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TOKYO, JAPAN

March 18, 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-11069

Subject: **MHI's Response to US-APWR DCD RAI No. 695-4934 Revision 2 (SRP Section 06.03)**

Reference: 1) "Request for Additional Information No. 695-4934 Revision 2, SRP Section: 06.03 – Emergency Core Cooling System Application Section: SRP 6.3" dated February 18, 2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 695-4934 Revision 2".

Enclosed are the responses to Question 06.03-88 through 06.03-97 that are contained within Reference 1.

As indicated in the enclosed materials, this submittal 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 Atsushi Kumaki (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 submittals. His contact information is below.

Sincerely,

Atsushi Kumaki for

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

D081
NRO

Enclosure:

1. Affidavit of Atsushi Kumaki
2. Response to Request for Additional Information No. 693-5428 Revision 2 (Proprietary Version)
3. Response to Request for Additional Information No. 693-5428 Revision 2 (Non-proprietary Version)

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

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Enclosure 1

Docket No. 52-021
MHI Ref: UAP-HF-11069

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Atsushi Kumaki, state as follows:

1. I am Group Manager, Licensing Promoting Group in 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 Response to US-APWR DCD RAI No. 695-4934 Revision 2 (SRP Section 06.03)", and have determined that portions of the document contain proprietary information that should be withheld from public disclosure. Those pages contain 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 technique of the US-APWR design.

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 MHI in their design of new nuclear power plants without incurring the costs or risks associated with the design 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 MHI in the U.S. nuclear plant market:

A. Loss of competitive advantage due to the costs associated with the empirical data obtained under MHI's chemical effects test program.

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 18th day of March 2011.

Atsushi Kumaki

Atsushi Kumaki,
Group Manager-Licensing Promoting Group in APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure 3

UAP-HF-11069
Docket No. 52-021

Responses to Request for Additional Information No. 695-4934
Revision 2

March 2011
(Non-Proprietary)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 695-4934 REVISION 2

SRP SECTION: 06.03 – EMERGENCY CORE COOLING SYSTEM

APPLICATION SECTION: 6.3

DATE OF RAI ISSUE: 2/18/2011

QUESTION NO.: 06.03-88

RAI 0.6.03-4-1 (DCD Section 6.3.2.2.5-1)

The pH of the ESF fluids is controlled during a DBA using NaTB baskets as a buffering agent. NaTB baskets are placed in the containment to maintain the desired postaccident pH conditions in the recirculation water. MHI's response to this RAI indicated that "DCD Section 6.3, Figure 6.3-10 shows the containment spray pattern on the floor where the NaTB baskets are installed. One spray pattern indicated in circle, regardless of its size, means that inside the circle is covered by the designed spray flow from one spray nozzle. The maximum spray flow rate that flows into the NaTB basket container was calculated by using conservatively larger number of these spray pattern circles which cover the container. Even if this conservatively estimated spray water flows into the container, the pressure loss in the transfer piping is lower than the difference of elevation between the container and RWSP, that is, the driving force to gravity injection. Therefore, the NaTB solution in the container does not overflow from the container to the outside of RWSP."

In response to RAI 6.3.2.2.5-1, MHI stated that if the driving head of the flow is greater than the corresponding pressure drop in the piping leading to the RWSP, then the basket will not overflow. The related questions are:

a. As stated in DCD Section 6.3.2.2.5 in the fourth paragraph that "The upper lips of the NaTB Basket Containers are approximately 1 ft. - 7 in. above the top of the NaTB baskets. This allows for the full immersion of the baskets and the optimum NaTB transfer to the RWSP." This indicates that the water level surrounding the NaTB must be maintained above the NaTB but below the top of the NaTB basket container. DCD Figure 6.3-12 appears to indicate that the fluid flow from the container is transferred through 6" piping that is submerged in the holding basket container and the pipe goes up from the lower part of the holding basket container to some point above the NaTB basket and through the basket container wall and down to the RWSP.

   1) Please provide a detailed description including elevations of this flow path and where it combines with the flow path from the other basket container (See DCD Figure 6.3-12). Provide a comparison of driving head and piping pressure loss and any relevant assumptions.

   2) Since the piping inlet for fluid removal from the basket container appears close to the bottom of the basket container, justify that debris cannot accumulate in the lower part of

the basket container and block the flow to the RWSP.

b. Under maximum flow conditions for the containment spray ring D can the flow into the NaTB basket container be great enough to overflow the container and spill into the containment deck? If so, discuss the potential for the flow to be diverted to a hold-up area and discuss the impact on RWSP pH.

c. What are the conservative flows into the NaTB container and what is the expected pressure drop through the piping to the RWSP? Provide the pressure drop and head comparison.

d. In Figure 6.3-12 Note 2 states "Raise the outlet piping to a level 4'-3" higher than the bottom of the NaTB basket container and layout piping with a down slope from the outlet piping to RWSP." Figure 6.3-11 indicates that the height of the NaTB basket is 4'-11". How do you know that you are getting enough water coverage on the NaTB baskets to satisfy the design basis of maintaining the correct pH of the RWSP? Provide a calculation or discussion that supports the claim that the NaTB baskets would be fully immersed during minimum flow conditions for the containment spray ring D.

