May 15, 2012

MEMORANDUM TO: Hossein Hamzehee, Branch Chief
Licensing Branch 2
Division of New Reactor Licensing
Office of New Reactors

FROM: Eileen McKenna, Branch Chief ***/RA/***
Balance of Plant and Technical Specifications Branch
Division of Safety Systems and Risk Assessment
Office of New Reactors

SUBJECT: AUDIT REPORT FROM APRIL 18-19, 2012 TO REVIEW US-APWR DESIGN CONTROL DOCUMENT, REVISION 3 ISSUES FOR CHAPTER 9 (INCLUDING CALCULATIONS)

Attached is the staff's audit report for selected areas related to US-APWR (Docket No, 52-021) Design Control Document (DCD), Revision 3, and Chapter 9, submitted to the U.S. Nuclear Regulatory Commission (NRC) for its US-APWR application in March 31, 2011.

The audit was conducted on April 18th and 19th, 2012 between Mitsubishi Heavy Industries, LTD (MHI), Mitsubishi Nuclear Energy Systems (MNES), and the NRC staff. During the audit, the staff performed a comprehensive review of the calculations that supported the design information contained in Revision 3 of the DCD and in the applicant's responses to the staff's requests for additional information (RAIs).

The staff concluded that for the most part, the information and calculations, provided by the applicant, supported the applicant's DCD and previous responses to the staff's requests for additional information (RAIs). However, the staff has found several items that need to be resolved. The staff presented these concerns to the applicant at the conclusion of the audit and discussed the possibility of a future dialog to ensure the concerns were addressed.

Enclosure: As Stated

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A. Introduction

A two day audit was conducted by the NRC/NRO US-APWR project team at the MHI and MNES office in Arlington, Virginia beginning on April 18, 2012. The focus of the audit was to review selected areas related to US-APWR (Docket No. 52-021) Design Control Document, Revision 3, Chapter 9 (including supporting calculations), submitted to the U.S. Nuclear Regulatory Commission (NRC) for its US-APWR application in March 31, 2011. The audit was necessary in order review supporting calculations related to DCD Revision 3 and the applicant's RAI responses. The audit primarily focused was on four systems which includes; the essential service water system (Section 9.2.1), component cooling water system (9.2.2), ultimate heat sink (9.2.5), and essential chilled water system (9.2.7).

During the audit, the staff reviewed MHI documentation such as system calculations that supported previous RAI responses.

B. Audit Team

Larry Wheeler (NRO, Audit Team Leader)
Chang Li (NRO – reviewer)
Gordon Curran (NRO – reviewer)
Paul Kallan (NRO, Project Manager)

C. Conclusions

The staff concluded that for the most part, the information and calculations, provided by the applicant, supported the applicant's DCD and previous responses to the staff's requests for additional information (RAIs). However, the staff has found several items that need to be resolved. The staff presented these concerns to the applicant at the conclusion of the audit and discussed the possibility of a future dialog to ensure the concerns were addressed. The attached audit report enclosure summarizes these concerns and provides a list of the calculations were reviewed.

MHI stated that they understood all the issues and will engage the NRC staff in future calls to resolve these issues.

Audit Report Comments

Generic Comments:

Many of the calculation have a preparer, reviewer, and approver all signing the same date in their review block. This is a generic comment that this gives a perception of non-independent reviews.

Specific Comments:

Attachment 1 of this report shows the scope of the audit. Attachment 2 of this report shows the detailed reviews that where conducted by the staff. The staff's comments at the exit meeting were given to the applicant as described in Attachment 2. There are eight actions items and one suggestion for MHI to resolve as part of the close out of this audit.

MHI Audit Report Attachment 1

Audit Scope:

9.2.1 Essential Service Water (ESW)

The staff identified three audit items for the ESW.

