MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

October 14, 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-10276

Subject: MHI's Responses to US-APWR DCD RAI No.626-4750 Revision 0

References: 1) "Request for Additional Information No. 626-4750 Revision 0, SRP Section: 06.03 – Emergency Core Cooling System Application Section 6.2.2 and 6.3" dated August 30, 2010.

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. 626-4750 Revision 0".

Enclosed is the response to 06.03-87 that is 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.

Enclosure:

1. Response to Request for Additional Information No. 626-4750 Revision 0

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

Contact Information
C. Keith Paulson, Senior Technical Manager
Mitsubishi Nuclear Energy Systems, Inc.
300 Oxford Drive, Suite 301
Monroeville, PA 15146
E-mail: ck_paulson@mnes-us.com
Telephone: (412) 373-6466

D081
NRO

Enclosure 1

UAP-HF-10276
Docket Number 52-021

Response to Request for Additional Information
No. 626-4387 Revision 0

October, 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/14/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 626-4750 REVISION 0**
SRP SECTION:	**06.03 – EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.2.2 AND 6.3**
DATE OF RAI ISSUE:	**8/30/2010**

QUESTION NO.: 06.03-87

RG 1.82 Revision 3 position 1.3.1.1 states:

> ECC and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps, assuming the maximum expected temperature of pumped fluid and no increase in containment pressure from that present prior to the postulated LOCA.
>
> For sump pools with temperatures less than 212F, it is conservative to assume that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for the containment pressurization during the transient.

NRC Standard Review Plan (SRP) 6.2.2, "Containment Heat Removal Systems" (NUREG-0800, Revision 5, dated March 2007) states that RG 1.82, Revision 3 describes methods acceptable to the staff for evaluating NPSH. SRP 6.3, "Emergency Core Cooling System" states that the design of the ECCS should conform to the recommendations of Regulatory Guide 1.1. (Note, RG 1.1 regulatory position is incorporated into RG 1.82 Revision 3.)

US APWR DCD Table 1.9.1-1 shows that US APWR conforms to RG 1.82 Revision 3.

In DCD Table 6.2.2-2 MHI addresses RG 1.82 position 1.3.1.1 as follows:

> Post-LOCA containment pressure is not credited for US-APWR NPSH evaluation of ECC and containment heat removal systems.

However, in MUAP-08001-NP, Revision 2, MHI states that

> For the minimum NPSH available calculation...containment pressure is assumed to equal the saturation pressure corresponding to the sump water temperature.

During a recent NPSH audit, it was confirmed that the NPSH calculations assume containment pressure is equal to the saturation pressure corresponding to the sump water temperature.

Given that US APWR postulated post accident peak sump temperature is reported to be around 250F, the corresponding vapor pressure is close to 30 psia. RG 1.82 clearly indicates that equating containment pressure to vapor pressure is conservative for sump temperatures less

than 212F. Given that US APWR sump temperatures are well above 212F, equating containment pressure to vapor pressure does not meet regulatory guidance recommendations.

To conform to the referenced guidance it is necessary that the proper performance of emergency core cooling and containment heat removal systems be independent of calculated increases in containment pressure caused by postulated loss of coolant accidents.

The alternative approach described by MHI in MUAP 08001 (use of saturation pressure in NPSH analysis) is inconsistent with the US APWR DCD commitment to follow RG 1.82, Revision 3 (for US-APWR, expect pressure around atmospheric pressure for NPSH analysis). MHIs alternative approach did not address the basic premise behind the regulatory criteria and did not evaluate how their alternative to the SRP (RG) criteria provides an acceptable method of complying with NRC regulations. Additional information is needed to complete a safety finding that is clearly tied to 10CFR 50.46(b)(5). Therefore the staff requests that MHI justify why the selected approach, use of containment accident pressure (CAP) to support ECCS NPSH analysis is acceptable.

ANSWER:

The approach used by MHI in MUAP-08001 (use of saturation pressure in NPSH analysis) is consistent with the intent of RG 1.82, Revision 3. The discussion below further clarifies how the approach complies with all NRC regulations.

RG 1.82 Rev. 3 (referenced by SRP 6.2.2), Position 1.3.1.1 states:

- ECC and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps, assuming the maximum expected temperature of pumped fluid and no increase in containment pressure from that present prior to the postulated LOCA. (See Regulatory Position 1.3.1.2.)

  For sump pools with temperatures less than 212 °F, it is conservative to assume that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for the containment pressurization during the transient.

Saturation Temperature at Initial Containment Pressure

For the purpose of NPSH evaluations and the discussion below, the saturation temperature at the nominal initial containment pressure (212°F at 14.7 psia) is adjusted based on US-APWR Technical Specification limits for the minimum initial containment pressure (-0.3 psig). In addition, the initial containment pressure is further reduced to conservatively neglect the vapor pressure (1.7 psia) at the maximum Technical Specification initial containment temperature (120°F). This corresponds to a minimum initial containment air partial pressure of 12.7 psia and a corresponding saturation temperature of 204°F. This is consistent with RG 1.82 Rev. 3 and accurately models the US-APWR design condition.

NPSH Available ($NPSH_A$) at Sump Temperatures above 204°F

The $NPSH_A$ determination at containment sump temperatures above 204°F is consistent with the intent of the guidance provided by RG 1.82 Position 1.3.1.1. It is not, however, consistent with the specific wording of the RG. For $NPSH_A$ determinations at high containment temperatures (i.e., above 204°F), it is assumed that the containment pressure is equal to the saturated vapor pressure of the sump water since conditions inside containment will be saturated. This recognizes the physical fact that at fluid temperatures above 204°F the containment pressure has to be greater than at -0.3 psig (the initial containment pressure), otherwise the fluid will boil.

