Performance Assessment of a Post-Closure Pyrophoric Event

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INTRODUCTION

The U. S. Department of Energy (DOE) spent nuclear fuel (DSNF) is categorized into eleven different spent fuel groups. Group 7, is predominantly uranium metal spent fuel from N Reactor that could oxidize rapidly in the presence of air when a waste package is breached. Such rapid oxidation constitutes a pyrophoric event.

The consequences of a post closure pyrophoric event were evaluated in terms of its potential to damage adjacent waste packages and consequences of it in terms of long-term dose to humans.

This work was conducted as part of the total system performance assessment (TSPA) of DOE spent fuel for the National Spent Nuclear Fuel Program. These analyses were performed in support of the site recommendation for a repository at Yucca Mountain, Nevada.

DESCRIPTION OF THE WORK

Thermal Analyses

The analysis of a post-closure pyrophoric event involved thermal calculations associated with the energy generated from a pyrophoric event. The thermal energy from an event is based on the oxidation reaction of uranium metal fuel to \( U_3O_8 \).

The energy generated by the formation of \( U_3O_8 \) is 1191.6 \( kJ/g \)-mole of uranium metal. The waste package for disposal of N Reactor spent fuel is a co-disposal package, which contains two Multi Canister Overpacks (MCOs) and two canisters of high level waste (HLW). The amount of uranium metal fuel in each MCO is 5284.72 kg. The energy from oxidation of one waste package is \( 5.29 \times 10^7 \) kJ.\(^1\)

The thermal calculations were performed using the thermal hydrologic flow and transport code NUFT\(^2\). The waste packages are disposed end-to-end in a thermal line load in the open drift under a drip shield. For disposal, N Reactor waste packages are placed between commercial spent fuel packages.

The energy generated from a pyrophoric event was applied over a range of times of 1 day, 7 days, and 30 days. The thermal calculations were then conducted for a range of waste package spacing of 0.10 m, 0.42 m and 3.7 m, which correspond to a thermal line loading of the repository drift of 1.54 kW/m, 1.45 kW/m, and 0.9 kW/m, respectively. The events were assumed to occur at different times after repository closure so that the pyrophoric events occur at selected drift wall temperatures. The times of event occurrence are 20 years, 10,000 years, and 100,000 years and correspond to drift wall temperatures of approximately 200°C, 50°C, and
25°C, respectively. The event time of 20 years represents the time of maximum waste package temperature, while 10,000 years and 100,000 years represent the approximate time of the first waste package failure and the approximate time of return of the repository to ambient temperature, respectively.

Dose Analyses

The calculations of dose to the receptor were conducted using the TSPA-SR model. For the dose calculations the waste was assumed to be released instantaneously from the package at the time of the event, and to be spread uniformly as particulate in the area bounded by the drip shield and the two adjacent waste packages. The event for the dose calculations was assumed to occur at 10,000 years after repository closure and the drip shield was assumed to have failed.

RESULTS

The highest temperature of 524°C at the adjacent waste package, occurred at 20 years after a 1-day pyrophoric event for 0.01-meter package spacing. This case is not considered to be realistic because no packages fail, in the TSPA-SR model, until 10,000 years after repository closure. At that time the calculated temperature of the adjacent waste package was 342°C for the highest thermal loading case, 1.54 kW/m.

The peak dose from the event is calculated to be about 1 millirem from the Group 7 DSNF package and about 2 millirem if both adjacent packages of commercial spent fuel fail. Sensitivity analyses of the area over which the particulate is distributed, particulate size, and particulate dissolution model (oxide fuel and instantaneous) had little effect on the peak dose.

CONCLUSIONS

The peak temperature on the adjacent waste packages caused by a pyrophoric event does not appear to be high enough to cause package failure. The peak dose from the pyrophoric event is about 1 millirem and increases to about two millirem if the two adjacent commercial fuel packages are assumed to fail. These analyses show that consequences of a post-closure pyrophoric event are small and an event is unlikely to damage other waste packages.

REFERENCES

