GENERIC REPOSITORY CONCEPT FOR RBMK-1500 SPENT NUCLEAR FUEL DISPOSAL IN CRYSTALLINE ROCKS IN LITHUANIA

P. POSKAS, A. BRAZAUSKAITE, E. NARKUNAS, A. SMAIZYS, A. SIRVYDAS

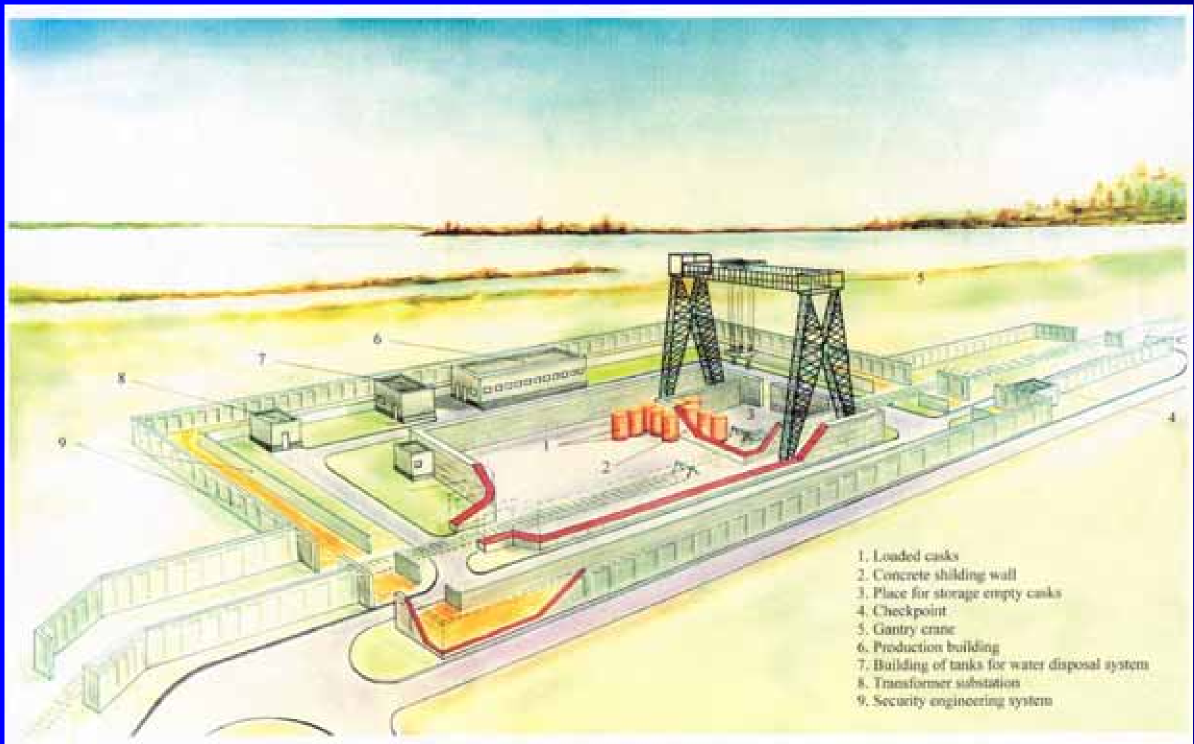
Nuclear Engineering Laboratory
Lithuanian Energy Institute

TopSeal 2006, Olkiluoto, Finland, September 17-20, 2006

- ✓ There is only one nuclear power plant in Lithuania – Ignalina NPP
- ✓ Two RBMK-1500 units with design electrical power of 1500 MW
- ✓ The units were commissioned in 1983 and 1987, respectively and provide approximately 70-80% of the electricity produced in Lithuania
- ✓ The Unit 1 has already been shutdown at the end of 2004 the Unit 2 is going to be shutdown by the end of 2009

