PIPE RUPTURE HAZARDS ANALYSES AUDIT REPORT

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1.0 SUMMARY

The purpose of this audit was for the staff to: (1) gain an understanding of the Advanced Power Reactor 1400 (APR1400) supporting documents to support the staff's review of the APR1400 design certification (DC) application; (2) review related detailed design information to evaluate conformance with the applicable Standard Review Plan (SRP) or technical guidance; and (3) verify that the APR1400 pipe rupture hazards analyses (PRHA) are performed in accordance with the methodology and criteria described in the APR1400 design control document (DCD).

A key document included in the audit was APR1400-E-N-NR-14004-P, "Summary Report of High-Energy Piping Rupture Analysis." In this report, the applicant indicated that the scope of the report is limited to piping within the reactor containment building and the main steam valve house according to the graded approach of APR1400 piping design for the DC application (as described in Tier 2, Section 14.3.3 of the DCD). Based on the information evaluated in the audit, the staff concluded that the supporting documents were prepared in accordance with the methodology and criteria described in the APR1400 DCD and are generally in conformance with the applicable SRP or technical guidance. However, it should be noted that the PRHA as presented are preliminary results (e.g., the fatigue usage factor is not considered in determining intermediate break locations for ASME Class 1 piping). Also, assessment of the dynamic effects of jet impingement and blast waves was not yet complete at the time of the audit and was therefore excluded from this audit. The applicant subsequently submitted Technical Report, APR1400-E-N-NR-14003-P, "Evaluation Methodology of Jet Impingement Loads on SSCs [structures, systems, and components]," dated October 6, 2015, for the staff's review. The staff is currently reviewing that report to determine the acceptability of the applicant's methodology. The staff will evaluate the applicant's final PRHA report that implements this methodology and includes fatigue considerations in a follow-up audit.

The audit was conducted from the U.S. Nuclear Regulatory Commission (NRC) Headquarters via Korea Hydro & Nuclear Power (KHNP's) electronic reading room on August 31, 2015, to September 9, 2015. The NRC staff conducted the audit in accordance with the NRC Office of New Reactors (NRO) Office Instruction NRO-REG-108, "Regulatory Audits." The plan for this audit, dated August 31, 2015, is available in the Agencywide Document Access and Management System (ADAMS) using Accession No. ML15243A015.

2.0 AUDIT SCOPE

The NRC staff audited the PRHA report, including supporting documents, to support the staff's review of the DC application in three areas:

- Determination of rupture locations and their associated dynamic effects excluding issues related to dynamic effects of blast wave and jet impingement (SRP Section 3.6.2 and Branch Technical Position (BTP) 3-4).

- Plant design for protection against postulated piping failures in fluid systems outside containment (SRP Section 3.6.1 and BTP 3-3).

- Internal flood protection for onsite equipment failures (SRP Section 3.4.1).

Specifically, the staff audited the following detailed information provided in the PRHA report including its supporting documents:

- Individual pipe whip and jet impingement load effects assessments including their associated assumptions.

- Individual piping system specifications as related to the associated PRHA assessments including pipe operation conditions and determination of postulated pipe failure locations.

- PRHA summary report, APR1400-E-N-NR-14004-P Revision 0, dated August 2015.

- Information related to environmental effects resulting from postulated pipe failures.

3.0 REGULATORY BASIS

Title 10 of the *Code of Federal Regulations* (10 CFR), paragraph 52.47(a)(3)(i) states that a DC application must contain a final safety analysis report (FSAR) that includes a description of principal design criteria for the facility. A regulatory audit is needed to evaluate the safety conclusions that need to be made regarding Chapter 3, "Design of Structures, Components, Equipment, and Systems," of the APR1400 DCD, and to identify detailed information related to the applicant's principal design criteria that might need to be included in the DCD. The NRC staff must have sufficient information to document its safety findings in the NRC staff's safety evaluation report (SER).

This regulatory audit is based on the following:

- General Design Criterion 4 in Appendix A to 10 CFR Part 50, as it relates to as it relates to SSCs important to safety being designed to accommodate the effects of postulated accidents, including appropriate protection against the dynamic effects and environmental effects associated with postulated pipe rupture.

- Additional detailed acceptance criteria in SRP Sections 3.4.1, 3.6.1, and 3.6.2, as well as BTP 3-3 and BTP 3-4.

