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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-11274

Subject: MHI's Responses to US-APWR DCD RAI No.783-5855 Revision 0 (SRP 19)

References: 1) "Request for Additional Information No. 783-5855 Revision 0, SRP Section: 19 – Probabilistic Risk Assessment and Severe Accident Evaluation," dated July 25, 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. 783-5855 Revision 0".

Enclosed are the responses to all of the RAIs 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.

D081
NRO

Enclosure:

1. Responses to Request for Additional Information No. 783-5855 Revision 0

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-11274
Docket Number 52-021

Responses to Request for Additional Information No.783-5855
Revision 0

August, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

08/24/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.: **NO. 783-5855 REVISION 0**

SRP SECTION: **19 – Probabilistic Risk Assessment and Severe Accident Evaluation**

APPLICATION SECTION: **19**

DATE OF RAI ISSUE: **07/25/2011**

QUESTION NO.: 19-546

The staff has reviewed the applicant's response to RAI 19.01-9. In Table 19.1-119, Key Insights and Assumptions, of the US-APWR DCD, Revision 3. It states, "nitrogen will not be injected in the SG tubes to speed draining in the US-APWR design. The SG will be filled with air during midloop." MHI stated that the pressurizer spray vent valve, which is 3/4 inch in diameter, provides a sufficient vent path during RCS draining such that the possibility of negative RCS pressure caused by the limited size of the RCS vent path during draindown does not restrict drainflow.

Given the information provided by MHI at the PRA public meeting in June 2011, the staff requests that the applicant provide: (1) the results of an NPSH calculation that demonstrate that the CS/RHR pumps have adequate NPSH given a vacuum in the pressurizer during draining to midloop conditions and (2) the results of a calculation that demonstrate that the anticipated RCS vacuum conditions do not impact the ability to remove the steam generator manways which is planned to occur before removal of three pressurizer safety valves.

ANSWER:

(1) CS/RHR Pump NPSH Available:

The results of the NPSH available calculation when draining to mid-loop conditions given a vacuum in the pressurizer are summarized as follows:

a) Assumptions:

- Water level is conservatively assumed to be at the center of the reactor coolant loop piping (EL 40.4ft).

- Pressure head is conservatively assumed to be 0 ft (absolute).

- Water temperature is assumed to be 140 deg F (representative temperature during mid-loop operation)

b) Calculation:

NPSH available is defined as follows;

NPSH available = Pat + EL – Hp – Pv

Where
Pat: Absolute pressure head (RCS pressure; conservatively assumed to be 0 ft)
EL : Elevation head (From loop center to CS/RHR pump center; 62.7 ft)
Hp : Form and frictional head loss (Suction piping et al; 25.4 ft)
Pv : Vapor pressure at prevailing water temperature converted to head (0.7 ft at 140F)

Therefore, NPSH available = 0 + 62.7 – 25.4 – 0.7 = 36.6 ft

Since the NPSH required for the CS/RHR pump is 16.4 ft, the NPSH available will be sufficient during mid-loop conditions.

c) Conclusion:

NPSH available for the CS/RHR pump is sufficiently greater than NPSH required given a vacuum in the pressurizer during draining to mid-loop conditions.

(2) Steam Generator Manway RCS Vacuum Conditions

MHI believes that there is no need to perform this calculation for the following reasons.

As described in US-APWR DCD Figure 19.1-23, mid-loop operation before refueling consists of the following steps:

1. Opening the pressurizer spray line vent valve, so that it acts as a RCS vent path (Before POS 4-1)

2. RCS drained via the chemical and volume control system (CVCS) (POS 4-1A)

3. SG tube drain (POS 4-1B)

4. Removal of SG manways on the H/L side, followed by removal of manways on the C/L side (End of POS 4-1)

5. Removal of at least three pressurizer safety valves (during POS 4-2)

Both the RCS and the SG tube drain steps are completed prior to removal of the first SG manways. During SG tube drain, which takes several hours, the RCS is vented by the pressurizer spray line vent valve. Because there would be a sufficient amount of time to allow for equalization of the RCS pressure with the containment atmospheric pressure prior to the removal of the SG manways, it is not anticipated that a vacuum condition within the RCS would affect the ability to remove the SG manways.

