SAND2019-7226C

Options for Modifying Existing and Future DPCs for Disposal

Ernest Hardin[1], Abdelhalim Alsaed[2] and Branko Damjanac[3]

[1]*Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185,* ehardin@sandia.gov
[2]*Enviro Nuclear Services, 3595 S. Town Center Dr., Las Vegas, NV 89135,* halimalsaed@environuclear.net
[3]*Itasca Consulting Group, Inc., 111 Third Avenue South, Suite 450, Minneapolis, MN 55401,* branko@itascacg.com

INTRODUCTION

Direct disposal of commercial spent nuclear fuel (SNF) in dual-purpose canisters (DPCs) currently located across the U.S. has the potential to simplify disposal operations, minimize the number of SNF shipments, reduce collective worker dose, and significantly decrease the cost for geologic disposal (compared to repackaging in purpose-built disposal canisters). The greatest technical challenge is associated with postclosure criticality control, because modern DPCs depend on aluminum-based materials for neutron absorption during storage and transportation, and those materials will degrade in a few decades when exposed to ground water in a repository. This paper focuses on postclosure criticality control in DPCs, with the understanding that questions related to safety, engineering feasibility, and thermal management can be readily resolved using available technologies [1].

Previous studies have shown that flooding of unmodified, as-loaded DPCs with chloride brine, as could be expected for a breached waste package in a salt repository, would ensure subcriticality for most, if not all existing DPCs and those that will be loaded in the future. For host media other than salt, DPC modifications or repackaging would be needed to decrease the probability of a criticality event below the level of regulatory concern. Without such measures, the consequences from in-package criticality events would need to be modeled and accounted for explicitly in regulatory performance assessment (PA) strategy for the repository.

By way of background, for the Yucca Mountain license application, in-package postclosure criticality was excluded from the PA on the basis of low probability. This was possible with the specified transport-aging-disposal (TAD) canister, for which the basket would include neutron-absorber plates made from borated stainless steel. A repackaging strategy for DPCs would resemble the approach proposed for Yucca Mountain, which included capacity to receive several hundred DPCs, cut them open, and repackage the fuel in disposal-ready TAD canisters. However, at present there are many more DPCs in service, increasing the attractiveness of potential solutions that make DPCs (and the SNF they contain) directly disposable. (Note that DPCs that are directly disposed of without repackaging, would very likely be sealed into a disposal overpack designed to maintain containment for some prescribed period of time depending on the performance strategy for the repository.)

DPC MODIFICATION APPROACHES

The U.S. Department of Energy (DOE) is conducting R&D in several areas to develop technical solutions for modifying DPCs of existing designs, to limit the probability of postclosure criticality in any repository host medium (e.g., clay/shale, crystalline rock, or unsaturated settings). The approaches are: (1) injectable fillers; (2) corrosion-resistant absorber plates that can be substituted for Boral in certain basket designs; (3) loading DPCs with blending of fuel assemblies from fuel pools based on reactivity; and (4) disposal control features such as rods or blades that can be inserted when the canisters are loaded. Each of these options could in principle be applied to both PWR and BWR fuel. The options could be used in any combination, with different sets of DPCs, to achieve a low-probability criticality screening approach.

FILLERS

Injectable fillers would be injected as liquids into existing DPCs, where they would solidify, and displace or exclude ground water from breached waste packages in a repository. Fillers is the only DPC treatment concept that if successful, could be applied to the entire existing fleet of DPCs, and eventually every SNF canister ever loaded in the U.S., without cutting them open for modification or repackaging. The R&D program has begun to investigate alternative filler materials and methods for injection. It is the subject of papers from ORNL and SNL and is not discussed further here.

CORROSION RESISTANT ABSORBER PLATES

Substituting absorber plates with corrosion-resistant materials would not require changes in the design of DPC baskets that use non-structural absorber plates. Basket fabrication with absorber plates held in place by stainless cover sheets is complex for large-capacity DPCs, especially for BWR fuel. Hence, the market is trending toward baskets constructed almost entirely from aluminum based materials that serve both the structural and neutron absorption functions. As time passes this trend could limit the total number of DPCs with absorber-plate baskets.

The absorber plate approach was adopted for specification of a standardized multi-purpose canister that could be used for disposal in any geologic medium [2,3]. Borated stainless steel was selected for that specification, with acknowledgment that laboratory testing would be needed to extend the applicability to media besides Yucca Mountain,

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

and that other materials may work as well or better. The absorber plate concept for criticality control is effective for storage and transportation, with intact fuel. However, for disposal applications the plates will corrode, so the challenge is to find and prove an absorbing material that lasts as long as the fuel assemblies, or at least through the regulatory period for a repository. Fuel assemblies are made from corrosion resistant materials, and reactivity persists beyond the regulatory period for a repository (i.e., beyond 10,000 years), complicating this requirement.