ANSWER:

a.1) RAI Figure 6.3.88-1 shows flow paths from NaTB basket containers A, B, and C to RWSP with elevations. RAI Figure 6.3.88-1 also shows the flow rate of each path that is used to evaluate piping pressure loss. Please refer to the response to Item (c) below for the comparison of driving head and piping pressure loss, and relevant assumptions.

a.2) The piping inlets are provided between NaTB baskets in the container as shown in RAI Figure 6.3.88-2. There are no obstacles above the piping inlet at the bottom of container. Therefore, debris flows into the pipe inlet with the NaTB solution and is discharged into the RWSP without blocking the connection to the transfer pipe.

b. Spray water will not overflow from the NaTB basket container under the maximum flow conditions for the containment spray ring D. Please refer to the answer to Item (c) below for a quantitative evaluation.

c. Head loss of flow paths under the maximum spray flow conditions are evaluated as follows:

<u>Calculation conditions</u>

i) Flow rate into the container

Flow rate into each NaTB basket container is estimated based on the spray pattern shown in Figure 6.3-10 of DCD Ch. 6.3. The following assumptions are made to estimate a conservative maximum spray water flow rate:

- All spray water from one spray nozzle flows into the container, even though only partial flow from the spray nozzle of the spray ring C covers the container,
- Four CS/RHR pumps are in operation,
- The spray water flow into the refueling cavity is the product obtained by multiplying all spray water by the ratio of the refueling cavity opening and the containment sectional area, and additionally multiplying safety margin, [ ] to estimate a conservatively increase flow rate.

Spray water flowing into each NaTB basket container and refueling (RF) cavity based on the conditions described above are shown in Table 6.3.88-1.

ii) Piping pressure loss

Piping pressure loss is calculated by following Darcy's equation (Ref. 6.3.88-1):

$$h_{lineloss} = \sum f \cdot {}^{L}\!/\!_{D} \cdot \frac{v^2}{2g} + \sum K \cdot \frac{v^2}{2g} \qquad \text{(Equation 6.3.88-1)}$$

Where:

$h_{lineloss}$	:	Piping head loss (m)
f	:	Friction factor (-)
${}^{L}\!/\!_{D}$	:	Equivalent length of a resistance to flow, in pipe diameters (-)
v	:	Flow velocity (m/s)
K	:	Resistance coefficient (-)
g	:	Gravity acceleration (m/s^2)

Flow rate and piping pressure loss of each flow path is shown in RAI Table 6.3.88-2. The flow rate of each path is the same as that in RAI Figure 6.3.88-1.

iii) Driving head

The gravitational driving head from A, B, and C-container to the RWSP is [ ], which is the static head differential between the elevation of free surface in the container and the elevation of transfer pipe outlet end, [ ]. The elevation of the free surface is the elevation of the horizontal region of the inverse U-pipe attached to the container outlet header, [ ].

iv) Comparison of head loss and driving head

RAI Table 6.3.88-3 shows the comparison of the head loss of transfer pipe from A, B, and C-container to RWSP and the gravitational driving head.

Head loss of transfer line from each container to RWSP is smaller than the driving head; therefore, the spray water would not overflow from the container, even though a conservative maximum flow rate is assumed.

d. The height of NaTB basket is 3' -11", as shown in RAI Figure 6.3.88-3, not 4' -11" as shown in DCD Figure 6.3-11. DCD Figure 6.3-11 will be revised to include the correct value as shown below.

As shown in RAI Figure 6.3.88-4, the transfer piping exits from the bottom of the container and rises to the horizontal portion of the U-pipe. The bottom of the U-pipe is located [ ] inches higher than the top of the basket, the U-pipe is 8.625 inches in diameter, and the top of the U-pipe is approximately 4 inches below the top of the basket container. As shown in RAI Figure 6.3.88-4, the spray water flowing into the container need to overflow the bottom of the U-pipe to be transferred to the RWSP. Therefore, the water level in the container is maintained at the level 4 inches higher than the top of the basket even though the minimum flow conditions for the containment spray ring D, and the baskets are completely submerged in the spray water.