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.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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SRP SECTION: **19 – Probabilistic Risk Assessment and Severe Accident Evaluation**

APPLICATION SECTION: **19**

DATE OF RAI ISSUE: **07/25/2011**

QUESTION NO.: 19-547

Chapter 19 of the DCD, Revision 3, states: "The assumptions of success criteria specific to the LPSD PRA are as follows:

When the RCS is atmospheric pressure (i.e., POS 4-2 and POS 8-2), it is assumed that the gravity injection from SFP is effective. The gravity injection from SFP is established by opening the injection flow path from SFP to RCS cold legs, and the water supply path from the RWSP to SFP. The validity of this function is determined by engineering judgment based on the previous RPA studies.

When the RCS is in mid-loop operation at the closed state (i.e., POS 4-1 and POS 8-3), it is assumed that the reflux cooling with the SGs is effective. The validity of this function is determined by engineering judgment based on previous PRA studies."

The justification for gravity injection and reflux cooling should not be determined by engineering judgment based on previous PRA studies, since the feasibility of gravity injection and reflux cooling are based on specific RCS configurations that vary according to different reactor designs. Rather, the feasibility of reflux cooling and gravity injection must be based on APWR design specific analyses. The staff is requesting that the applicant update the DCD and PRA to describe the results of analyses that were performed to justify the feasibility of gravity injection and reflux cooling.

ANSWER:

MHI has conducted a system analysis and determined that the SG manways openings can serve as a RCS vent path ensuring that the RCS is maintained at atmospheric pressure. Refer to the MHI letter UAP-HF-10345, RAI Response 19-492. Additionally, MHI has calculated that the minimum flowrate between the SFP and RCS substantially exceeds the loss of RCS inventory as vapor escapes the RCS.

Regarding SG reflux cooling, MHI letter UAP-HF-08260, RAI Response 19-45, describes the results of a SG reflux calculation which determined the temperatures, pressures, time to boil, and operator actions during the first twenty four hours following of the event.

MHI will revise the DCD discussion regarding the feasibility for using gravity injection from the SFP and SG reflux cooling during mid-loop operation, by replacing "engineering judgment based on previous PRA studies" with the text provided in the attached markup.

Impact on DCD

DCD Section 19.1.6 will be revised, shown in the attached mark-up. (See Attachment-1.)

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.

Following blackout sequence, CCW pumps and essential service water pumps automatically start (or re-start) up after power is supplied to the Class 1E ac bus. If this function fails, the mitigation systems cooled by CCWS are unavailable.

The other top events are the same as described previously for a LOCA or LOCS.

The process of FT analysis is same as for the Level 1 internal events PRA at power (see Subsection 19.1.4.1.1).

Core damage for the LPSD PRA is defined as uncovery of reactor core. Either decay heat removal functions or RCS inventory make-up functions can prevent core damage, regardless of containment cooling.

The assumptions of success criteria specific to the LPSD PRA are as follows:

- When the RCS is at atmospheric pressure (i.e., POS 4-2 and POS 8-2), it is assumed that the gravity injection from SFP is effective. The gravity injection from SFP is established by opening the injection flow path from SFP to RCS cold legs, and the water supply path from the RWSP to SFP. The validity of this function is determined by ~~engineering judgment based on the previous PRA studies~~a system analysis and calculations determining the loss of RCS inventory due to boiling as a function of time and the minimum gravity injection flowrate at atmospheric pressure. DCD_19-547
- When the RCS is in mid-loop operation at the closed state (i.e., POS 4-1 and POS 8-3), it is assumed that the reflux cooling with the SGs is effective. The validity of this function is determined by ~~engineering judgment based on previous PRA studies~~calculating peak RCS temperatures and pressures during various mid-loop POS scenarios as a function of time with consideration of the time required for successful operator mitigative actions. DCD_19-547
- Containment cooling function is unnecessary to prevent core damage and to sustain RCS injection due to allowable time until core uncovery and lower decay heat level.
- The success criteria of mitigation functions for LPSD PRA are established based on the engineering judgment, taking into account the similar success criteria of level 1 PRA at power, the decay heat, plant configuration and so on. As an example, the success criteria for each system for POS 4-3 and POS 8-1 are respectively given in Table 19.1-142 and Table 19.1-85.