9.2.1-1: ESW Pump NPSH
- Applicant's Response: NPSH for ESW pumps will be determined by COL applicant.
- Staff's Evaluation: COL Item 9.2(6) addresses the issue.
- Follow-up Actions: NPSH for ESW pumps should be reviewed or audited by the staff for COL applications.

9.2.1-2: ESW Heat Transfer
- Applicant's Response: Calculation 4BS-UAP-100220R1 is available in Audit Binder #1, Tab #8.
- Staff Evaluation: Detailed audit review is needed.

9.2.1-3: ESW Flow Velocities
- Applicant's Response: Calculation 4BS-UAP-120030R0 is available in Audit Binder #1, Tab #10.
- Staff Evaluation: Detailed audit review is needed.

9.2.2 Component Cooling Water (CCW)

The staff identified five audit items for the CCW.

9.2.2-1: CCW pump flow network calculation, TDH basis, NPSH, vortex determination.
- Applicant's Response: Calculations 4BS-UAP-100049R1, 4BS-UAP-100192R2, 4BR-UAP-100193R2, 4BS-UAP-100194R1 and 4BS-UAP-120031R0 are available in Audit Binder #1.
- Staff Evaluation: Detailed audit review is needed.

9.2.2-2: CCW surge tank capacity and min/max tank setpoints.
- Applicant's Response: Calculation 4BS-UAP-100196R2 is available in Audit Binder #1.
- Staff Evaluation: Detailed audit review is needed.

9.2.2-3: CCW system heat transfer and heat exchanger calculations.
- Applicant's Response: Calculation 4BS-UAP-100198R1 and 4BS-UAP-100200R1 are available in Audit Binder #1.
- Staff Evaluation: Detailed audit review is needed.

9.2.2-4: CCW flow velocities related to worst case conditions.
- Applicant's Response: Calculations 4BS-UAP-100192R2 is available in Audit Binder #1.
- Staff Evaluation: Detailed audit review is needed.

MHI Audit Report Attachment 1

9.2.2-5: CCW surge tank pressure for beyond DBA.
- Applicant's Response: Calculations 4BS-UAP-120031R0 is available in Audit Binder #1.
- Staff Evaluation: Detailed audit review is needed.

9.2.5 Ultimate Heat Sink (UHS)

The staff identified three audit items for the UHS.

9.2.5-1 Cooling Tower Basin Volume
- Applicant's Response: Cooling Tower Basin Volume will be determined by COL applicant.
- Staff's Evaluation: COL Item 9.2(20) addresses the issue.
- Follow-up Actions: Cooling Tower Basin Volume should be reviewed or audited by the staff for COL applications.

9.2.5-2 Heat Transfer (Cooling Capacity)
- Applicant's Response: Calculation 4BS-UAP-100220R1 is available in Audit Binder #1, Tab #8. DCD Table 9.2.5-2 provides UHS heat load for LOCA and safe shutdown with LOOP.
- Staff Evaluation: Detailed audit review is needed.

9.2.5-3 Makeup Requirements Post -72- hours
- Applicant's Response: USAPWR is designed to provide minimum of 30 days water without makeup in accordance with RG 1.27. There is no need for specific requirement of 72 hours because it is covered by the 30-day requirement.
- Staff Evaluation: The staff confirmed in DCD Section 9.2.5.1 regarding the 30-day water requirement. It is acceptable based on RG 1.27. This issue is closed, and no further action is needed.

9.2.7 Essential Chilled Water System (ECWS)

The staff identified four audit items for the ECWS.

9.2.7-1: ECWS surge tank capacity and min/max tank setpoint basis
- Applicant response: The detailed setpoint basis and setpoint value will be determined in the US-APWR detailed design.
- Staff Evaluation: Surge tank setpoint could be reviewed or audited when reviewing NPSH and pipe routing.

9.2.7-2: ECWS pump flow network calculations and NPSH
- Applicant response: ECWS pumps and routing will not be specified or selected until the detailed design phase so the NPSH for these pumps is not yet available. In addition, the pumps will have a minimum of 10% margin to the required NPSH.