<u>Reference</u>

6.3.88-1 CRANE Technical Paper 410M, P. 3-4

RAI Table 6.3.88-1 Maximum Spray Flow Rate

RAI Table 6.3.88-2 (1/3) Flow Rate and Piping Pressure Loss
(From A-Container to RWSP)

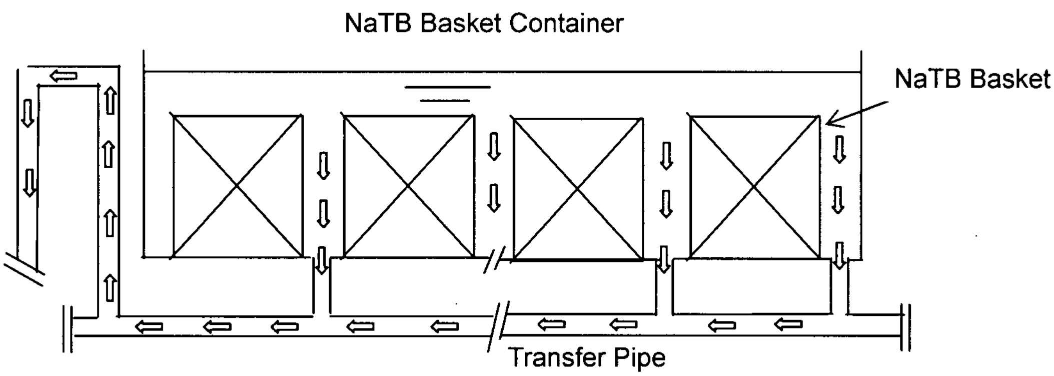
RAI Table 6.3.88-2 (2/3) Flow Rate and Piping Pressure Loss
(From B-Container to RWSP)

RAI Table 6.3.88-2 (3/3) Flow Rate and Piping Pressure Loss
(From C-Container to RWSP)

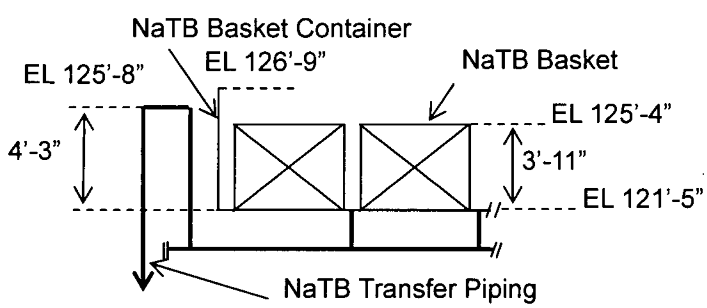
RAI Table 6.3.88-3 Comparison of Head Loss and Driving Head

[ ]

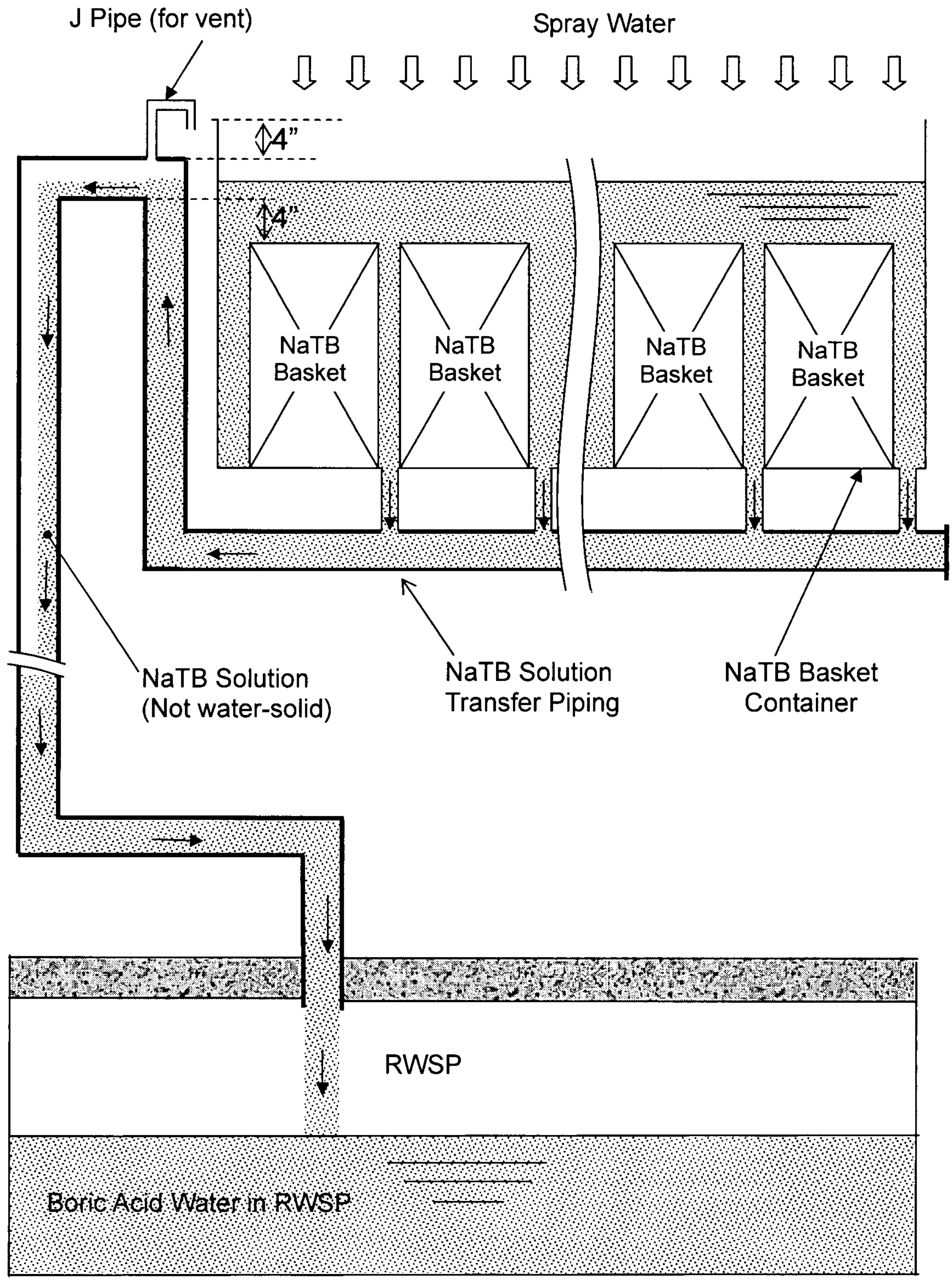
RAI Figure 6.3.88-1 NaTB Solution Transfer Piping Diagram



