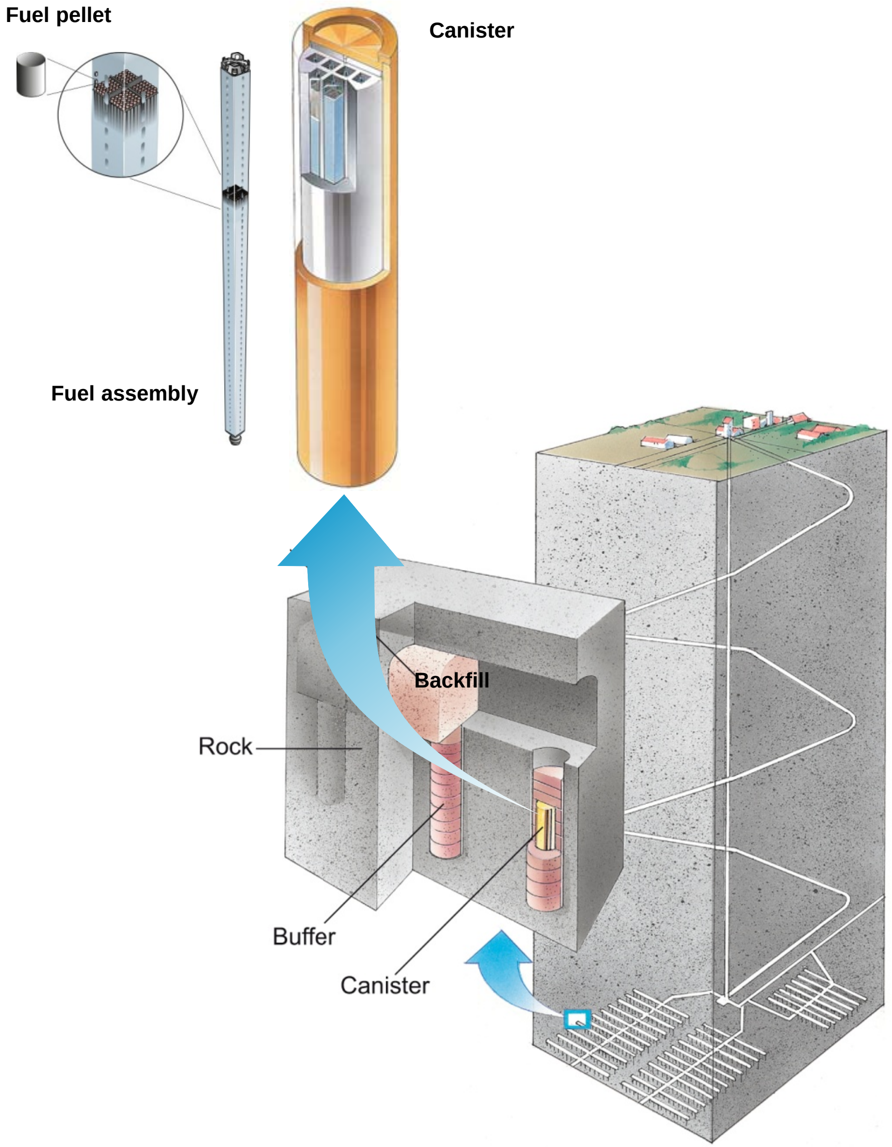
Requirements on spent nuclear fuel for disposal in a KBS-3-repository

Lena Morén, SKB

Background to requirements

- Post closure radiation safety of the final repository
- Radiation safety during the operation of the waste management system
- Generally everything, i.e. every property, that is stated as contributing to or affecting radiation safety must be determined and quality assured
- For the spent nuclear fuel requirements exists for properties that
  - contribute to, or affect, functions of importance for the radiation safety
  - constrain the validity of verifying analysis
  - must be known to assess the radiation safety
  - constitute design premises for the barriers of the final repository or for technical systems used during operation
- radiation safety = radiation protection, nuclear safety, nuclear security and nuclear safeguards
- In final repositories only properties that on scientific basis can be demonstrated to be preserved in a long-term perspective can be stated as contributing to safety

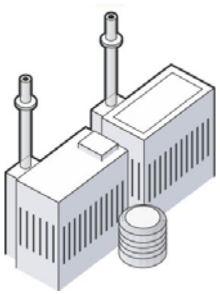
KBS-3 repository



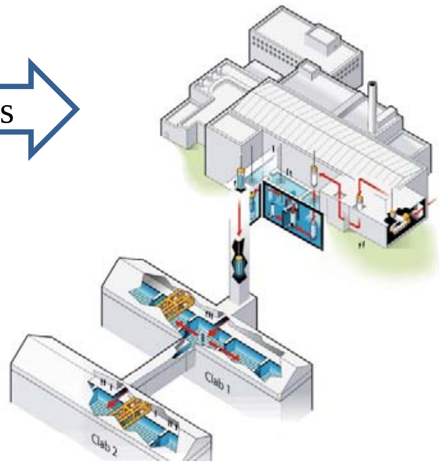
Barrier functions

- **contain**
  - watertight canister
- **retain, prevent and retard dispersion**
  - spent fuel – low solubility
  - buffer – transport only by diffusion and no transport of colloids
  - host rock – slow transport and sorption
- **protect and preserve the functions of the barriers**
  - long-term stable environment where the containment can be preserved
  - backfill and close underground openings

