Design Methodology Comparison for HLW/SNF Repositories in Germany and the US

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INTRODUCTION

Recently, Germany has restarted the site selection process and the US are investigating generic options for the final disposal of high level nuclear waste (HLW) and spent nuclear fuel (SNF). While conditions between geological sites will differ, the corresponding repositories have to be designed according to similar standards that are aligned with the latest state of the art. This allows design improvement over time and comparability between sites.

Within the last years both BGE TECHNOLOGY and the Department of Energy Office of Nuclear Energy's Spent Fuel and Science and Technology Campaign independently developed repository design methods. Within the ongoing joint US-German project RANGERS (Design and Integrity Guideline for Engineered Barrier Systems for a HLW Repository in Salt) both were used to develop a repository based on two generic geological sites. This poster presents parts of the general design process of each institution.

OBJECTIVES

The overall objective is to establish an effective and complete design approach for repositories in bedded salt formations. Following subgoals are formulated:

- Demonstrate function of methodologies
- Highlight major steps of the design process
- Identify similarities and differences
- Improve or assure methodologies

The comparison comprises the state of the art. Consequently it can serve as a starting point for further analyses and improvements of the repository design process in salt.

REPOSITORY DESIGN FOR A SALT PILLOW IN GERMANY

DESIGN METHODOLOGY

HLW/SNF-repositories require long term safety without jeopardizing working safety. The design of the underground workings balances geological conditions, technical feasibility and regulatory requirements. In order to approximate an optimum, multiple design cycles are run.

The design of the repository is carried out in a considered geological formation in compliance with the safety concept and safety distances given by the regulatory framework. The latter are defined to ensure the geomechanical stability or to increase the overall long term safety of the repository system.

The main steps of the design process include:

- The development of a repository concept and the selection of the disposal casks based on the waste inventory
- The dimensioning of the emplacement fields through the optimization of the spacing between boreholes, drifts or casks by means of thermal or geomechanical analyses
- The selection of the necessary equipment for excavation, disposal or retrieval purposes

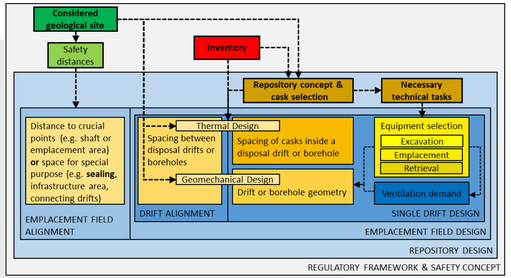

Fig. 1: Schematic illustration of the repository design method – BGE TECHNOLOGY 2020

Furthermore, technical components and the ventilation system have to be considered. They define, together with the selected equipment, the required space and geometry of the drifts to allow a smooth operation.

This design is then used to plan geotechnical barriers, to verify their integrity considering different scenarios (based on FEP analysis) and finally to simulate radionuclide migration. If these assessments are successful, the layout can be considered as the final one.

RESULTS

This German repository design disposes self-shielded casks in 250 m long horizontal emplacement drifts (ED) which are later backfilled with crushed rock salt. A generic salt pillow formation with a maximum thickness of more than 500 m hosts the repository with a minimum safety distance of 200 m to the overburden or at least 750 m to the surface. The sublevel structure is composed of two main emplacement wings with a width of 800 m and a central infrastructure area that hosts two shafts. The infrastructure area and the emplacement fields are separated by at least 300 m of undisturbed rock salt. Each access drift to the emplacement wings reserves a distance of 500 m for the construction of drift seals. The shafts can be sealed within the thickest part of the salt pillow.

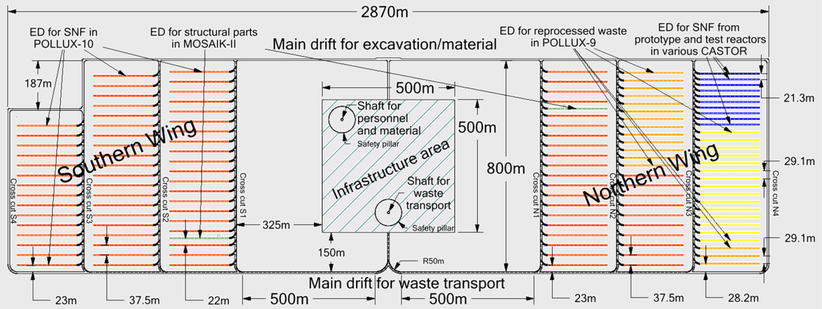

Fig. 2: Layout of an HLW/SNF-repository in a generic salt pillow formation

REPOSITORY DESIGN OF FLAT BEDDED SALT IN THE US

DESIGN METHODOLOGY

The development of a design concept and safety assessment methodology for a geologic repository takes many years. As the repository program evolves, the level of completeness and rigor in the associated safety assessment becomes more robust. This is typically accomplished via an integrative and iterative process between site characterization, repository design, process models, and performance assessment (PA) activities.

