Numerical Investigation of the Mechanical Response of Dual-Purpose Canisters to Internal Pressurization

PROJECT DESCRIPTION

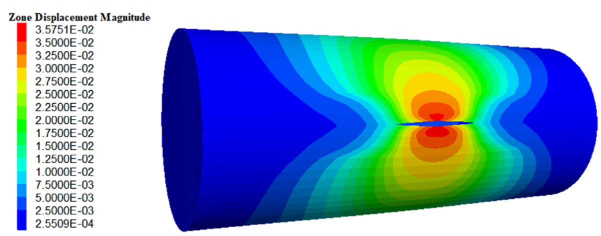
United States Department of Energy

USA

Storage, transportation, and long-term disposal of spent nuclear fuel (SNF) is an on-going challenge in many countries. Around 20% of the electricity generated in the United States is from nuclear power plants. These plants generate around 2,000 tons of SNF annually, and there is presently an inventory of around 25,000 tons of SNF. Dual purpose cannisters (DPCs) are used for temporary storage and transportation of spent fuel rods. The U.S. Department of Energy is investigating the performance of DPCs for direct geological disposal of spent nuclear fuel. Post closure criticality control is an important aspect of this investigation. A breach in the canister could allow groundwater to fill the canister. Thus, if the canister internals and fuel assemblies have been sufficiently degraded, a criticality event (an uncontrolled nuclear chain reaction) could occur. Such an event would create a transient high temperature and pressure within the canister and cause radionuclides to leave the canister. This internal pressurization may cause the initial fractures in the canister and overpack to grow, and the criticality events may be cyclical.

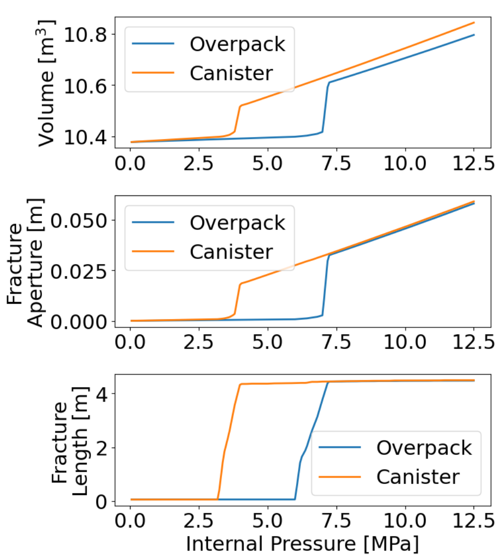
ITASCA'S ROLE

Itasca Consulting Group has developed a numerical modeling methodology to better understand how a DPC will respond to a criticality event. The modeling assumes that the canister has an initial breach (crack), and that the canister is filled with water. *FLAC3D* is used to model deformation, yielding, and fracturing of the canister and overpack. The models are quasi static; a spatially uniform and time-constant pressure is applied to the inner surface of the canister. The model is solved to equilibrium. Once mechanical equilibrium is reached at a given pressure, the pressure is increased, and mechanical equilibrium is reestablished. The model is stopped when the critical pressure (that causes canister failure) is reached. Failure may be by either fracture growth or yielding.



Displacement magnitude contours for a longitudinal fracture.

PROJECT RESULTS



Canister mechanical response curves.

Fracture growth will not happen if the ultimate strength of stainless steel is reached before the critical pressure for fracture growth. In all cases analyzed in this study, the failure processes (both fracturing and plastic yielding, if a perfectly plastic model is assumed) are unstable. Once failure starts, it continues at a constant pressure. Note that these models are quasistatic and with constant pressure. For both the canister and a thicker overpack, longitudinal initial fractures around 1 cm and longer will grow due to internal pressurization. The critical pressures required to fail the overpack are greater than those for the thinner canister. In both the canister and overpack, hoop fractures for the assumed initial fracture lengths of approximately 6 cm or less will not grow before plastic yielding occurs. For fracture lengths more than approximately 6 cm, failure is controlled by fracture propagation.

The *FLAC3D* modeling results are recorded as a series of mechanical response curves shown to the left. These curves are used as input to a zero-dimensional thermal hydraulic model of the water inside the canister. The coupled model considers fluid pressure changes due to canister strain and mass flow out of the canister. The model is used to better understand criticality event periodicity and consequences.

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Itasca Consulting Group, Inc.
111 3rd Ave. South, Suite 450
Minneapolis, MN, 55401, USA

www.itascainternational.com
www.itascacg.com