4.0 OBSERVATIONS AND RESULTS

The staff reviewed the information provided by the applicant to gain an understanding of the APR1400 PRHA to: (1) support the staff's review of the DC application, (2) to evaluate conformance with the relevant SRPs or technical guidance, and (3) verify that the APR1400 PRHA are performed in accordance with the methodology and criteria described in the APR1400 DCD. In addition, the staff discussed with the applicant seven questions that were identified during the audit. These questions are included as Enclosure 2 to this audit report.

Audit observations within the scope of SRP Section 3.6.2 and BTP 3-4:

As mentioned in Section 1.0 of this audit report, the information made available to staff for this audit is limited to piping within the reactor containment building and the main steam valve house according to the graded approach of APR1400 piping design for DC application. In addition, the PRHA as presented are preliminary results (e.g., the fatigue usage factor is not considered in determining the intermediate break location for ASME Class 1 piping). Also, the APR1400 methodology and evaluation of the dynamic effect of jet impingement and blast wave were not completed by the applicant at the time of the audit and were, therefore excluded from this audit. The applicant subsequently submitted the related topical report mentioned above, which is currently under staff review.

Moreover, the applicant has not formally responded to three questions issued as part of the DCD Tier 2, Section 3.6.2 review of PRHA methodologies. These questions are request for additional information (RAI) 41-7957 (ADAMS Accession No. ML15174A383), Questions 03.06.02-1 and 03.06.02-2, and RAI 166-8198, (ADAMS Accession No. ML15006A042), Questions 03.06.02-3. Upon receiving the applicant's formal responses, the staff will review these issues separately.

Based on the audit of information provided by the applicant, the staff did not identify any issues with the performance of the APR1400 PRHA as related to the methodology and criteria described in DCD Tier 2, Section 3.6.2. Furthermore, based on the audit of the applicant's preliminary summary PRHA report, the staff concluded that this summary PRHA report is presented in a format appropriate to document the detailed design information. The staff will evaluate the applicant's final PRHA report in a follow-up audit.

Audit observations within the scope of SRP Section 3.6.1 and BTP 3-3:

The scope of review within SRP Section 3.6.1 and BTP 3-3 is the plant design for protection against postulated piping failures in fluid systems outside containment. However, as noted in earlier sections of this audit report, the information included in the PRHA summary report is limited to piping within the reactor containment building and the main steam valve house. Therefore, the staff reviewed that summary report and several of the piping diagrams to assess how the applicant implements the methodologies for the protection of essential components inside containment.

Based on the audit on the information provided by the applicant, the staff did not identify any issues with the implementation of the relevant approved methodology as described in DCD Tier 2, Section 3.6.1. However, it should be noted that for assessing numerous pipe rupture effects, the applicant has relied upon a separation approach for the protection of safety-related SSCs. Therefore, the staff determined that a follow-up audit on other piping segments (e.g., piping segments outside containment, if available) is needed to ensure that the applicant implements appropriately for all aspects of the pipe rupture methodology including the "separation" criteria within the scope of SRP Section 3.6.1.

Audit observations within the scope of SRP Section 3.4.1:

For the areas within the scope of SRP Section 3.4.1, the staff noted that Section 5.1 of the summary report of the high-energy pipe failures describes the methodology and result of the flooding analyses. However, the staff found that Section 5.1 of that report does not have more detailed information than that provided in DCD Tier 2, Section 3.4.1, combined with the documents provided by the applicant for a previous internal flood protection audit (as summarized in the audit report available in ADAMS via Accession No. ML15208A386). It should be noted that as the result of the DCD Tier 2, Section 3.4.1 review and the previous audit, the staff issued RAI 114-8041 (ADAMS Accession No. ML15208A282). The staff has not found any new information in this audit that would resolve or change the questions in RAI 114-8041 and the staff's audit observations documented in ML15208A386.

5.0 CONCLUSION

This summary audit report supports the staff evaluation that will be documented in Sections 3.6.1 and 3.6.2 of the SER. The NRC staff will conduct a follow-up audit of the final APR1400 PRHA report when KHNP notifies the NRC staff that the report and its associated supporting documents are available in the KNHP electronic reading room.