The US-APWR meets the intent of RG 1.82 Rev. 3 in the following manner:

- The assumption of saturated conditions inside containment at high sump temperatures is appropriate and reasonable. The assumption of saturated conditions is conservatively bounded by the actual accident containment pressure, i.e. the saturation pressure is at all times less than the containment pressure during all design basis LOCA conditions and is therefore appropriate. This assumption minimizes $NPSH_A$. The assumption of saturated conditions inside containment at high sump temperatures is reasonable as it is consistent with the thermo-dynamic properties of water and takes no credit for any outside influences.

- Design changes required to strictly meet the wording stated in Position 1.3.1.1 of RG 1.82 Rev. 3 for temperatures above 204°F ("assuming the maximum expected temperature of pumped fluid and no increase in containment pressure from that present prior to the postulated LOCA") would be impracticable or otherwise negatively affect overall system health. Design changes would necessitate providing either an additional design source of pressure to keep the containment fluid from boiling or vast quantities of additional fluid to account for both surface and sub-surface boiling at 14.7 psia.

- The contribution to plant risk from inadequate containment pressure at high sump fluid temperatures (i.e., rapid depressurization due to impaired containment integrity or operation of containment heat removal systems at too high a rate) is negligible.

Containment Pressure during LOCA

During LOCA and post-LOCA conditions for the US-APWR, containment pressure always exceeds the saturated steam pressure at the RWSP liquid temperature, due to the US-APWR design and strong phenomenological correlations for the postulated LOCA described below.

During a LOCA, mass and energy are released from the primary system to both the vapor phase (containment atmosphere) and to the RWSP (liquid phase) inside the containment volume. Steam released from the primary system postulated break maintains the containment atmosphere at saturated conditions during almost all parts of the LOCA transient. Also, fluid condensed by passive heat sinks (such as the containment shell liner, supporting structures and concrete) and the containment sprays is added to the RWSP. During the accident, the RWSP vapor phase will be at the saturated temperature corresponding to the steam pressure in the containment atmosphere. Over the long-term, the RWSP liquid temperature is strongly affected by the liquid water condensed from the atmosphere during the containment spray operation. This condensed water is also saturated at the steam pressure. Therefore, a higher containment pressure provides higher temperature condensed water, and higher RWSP liquid temperatures. Similarly, a lower containment pressure provides lower temperature condensed water and a lower RWSP liquid temperature. For the purposes of ECCS pump $NPSH_A$ determinations, based on these phenomenological correlations, the US-APWR RWSP vapor saturation pressure (based on RWSP liquid temperature) will not exceed the containment pressure for any postulated DBA.

MHI considers the proposed methodology to be appropriate and conservative under all accident conditions for the following reasons:

- Anticipated Accident Conditions – As mentioned above, the containment RWSP water temperature used for the $NPSH_A$ evaluation is dependent on the mass and energy release time-history and mixing with the condensed water flow from containment sprays, which is dominated by the containment atmospheric vapor saturation pressure. As a result, there are no situations where a rapid containment depressurization can induce RWSP water boiling at any given RWSP liquid temperature, even assuming a conservative minimum containment pressure.

- Saturated Conditions – There are no heat sources in the RWSP that would change local temperature or pressure conditions. Furthermore, containment spray injection occurs at post-LOCA. Therefore, it is appropriate to assume that the containment atmospheric conditions are saturated.

Containment pressure is at all times above the saturation pressure at the RWSP liquid temperature. Therefore, the assumption that containment pressure and RWSP vapor pressure are equal (to the saturation pressure at the RWSP liquid temperature) when evaluating $NPSH_A$ is appropriate and conservative for the US-APWR recirculation system.

Contribution to Plant Risk

In the evaluation of $NPSH_A$, containment pressure is assumed to be equal to the RWSP fluid vapor temperature for high sump fluid temperatures (greater than 204°F). A rapid depressurization of containment during this period could potentially cause a loss of sufficient NPSH margin.

The evaluation to assess the contribution to plant risk from inadequate containment pressure during periods of high sump temperatures during post-LOCA operation was performed and addresses the five key principles of risk-informed decision making of RG 1.174 Rev. 1. The assessment evaluates the maximum time that the RWSP temperature is above 204°F; identifies potential events which may cause a loss of containment pressurization; and evaluates the contribution to plant risk from the most limiting event, a failure of containment isolation. The assessment concludes that the frequency of the sequence is two orders of magnitude lower than the core damage frequency described in Chapter 19 of the DCD and is therefore considered negligible. This assessment and the elements noted above will be included in the next revision to the strainer technical report.

Based upon the above discussion, MHI believes that its approach used to assess the $NPSH_A$ for ECCS pumps (including the use of containment accident pressure (CAP) in the ECCS NPSH analysis) is acceptable, consistent with the intent of RG 1.82 Revision 3, and complies with all NRC regulations.

Impact on DCD

There is no impact on the DCD. MUAP-08001, Revision 2, will be revised to clarify the methods that are used to assess $NPSH_A$ of the ECCS pumps. The evaluation to assess the contribution to plant risk from inadequate containment pressure during periods of high sump temperatures during post-LOCA operation will be included in the next revision to the technical report.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.