the RCS and raising the RCS level. The "LOW" set point therefore is the minimum RCS level during SG tube drain down including expected fluctuation and margin to warn operators of abnormal loss of inventory in order to preserve RHR pump integrity.

Impact on DCD

There is no additional impact on the DCD as a result of this RAI response.

Impact on R-COLA

There is no additional impact on the R-COLA as a result of this RAI response.

Impact on S-COLA

There is no additional impact on the S-COLA as a result of this RAI response.

Impact on PRA

There is no impact on the PRA.

Impact on Topical/Technical Reports

There is no new impact on any of the referenced technical reports as a result of this RAI response.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

2/1/2013

US-APWR Design Certification

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SRP SECTION: **05.04.07 – RESIDUAL HEAT REMOVAL (RHR) SYSTEM**

APPLICATION SECTION: 5.4

DATE OF RAI ISSUE: **12/10/2012**

QUESTION NO.:05.04.07-15-4

Regarding the test data:

a. What were the various test times? Justify that the test times were run long enough to ensure no pump damage/degradation. Were tests performed to determine possible pump degradation (i.e., repeatability tests)?
b. Following the tests, did MHI dismantle the pump and check for damage? If so, explain the inspections performed and results.
c. Was pump inlet void fraction versa time recorded? If not, justify how the integrated air volume is an acceptable measure of vortexing?
d. The report indicated that vortexing was observed during some of the tests. Provide detailed descriptions of the vortexing and which tests (e.g., pipe type, flow rates) vortexing was observed.
e. The testing measured integrated air volume. Justify that the measured integrated air volume represents actual air volume. For example, were there locations where air bubbles could be trapped which were not measured? Was sufficient time allowed before measuring to ensure that all bubbles reached the measuring location? What other uncertainties (e.g. instrumentation) were included in determining the integrated air volume?
f. Was the water saturated with air?

ANSWER:

Introduction

The RHR nozzle air ingestion performance testing was performed approximately 10 – 20 years ago by MHI to support operability evaluations for existing Japanese PWRs and support basic design of the J-APWR. As discussed previously in RAI response 925 (MHI Letter UAP-HF-12172), this testing was not performed according to NQA-1 requirements and details of the test methods and results requested by the NRC for licensing of the US-APWR are not available. The responses below estimate the testing impacts based on the best available information and engineering judgment.

Overall, MHI considers the scaled testing to be sufficiently accurate based on the items below. Pump operation during mid-loop will be confirmed as part of pre-operational testing:

- Margin between the specified allowable air ingestion and the void fractions required to impact pump performance and pump integrity.

- Margin between the allowable air ingestion level observed in testing and the Low-Low water level
- Margin between the Low-Low water level and the anticipated operating range (i.e., above Low Level)
- The air ingestion level observed in testing corresponds to the air ingestion at approximately the MCP elevation. The CS/RHR pumps in the US-APWR are located approximately 60 ft below the MCP piping. This additional hydrostatic head will compress any ingested air and reduce the overall void fraction before reaching the pump suction.
- The impact of air ingestion on pump head can be modeled as an increase in NPSH required per RG 1.82, Rev. 4. The US-APWR CS/RHR pumps have significant NPSH available, due to the elevation difference and will reduce the impact of air ingestion on pump performance.

4. a. Test times were not taken during the RHR nozzle testing. The data collected were time integrated values for air ingestion.

Pump performance was evaluated in separate pump tests, which was separate from the nozzle air ingestion performance testing which the staff reviewed. Details for this pump testing are not available, but the limits are similar to standard industry limits (see #4.b below).The RHR pumps will be QME-1 qualified for the US-APWR for operation over the anticipated range of design-basis conditions.

4. b. Acceptable pump void fractions were determined in pump air ingestion testing which was separate from the nozzle air ingestion performance testing reviewed by the staff. Test data from thepump air ingestion testing is not available. However 2% air ingestion is considered to be a standard industry value for acceptable pump air ingestion, as discussed in RG 1.82 Rev. 4. Air ingestion impacts at these low levels are acceptable for continuous operation without significant impact on pump lifetime. Furthermore, the large amount of NPSHa and the large amount of elevation head will further reduce the void fraction prior to any air entering the pumps.

4. c. Actual air ingestion void fraction at the pump was not recorded during RHR nozzle testing since this can be evaluated separately for the pump, and gas transport to the pump will depend on final piping system arrangement and layout which will be determined during detailed design. Gas transport to the pump was not considered during this test since the purpose of this test was not to evaluate gas transport in the suction piping.

Measured air during the test did not account for hydrostatic pressure acting on the ingested air bubbles prior to entering the pumps. The bubble measurement tube during the test was at approximately the same elevation as the RHR nozzle. On the other hand, in the as-built plant, the RHR pump will be approximately 60 ft below the MCP. Therefore, when hydrostatic pressure is considered, the ingested void at the RHR nozzle will be significantly greater than the void fraction actually entering the pump in the US-APWR. Furthermore, as air ingestion increases, the first effect on the pump is an increase in NPSH required to prevent a reduction in head. As discussed in RAI 783-5855 (MHI Letter UAP-HF-11274), the CS/RHR pumps have significant margin in NPSH available during mid-loop conditions.

