PRE-CLOSURE SAFETY ANALYSIS: SENSITIVITY STUDIES AND PRELIMINARY DOSE RESULTS

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INTRODUCTION

The U.S. Department of Energy (DOE) is responsible for the design, construction, and operation of a permanent high-level waste (HLW) repository at the potential Yucca Mountain (YM) site. The potential YM functional lifetime will consist of a pre-closure period (construction and operation) and a post-closure period (long-term waste isolation). DOE must submit a license application to the U.S. Nuclear Regulatory Commission (NRC) for the construction and operation of the YM facility. NRC will evaluate compliance with the performance objectives of 10 CFR Part 63.

This paper evaluates the source term of a radionuclide release from spent nuclear fuel (SNF) and its potential consequences during the preclosure period of the potential YM repository.

WORK DESCRIPTION

Various potential initiating events are considered during the pre-closure period that may lead to a radionuclide release to the environment. Current preliminary design for the pre-closure facilities include a dry transfer building where bare assemblies will be transferred from the transportation cask to the waste package in air. Bare SNF assemblies are susceptible to damage from drops or collisions. Additionally, this is likely the first time the SNF is exposed to an air environment. SNF pellets in rods with breached cladding may oxidize in air. SNF oxidation may lead to pellet pulverization and clad unzipping.

The Pre-closure Safety Analysis (PCSA) Tool was designed by the Center for Nuclear Waste Regulatory Analyses, for NRC use in their evaluation of DOE compliance with the pre-closure performance objectives of 10 CFR Part 63.111. The tool incorporates several software packages that allow the user to perform event sequence analysis (SAPHIRE), consequence analysis of an atmospheric radionuclide release (RSAC), and calculations of building discharge fractions (MELCOR) [1].

This paper assesses the atmospheric release of radionuclides from the dry transfer facility at YM through consequence and sensitivity analyses. PCSA Tool, Version 3.0 was used to calculate doses for various initiating events and corresponding source terms. In these dose calculations, radionuclides are assumed to leave the building through a filtered ventilation stack at a height of 30 meters. The receptor is assumed to be located downwind at ground level.

The source term for a given event sequence is the product of the damaged material, release fraction, building discharge fraction, and high efficiency particulate air (HEPA) filter mitigation factor. The PCSA tool allows the user to input the various components of the source term. The user may choose the number, type (BWR/PWR), and burnup of SNF assemblies damaged, as well as the release fraction, building discharge fraction, and HEPA mitigation factor.

The release fractions used in the generation of the source term depend on the physical and chemical form of the material at risk, as well as the initiating stress. The methodology for formulating these factors draws upon empirical correlations, models, and experimental data [1, 2].

	Release Fraction	
Material at Risk	**Assembly Drop/ Collision**	**SNF Oxidation/ Pulverization**
H^3	0.3	0.3
Noble Gases	0.3	0.3
I^{129}	0.3	0.3
Co^{60} Crud	0.15	0.15
Ru^{106}	2.0E-04	2.0E-03
$Cs^{134,135,137}$	2.0E-04	2.0E-03
Sr^{90}	2.0E-06	1.2E-03
All Others	2.0E-06	1.2E-03

Table 1- Release Fractions for Spent Nuclear Fuel

In Table 1, impact analysis results are the basis for Assembly Drop/Collision release fractions. For SNF Oxidation/Pulverization, the release fraction is based primarily on experimental data involving the oxidation of spent fuel.

DOE's design of the dry transfer facility is not finalized, and analyses are ongoing to determine the risk associated with assembly drops, collisions, and SNF oxidation. Considering the current status, a range of inputs is explored through sensitivity analyses. Potential doses are calculated for various building sizes, ventilation stack heights, filter efficiencies, and distances.

RESULTS

Current DOE designs indicate a site boundary of 11 km (6.84 miles). The potential dose at this site boundary per assembly damaged is shown in Figure 1 as the leak path factor (LPF) for solid radionuclides is varied. All gaseous radionuclides released from SNF are assumed to leak from the building. The LPF for solid radionuclides is the product of the building discharge fraction and HEPA filter mitigation factor. The default LPF values used in the PCSA Tool are 3E-6 for Crud and 6E-7 for other particulates.

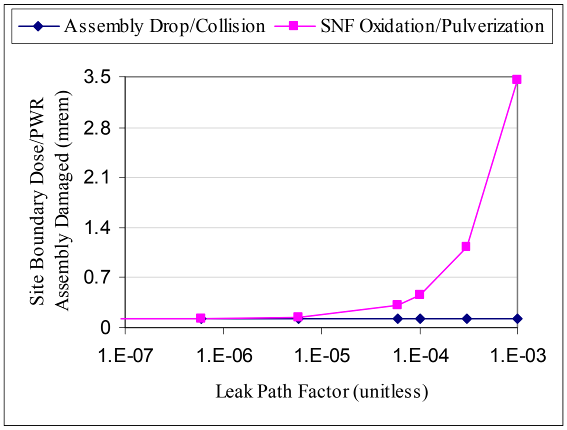

Figure 1- Dose per Assembly Damaged at the Site Boundary (11 km [6.84 mi] from release)

It is also of interest to see how the dose will vary as a function of distance from the release. As the release travels downwind, radionuclides are dispersed and deposited. Figure 2 shows the onsite dose that may be expected when a PWR SNF assembly is damaged in the dry transfer facility. The default LPF was used.

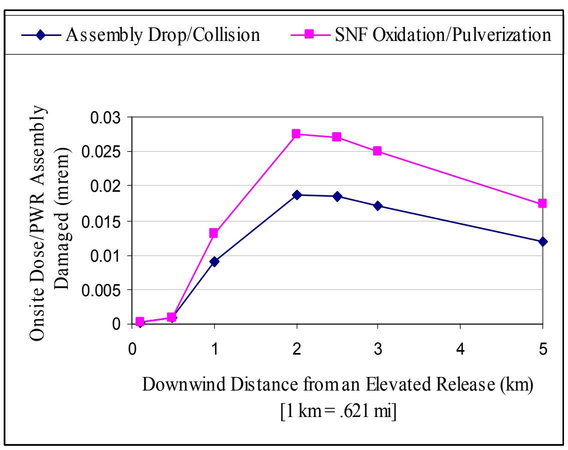

Figure 2- Onsite Dose per Assembly Damaged

The doses presented here are given per assembly damaged. In the actual compliance assessment, the dose per assembly would be multiplied by the number of SNF assemblies damaged, as determined by event sequence analysis.

CONCLUSIONS

The radionuclide release from a SNF assembly drop or collision appears to be insignificant. In evaluating dose consequences from SNF oxidation, it is important to determine whether or not detrimental oxidation would occur in fuel rods with pinhole leaks or hairline cracks. The realistic risk of SNF oxidation will depend on DOE's ability to prevent or mitigate oxidation through design. In the worst case, where temperature is high enough for detrimental oxidation ($UO_2 \rightarrow U_3O_8$) to occur, the potential exists for clad unzipping, and pellet pulverization. Detrimental oxidation is not believed to occur below a threshold temperature of about 275^0C [530^0F] in medium burnup PWR SNF. Above the threshold, the rate increases with temperature [3].

Credit taken for the deposition, agglomeration, and filtration of particulate radionuclides prior to atmospheric release may greatly reduce the dose; however, SNF oxidation, coupled with low building leakage, may severely contaminate the hot cell.

DISCLAIMER

The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of a license application for a geologic repository at Yucca Mountain.

REFERENCES

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