6.0 REFERENCES

1. NRO-REG-108, "Regulatory Audits," ADAMS Accession Number ML081910260, issued April 2, 2009.

2. APR1400 Design Control Document, Revision 0, dated December 2014.

3. SRP Section 3.4.1, "Internal Flood Protection for Onsite Equipment Failures" Revision 3, issued March 2007.

4. SRP Section 3.6.1, "Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," Revision 3, issued March 2007.

5. SRP Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," Revision 3, issued March 2007.

6. Branch Technical Position 3-3, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," Revision 3, issued March 2007.

7. Branch Technical Position 3-4, “Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment,” Revision 2, issued March 2007.

AUDIT QUESTIONS

No.	Item Description	Response/Status
1	Page A1 of the Summary Report states that Table A1-1 and Table A1-2 show only terminal end break loads. It further states that the intermediate breaks will be determined based on stress analysis results of the piping after the stress analysis is completed. However, it should be noted that intermediate breaks for ASME Class 1 piping should be determined based on stress analysis and CUF (cumulative usage factor) analysis as described on Page 8. The applicant was requested to provide clarification.	The applicant will include a footnote or a statement to clarify that intermediate break locations for ASME Class 1 piping are determined based on stress analysis, including the fatigue usage factor.
2	The term "No pipe whip occurs" on Page A8, Table A1-2 of the Summary Report is not clear and needs to be clarified. Does it mean that there is no concern of pipe whipping effect because no essential targets nearby? Or does it mean that the geometric configuration and the design of the pipe will result in a very limited movement of the broken end of the ruptured pipe?	The applicant will include a note on Table A1-2 to clarify the term "No pipe whip occurs." This clarification will include that the geometric configuration and design of the pipe will result in a very limited movement of the broken end of the ruptured pipe.
3	Section 2.4.3, "Specific Protection Measure," on page 5 states that "the effects of high-energy pipe breaks are not analyzed where it is determined that all essential SSCs are sufficiently physically remote from postulated break in that piping run." The applicant was asked to define "sufficiently physically remote" and clarify if this statement is also applicable to environmental effects or just dynamic effects.	The term "sufficiently physically remote" will be revised to state "if SSC are outside the zone of influence of the dynamic effects of jet impingement (including blast wave) and pipe whip for high energy break." In addition, the applicant will revise the statement to explain that dynamic and environmental effects are considered in the analysis.
4	In numerous pipe whip (PW) & jet impingement (JI) survey and load calculations (e.g., PW & JI Survey and Load Calculation for RC line inside containment), the applicant states that an unrestrained whipping pipe is considered to be capable of causing damage on the impacted pipe of smaller nominal pipe size and developing through wall crack in equal or larger nominal pipe size with thinner wall thickness. It further states that even though the target pipe is larger than the impacting pipe in nominal pipe size and wall thickness, pipe whip load and jet impingement load on the impacting location should be given to Plant Design stress group to evaluate the stability of the piping system. Clarification is needed for how "to perform stress analysis." Also, clarification is needed to address whether the dynamic pipe whip load and jet impingement load are considered in the design of the impacted target pipe with equal or larger nominal size and wall thickness.	The applicant will revise the statement of "to evaluate the stability of the piping system" as "to perform stress analysis of the piping system" in the calculations.
5	During the audit, the staff noted that the versions of ANSYS Code identified for some piping and structural analyses are different from what identified in the DCD Sections 3.9.1, 3.7.2, and 3.8. The versions identified in these DCD sections include "Computer Code ANSYS Release 12.0, ANSYS INC. 2009", "ANSYS Release 14.0, ANSYS Inc., Nov. 2011", and "Computer Code Version 12.1, Verification Document No DAVM121, Rev. 0 December 2010". However, the staff noted that different versions (e.g., ANSYS APDL Version 13" in Summary Report 1-037-N419-006 and "ANSYS Version 15" in Report 1-035-N383-012) are identified for pipe structural analyses and for structural analysis calculation of nozzle and pipe support loading. The applicant was requested to clarify whether all the different ANSYS Code versions as identified in the pipe rupture related analyses reports/calculations have been verified from the vendor (or code developer).	ANSYS Release 13.0 is used in the analysis of "Loads and moments on S/G nozzles due to MS/FW," calculation number (1-035-N383-010). The version number "15" on page 7 of this calculation is typographical error. It will be revised to "13". KEPCO E&C has Software Verification and Validation Document which contains detailed verification document provided by ANSYS software provider and in-use test report in accordance with KEPCO E&C QA manual. Many benchmark test problems provided by software vendor have been solved to confirm the correct installation and use of the program. Other versions of ANSYS are appropriately controlled and maintained under same QA policy.

Attachment