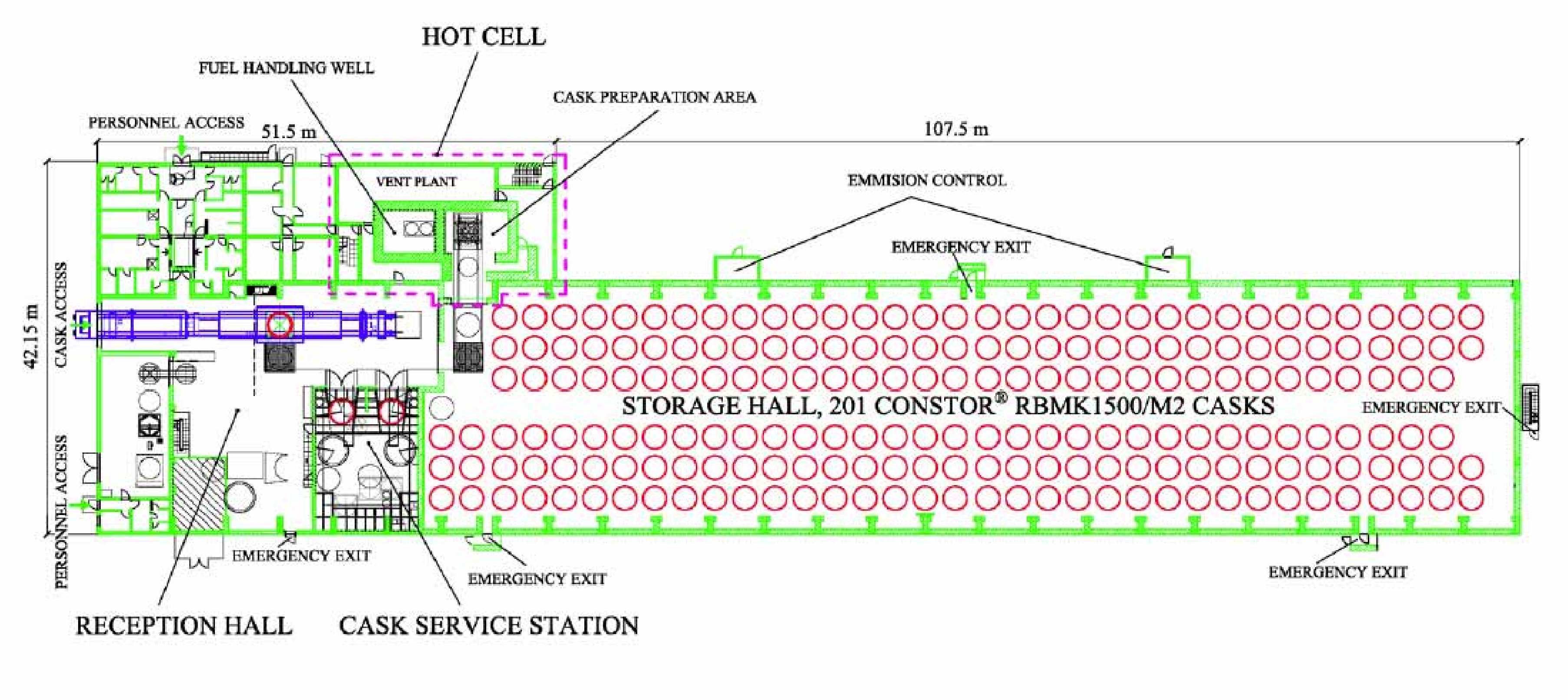
Ignalina nuclear power plant

- ✓ Expected total amount of RBMK-1500 spent nuclear fuel (SNF) in Lithuania till 2010 is app. 22 thousands of fuel assemblies
- ✓ It is foreseen to store the SNF at interim storage facility at Ignalina NPP site for 50 years



Existing SNF dry storage facility (capacity for 80 casks)

- ✓ New interim dry storage facility is under implementation (capacity for 201 cask)

