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October 12, 2011

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-11353

Subject: Amended MHI's Response to US-APWR DCD RAI No. 464-3520 Revision 0 (SRP 05.04.07)

Reference: 1) "Request for Additional Information 464-3520 REVISION 0, SRP Section: 05.04.07 – Residual Heat Removal (RHR) System Application Section: 5.4.7, Questions for Reactor System, Nuclear Performance and Code Review (SRSB)" dated October 6, 2009.
2) "MHI's Response to US-APWR DCD RAI No.464-3520 Revision 0", dated November 4, 2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Amended Response to Request for Additional Information No. 464-3520 Revision 0". This amended response is submitted to address design features to prevent gas accumulation.

Enclosed is the response to Question 05.04.07-11 that is contained within Enclosure 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.

Enclosure:

1. Amended Response to Request for Additional Information No. 464-3520 Revision 0

D081
NRO

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

<u>Contact Information</u>

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Enclosure 1

UAP-HF-11353
Docket No. 52-021

Amended Response to Request for Additional Information No. 464-3520 Revision 0

October 2011

10/12/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 464-3520 REVISION 0**
SRP SECTION:	**05.04.07 – RESIDUAL HEAT REMOVAL SYSTEM**
APPLICATION SECTION:	**5.4.7**
DATE OF RAI ISSUE:	**10/6/2009**

QUESTION NO.: 05.04.07-11

Gas accumulation can cause water hammer, gas binding in pumps, and inadvertent relief valve actuation that may damage pumps, valves, piping, and supports and may lead to loss of system operability. Recently, GL 2008-01 (ML080110126) provided past instances of gas accumulation in operating plants and discussed the regulatory requirements related to gas accumulation prevention.

Have potential pathways for gas intrusion in the CS/RHR system been evaluated? If so, identify the pathways. What features are present in the US-APWR design which prevent gas accumulation to ensure CS/RHR system operability? What design features and operating procedures include means for detecting and controlling gas accumulation?

Describe the ITAAC test conditions for the CS/RHR pumps, NPSH (Tier 1, Table 2.4.5-5, 8f) test. Explain why these test conditions are conservative especially with regard to gas entrainment and its effect on NPSH.

ANSWER:

This response revises and replaces MHI's initial response to RAI 464-3520, Question 05.04.07-11 submitted in MHI Letter UAP-HF-09511 dated November 4, 2009.

MHI has considered Generic Letter 2008-01 (Reference 1), as well as Nuclear Energy Institute (NEI) and the Institute of Nuclear Power Operations (INPO) recommendations, in the design of the US-APWR. The US-APWR design includes gas accumulation counter-measures that prevent or significantly mitigate gas accumulation in primary fluid systems as identified in industry documents (Reference 1, 2, and 3). Potential US-APWR sources of CS/RHR system gas accumulation include:

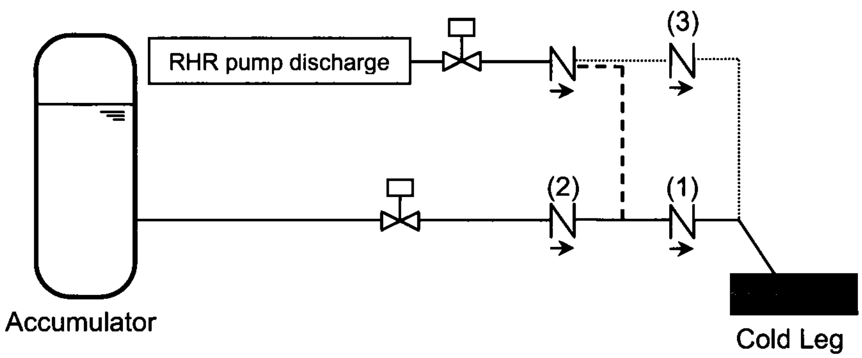
1) Nitrogen evolution from accumulator leakage into the RHR system
2) Air ingestion due to vortex formation during mid-loop operation
3) Inadequate venting during maintenance evolutions

US-APWR GAS ACCUMULATION MITIGATION DESIGN FEATURES

Accumulator

With regard to nitrogen evolution from accumulator leakage, the US-APWR design prevents this issue through the following features:

