Audit Report

Nuclear Regulatory Commission Staff Audit of the U.S. EPR Source Term and Shielding Calculations

INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) staff conducted an audit of the U.S. EPR (the applicant) source term and shielding calculations (including radiation zoning) for radiation sources outside of containment. The audit was performed by reviewing the applicant's calculations via the applicant's Electronic Reading Room. In addition, an audit meeting was held at the applicant's Marlborough, Massachusetts (MA) office on December 9 – 10, 2014. The NRC staff audited the reading room material periodically from November 2014 through March 2015.

OBJECTIVES

The objective of the audit was to review the applicant's radiation source term and shielding calculations to determine if they were consistent with NUREG-0800, Chapter 12, and that the assumptions used in developing the source terms and shielding were appropriate and that the calculations were adequate.

BACKGROUND

The NRC staff issued Request for Additional Information (RAI) 539, Question 12.03-12.04-29 and RAI 548, Question 12.03-12.04-31 in 2012, requesting that the applicant provide additional information regarding certain radiation sources and minimum shield wall thicknesses for various equipment and plant areas. In a draft response, the applicant proposed Final Safety Analysis Report (FSAR) revisions to update most of the plant radiation sources outside containment and revised shielding information for those sources. Those proposed changes have been incorporated into the FSAR. Discussions with the applicant regarding this draft RAI response led to a review of the applicant's source term and shielding calculations in the applicant's Electronic Reading Room. The NRC staff provided various comments to the applicant upon the review of the reading calculations. Some comments requested additional clarity from the applicant, while others pointed out inadequacies or apparent inconsistencies between the source term and shielding calculations and the FSAR. The NRC staff acknowledged that while the applicant provided numerous comments, they were unable to complete the review of the material in the reading room because of some apparent errors that were discovered, as well as time constraints.

The NRC staff also expected the applicant to review the calculations to ensure that other errors, beyond those apparent errors discovered by the NRC staff were corrected. In November 2014, the applicant provided responses to the NRC staff's comments, as well as revised calculations and additional information in the applicant's Electronic Reading Room. Therefore, the NRC staff began auditing the material provided.

AUDIT ACTIVITIES

As indicated above, the audit was focused primarily on the source term and shielding calculations for plant sources outside containment. FSAR Section 12.2 provides source term information for plant radiation sources and lists the radionuclide inventory and photon spectra for major sources throughout the plant. FSAR Section 12.3 provides radiation protection design features, including radiation shielding and zoning information for the entire plant site.

The review of the audit material can be broken down to four separate areas of review, (1) FSAR Section 12.2 radiation sources (i.e., the most significant radiation sources in the plant for which specific source terms information is provided in FSAR Section 12.2; (2) shielding for the FSAR Section 12.2 radiation source; and (3) zoning and shielding for other radiation sources (less significant radiation sources which were not included in FSAR Section 12.2); (4) Other items related to the material being audited, such as ensuring consistency within the FSAR as a result of the source term and shielding calculations and updates.

A general discussion of each of these four areas is provided below. Detailed NRC staff comments related to the audit material and discussions can be found in the Appendix 1 to this audit report.

The NRC staff notes that while the applicant provided slides related to FSAR Revision 5 comments, the NRC staff was unable to review these slides as part of the audit, as they were outside the scope of the calculation packages and the material being audited, and due to time limitations.

FSAR Section 12.2 Radiation Sources

The applicant provided the calculation for the major sources outside containment in Calculation Package 126-9043718-008. The methodology used for determining the radiation source is consistent with Standard Review Plan (SRP) Section 12.2 criteria.

To develop the source terms the maximum core inventory was calculated using the ORIGEN-2 code. From the core inventory, the reactor coolant system (RCS) equilibrium activity was calculated assuming a 0.25 percent failed fuel fraction, applicable escape rate coefficients, consideration of flow to the coolant purification system for clean-up and coolant loss for boron control, and an operating time of one year. The ELISA-2 computer program was then used to determine the radionuclide transfer to each component, using applicable input parameters.

While the general approach to developing source terms was acceptable, the NRC staff had various questions related to assumptions used for specific sources. For example, the volume control tank (VCT) source term was calculated assuming average pressure and the assumptions used for shielding were based on a half liquid and half gas source. The VCT pressure, along with the liquid and gaseous volume, varies during operation based on operating conditions. The gaseous source term results in higher dose rates. Therefore, a higher gaseous pressure would result in a higher concentration of gaseous radionuclides (mostly noble gases) and a larger VCT source term. In addition, the VCT gaseous source term was modeled based on the radionuclide concentrations in the purge gas circuit, adjusted for differences in pressure. The NRC staff questioned why the calculation did not consider gaseous material coming directly through the primary coolant and why the maximum pressure was not considered in the VCT calculation.

In response to NRC staff questions, the applicant acknowledged that both the chemical volume control system (CVCS) and the degasification system could both be operational at the same time, especially prior to a refueling outage (when primary coolant concentrations are at their maximum). Therefore, the applicant agreed to update the VCT gaseous source term, the change results in a source term increase by a factor of about 1.8. The applicant indicated that the FSAR will be updated to include the revised source term. The applicant also agreed to update the coolant storage tank gaseous source terms based on the same type of concern.

While the applicant agreed to update the VCT source term to account for both gaseous activity pathways, the applicant did not agree to increase the source term based on a pressure increase. The applicant acknowledges that the VCT pressure and volume will vary during operation; however, the applicant states it is reasonable to assume a pressure of 29 (pounds per square inch gauge (psig), as the applicant assumed in their calculations, since a reducing station will be in place to correct tank pressure to 29 psig. The NRC staff notes that the applicant did not provide sufficient justification to support their position, therefore, the NRC staff requests additional information from the applicant in Appendix 1.