MHI Audit Report Attachment 1

- Staff Evaluation: DCD ITAAC Table 2.7.3.5-5 (Item 13) verifies that the ECWS pump has sufficient NPSH. NPSH for ECWS pumps could be reviewed or audited for COL applications.

9.2.7-3 ECWS system heat transfer and heat exchanger calculations

- Applicant's Response: Calculation NO-EE23501R2 is available in Audit Binder #1, Tab #12.
- Staff Evaluation: Detailed audit review is needed.

9.2.7-4 ECWS flow velocities related to worst case conditions since R/3 removed the piping sizes from the DCD Figures

- Applicant's Response: Calculation NO-EE23501R2 is available in Audit Binder #1, Tab #12 and Pipe size based on MHI technical standards
- Staff Evaluation: Detailed audit review is needed.

MHI Audit Report Attachment 2

Detailed Staff's Review

9.2.1 ESW

The applicant identified two calculation documents (4BS-UAP-100220R1 and 4BS-UAP-120030R0) to address items 9.2.1-2, 9.2.1-3, and 9.2.5-2.

1. Calculation 4BS-UAP-120030R0, "ESWS Flow Velocity Calculation for Section of Pipe Sizes"

   This calculation document addresses Item 9.2.1-3, "ESW Flow Velocities." The staff reviewed input, assumptions, methodology, calculation results and found the calculation adequate. The results show the flow velocities at different locations. The maximum velocity is 3.0 meters per second (mps) (9.8 feet per second (fps)). The staff found it acceptable. This item is closed, and no further action is needed.

2. Calculation 4BS-UAP-100220R1, "Basis for ESWS Heat Load"

   This calculation addresses Items 9.2.1-2, "ESW Heat Transfer," and 9.2.5-2," Heat Transfer (Cooling Capacity)". The staff reviewed input, assumptions, methodology, calculation results, and found the following two issues:

   (1) The results of the calculation are inconsistent with the heat load listed in DCD Table 9.2.5-2.
   Applicant's Response: The results in the DCD were compared and are more conservative, and the applicant determined to keep the more conservative values in the DCD unchanged.
   The staff found the response acceptable because more margins are available for the UHS heat transfer cooling capacity

   (2) Two related calculation documents were identified for further audit review: 4BS-UAP-100199R1 and NO-EB20006R1.

3. Calculation 4BS-UAP-100199R1, "Cooldown Calculation"

   - The staff reviewed input, assumptions, methodology, calculation results, and found that the input of CCW flow and ESW flow are inconsistent with the flow rates in DCD Table 9.2.2-2.

   - The applicant responded that the CCW flow rate 12,500 gpm (47,317 lpm) and ESW flow rate 14,300 gpm (54,131 lpm) are higher than the flow rates in the DCD. This input resulted in higher heat transfer for CCW heat exchanger and higher heat load for the ultimate heat sink compared to the input of DCD flow rates. This approach built in some conservatism for the UHS cooling capacity, which provided some flexibility for future design changes.

MHI Audit Report Attachment 2

- The staff agreed that the input inconsistency was conservative for UHS. However, this input was non-conservative for RCS cooldown calculation.

- The applicant's responded that the purpose of this calculation is only for the UHS, and admitted that the title of this calculation was misleading. The applicant would revise the title of this calculation and clarify the focus in the "Object" of this calculation.

- In addition for the purpose of RCS cooldown calculation, the applicant showed the staff a separate calculation, 4BS-UAP-100120, entitled "Residual Heat Removal Cooldown Performance Calculation." In this calculation, the CCW flow and ESW flow were assumed to be 10126 gpm and 9686 gpm respectively, which are conservative for the purpose of RCS cooldown. Different values of flow rates were assumed in two different calculations with different objectives; both assumptions are conservative on their own merit.