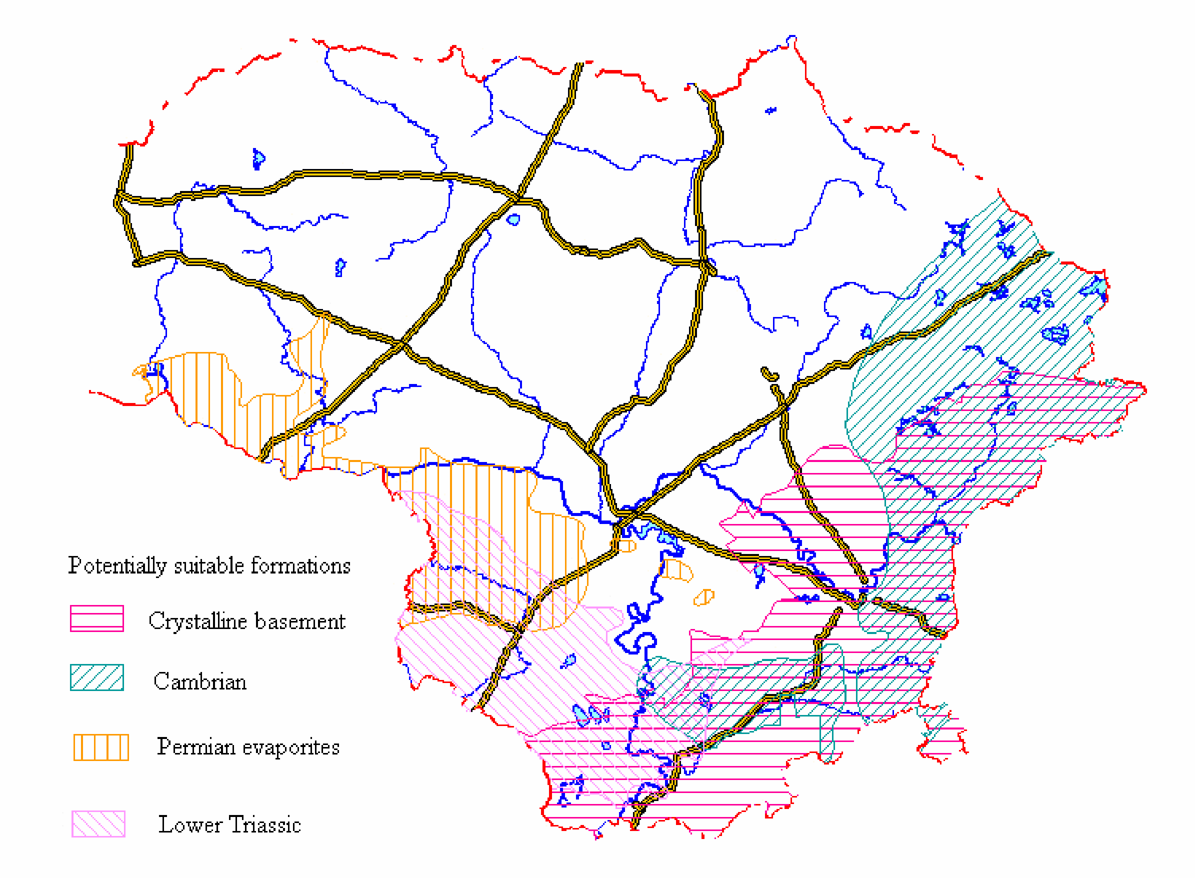


- ✓ New interim dry storage facility is under implementation (capacity for 201 cask)

Concept of the main storage building

Concept of the security and administration building (the gate-house) and the vehicle and rail transport inspecion area