RAI Figure 6.3.88-2 NaTB Solution Flow Path



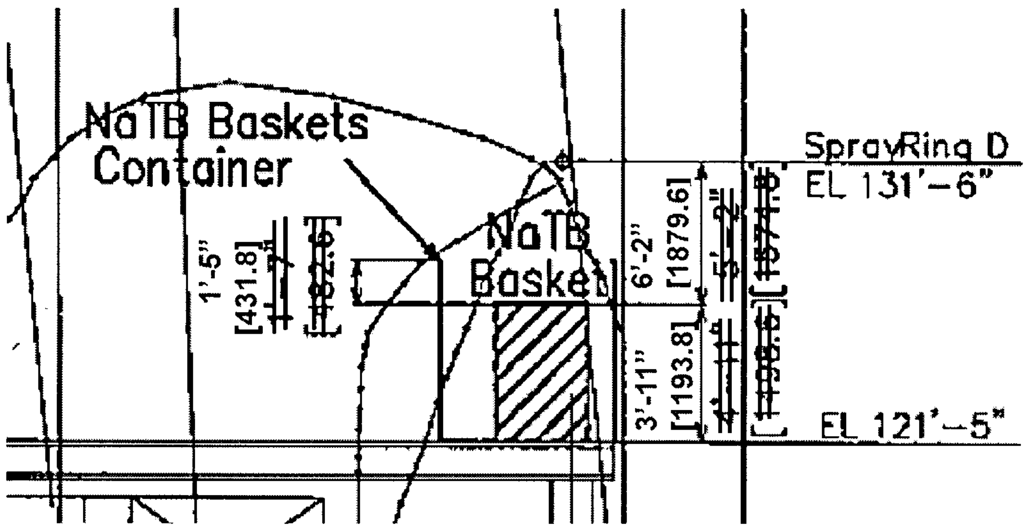
RAI Figure 6.3.88-3 Elevations around NaTB Basket



RAI Figure 6.3.88-4 NaTB Solution Flow during an Accident

Impact on DCD

Distances written in DCD Figure 6.3-11 will be corrected as shown below:



Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 695-4934 REVISION 2

SRP SECTION: 06.03 – EMERGENCY CORE COOLING SYSTEM

APPLICATION SECTION: 6.3

DATE OF RAI ISSUE: 2/18/2011

QUESTION NO.: 06.03-89

RAI 06.03-54-1 (6.3.3.1-1):

In its response to RAI 06.03-54, MHI provided the limiting conditions for operation (LCOs) for the Accumulators in TS 3.5.1. The staff asked, as a follow-up to MHI's response, to:

(a) Describe how the accumulator volume TS value (specified in gallons) is confirmed since only the accumulator pressure and level are know but not the temperature.