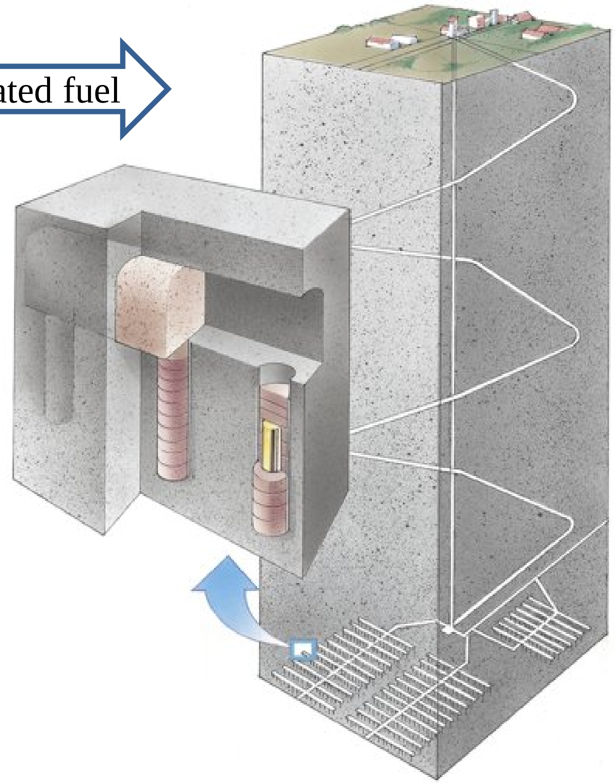
The KBS-3-system (in Sweden)



assemblies



encapsulated fuel



Safety functions

- maintain sub-criticality
- remove heat
- contain radioactive material
- shield radiation
- retrieve - for inspection or reworking

Criticality – must not occur

- neither during handling, interim nor final storage
- $k_{eff} < 0.95$ in the most reactive identified possible case
- in a canister filled with water burnup credit is necessary for PWR and credit of burnable absorbers (BA) is required for BWR
- if the acceptance criteria is not met – the spent fuel geometry must be altered

SKB

Low solubility - is required

- the fuel pellet and fuel cladding are barriers that physically contain radioactive material during operation
- in the final repository in case of leaking canisters
  - the low solubility of fuel pellets contribute to the retardation and retention of fission products and actinides
  - the construction materials must be assigned a corrosion resistance that delay the release of activation products
- leaking fuel cladding cause exposure of fuel pellets to air and water
  - will result in radionuclide release during operation
  - may by oxidation of the fuel matrix from U(IV) to U(VI) result in considerably higher solubility of the fuel pellets

SKB

Decay power and dose rate – must be known and limited within the waste management system

- during handling and interim storage cooling is required to avoid temperatures that may damage the fuel cladding or fuel pellets
- the decay power in the canister must be limited so that unacceptable temperatures are avoided
  - if the temperatures are too high the function of the buffer cannot be preserved
  - the material models for the canisters are only valid up to a temperature limit
- the dose rate must be known with respect to radiation protection during operation
- the dose rate on the canister surface must be limited to avoid corrosion due to radiolysis

Radionuclide inventory – must be known

- fissionable nuclei with respect to nuclear safeguards
- inventory of all nuclei since acceptance criteria for the facilities and repository are stated as acceptable doses or acceptable dose related risk
- the inventory in fuel pellets, gap, construction materials and crud respectively
  - crud inventory – since it can be released during operation and is assumed to be released instantly in case of leaking canisters
  - gap inventory – since it can be released during operation in case of leaking fuel cladding and since it is assumed to be released instantly in case of leaking canisters
  - construction material inventory – since it can be released during operation and in case of leaking canisters is assumed to be released fast in relation to the inventory in the fuel pellet UO_2-matrix

SKB

Other properties that must be considered

- dimensions and weight of fuel assemblies
  - constitute design premises for technical systems during operation and dimensions of the canister insert for final storage
  - once the technical systems and insert dimensions are determined they will constitute restrictions for allowed fuel assembly weights and dimensions
- content of water and air in the sealed canister
  - must be limited due to build up of internal pressure and internal corrosion
  - the spent fuel assemblies must be possible to dry

SKB

Implications for new reactors

- low solubility is required for HLW and spent nuclear fuel for disposal in geological repositories in crystalline bedrock
- processes that may impact the release rate of radionuclides must be considered
  - e.g. the linear power density and its impact on the fission gas release (FGR)
  - since the gap inventory is important for the post closure safety and related to the FGR
- high burnup and decay power
  - may impact the fuel pellet matrix solubility
  - will require more extensive cooling
  - may require longer interim storage period
- alterations in geometry and weight will generate costs if mayor changes are required in existing waste management systems
- leaking fuel cladding and other fuel damages shall always be avoided and may require specific measures that may be expensive and impact radiation safety during operation

SKB

Thank you

Lena Morén, SKB