PROBABILISTIC RISK ASSESSMENT AUDIT REPORT

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1.0 SUMMARY

Mitsubishi Heavy Industries, Ltd. (MHI) submitted to the U.S. Nuclear Regulatory Commission (NRC), a Final Safety Analysis Report for its application of the United States - Advanced Pressurized Water Reactor (US-APWR) on December 31, 2007. During the review of the US-APWR Design Certification (DC) application, the NRC staff identified the need for additional clarification concerning Chapter 19, "Probabilistic Risk Assessment and Severe Accident Evaluation," information and the probabilistic risk assessments (PRA).

On July 8, 2010, the NRC staff conducted an audit of the US-APWR low power, shutdown, fire and flood PRA which supports the US-APWR DC, Chapter 19. The audit was conducted at the Mitsubishi Nuclear Energy Systems, Inc. offices in Arlington, Virginia. The NRC staff conducted the audit in accordance with the NRC Office of New Reactors (NRO) Office Instruction NRO-REG-108 (Reference 1).

Included in this audit report is the basis of the audit, observations, results, and the NRC staff's conclusion.

2.0 BASIS

To satisfy the requirements of Title 10 of the *Code of Federal Regulations*, Part 52.47(a)(27) that requires a description of the design specific PRA and its results.

3.0 OBSERVATIONS AND RESULTS

The audit was conducted by a team of NRC staff whom are knowledgeable in the US-APWR PRA. The audit focused on the low power and shutdown PRA for internal and external events, including fires and floods.

Shutdown Internal Events:

Identification of Plant Operational States and Method for Draining the Reactor Coolant System (RCS)

Following the review of Section 19.1.6.1 of the Design Control Document (DCD) and the shutdown PRA, to start the audit, the NRC staff needed clarification on:

- The definition of the individual plant operational states (POSs).
- The key operational activities being performed in each of the POSs.

- Method for draining the RCS and isolating the steam generators for maintenance.
- The configuration of the RCS for each assigned POS.
- The assumed time to RCS boiling and time to core damage following an extended loss of the residual heat removal system (RHR) function for each POS.

MHI confirmed that RCS draining starts in POS 4, and the reactor vessel head is removed in POS 5. MHI explained that de-tensioning of the reactor head stud bolts is performed with the reactor vessel level one foot below the reactor vessel flange.

To drain the pressurizer to reach midloop conditions, which occurs in POS 4-1; MHI stated that a pressurizer vent in the pressurizer spray line is open to maintain the RCS at atmospheric pressure. In POS 4-2 and 4-3, a pressurizer safety valve is opened.

Following refueling, MHI confirmed that the head is installed in POS 7, but not tensioned until POS 8. In POS 7, the reactor vessel head is installed with the reactor vessel level approximately one foot below the reactor vessel flange. MHI confirmed that the shutdown PRA assumes that POS 6 still has fuel in the core. During refueling, approximately half of the core is replaced. MHI confirmed that a total core offload is not performed.

This discussion of POSs resulted in several open items:

1. Section 19.1.6.1 of the DCD and the shutdown PRA needs to be updated to state that fuel is in the core during POS 6 which is currently defined as having no fuel in the core. This issue is documented in request for additional information (RAI) 4947 (Question 19.01-2).

2. Section 19.1.6.1 of the DCD and the shutdown PRA needs to be updated to state the size of the pressurizer vent and to include a description of how the pressurizer is drained in POS 4-1 (midloop prior to refueling). This issue is documented in RAI 4947 (Question 19.01-3).

3. MHI needs to document in Section 19.1.6.1 of the DCD and the shutdown PRA, whether gravity injection can be credited in POS 8-1 and 8-2 (midloop following refueling), since a safety valve is removed. This issue is documented in RAI 4947 (Question 19.01-4).

4. Section 19.1.6.1 of the DCD and the shutdown PRA for internal and external events needs to be updated to include the duration of time where the RCS is in a reduced inventory state due to reactor vessel head removal and installation. Currently, these activities are assumed to occur in POS 5 and POS 7, respectively. In these POSs, the DCD and the PRA states that the refueling cavity is filled with water, which is non-conservative. In response to the NRC staff's questions, MHI is considering adding reactor vessel head removal and installation activities in POS 4 and POS 8, respectively. This open item will require re-solving and re-quantification of the shutdown PRA for internal and external events. This open item is covered in RAI 19-441.

5. Section 19.1.6.1 of the DCD and the shutdown PRA for internal and external events needs to be updated to state that MHI plans to refill the RCS using a vacuum refill in POS 8-3. MHI needs to summarize this process in the shutdown PRA and the DCD including how the RCS will be configured for a vacuum refill and how the RCS will be configured if the RHR function is lost. This issue is documented in RAI 4947 (Question 19.01-5).

6. Section 19.1.6.1 of the DCD and the shutdown PRA needs to be updated to include the revised times for RCS boiling and the revised time to core damage assuming an extended loss of the RHR function for POSs 4-1, 4-2, 4-3, 8-1, and 8-2, given that POS 4 and POS 8 will be redefined. This issue is documented in RAI 4947 (Question 19.01-6).

Instrumentation at Shutdown and Shutdown Technical Specifications (TS):

The NRC staff discussed proposed responses to supplemental RAI 19-436, RAI 19-437, RAI 19-442, 19-439, and 19-440. In response to RAI 19-436, MHI agreed to update the DCD and Table 19.1-119, "Key Insights and Assumptions" to be consistent with Generic Letter 88-17 regarding shutdown instrumentation. In response to RAI 19-437, MHI agreed to update Revision 3 of the DCD, Chapter 7.6.1.7 to include the narrow range midloop level indication and agreed to confirm that the level instrumentation discussion is consistent among applicable DCD chapters. In response to RAI 19-439, MHI agreed to include the core exit thermocouple instrumentation into DCD Table 17.4-1 as a risk significant structure, system, and component. In response to RAI 19-440, MHI agreed to revise the DCD to include both listed mitigative measures to reduce the risk from surge line flooding.