(b) Describe how the RWSP volume TS value (specified in gallons) is confirmed since only the RWSP pressure and level are know but not the temperature.

ANSWER:

(a) The accumulator volume TS value is confirmed using the accumulator water level instruments. The relationship between actual volume in the tank and indication of the accumulator water level instruments will be prepared during the detail design phase before fuel load. Therefore, operators can confirm actual water volume in the tank by using the accumulator water level instruments.

As for temperature of water in the tank, temperature does not significantly affect density since the water temperature of the accumulator does not vary significantly. The accumulator has no internal heat source, so the water temperature of the tank is considered to be equal to temperature of atmosphere in the containment vessel. The temperature of atmosphere in the containment vessel (C/V) is controlled below 120°F. In this temperature range, variation of water density is negligibly small.

(b) The RWSP volume TS value is confirmed using the RWSP water level instruments. The relationship between actual volume in the RWSP and indication of the RWSP water level instruments will be prepared during the detail design phase before fuel load. Therefore, operators can confirm the actual water volume in the RWSP by using the RWSP water level instruments.

As for temperature of water in the RWSP, temperature does not significantly affect density since the water temperature of the RWSP does not vary significantly. The RWSP has no internal heat source, so the water temperature of the RWSP is considered to be equal to temperature of atmosphere in the containment vessel. The temperature of atmosphere in C/V is controlled below 120°F. In this temperature range, variation of water density is negligibly small.

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 695-4934 REVISION 2**

SRP SECTION: **06.03 – EMERGENCY CORE COOLING SYSTEM**

APPLICATION SECTION: **6.3**

DATE OF RAI ISSUE: **2/18/2011**

QUESTION NO.: 06.03-90

RAI 06.03-28-1 (6.3.2.2-2):

In UAP-HF-09408 the following RAI response given was, "From the mechanism as shown in Figure 6.3.28-2, the following two conditions must be met for steam hammer generation:

Condition 1: Two-phase environment where vapor and liquid exist together

Condition 2: Steam void is surrounded by cold water

For the SI piping of the US-APWR, even if the condition 1 is realized, the condition 2 is not realized since the inner diameter of SI piping is as small as 3.44 inch and flow velocity is too high to form the separated flow of vapor and liquid as shown in Figure 6.3.28-2(2). Consequently, steam void is not entrained into liquid phase, and is pushed out without the steam hammer as shown in Figure 6.3.28-1 (2)." Please augment the discussion, and provide a reference, that includes details based on flow regime mapping (expected flow, pressure temperature ranges) to support this conclusion.

ANSWER:

As described in the previous response, water hammer does not occur in the SI piping of the US-APWR.

Since water hammer during injection occurs due to steam covered by water, it does not occur when piping is completely water-solid (i.e., zero void fraction). The laminar flow condition limit which corresponds to zero void fraction in piping cross-section (i.e., vapor-liquid separation does not occur) can be evaluated by using Froude number as shown in Equation 6.3.90-1 (Ref. 6.3.90-1):

$$Fr^2 = u_{l0}^2 / gd \geq 0.25 \qquad \text{Equation 6.3.90-1}$$

Where
Fr : Froude Number

u_{l0} : Absolute velocity when piping is water-solid

d : Diameter of the piping

g : Gravity

Representative conditions for SI piping during LBLOCA are shown as follows:

Pressure	: approx. 27 psia
Temperature	: approx. 240 deg F
Velocity	: approx. 43 ft/sec
Diameter of the SI piping	: 3.438 inches (inner diameter)

Froude Number of these conditions is approx. 14 and this value sufficiently exceeds the limit shown in Equation 6.3.90-1. This means the safety injection flow in the piping is in the water-solid condition, so the steam hammer, which would not make a large steam slug exist and induces a large pressure wave that may impact integrity of structures, does not occur.

In addition, flow regime mapping for horizontal piping is shown in Fig. 5 of Ref. 6.3.90-2. Even if steam and water flow simultaneously in the piping under the above condition, steam hammer will not occur because it is a dispersed flow condition in the piping.

For these reasons, steam hammer does not occur under accident conditions for the US-APWR.

<u>Reference</u>

6.3.90-1 Block J.A. Rothe P.M. Crowey C.J. Wallis G.B. Young C.R., An Evaluation of PWR Steam Generator Water Hammer:, NRC Report NUREG-0291,(1977)

6.3.90-2 Taitel Y. Dukler A.E.: A Model for Predicting Flow Regime Transition in Horizontal and Near Horizontal Gas-Liquid Flow, AIChE Journal, Vol.22, Issue 1 ,pp.47-55 (Jan 1976)

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 695-4934 REVISION 2**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-91

RAI 06.03-29-1 (6.3.2.2-3):

In UAP-HF-09408, RAI response 06.03-29 did not indicate that the DCD Tier 2 Section 6.3 would be modified to provide the description of the CCWS for SI pump cooling during an accident. The text of the RAI response should be added to DCD Tier 2 Section 6 to support a conclusion that the US-APWR design meets the GDC 35.