- The staff found the explanation of conservatism acceptable, and the issue is resolved based on the changes in the title and objectives of Calculation 4BS-UAP-100199R1, "Cooldown Calculation"

- **MHI consideration: The staff requested the applicant to revise the title of Calculation 4BS-UAP-100199R1, "Cooldown Calculation," and clarify the objectives of this calculation.**

4. Calculation NO-EB20006R1, "Heat Load Evaluation of Ultimate Heat Load for LOCA"

   The staff reviewed input, assumptions, methodology, calculation results, and found the information adequate.

9.2.2 CCW

1. 4BS-UAP-100049, CCW Surge Line Pressure Loss Calculation (R/1, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-1 of the audit plan, "CCW pump flow network calculation, TDH basis, NPSH, Vortex Determination." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the pressure loss of the piping system reasonable assuming a circulating flow of 240 gpm (980 lpm) with a feed and bleed of 75 gpm (284 lpm). Action by MHI, see below; otherwise, no further NRC action.

   MHI action #1 (minor issue): Input table has pipe OD and pipe thickness reversed.

MHI Audit Report Attachment 2

2. 4BS-UAP-100192, CCW Flow Balance Calculation (R/2, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-1 of the audit plan, "CCW pump flow network calculation, TDH basis, NPSH, Vortex Determination," and Item 9.2.2-4, "CCW flow velocities related to the worst case conditions." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   During the staff's review of the calculation data sheets, it was discovered that the CCW piping flow velocities for normal conditions were as high as 4.83 meters per second or 15.8 feet per seconds (fps).

   As stated in "Piping Handbook- 16th Edition" and "Crane Technical Paper No. 410", reasonable design velocities for general service are between 4 to 10 fps (1.2 to 3 mps) and boiler feed between 8 to 15 fps (2.4 to 4.5 mps). The staff has found operating experiences that higher piping flow velocities have contributed to general erosion and erosion-corrosion in typical water systems. MHI stated that these flow rates above 10 fps are typical for the Japan nuclear plants.

   EPRI Service Water Piping Guideline, Technical Report dated December 6, 2006 states that corrosion allowances for service water piping are based upon 40 years of operation at design flows and design temperature in the nominal water chemistry. Typical fluid velocities may range from less than 1 foot per second to flows of the order of 10 fps (3 mps). Most often, normal flows produce fluid velocities of 3 to 7 fps (0.9 to 2.1 mps). Normally flowing conditions, and the associated general corrosion, are what the piping was designed for. Under these conditions, uncoated carbon steel or cast iron would be expected to degrade by general corrosion that produces a fairly protective oxide film.

   There are no regulatory direct requirements related to excessive flow velocities. However, 10 CFR 52.47 (a)(22) requires the applicant to demonstrate how operating experience insights have been incorporated into the plant design. The designer is responsible to maintaining the system pressure drop and flow velocities within reasonable limits. This is related to RAI 362-2278 Question 09.02.02-27, part 1. MHI's response stated that "pipe sizing for all systems including the CCWS has been conducted in accordance with accepted engineering practices and in conformance with the appropriate codes and standards as described in DCD Tier 2 section 3.12.2." Therefore, there is no further action required by MHI.

   NRC observations: The COLs should be aware that with the CCW piping velocities corrosion of the CCWS may be a future issue.

   The results show the CCW flow balance and system velocities reasonable. Action by MHI, see below. The NRC may revisit these items in future audits.

MHI Audit Report Attachment 2

MHI action #2: When asked to see the controlled latest P&IDs of the CCWS, they were not up to date to match all the RAIs and DCD markups. This needs to be corrected and MHI was notified and agreed the P&IDs are out of date.

MHI action #3: Under the assumptions, it was noted that during accidents, flow is stopped to the RCP motors. This does not match RAI responses that maintain flow to the RCPs during accidents. This needs to be corrected and MHI agreed to correct the calculation.