ZONE LOADING

The concept of zone loading DPCs to decrease reactivity was extensively analyzed for 32-PWR size canisters by EPRI [4]. Recent criticality calculations [5] for as-loaded DPCs demonstrated that many existing DPCs could have been loaded with the same SNF inventory in a configuration optimized such that they would be subcritical without any credit for fixed neutron absorbers. These calculations were performed for several hundred as-loaded DPCs, and they also showed an evolution of modern DPCs toward less reactivity margin. Projecting the approach to large-capacity, burnup-credit basket designs loaded in the future indicates that for the ultimate DPC inventory in the U.S., that the effectiveness of zone loading for postclosure criticality control will be limited.

INSERTED DISPOSAL CONTROL FEATURES

The concept of "surrogate control rods" was originally analyzed by EPRI [4,6] with potential application to a Yucca Mountain repository. The criticality control effectiveness of control rods and blades is proven based on their use in reactors. Insertion of control rods into PWR assemblies would use existing assembly guide tubes (not occupied by spent reactor control rods). Disposal control rod assemblies (DCRAs) would be similar in design to reactor rod cluster control assemblies (RCCAs), and would have similar corrosion and mechanical properties to Zircaloy-clad fuel rods, filled with pellets of sintered B_4C. By analogy to reactor core configurations, only a few DCRAs would be needed in a DPC; the required number and arrangement would be determined from detailed reactivity calculations.

Modeling approaches have been developed to show how fuel rods and control rods would degrade, and change configuration, over many thousands of years in a repository (Fig. 1). As the basket and fuel assemblies collapse, the control features would collapse with them, and the evolving configuration would tend to have less neutron moderation. However, there could be operational challenges caused by bowing of guide tubes, the presence of RCCAs, or other fuel assembly design features that block access for insertion.

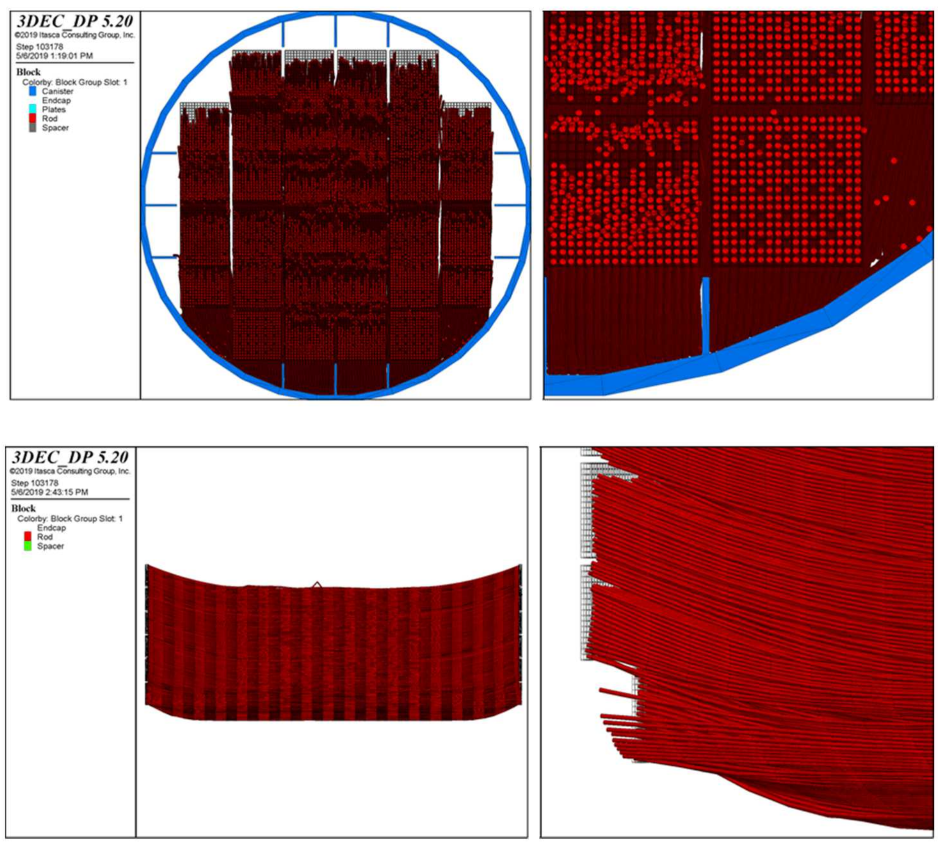

Fig. 1. Numerical Distinct Element Simulation of DPC Basket and Fuel Collapse Due to Corrosion.