ANSWER:

MHI will add the description that is mentioned in RAI response 06.03-29 to DCD Subsection 6.3.2.2.1.

Impact on DCD

(Note: This mark-up includes "Impact on the DCD" of RAI responses to questions 06.03-91 and 06.03-92.)

DCD Subsection 6.3.2.2.1 will be revised as follows:

6.3.2.2.1 Safety Injection Pumps

The SI pumps are horizontal, multi-stage centrifugal type pumps **which are supplied with cooling water from the Component Cooling Water System (CCWS) and installed in the Safeguard Component Area in the reactor building**. The design flow of the SI pumps is 1,540 gpm at 1,640 ft. design head. The pumps are made of stainless steel. Figure 6.3-4 presents the SI pump characteristic curve. Table 6.3-5 presents the relevant SI pump data.

For an assumed large-break LOCA, the SI pumps are sized to deliver 2,113 gpm of injection flow following 180 seconds of small accumulator injection flow. The accumulator flow rates and sequence noted above, followed by this SI flow rate, ensure that the level in the reactor vessel downcomer is maintained for re-flooding the core. This SI pump flow rate is based on two SI pumps operating (active failure of one SI pump and one SI pump out of service), with each SI pump delivering 1,057 gpm against near atmospheric pressure.

For an assumed small-break LOCA, 757 gpm SI pump flow is required to maintain the core re-flooding conditions. This SI flow rate is maintained by one SI pump against 972 psig reactor pressure.

The design temperature of the SI pumps is 300°F, which is consistent with the design temperature of the containment. The RWSP, which is the water source of the SI pumps, is located in the containment. The design pressure of the SI pumps is 2,135 psig. This value provides margin to 2,028 psig, which is the sum of the design pressure of containment (68 psig) and the shutoff pressure of the SI pumps (1,960 psig).

During an accident, the CCWS supplying cooling water to the SI pumps is divided into four independent trains, and the failure of one CCWS train does not result in the simultaneous loss of function of more than two SI pumps. Also, during an accident, the Safeguard Component Area where the SI pump is installed is maintained in an adequate environmental condition by the Safeguard Component Area HVAC System. The Safeguard Component Area HVAC System consists of four trains of completely independent subsystems; therefore, the failure of one train does not result in simultaneous loss of SIS function of more than two trains.

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 695-4934 REVISION 2**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-92

RAI 06.03-30-1 (6.3.2.2-4):

In UAP-HF-09408, RAI response 06.03-30 did not indicate that the DCD Tier 2 Section 6.3 would be modified to provide the description of the HVAC for SI pump cooling during an accident. The text of the response should be added to DCD Tier 2 Section 6 to support a conclusion that the US-APWR design meets the GDC 35.

ANSWER:

MHI will add the description that is mentioned in RAI response 06.03-30 to DCD Subsection 6.3.2.2.1.

Impact on DCD

Please see the "Impact on DCD" section of the response to question 06.03-91.

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 695-4934 REVISION 2**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-93

RAI 06.03-37-1 (6.3.2.2-13)

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.

(1) Have potential pathways for gas intrusion into the safety injection system (SIS) and containment spray/residual heat removal system (CS/RHRS) been evaluated? If so, identify the pathways. What features are present in the US-APWR design to prevent gas accumulation to ensure SIS and CS/RHRS operability? Which design features (e.g., number and location of high point vents, piping slopes) are present for controlling gas accumulation?

(2) Describe the ITAAC test conditions for the SIS test (Tier 1 Table 2.4.4-5 Emergency Core Cooling System Inspections, Tests, Analyses, and Acceptance Criteria, Item 7.d Tests to measure the as built safety injection pump suction pressure will be performed. Inspections and analysis to determine NPSH available to each safety injection pump will be performed.). Explain why these test conditions are conservative especially with regard to gas entrainment and its effect on NPSH.

(3) Describe the ITAAC test conditions for the CS/RHRS test (Tier 1 Table 2.4.5-5 Residual Heat Removal System Inspections, Tests, Analyses, and Acceptance Criteria, and Acceptance Criteria, Item 8.f Tests to measure the as built CS/RHR pump suction pressure will be performed. Inspections and analysis to determine NPSH available to each CS/RHR pump will be performed.). Explain why these test conditions are conservative especially with regard to gas entrainment and its effect on NPSH.