3. 4BS-UAP-100193, CCW NPSH Calculation (R/2, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-1 of the audit plan, "CCW pump flow network calculation, TDH basis, NPSH, Vortex Determination." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the NPSH calculation reasonable since there is a 50% margin added to the NPSH calculation. For example, at 12,000 gpm (45425 lpm) CCW flow rate the actual NPSH is calculated to be 141 ft (43 m) and the NPSH actual used in the design is 70 ft (21.4 m). Action by MHI, see below. The NRC may revisit these items in future audits.

   MHI action #4: There was a condition of CCW pump run-out as part of the NPSH calculation with flow rates of 17,000 gpm (64,352 lpm). The CCWS pump run-out and flows to 17,000 gpm (64,352 lpm) are not discussed in the DCD. MHI plans to review this item and have follow-up phone calls with the NRC.

   MHI action #5. The CCW component that may see the 17,000 gpm (64,352 lpm) flow rate are not described in the DCD as being designed to these higher flow rates. MHI plans to review this item and have follow-up phone calls with the NRC.

4. 4BS-UAP-100194, CCW Pump Required Head Calculation (R/1, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-1 of the audit plan, "CCW pump flow network calculation, TDH basis, NPSH, Vortex Determination." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the CCW pump head calculation reasonable since this is a 5% margin added to the pump head calculation. The highest pressure drop across the system is with the CCW B pump running with flow through the A charging pump motor. No further action by MHI.

MHI Audit Report Attachment 2

5. 4BS-UAP-100196, Tanks Size Calculation (R/2, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-2 of the audit plan, "CCW surge tank capacity and min/max tank set-point." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the CCW surge tank calculation reasonable. The calculation includes provision for inflow in the surge tank due to a RCP thermal barrier breach, normal system heat-up, loss of surge tank volume due to normal system leakage, and loss of surge tank volume due to a nonsafety-related pipe rupture. This is also a 20% margin added to the total volume of the CCW surge tank. Action by MHI, see below. The NRC may revisit this item in future audits.

   MHI action #6: Some of the calculation sheets had the wrong revision number.

   NRC observation: The calculation assumes the system heat up is from the boric acid evaporator in which North Anna Unit 3 has a departure. Therefore, this calculation will have to be revisited at the COL audit.

6. 4BS-UAP-100198, CCW HX Capability Calculation (R/1, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-3 of the audit plan, "CCW system heat transfer and heat exchanger calculations." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the heat transfer and heat exchanger calculation reasonable. The calculation includes provision for normal, startup, cooldown, accident, safe shutdown, and refueling heat loads. There are also various margins added to the calculation including a vendor design margin of heat exchanger area of 20%. Action by MHI, see below. The NRC may revisit this item in future audits.

   MHI action #7: The data sheet as part of this calculation does not match (minor differences) RAI 571-4365, Question 9.2.2-52 response. MHI plans to review this item and have follow-up phone calls with the NRC.

7. 4BS-UAP-100200, Flow Rate and Heat Load Calculation (R/1, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-3 of the audit plan, "CCW system heat transfer and heat exchanger calculations." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

MHI Audit Report Attachment 2

The results show the flow rates and heat exchanger calculation reasonable. The calculation results where compared to the latest DCD markup and no issues where noted. During the review, MHI was asked about the assumptions related to 'all heat loads as assumed from domestic PWRs' and how the assumptions would be later verified. MHIs response stated that the detail design will revisit these assumptions. The staff finds this explanation acceptable, no further action required.

8. 4BS-UAP-120029, CCW Surge Tank Pressure for Alternate Containment Cooling System (R/0, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-5 of the audit plan, "CCW surge tank pressure for beyond DBA." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the upset pressure condition to 100 psig for the CCW surge tank calculation is reasonable for severe accidents. The calculation results where compared to the latest DCD markup and no issues where noted; no further action required.

9. 4BS-UAP-120031, CCW Pump Air Ingestion Water Height Calculation (R/0, 4/13/12) – Safety related stamp on cover page.