The major steps in the development of the conceptual model and as a result the repository design, include:

- System Characterization – characterization of the regions and features of the disposal system, including property values and quantification of uncertainty
- System Design – specification of a disposal concept, repository layout, and engineered design features
- FEP (Features Events and Processes) and Scenario Analysis – identification and screening of potentially relevant FEPs and scenarios, for inclusion in scenario analysis and PA model(s)
- PA Model Construction – conceptual and numerical implementation of the FEPs and scenarios

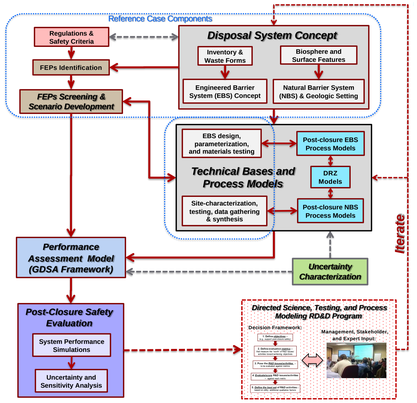

Fig. 3: Model of the repository design (Sevougian et al., 2016)

RESULTS

This generic US repository design is for high-thermal output 24- and 37-PWR (pressurized water reactor) waste packages with a 50/50 split by weight of heavy metal for each canister size. The conceptual model assumes a mined repository located 600 m below land surface, accessed by vertical shafts, and containing 32,000 metric tons heavy metal (MTHM) of commercial SNF in 24-PWRs and another 35,000 MTHM in 37-PWRs. This inventory is accommodated with 3065 24-PWR waste packages and 1988 37-PWR waste packages in 102, 1525-m long emplacement drifts (62 drifts contain 24-PWRs and 40 contain 37-PWRs). Each drift, regardless of package type, contains 50 waste packages emplaced lengthwise and spaced 30 m center-to-center. Drifts are 5.0 m per side spaced 30 m center-to-center resulting in a total emplacement footprint of approximately 4.88 km^2 (5.24 km^2 including area for shafts and access halls). The drift and package spacing results in ~11 W/m^2 peak heat production, after aging.

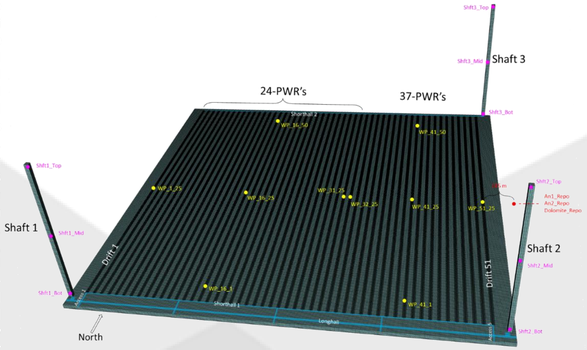

Fig. 4: Design of an HLW-repository in a generic flat bedded salt formation (LaForce et al., 2020)

SUMMARY

In summary, two methodologies for the design of HLW/SNF-repositories in Salt in Germany and in the US have been presented. In Germany both, the site selection as well as the assessment of the repository design, are driven by safety requirements according to national legislation and ordinances. Hence the repository design process concentrates on the implementation of the safety concept by means of technical design. The preliminary US design presented here is largely driven by preliminary safety assessments.

The main difference in the design methodologies can be seen in the shape of the repository layouts. The German approach leads to more elongated repository layout as a consequence of the geological boundary conditions as well as of mining regulations in Germany. US repository layouts tend to be more quadratic due to the large size of bedded salt formations in the US.

The German methodology tends to minimize the number of shafts because these represent the main migration fluid paths to the mine. In the US, the design approach tends to limit the distance from the shaft to the emplacement regions and therefore limit the service life of the drifts inside the repository because openings in bedded salt are more difficult to maintain due to heterogeneities in the rock formation.

Both repository design methodologies are just one component of the whole process of radioactive waste management and are subjected for further changes and improvements when the national programmes will mature.

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