- In current PWR plants, the primary check valve (1) for the RHR and Accumulator system is shared, as shown by the dashed line in Figure 05.04.07-11A. If the water in the accumulator leaks through the secondary check valve (2) during normal power operation, gas accumulation from evolution of dissolved nitrogen in the accumulator fluid can occur in the upstream pipe of the check valve (2).
- In the US-APWR, the nozzles from the RHR pump discharge line to the RCS are separated from the accumulator injection line, as shown by the dotted line in Figure 05.04.07-11A. By this design, there are two check valves between the accumulator system and the RHR system, so potential accumulator leakage into the RHR system is decreased. (Ref: DCD Table 6.3-4, Sheet 10 of 11)
- The US-APWR uses independent primary check valves for the accumulator injection line (1) and RHR return line (3). In addition, there is a normally closed valve between the accumulator system and the RHR system because the RHR system is not used as a low head injection system.



Note: The dashed line shows the typical arrangement in operating plants.
The dotted line shows the US-APWR configuration.

Figure 05.04.07-11A

Accumulator system functional arrangement will be verified by US-APWR DCD Revision 3 Tier 1 Table 2.4.4-5, ITAAC 1.a.

Mid-Loop Operation

The RHR system is designed to prevent vortex creation in all modes of operation. Mid-loop operation considerations are discussed in DCD Tier 2 Section 5.4.7.1. Air ingestion caused by vortex creation during mid-loop operation is addressed by DCD Tier 2 Section 5.4.7.2.3.6, which describes mid-loop operation and operating parameter limits that prevent air ingestion during this mode. RHR pump operation will be verified by DCD Tier 1 Table 2.4.5-5 ITAAC #8.a and by preoperational testing described in DCD Tier 2 Section 14.2.12.1.22, which includes demonstration that vortex creation is prevented during mid-loop operation. This test is performed with the CS/RHR pump suction aligned to the RCS hot leg and the RCS water level at the minimum level for mid-loop operation. This is the bounding operating condition for vortex creation.

CS/RHR pump NPSH is verified by DCD Tier 1 Table 2.4.5-5 ITAAC #8.f and Table 2.11.3-5 ITAAC #7.c.

Inadequate Venting

GL 2008-01 describes gas voids caused by inadequate venting. Inadequate venting is attributed in GL 2008-01 to one or more of the following causes:

1) Inadequate Vent Capability – Vent valves were either not included in the design or were in the design but were not installed during construction.
2) Incorrect Vent Valve Location – Vent valve locations were either not properly designed or were properly designed but not installed in the correct location during construction.
3) Inadequate Human Interface – Adequate venting could not be accomplished due to vent valve locations that prevented access. For example, vent valves were inaccessible due to piping configurations, were located in high radiation areas, or could not be located.
4) Inadequate Venting Procedure – Vents were properly designed and constructed but the procedurally required venting process left gas voids in the system.
5) Human Performance Failure – Inadequate venting was caused by human error. Vent design, construction, and procedures were adequate but operators did not follow procedure.

US-APWR detailed piping design will include venting design features that adequately consider design inadequacies described by GL 2008-01. Adequate venting requirements, procedures, and adherence to procedures must be addressed by licensees.

US-APWR design features provided to address concerns discussed by GL 2008-01 include:

1) Specific design features such as:
   - Addition of vent valves or depressurization valves
   - Placement of vent valves in accessible locations
2) Proper venting instructions provided to US-APWR owners to be used in plant procedures

A simplified CS/RHR system diagram is shown in Figure 05.04.07-11B. This figure shows the CS/RHR system configuration and features provided to allow adequate venting. For example, CS/RHR piping is designed with a continuous slope. Dynamic venting procedures will sweep non-condensable gases from piping sections that are difficult to vent using static vent procedures, such as gas accumulation downstream of check valves.

DCD Subsection 3.9.6.2 in-service-testing includes periodic testing using full flow test lines that discharge to the RWSP (DCD Chapter 16 SR 3.6.6.2). These tests discharge voids to prevent binding of safety related pumps and minimize unacceptable dynamic effects, such as water hammer, to ensure suction and discharge line operability.