Also, IN 2010-11 (ML100640465) discusses operating experience in which there was a potential for the RHR system to be inoperable due to steam voiding.

(4) How does the design of the US-APWR address this issue? Is it sufficient to use forced cooling through the RHR minimum-flow recirculation method of cooling for the US-APWR to prevent steam voiding or are additional procedures required to preclude the potential for steam voiding?

ANSWER:

(1) The following are potential pathways for gas intrusion in the US-APWR SIS and CS/RHRS:

- Open connections to the refueling water storage pit (RWSP) via SIS and CS/RHRS. (Such as pump suction lines and pump discharge lines)
- Open connections to the containment atmosphere via residual heat removal system (RHRS) suction lines during reactor coolant system (RCS) mid-loop operation (i.e., refueling).

The following design features prevent or control gas accumulation to acceptable levels:

- Pump suction piping is designed to be a continuous downward slope and does not include inverse slope which may trap or prevent venting of accumulated gases.
- Pump discharge piping is designed to be a continuous upward slope and does not include inverse slope which may trap or prevent venting of accumulated gases. Some portions of the piping such as downstream of the check valve in the pump discharge piping are difficult to vent statically, but the air in such portions will be removed by dynamic venting.
- Full-flow test lines are located at the high point of the SIS and CS/RHRS and discharge into the RWSP. Periodic dynamic venting will be applied to the SIS and CS/RHRS. In-service testing required by DCD Subsection 3.9.6.2 includes periodic testing through the full flow test lines, which discharge to the RWSP (DCD Chapter 16 SR 3.6.6.2). These tests periodically discharge voids, minimize unacceptable dynamic effects such as water hammer, and ensure operability of the suction and discharge lines.
- Sump strainers are installed in the RWSP to prevent vortex formation when the SI pumps and CS/RHR pumps are taking suction from the RWSP.

(2) ITAAC test conditions for SIS test will be done at minimum RWSP water level in case of an accident. Lowest water level of the RWSP is the most conservative with regard to gas entrainment (i.e., vortex) and NPSH.

(3) ITAAC test conditions for a CS/RHR pump test will be done at minimum RWSP water level in case of an accident. Lowest water level of the RWSP is the most conservative with regard to gas entrainment (i.e., vortex) and NPSH. With regard to vortex, mid-loop operation is the most severe condition for a CS/RHR pump since the distance between CS/RHR pump suction nozzle on the main coolant pipe and water surface is the smallest. Tier 1 Table 2.4.5-5, Item 8a.ii shows ITAAC for this operation mode. Therefore, current ITAAC covers the conservative conditions with regard to gas entrainment and its effect on NPSH.

(4) Appropriate countermeasures to this issue such as appropriate procedures will be developed to preclude the potential for steam voiding. In the view point of the procedure, for example, in the start up operation, three of four trains of the RHR system will be isolated from the RCS before entering Mode 4. One train will remain in operation as RHR system. The other three trains will be standby as CSS. Such appropriate countermeasures will be developed in the detailed design phase.

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 695-4934 REVISION 2**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-94

RAI 06.03-55-1 (6.3.3.1-2):

Justify why the LBLOCA analysis range only covers RWSP temperature down to 45 °F while T.S. SR 3.5.4.1 states a minimum RWSP temperature of 32 °F. Should the T.S. SR be revised to reflect the safety analysis value of 45 °F? Include the effects of temperature on the boron precipitation in the RWSP.

ANSWER:

The applicable range of the thermodynamic properties in the WCOBRA/TRAC (M1.0) code used in the LBLOCA analysis is ≥ 280 K (Ref. 6.3.94-1). Therefore, the LBLOCA analysis assumes that the range of the safety injection (SI) water temperature is 45 °F ≤ T_{SI} ≤ 120 °F in DCD Revision 2.

The temperature range in the LBLOCA analysis does not cover the temperature range stated in T.S. SR 3.5.4.1. However, it is not necessary to have a decreased lower bound RWSP water temperature of 32°F because the LBLOCA analysis with the RWSP water temperature range of 45 °F ≤ T_{SI} ≤ 120 °F adequately captures the safety evaluation results of peak cladding temperature (PCT), local maximum oxidation (LMO) and core wide oxidation (CWO) for the US-APWR. That is, the RWSP water does not have an impact on PCT in LBLOCA analysis space as safety injection (SI) is conservatively assumed to start after the PCT occurs. The effects of SI water temperature on LMO and CWO are expected to be small, and higher water temperature phenomenologically provides more conservative results. In addition, the minimum containment pressure that is a boundary condition in the LBLOCA analysis is evaluated with the condition of the RWSP water temperature of 32°F.