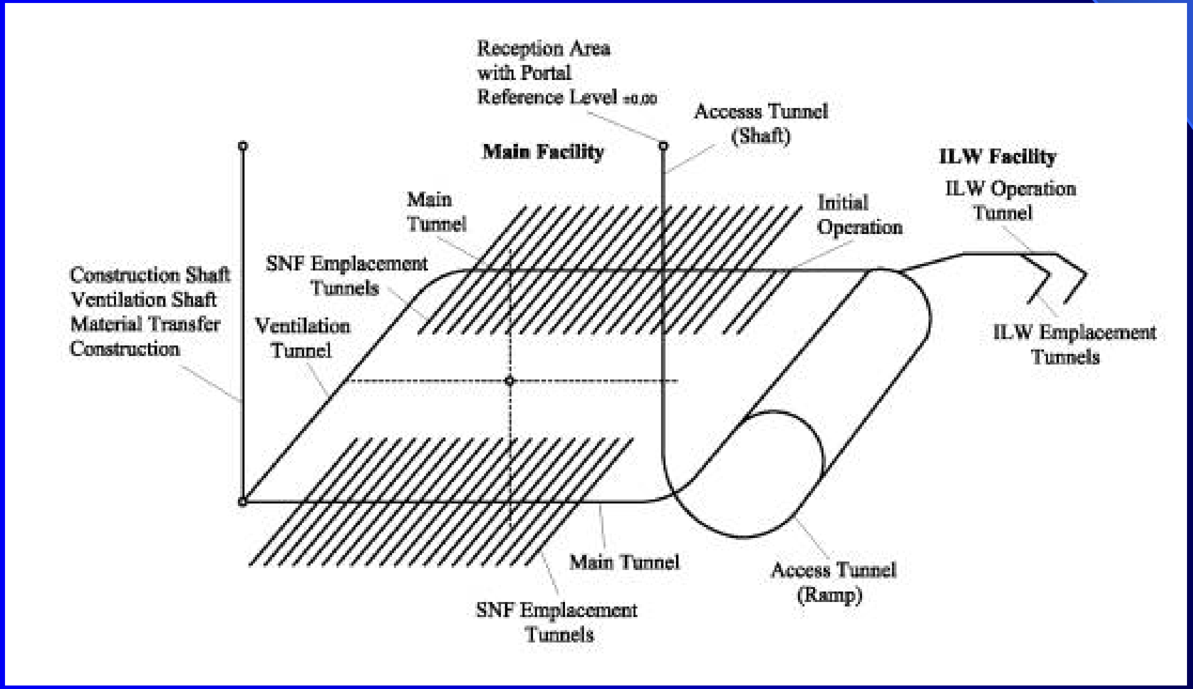
- ✓ During 2002-2005 investigations on the possibilities to dispose of SNF in Lithuania were performed with support of Swedish experts
- ✓ Geological formations prioritized as prospective formations for SNF disposal in Lithuania:
  - The crystalline rocks in the southern Lithuania
  - The Lower Cambrian Baltic Group clay formation
  - The Lower Triassic clay formation



- ✓ The proposed repository concept is based on KBS-3 concept developed by SKB for disposal of the SNF in Sweden
- ✓ The KBS-3H design with horizontal canister emplacement is proposed as a reference design for Lithuania, and vertical canister empalcement is left as alternative one

Possible repository layout

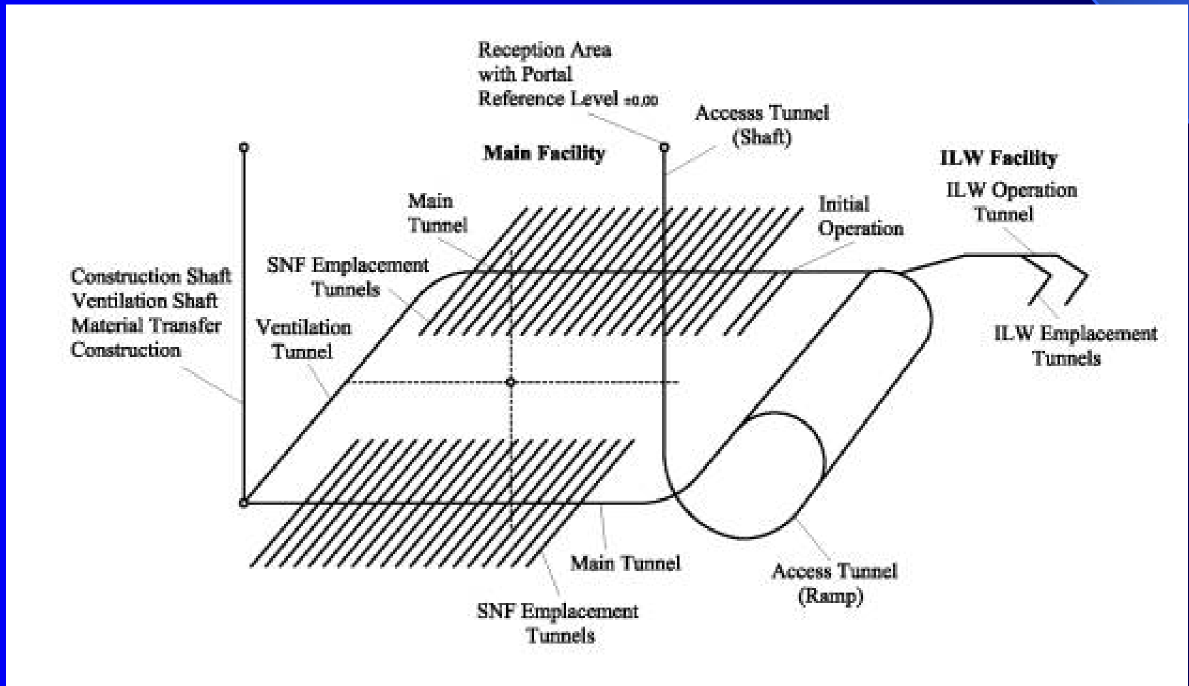
- ✓ The main elements of the repository are:
  - an access shaft, transport tunnels;
  - an array of SNF emplacement tunnels (deposition drifts);
  - emplacement tunnels for intermediate level waste (ILW).