US-APWR detailed design will appropriately consider vent valves and piping layout to prevent gas accumulation voids and ensure adequate venting. Basic vent valve placement and piping layouts avoid gas accumulation in the following manner:

Vent Design Requirements

1) Vents will be located at piping high points. (Figure 05.04.07-11B)

2) Vents will be installed on upper pipe surfaces, not sides or bottom. (Figure 05.04.07-11C)

3) Horizontal piping runs will be sloped upward in direction of flow. (Figure 05.04.07-11B, -11D)

4) Vents will be installed at high points of inverted-U piping sections. (Figure 05.04.07-11E)

5) Pump suction piping will be connected on lower sides of inlet headers. (Figure 05.04.07-11F)

6) Vent accessibility will be assured by provision of adequate space, ladders, platforms, etc.

7) Vent areas will be thermally shielded to protect operators during venting operations.

8) Vent areas will be radiation shielded to protect operators during venting operations in accordance with ALARA principles.

9) Vent valves will be clearly identified by tagging.

10) Vent areas will be adequately lighted.

MHI 10CFR50 Appendix B qualified engineering design controls will verify vent design conformance with these requirements during detailed design. Construction inspections will verify that as-built vents are fabricated and constructed in accordance with approved design.

References

1. USNRC Generic Letter GL 2008-01, Managing Gas Accumulation In Emergency Core Cooling, Decay Heat Removal, And Containment Spray Systems, January 11, 2008
2. INPO 06-001, “Operating Experience to Apply to Advanced Light Water Reactor Designs,” March 2006
3. NEI 09-10, Rev. 0, “Guidelines for Effective Prevention and Management of System Gas Accumulation,” October 2009