Therefore, the LBLOCA analysis described in DCD Chapter 15 covers the results in the RWSP temperature range of 32 °F ≤ T_{SI} ≤ 120 °F. The RWSP temperature range in T.S. SR does not need to be revised.

As for the effect of temperature on boron precipitation in the RSWP, there is no effect as precipitation does not occur in the RWSP, even at the lower limit of 32°F.

Reference

6.3.94-1 T. Suzuta, *et al.*, "Large Break LOCA Code Applicability Report for US-APWR," MUAP-07011-P (R0), July 2007.

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

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SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-95

RAI 06.03-13-1 (6.3.1.4-9):

In UAP-HF-09408 the RAI response indicated that Generic Letters and Bulletins BL 01- 01 and BL 02-01 will be addressed in DCD Section 5.2.4. Revise DCD Table 6.3-4 referring to BL 01-01 and BL 02-01 such that it points to the ISI plan.

ANSWER:

Table 6.3-4 will be revised to add a reference to the ISI for the reactor vessel head.

Impact on DCD

Table 6.3-4 (Sheet 12 of 15) will be revised as follows:

BL 01-01; US-APWR Design
N/A
RV head does not have penetration for safety injection in the US-APWR.
ISI for the reactor vessel head is discussed in Subsection 5.2.4.

BL 02-01; US-APWR Design
N/A
RV head does not have penetration for safety injection in the US-APWR.
ISI for the reactor vessel head is discussed in Subsection 5.2.4.

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 695-4934 REVISION 2**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**2/18/2011**

QUESTION NO.: 06.03-96

RAI 06.03-87 (6.3.4.1-10):

(1) Provide a description of how the temperature is controlled in the RWSP? Is there a high temperature alarm for the RWSP? Provide a description of the RWSP system components controls, including temperature controls.

(2) Section 6.3.5.4 states that there is a low temperature alarm for the RWSP, but does not state that there is high temperature alarm. Provide a justification of why a high temperature alarm is not necessary for the RWSP.

(3) Where does the DCD discuss how the RWSP level instrumentation and alarms are tested?

ANSWER:

(1) Plant Technical Specifications specify the lowest RWSP temperature limit as 32°F. 32°F is the freezing point of water; therefore, RWSP water temperature does not decrease below this temperature limit.

The RWSP is located at the lowest part of the containment, and there is no heat source in the pit. Heat transferred from the containment air space is the only method to increase the RWSP water temperature during normal plant operation. Therefore, the RWSP water temperature during normal operation is usually maintained at a temperature less than or equal to the temperature of containment air space, which is controlled by the containment recirculation cooling units. The highest temperature limit of the RWSP is consistent with that of the containment air space, 120°F; therefore, no specific temperature control is needed to maintain the RWSP water temperature within the limit.

High temperature alarm is not provided for the RWSP.

(2) The high temperature alarm is not provided for the RWSP for the following reasons:
As described in (1), the RWSP water temperature is usually maintained at less than or equal to the containment air temperature during normal plant operation, and the highest temperature limit of the RWSP water temperature is consistent with that of the containment air temperature. Therefore, if the containment air temperature is lower than the limit prescript in Tech Spec

3.6.5, then the RWSP water temperature is also maintained at lower than the limit.

(3) Inspection and testing methods for the RWSP water level instrumentation and alarms are described in DCD Ch. 14, "VERIFICATION PROGRAM", Subsection 14.2.12.1.59, "Refueling Water Storage System Preoperational Test."

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

3/17/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 695-4934 REVISION 2

SRP SECTION: 06.03 – EMERGENCY CORE COOLING SYSTEM

APPLICATION SECTION: 6.3

DATE OF RAI ISSUE: 2/18/2011

QUESTION NO.: 06.03-97

RAI 06.03-88 (6.3.4.1-8):

For test 14.2.12.1.57, how does a "partially pressurized" accumulator satisfy the test Acceptance Criteria to demonstrate the discharge performance in the design specifications since the RCS is open and at atmospheric pressure?

ANSWER:

The purpose of the accumulator injection test is to confirm if the accumulator flow characteristics are appropriate for the safety analysis. The safety analysis uses the accumulator flow damper characteristic equation (the relationship between cavitation factor and flow coefficient). During the injection test, cavitation factor and flow coefficient are calculated using various measured parameters, and are verified to be within the expected limits.

The flow coefficient was obtained from the full-height and 1/2 scale test, which was performed under the conditions simulating pre-operational testing of the prototype. These conditions were verified to sufficiently cover the flow characteristics during an accident. (Refer to p.4.2.4-10 of the Ref. 6.3.97-1, "Results of the Test Assuming Pre-Operational Test Conditions.")

Reference

6.3.97-1 MUAP-07001-P (R2) THE ADVANCE ACCUMULATOR

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.