The method for human error analysis is the same as for the Level 1 internal events PRA at power (see Subsection 19.1.4.1.1). Detailed analysis by THERP method was performed for human errors associated with a LOCA and a loss of RHR due to OVDR event.

The system fault trees are quantified and the results of the quantification are fault tree cutsets and system unavailability. The fault trees are quantified using the same methods that were followed in quantifying the Level 1 internal events PRA at power (see Subsection 19.1.4.1.1).

c. In case the RCS water level decreases during mid-loop operation and the failure of automatic low-pressure letdown isolation valve occurs, operator will perform the manual isolation of low-pressure letdown line.

d. When the RCS is at atmospheric pressure, gravity injection from SFP is effective. Operator will perform the gravity injection by opening the injection flow path from SFP to RCS cold legs, and supplying water from RWSP to SFP. The validity of this function is determined from ~~previous PRA studies~~a system analysis and calculations determining the loss of RCS inventory due to boiling as a function of time and the minimum gravity injection flowrate at atmospheric pressure. DCD_19-547

e. When the RCS is mid-loop operation with the closed state, it is assumed that the reflux cooling with the SGs is effective. The validity of this function is determined from ~~the previous PRA studies~~calculating peak RCS temperatures and pressures during various mid-loop POS scenarios as a function of time with consideration of the time required for successful operator mitigative actions. DCD_19-547

f. The success criteria of mitigation functions for LPSD PRA are established based on the engineering judgment, taking into account the similar success criteria of level 1 PRA at power, the decay heat, plant configuration and so on.

g. Various equipments will be possible temporary in the containment during LPSD operation for maintenance. However, there are few possibilities that these materials fall into the sump because the debris interceptor is installed on the sump of US-APWR. (see Chapter 6, Subsection 6.2.2) Therefore, potential plugging of the suction strainers due to debris is excluded from the PRA modeling.

h. During plant shutdown, the operability of I&C systems used for mitigation functions such as RHR, charging injection, RWSAT replenishment by refueling water recirculation pump are frequently checked through maintenance activities and evolution of plant operating states. Local I&C equipments of these components as well as the safety logic system can be checked and the I&C hardware are considered to be reliable during plant shutdown. Local I&C equipments of the safety injection pumps, which is a mitigation function during plant shutdown, may not be operated or tested during plant shutdown. However, the DAS can be used to initiated safety injection when the I&C systems have failed, and therefore, signals to actuate safety injection pumps are also reliable. Manual operation of the safety injection pumps through the DAS is available during plant shutdown.

i. Restoration of I&C equipments can be performed within a short period of time by exchanging the faulted card.

j. One of the characteristic designs of the US-APWR is installation and removal of the in-core instrumentation system (ICIS) from the top of the RV head. Operators can start to remove (before refueling) and install (after refueling) the ICIS after the end of RCS draining as shown in Figure 19.1-23. This action cannot be done during RCS draining, which results in an extended duration of mid-loop operation. During actual plant operation, the action to install or remove the ICIS is performed

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SRP SECTION: **19 – Probabilistic Risk Assessment and Severe Accident Evaluation**

APPLICATION SECTION: **19**

DATE OF RAI ISSUE: **07/25/2011**

QUESTION NO.: 19-548

The staff has reviewed the applicant's response to RAI 9.01.04-21 regarding drain paths from the refueling cavity. The staff has also noted that RCS leakage detection or containment isolation of lines connected to the RCS are not required to be operable during Modes 6 according to TS, and failures of RCS level indication have occurred during Mode 6. The staff agrees that there would be considerable time to core boiling given a loss of the decay heat removal function with no inventory loss when the refueling cavity is flooded. However, the staff requests MHI to evaluate inadvertent losses of RCS inventory during POSs 5, 6, and 7 when fuel is in the vessel using generic operational data. These POSs were screened from evaluation in the shutdown PRA.

ANSWER:

A quantification of risk from inadvertent losses of RCS inventory during POSs 5, 6, and 7 has been performed using generic operational data has been performed and the results show that the risk is low compared to other POSs with reduced RCS inventory. The conditions and assumptions applied to the quantification are described below.