   This calculation addresses part of Item 9.2.2-1 of the audit plan, "CCW pump flow network calculation, TDH basis, NPSH, Vortex Determination." The staff reviewed the objective, input, assumptions, methodology, calculation results, summary, attachments, and references and found the calculation reasonable.

   The results show the air ingestion calculation reasonable. The applicant elected to use the old $8m^3$ verses the new $12m^3$ CCW surge tank volume as an input into this calculation. The calculation results where compared to the latest DCD markup and the staff found there was no DCD discussion describing a possible issue with air ingestion in the CCW pumps at a CCW surge tank level below 1.078 meters while in CCW feed and bleed. Action by MHI, see below. The NRC may revisit this item in future audits.

   MHI action #8: Air ingestion into the CCW pumps is not described in the DCD. MHI plans to review this item and have follow-up phone calls with the NRC.

MHI Audit Report Attachment 2

9.2.7 ECW

The applicant identified calculation document NO-EE23501R2 to address Item 9.2.7-3 and Item 9.2.7-4. This calculation contains a summary defining the overall system design.

1. Calculation NO-EE23501 R/2 "Essential Chilled Water system (ECWS) calculations"

This calculation is a summary calculation defining the overall system design values and addresses Item 9.2.7-3 "CWS system heat transfer and heat exchanger calculations" and Item 9.2.7-4, "CWS flow velocities related to worst case conditions since R/3 removed the piping

sizes from the DCD Figures." The staff reviewed input, assumptions, methodology, calculation results, and found the following issues:

(a) This calculation addressed Item 9.2.7-3 of the audit plan, "CWS system heat transfer and heat exchanger calculations"

- The staff found the results of this ECWS calculation contain heat load values that are consistent with Table 9.2.7-2 of the DCD. . These DCD heat load values include a 15% margin as documented in supporting Calculation NO-EE21101 R/4.

- The staff questioned that Table 5-1 of calculation NO-EE23501 R/2 contains heat load values for all AHUs and the ECWS chilled water pump that are missing from Table 9.2.7-2 of the DCD

- The applicant responded that the purpose of the DCD Table 9.2.7-2 is to provide values for only AHU heat loads. However, for clarity MHI indicated that DCD Table 9.2.7-2 will be revised to include ECWS chilled water pump heat load.

- The staff found this response acceptable and all DCD values are properly supported by the calculation.

- The staff found that NO-EE23501 R/2 contains identical heat load values for all modes of operation (normal operation, LOOP and accident condition). The staff questioned the basis for providing the same values for both normal and abnormal operation.

- The applicant indicated that the heat load values provided in DCD are all based on worst case condition for all modes of operation (i.e., both normal and abnormal operation). For clarity, MHI indicated that DCD Table 9.2.7-2 would be modified to remove the reference to normal operation and show only the worst case condition.

MHI Audit Report Attachment 2

- The staff finds it acceptable for DCD to include worst case condition to design ECWS.

(b) Calculation NO-EE23501 R/2 also addressed Item 9.2.7-4 of the audit plan, “CWS flow velocities related to worst case conditions since R/3 removed the piping sizes from the DCD Figures.”

- The staff was unable to locate basis for pipe sizes and flow velocities in the calculation. Therefore, the staff questioned whether these have been completed by MHI.

- The applicant explained that the piping sizes are based in MHI technical standards. It was further explained that the piping size of the ECWS is selected using the same method and tables as the CCWS, since the piping specifications is similar to the ECWS piping specification. During the development of pipe sizing, standard flow velocity will be used.

- The staff found the explanation acceptable and no further action is needed.

MEMORANDUM TO: Hossein Hamzehee, Branch Chief
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Office of New Reactors

FROM: Eileen McKenna, Branch Chief ***/RA/***
Balance of Plant and Technical Specifications Branch
Division of Safety Systems and Risk Assessment
Office of New Reactors

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Enclosure: As Stated

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