Shielding for the FSAR Section 12.2 Radiation Sources

The radiation shielding programs Microshield, Version 8, and DIDOS-V were used to determine minimum shield wall and floor thicknesses for various plant areas, for the source terms developed in calculation 126-9043718-008. The NRC staff reviewed the technical manual and validation provided by AREVA for DIDOS-V, at the request of the NRC staff, and the NRC staff agrees that the DIDOS code appears to provide comparable results to Microshield and has in certain instances more versatility than the Microshield code. Microshield is an acceptable code for modeling gamma radiation source shielding. In addition, the NRC staff could find no problems or inadequacies with the use of the code, as long as it is used properly. Therefore, the NRC staff accepts the use of the DIDOS code for the U.S. EPR design, as described by the applicant.

The general approach used by the applicant is acceptable; however, the NRC staff identified several problems in individual calculation results and assumptions. A few of these issues are discussed below, additional NRC questions and comments can be found in Appendix 1 of this report:

- The NRC staff identified several inconsistencies between the calculation results and the information provided for the minimum shield wall thicknesses in the FSAR. For example, for a few of the wall thicknesses, the calculation results indicated that more shielding was needed than the minimum wall thickness provided in the FSAR figures in Section 12.3. The applicant agreed to correct those type errors that were presented to them during the initial audit.

- The NRC staff questioned whether the applicant considered the dose rates from multiple sources in the same vicinity, particularly from the coolant storage tanks. The applicant agreed to review this calculation and correct the FSAR, if necessary.

- The NRC staff notes that the spent fuel (SF) source term and maximum assembly source term developed in Calculation Package 126-9043718-008 did not appear to be used in the shielding evaluation and the minimum shield wall thicknesses around the spent fuel pool (SFP) are less than other reactor designs.

Zoning and Shielding Calculations for Other Radiation Sources

The applicant's Calculation Package 126-904-636-002 describes their approach for determining radiation zoning and shielding for sources not provided in FSAR Section 12.2. The approach is based on comparing the dose rates from a fictitious small tank filled with the 0.25 percent RCS fluid source term for U.S. EPR, to the dose rate from a tank of the same dimensions filled with Olkiluoto 3 (OL3) design basis source term through various concrete shield thicknesses. OL3 is a Finnish reactor, comparable to the U.S. EPR whose design basis source term is based on expected operating conditions (instead of 0.25 percent failed fuel). The applicant determined that the dose rate for U.S. EPR was approximately 3.8 times the source term for OL3. The applicant then divided that value by 2 since the dose rates are not always at the top of the zone range. The applicant then compared zoning and shielding for OL3 to U.S. EPR and used the factor of 1.9 to determine U.S. EPR shielding and zoning for many of the sources not provided in FSAR Section 12.2.

The approach described above was not described in the FSAR and the NRC staff concluded that there was inadequate basis to approve this approach. The NRC staff was particularly concerned with the lack of a basis for dividing the factor of 3.8 by two. The only basis the applicant provided was because not all of the dose rates for OL3 were at the top of each zone. The NRC staff determined that this was inadequate justification.

As a result, at the December 9 and 10, 2014, audit, the NRC staff notified the applicant that their approach was unacceptable. The applicant agreed to reconsider the approach used for the radiation zoning and shielding for these sources. The applicant is expected to develop an approach in this area with sufficient justification for its acceptability and submit to NRC staff for review. The applicant is also expected to update the FSAR in the future to describe the approach that is developed and make other changes as necessary.

In addition to the concern discussed with the applicant at the December 9 and 10, 2014, audit, the other major concern the NRC staff has with the applicant's approach is that the factor of 3.8 was developed entirely on an analysis of a source term of RCS fluid. There is no analysis regarding if the factor of 3.8 would still be an adequate factor for the differences in other plant sources, which will have different radionuclide ratios compared to RCS fluid. For example, a demineralizer will collect nearly all of certain isotopes from RCS fluid, while others, such as noble gases, will pass directly through. Therefore, the demineralizer and all components downstream the demineralizer will have a different radionuclide ratio than the RCS fluid. The applicant's calculation does not consider if the factor of 3.8 remains an adequate comparison between OL3 and U.S. EPR design basis source terms for different isotopic compositions.

Other

Other information reviewed during the audit included ensuring that there were no inconsistencies between FSAR Chapter 12 and other FSAR sections (including Tier 1), and ensuring the changes to source terms did not affect other analysis in the FSAR, such as equipment qualification. For example, the applicant did not account for steam generator blowdown resin in the FSAR Chapter 11 waste storage and shipping volume estimates. The applicants Chapter 12 source terms for the steam generator blowdown mixed bed demineralizer are based on a change out frequency of 36 weeks and the steam generator blowdown cation demineralizer was based on a change out frequency of 12 weeks. The applicant indicated that since the resins are re-generated or the waste is sluiced directly to a truck and shipped offsite that it does not need to be included in the FSAR Chapter 11 waste or

shipping estimates. The staff disagrees with the applicant's approach. Specific questions related to this topic are found in Appendix 1 of this report.

CONCLUSIONS

During the audit, the applicant addressed many of the NRC staff's questions and concerns. However, as discussed above, the NRC staff's initial round of questions were not based on a complete review of the material. Therefore, the NRC staff has additional questions and feedback for the applicant, including follow up questions to the answers previously provided. This information is found in Appendix 1 of this report.

In addition, the applicant previously agreed to various actions and FSAR updates that have not yet been completed, including revising the methodology used for shielding and zoning of the radiation sources not explicitly modelled in FSAR Section 12.3.