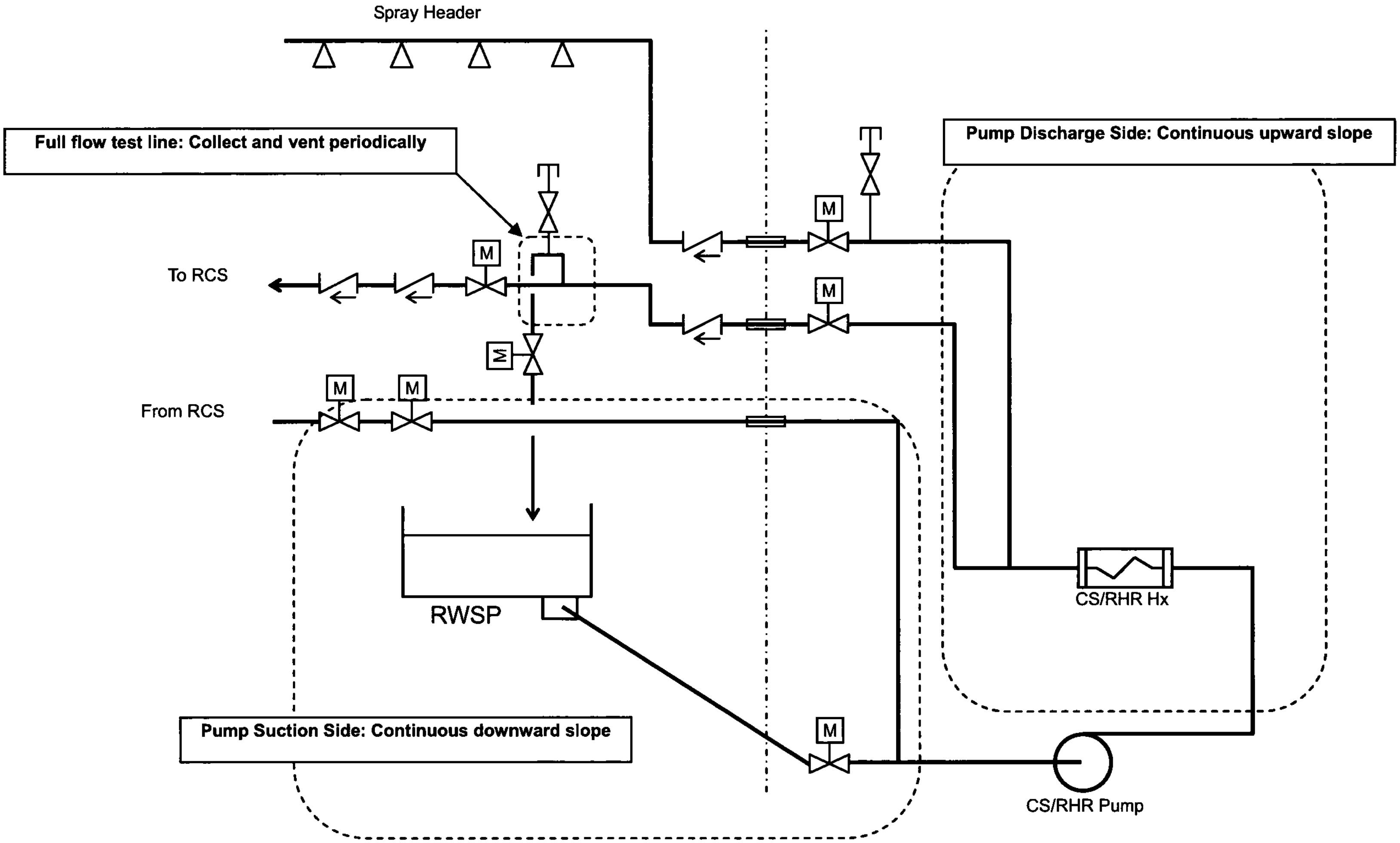


Figure 05.04.07-11B Simplified CS/RHR system diagram

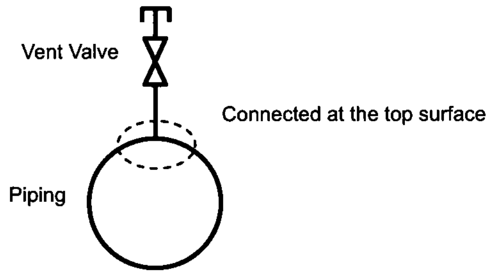


Figure 05.04.07-11C

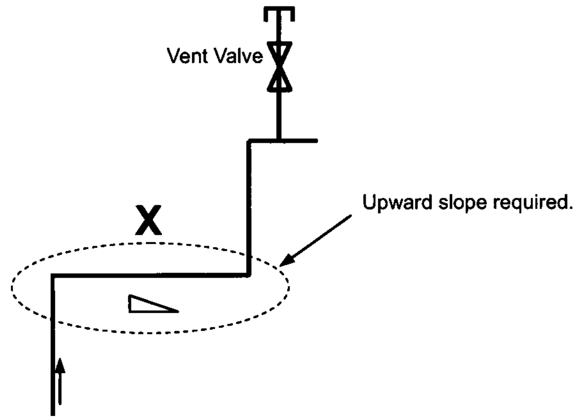


Figure 05.04.07-11D

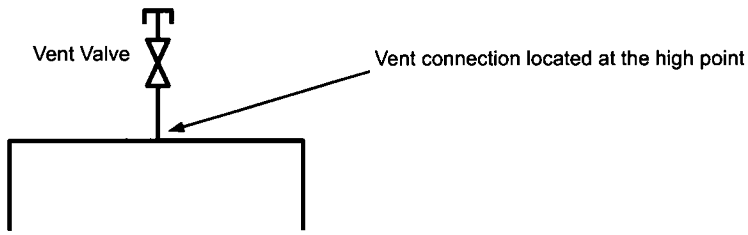


Figure 05.04.07-11E

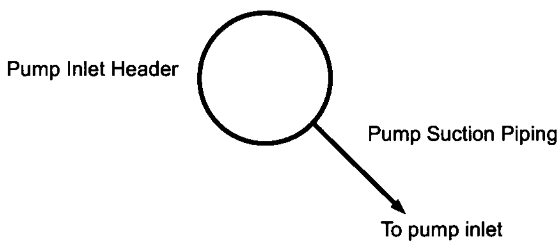


Figure 05.04.07-11F

Impact on DCD
There is no impact on the DCD.

Impact on R-COLA
There is no impact on the R-COLA.

Impact on S-COLA
There is no impact on the S-COLA.

Impact on PRA
There is no impact on the PRA.