With respect to gas accumulation, MHI will address gas accumulation during mid-loop operation through gas transport analysis as part of the GL 08-01 evaluation of the final detailed piping design. Gas accumulation features already discussed in the 2nd Amended Response of RAI 464-3520, Question 05.04.07-11 (MHI Letter UAP-HF-12223) includes:

1. The RHR suction line piping shall have a continuous slope towards the pump inlet to reduce gas transport and allow continuous venting.
2. The RHR suction piping does not include any inverted U-piping which could fill with accumulated voids and result in slug flow to the pump.
3. The RHR piping shall include vents and be periodically surveyed at areas susceptible to gas

accumulation.

If air ingestion does occur at the RHR nozzle during mid-loop operation, the ingested air will be transported to the pump without causing accumulation within the system which could cause slug flow to the pump. Gas will not be transported for Froude numbers below approximately 0.4 (Reference 1), while a Froude number of 1.0 is considered sufficiently large enough to ensure the bubbles are uniformly dispersed and transported at approximately the liquid velocity (p. 3-14, Reference 2). From the response to RAI 925-6413 (MHI Letter UAP-HF-12172), the Froude number in the RHR piping will be much greater than 1.0 at maximum flow. These high flow rates and height of vertical piping are expected to mix and disperse any ingested air such that use of an integrated volume measurement during scaled testing is considered acceptable. It is not necessary to specifically address lower RHR flow rates (i.e., lower Froude numbers) which may not transport ingested air because the potential for air ingestion at the RHR nozzle is significantly reduced at these lower flow rates.Testing at the highest flow rate will be representative of the bounding case for air ingestion.

Therefore, if some amount of air is ingested during mid-loop operation, no accumulation or slug flow to the pump is expected, and the ingested air will transport to the pump. The pump will be qualified for a certain amount of air ingestion, and pre-operational testing will confirm that any mid-loop air ingestion is below allowable limits based on pump head, pump integrity, and motor current. The pump will be qualified for air ingestion up to Reg. Guide 1.82 limits. Pre-Operational Testing will confirm that air ingestion does not exceed the Reg. Guide limits. Therefore, MHI does not require any limits on mid-loop operation to prevent gas accumulation from impacting system operation. Evaluation of final detailed piping layout for GL08-01 closure will be performed for all safety-related piping systems and verified as part of ITAAC (2nd Amended Response of RAI 464-3520, Question 05.04.07-11, UAP-HF-12223).

4. d. The objective of the RHR nozzle testing was to measure integrated air ingestion during the course of each test. Limited information is available as to specific occurrences of vortex formation (versus air ingestion without vortex formation). However, the overall observation summary concluded that at a high flow rate and an approximately low-low water level, suction vortices may still occur from time to time.

4. e. It is not known that 100% of ingested air entrained into the nozzle was transported to the measuring channel. It is reasonable to assume that this minimum bubble diameter is based on the minimum flow velocities within the tank necessary to entrain the bubbles and prevent separation. Based on the test-setup (Please see Figure 3-1 of RAI 925 response, UAP-HF-12172), the minimum velocity inside the tank would be at the baffle attached to the pump suction with a large diameter. This is considered to be much larger than (with velocities much less than) other areas in the test flow path. Therefore, it is expected that no significant separation occurred elsewhere in the test apparatus which could lead to inaccuracies in the measured result. However, the overall size distribution of the ingested air was not known.

Uncertainty is qualitatively addressed in Attachment 3 of the RHR nozzle test report when testing for overall reproducibility.Test records are not available to provide quantitative uncertainties for flow rate and RCS level. For void fraction measurement, it is reasonable to assume that the bubble measurement tube at least 1/4-full at the end of each test (on average) and was measured by hand.

4. f. Specific water conditions are not given in the test report. It is likely that the water used was ordinary potable tap water at room temperature. The test report does not describe concerns or controls for dissolved air. It is reasonable to assume that no specific heating or deaeration was performed and that the dissolved air in the test water was near saturation conditions.However, a conservatively bounding impact may be estimated by assuming that the test water was free from dissolved air at the RHR nozzle and absorbed air to become saturated within the measurement tank.

References:

1. "NRC Staff Criteria for Accessing Gas Movement in Suction Lines and Pump Response to Gas—Revision 1; For NRC Staff Review of Responses to GL 2008-01." January 7, 2009, attached to an NRC Public Meeting Notice under ADAMS Accession Number ML090150637.
2. EPRI Report 1026498, "Report of the Expert Panel on the Effect of Gas Accumulation on Pumps," August 2012.

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