RAI-442 requests a sensitivity study which removes credit for systems not required in TS. This sensitivity study is necessary for the NRC staff to understand what level of protection at shutdown is provided by voluntary initiatives. The management of shutdown risk using the Maintenance Rule and the implementation of a Configuration Risk Management Program was discussed. The NRC staff noted that NUMARC 93-01, Section 11, Revision 2, Scope of Assessment for Shutdown Conditions, is based on NUMARC 91-06. NUMARC 91-06 only involves a qualitative assessment of the five key shutdown safety functions: decay heat removal, inventory control, power availability, reactivity control, and containment. Following the discussion, MHI agreed to consider TS or other options as a method for the Combined License Application applicant to achieve the reported shutdown risk results.

Shutdown Floods:

MHI confirmed that flood barriers between the east and west side of the reactor are not breached during maintenance at shutdown. The PRA assumes that one train of mitigation on each side of the reactor building should be available during shutdown (example; trains A and C, or trains B and D). This key risk insight is documented in Table 19.1-119 of the DCD. As stated earlier in this report, the shutdown flooding assessment needs to be re-solved and re-quantified given the open items listed in this report.

Shutdown Fires

After discussing PRA Chapter 23Q on fires in containment, MHI committed to reviewing the discussion on page 23Q-3 to ensure that the drawing is consistent with the discussion. MHI will also update the PRA and the DCD as applicable, once MHI checks the assigned fire zones and compartments in containment to be consistent with the definitions in the fire PRA. This issue is documented in RAI 4949 (Question 19-446).

During preparation for the audit, the NRC staff found that the refueling water recirculation pumps are included in Reliability Assurance Program and have a Risk Achievement Worth (RAW) of 12 for Large External Leaks and a RAW of 3.9 for Fail to Start (CCF) and Fail to Run (CCF). The refueling water recirculation pumps are used to transfer boric acid water from the RWSP to the SFP. Based on page 23A-9 of the US-APWR PRA, it appears that the refueling water recirculation pumps are located next to each other in the same fire zone. The NRC staff needs clarification if the refueling water recirculation pumps are in separate fire zones or fire compartment boundaries or if they are in the same fire zone. If the refueling water recirculation pumps are not in separate fire compartments, the NRC staff needs additional information on how redundancy and diversity are maintained. The NRC staff also needs clarification whether the common cause failure of both refueling water recirculation pumps due to fire is analyzed in the PRA and, if so, where. This issue is documented in RAI 4863 (Question 19-443).

During preparation for the audit, the NRC staff reviewed Attachment 23N, “Control Room Fires and I&C Rooms.” On page 23N-2, it states “the boundary of each floor is not comprised of a fire resistant barrier.” At the audit, the NRC staff requested additional information regarding how a postulated fire in an I&C room does not spread to the Main Control Room or vice versa. The NRC staff requested MHI to update the PRA and the DCD, as necessary, to clearly state each fire boundary between the I&C rooms and the Main Control Room and to document why a fire from an I&C Room cannot spread to the Main Control Room and vice versa. This issue is documented in RAI 4949 (Question 19-444).

In Attachment 23N, on pages 23N-5 and 23N-6, it states, “because the control room fire has the potential to spread to safety related I&C rooms including raised floor spaces, with some probability, it should be confirmed that the fire scenario will not be the dominant contributor to CDF.” At the audit, the NRC staff requested clarification whether it has been confirmed that this fire scenario is not the dominant contributor to CDF and, if so, specifically where this assessment can be found. The NRC staff requested that the statement in Attachment 23N should be modified, as well as the DCD as necessary, to clarify if it has been confirmed that the fire scenario is not the dominant contributor to CDF and specifically where this assessment can be found. This issue is documented in RAI 4949 (Question 19-445).

Shutdown Seismic Margins Approach:

The NRC staff needs the shutdown PRA and the DCD to be updated to provide a discussion on how the min-max seismic margins approach was applied to the shutdown. MHI needs to provide the seismic cutsets and the sequence high confidence in low probability of failure capacities using the min-max method. MHI also needs to provide the dominant mixed cutsets containment seismic failures and random failures. This issue is documented in RAI 4947 (Question 19.01-7)

4.0 CONCLUSION

The NRC staff conducted the exit meeting with MHI on Thursday July 8, 2010. The NRC staff summarized its activities during the audit and discussed the following key preliminary results:

- Several new issues regarding the identification of shutdown POSs were identified and the method for RCS draindown were identified as documented in Section 3. The resolution of these issues will necessitate in the shutdown PRA for internal and external events being resolved and requantified. The resolution of these issues will necessitate a re-evaluation of the time to boiling and the time to core damage for each POS.

- Two issues regarding the shutdown fire analysis as documented in Section 3 were identified.

- The NRC staff needs MHI to submit a discussion on how the min-max seismic margins method was applied at shutdown. The NRC staff also needs the results of this analysis.

REFERENCES:

- NRO Office Instruction, NRO-REG-108, “Regulatory Audits”, April 2, 2009.
- Design Certification Chapter 19, Low Power, Shutdown Fire, and Flood Probabilistic Assessment Audit Plan, July 2, 2010.
- Technical Report MUAP-07030(R2) “US-APWR Probabilistic Risk Assessment,” Revision 2, Mitsubishi Heavy Industries, Ltd., Proprietary.
- Mitsubishi Heavy Industries, Ltd., US-APWR Design Control Document, Revision 2.