SAND2013-7410C

Waste Management Conference
WM2014 : “40 Years of Meeting Global Radioactive Waste Management Challenges”
March 2 - 6, 2014
Phoenix, Arizona

Preliminary Evaluation of Dual-Purpose Canister Disposal Alternatives

E.L. Hardin, Sandia National Laboratories
R.L. Howard, J.M. Scaglione, Oak Ridge National Laboratory
H.R. Greenberg, Lawrence Livermore National Laboratory
J.T. Carter, Savannah River National Laboratory
W.M. Nutt, Argonne National Laboratory

Abstract

Disposition of commercial spent nuclear fuel (SNF) that is stored in thousands of dry casks at reactor sites, will become a major part of back-end fuel management over the next few decades. The Department of Energy, Used Fuel Disposition R&D campaign is conducting a multi-year project to understand the technical feasibility and logistics of direct disposal of SNF in existing dual-purpose canisters (DPCs) and other types of storage casks. The first phase includes a set of alternative disposal concepts, thermal and criticality analyses, identification of additional information needs, and a recommendation to proceed with the evaluation. Results from the first phase of the study are summarized as follows:

Disposal Concepts – A wide range of alternative concepts exists for DPC direct disposal. These include the salt concept, and emplacement in hard rock (i.e., crystalline) or argillaceous sedimentary rock, with or without backfill. This set is not exhaustive but covers a range of potentially important behaviors. Other factors such as ground support, waste package transport and emplacement, and shaft vs. ramp access, are also important and tend to depend more on site-specific characteristics.

The salt concept would be backfilled immediately after emplacement, while openings in hard rock and sedimentary rock would be ventilated for decades (approximately 50 years or longer) to remove heat. Hard rock formations exist that could have excellent long-term stability, heat dissipation properties, and conditions conducive to waste isolation. Argillaceous (clay-bearing) sedimentary media could have very low permeability and chemically reducing conditions, but are likely to have more restrictive thermal constraints, low thermal conductivity, and more limited long-term stability. Backfill is an option for open-mode concepts but would significantly elevate engineered barrier system (EBS) temperatures.

The cavern-retrievable storage and disposal concept was first proposed about a decade ago and remains a potential alternative. Shielded dry-storage casks or vaults could be emplaced or constructed underground, ventilated for decades to remove heat, and closed by installation of an encapsulating buffer.

Safety – Important factors that help to ensure postclosure safety for DPC direct disposal include: 1) diffusion-controlled radionuclide transport in the EBS and natural barriers; 2) near-field transport properties that are relatively insensitive to temperature; 3) limited radionuclide

transport in backfill (if present) and the host rock; and 4) attributes that limit potential postclosure criticality. These characteristics could benefit any geologic repository. When prospective repository sites are identified, site-specific data will support more resolution of postclosure safety.

Thermal Management – The salt concept and the unbackfilled hard rock concepts could accept SNF in 32-PWR size packages, with SNF burnup to 60 GW-d/MT, and approximately 50 to 100 years decay storage depending on burnup. These concepts could close within 150 years (out-of-reactor) while meeting target values for peak host rock temperature (200°C in both types of media). Required repository layout area to meet the peak temperature targets ranges from 60 to 100 m^2/MTHM.

In sedimentary media, which have a lower target value for peak rock temperature (100°C) lower burnup PWR SNF (and BWR SNF with similar heat output) could be accommodated with layout area similar to the hard rock concept. For higher burnup SNF (e.g., greater than 40 GW-d/MT) a modified concept would be needed that uses some combination of: 1) longer decay storage plus ventilation; 2) larger spacing (e.g., doubling the repository layout area); and/or 3) peak host rock temperature target greater than 100°C.

When backfill is added to the hard rock or sedimentary concepts, and installed at repository closure, the waste package temperature increases significantly. Better understanding of clay behavior, or alternative materials, is needed to facilitate backfill options for DPC direct disposal. Thus, it is important to continue R&D that could support relaxation of thermal constraints on argillaceous host media and backfill/buffer materials.

Engineering Feasibility – Handling and packaging of DPCs in repository surface facilities would be similar to current practice at power plants and storage sites. Although engineering details need to be worked out, there appear to be no significant technical feasibility questions associated with repository operations until the waste is transported underground.

Several options exist for surface-to-underground waste transport in shafts or ramps, including shaft hoists, funiculars, and rubber-tire or rail-mounted ramp transporters. These options are technically feasible although some systems would be the largest of their kind. The choice is likely to depend on site-specific geology and local experience.

Criticality – Understanding the likelihood and consequences of in-package nuclear criticality for at least 10,000 years is a key issue. Site characteristics and engineered system attributes that limit the probability of groundwater intrusion into breached waste packages are important. Additional reactivity margin is available using as-loaded assembly information and updated burnup credit. Intrusion of brine (a possibility for the salt concept) could be inconsequential because natural ^{35}Cl is a neutron absorber. Preliminary analyses indicate that many, although not all existing DPCs could be sub-critical even if chemically and mechanically degraded in the disposal environment. With further analysis, existing DPCs could be categorized according to the potential for criticality in different disposal environments. The consequences of criticality, conditioned on the probability of its occurrence, should also be evaluated as part of a complete postclosure safety analysis.

Waste Management Operational and Logistical Considerations – An approach that uses DPC direct disposal to dispose of all SNF from existing or decommissioned nuclear plants in the U.S., could take longer to implement than a re-packaging approach with a higher rate of throughput (e.g., 3,000 MTHM/yr), because of the decay storage needed for DPC-based packages to cool sufficiently for disposal (e.g., 10 kW). One advantage of extended operations is that smaller capacity facilities could be deployed.

Re-packaging could expedite disposal by using smaller canisters containing less SNF, reducing the cooling time. The incremental cost of extended dry storage for cooling DPCs could be less than the life-cycle cost of building and operating a re-packaging facility. Depending on the thermal requirements and the size of new canisters used in re-packaging, cost savings on the order of $10B or more could be realized from DPC direct disposal. Note that this preliminary result may not account for significant cost items, for example, disposal costs which go up significantly with smaller waste packages.

Acceptance – Once technical feasibility, safety and cost have been evaluated, it is important to communicate analysis findings, collaborate with industry, discuss safety with regulatory bodies, and promote reviews by external stakeholders. The current, ongoing feasibility evaluation represents the beginning of that process.

Summary – There appear to be no significant technical feasibility questions associated with handling and packaging DPCs, by analogy to current practices. For transport underground, a recent technology review concluded that while substantial engineering effort would be needed, the challenge of transporting and emplacing large, heavy DPC-based packages could be met.

For DPC direct disposal, preliminary analyses summarized above indicate that demonstration of pre-closure and post-closure safety, and repository implementation, could be technically feasible at least for certain disposal concepts. The analyses also suggest that important cost savings might be realized compared to re-packaging DPCs, although further analysis is needed.