(1) The Likelihood of Initiating Events

During plant conditions when the refueling cavity is full, large draindowns that result in a decrease of RCS water elevation below the main coolant piping center would result in a loss of RHR function and result in an initiating event. According to generic operational data in EPRI report 1003113 "*An Analysis of Loss of Decay Heat Removal Trends and Initiating Event Frequencies (1989 - 2000),*" the mean frequency for events which resulted in more than 10,000 gallons of lost or diverted RCS inventory between 1994 and 2000 was 4.3E-06/hr. Considering that the estimated durations for POSs 5, 6, and 7 are 72hrs, 168hrs, and 72hrs (312hrs cumulative) respectively, the frequency of this initiating event for the US-APWR according to generic data is 1.7E-04/RY, 3.6E-04/RY, and 1.7E-04/RY (6.9E-04/RY cumulative) for each POS. CDF for each POS is estimated using these initiating event frequencies.

(2) Available Mitigation Systems

Mitigation measures available to prevent core damage at POSs 5, 6, and 7 include the RHRS, safety injection system, and charging injection system. Additionally gravity injection flow from the refueling water storage auxiliary tank (RWSAT) via the spent fuel pit (SFP) is available to supplement the RCS makeup inventory – the reactor vessel head would be removed for refueling for these POSs thus preventing RCS pressurization in the event of a loss of RHRS. These mitigation systems are the same measures available during POSs 4-2 and 8-2.

(3) Allowable Time for Operator Action

As the RAI mentions, these particular POSs have considerable time before core boiling would occur because of the increased inventory with the reactor refueling cavity flooded. This condition suggests that sufficient amount of time is available for operator actions and dependency between operator mitigative actions could be considered to be negligible. Considering that human error, including the dependencies between unsuccessful operator actions, is the dominant risk contributor during LPSD operation, the additional time available for operator action would further reduce CCDP

The risk from inadvertent losses of RCS inventory during POSs 5, 6, and 7 were quantified applying the initiating frequencies described in (1), and the conditional core damage probability (CCDP) estimated with consideration of the discussions in (2) and (3). Three cases were quantified considering the uncertainty of human error probabilities for prolonged available time for operation. As the base case, the CCDP for LOCA events during POS 8-1, which does not consider prolonged available time for operation, was applied as a bounding value. Two sensitivity cases were performed applying CCDPs assuming no dependency between operator actions, and zero human error probability, respectively. CCDPs for the sensitivity cases were quantified using the PRA model for LOCA initiating events during POS 8-1. The results are shown in Table19.548-1.

Additionally, regression analysis in the EPRI report suggests that the Large Draindown Recovery rate within 4 hours is 96%. Considering that the inventory in the refueling cavity will not approach losses leading to fuel uncovery in that timeframe, the actual CDFs for POS 5, 6, and 7 are an order of magnitude lower ~1E-9 to ~1E-11.

In summary, the actual risk posed during these screened out POSs is considerably lower than the risk assumed during other POSs.

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.

Table 19.548-1 Total CDF in POSs 5, 6 and 7

POS	Duration [hr]	Initiating Event Frequency [/RY]	CCDP*	CDF [/RY]
Base Case				
5	72	1.5E-04	2.7E-04	4.2E-08
6	168	3.6E-04		9.7E-08
7	72	1.5E-04		4.2E-08
5-7	312	-	-	1.8E-07
No Dependency between Operator Errors				
5	72	1.5E-04	3.9E-05	6.0E-09
6	168	3.6E-04		1.4E-08
7	72	1.5E-04		6.0E-09
5-7	312	-	-	2.6E-08
No Operator Errors				
5	72	1.5E-04	1.3E-06	2.0E-10
6	168	3.6E-04		4.6E-10
7	72	1.5E-04		2.0E-10
5-7	312	-	-	8.6E-10
DCD Rev.3				1.8E-07

* Base Case CCDP values derived from POS 8-1. POS 8-1 represents the most restrictive plant configuration in that this POS includes the fewest available mitigation functions for LOCA events, and thus the CCDP value is bounding.