For BWR fuel, control blades could be inserted between assemblies (or groups of four) from the top. There is no precedent for installing control blades in current DPC designs for BWR SNF. Control blades would likely require DPC basket redesign to accommodate blade thickness, and because BWR reactor control blades are inserted from underneath the vessel during operation. Control rods could also be developed for insertion into the "water rod" voids, which vary significantly for different fuel types. The absorption effectiveness and logistical feasibility of all disposal criticality control solutions, for PWR and BWR fuel, will be verified by analysis.

In summary, disposal criticality control features for BWR fuel are less technically mature than for PWR fuel. From a technical perspective implementation of DCRAs in PWR DPCs could be implemented sooner (e.g., with a goal to treat 50% of the eventual overall inventory of PWR fuel in DPCs). There are no anticipated regulatory or technical barriers anticipated for the insertion of control rods or blades, for postclosure criticality control.

The DCRA concept, and each of the other concepts discussed above would be effective and compatible with the disposal concept detailed in the Yucca Mountain repository license application.

SUMMARY

The overall DOE R&D strategy for DPC disposition includes a significant effort directed toward consequence screening to determine if engineered solutions discussed above are needed. Work to develop injectable filler technology will continue. The disposal criticality control features approach, and zone loading, have not been investigated since the EPRI studies in 2008-2009. The utility of such measures would be maximized by implementing them soon. This ongoing study is motivated by comparative cost analysis [7] that showed the potential cost savings using the control rods/blades approach, compared to repackaging (comparing the two most technically mature options for DPC disposition and retaining the low-probability criticality screening objective) would be approximately *$2 million per DPC.*

REFERENCES

1. Hardin, E., L. Price, E. Kalinina, T. Hadgu, A. Ilgen, C. Bryan, J. Scaglione, K. Banerjee, J. Clarity, R. Jubin, V. Sobes, R. Howard, J. Carter, T. Severynse and F. Perry 2015. *Summary of Investigations on Technical Feasibility of Direct disposal of Dual-Purpose Canisters*. FCRD-UFD-2015-000129, Rev. 0. U.S. Department of Energy Used Fuel Disposition Campaign. May 2015.

2. ORNL (Oak Ridge National Laboratory) 2015a. *Performance Specification for StandardizedTransportation, Aging, and Disposal Canister Systems*. FCRD- NFST-2014-000579, Rev. 2. U.S. Department of Energy, Nuclear Fuel Storage and Transportation Planning Project.

3. ORNL (Oak Ridge National Laboratory) 2015b. *Rationale for the Performance Specification for Standardized Transportation, Aging, and Disposal Canister Systems*. FCRD- NFST-2015-000106, Rev. 1. U.S. Department of Energy, Nuclear Fuel Storage and Transportation Planning Project.

4 EPRI (Electric Power Research Institute) 2008. *Feasibility of Direct Disposal of Dual-Purpose Canisters in a High-Level Waste Repository*. 1010851. Palo Alto, CA.

5. Liljenfeldt, H., K. Banerjee, J. Clarity, J. Scaglione, R. Jubin, V. Sobes, R. Howard, E. Hardin, L. Price, E. Kalinina, T. Hadgu, A. Ilgen, C. Bryan, J. Carter, T. Severynse and F. Perry 2017. *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters*. SFWD-SFWST-2017-000045. U.S. Department of Energy, Office of Spent Fuel and Waste Science and Technology. September, 2017.

6. EPRI (Electric Power Research Institute) 2009. *Feasibility of Direct Disposal of Dual-Purpose Canisters: Options for Assuring Criticality Control*. 1016629. Palo Alto, CA.

7. Alsaed, A. 2019. *Comparative Cost Evaluation of DPC Modifications for Direct Disposal*. SAND2019-4070. Sandia National Laboratories, Albuquerque, NM (Enviro Nuclear LLC).

absent a mutually agreed-to contract amendment. To the extent discussions or recommendations in this presentation conflict with the provisions of the Standard Contract, the Standard Contract provisions prevail.

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. Approved for Unclassified, Unlimited Release. SAND2019-*****.