- ✓ The deposition area for SNF would cover app. 0.4 km^2.

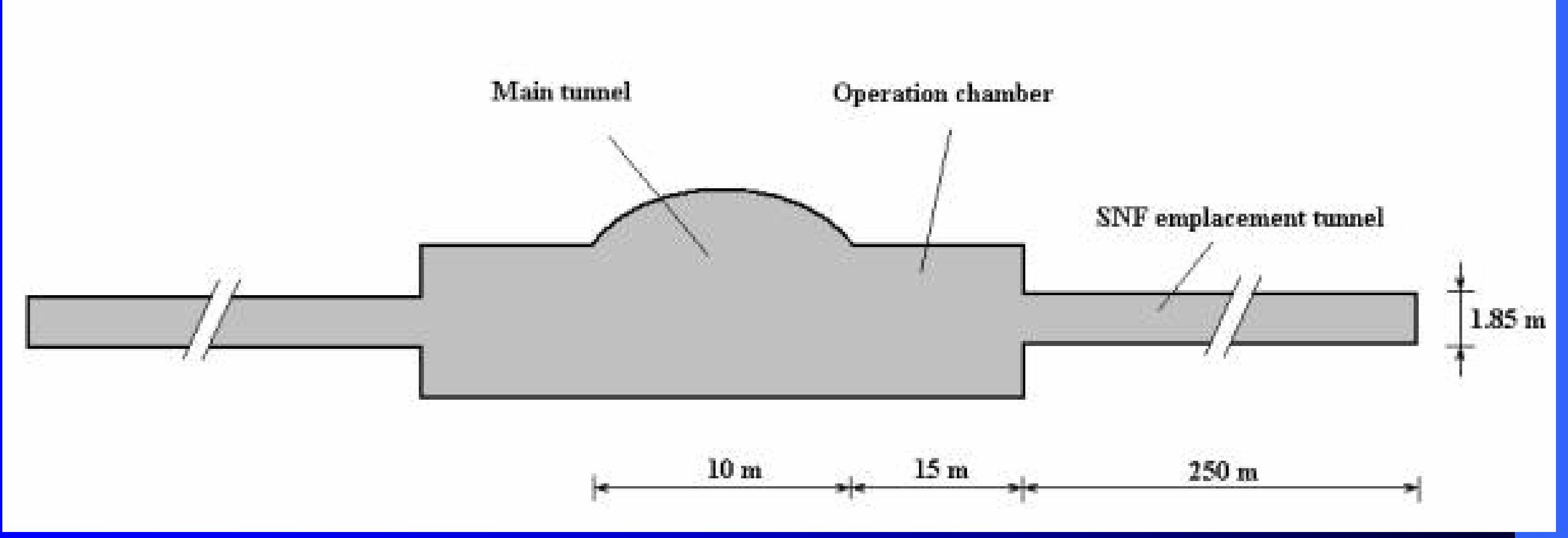
Possible repository layout (cont.)

- ✓ There is no decision yet if the long-lived ILW will be disposed of in the same repository as the SNF or separately

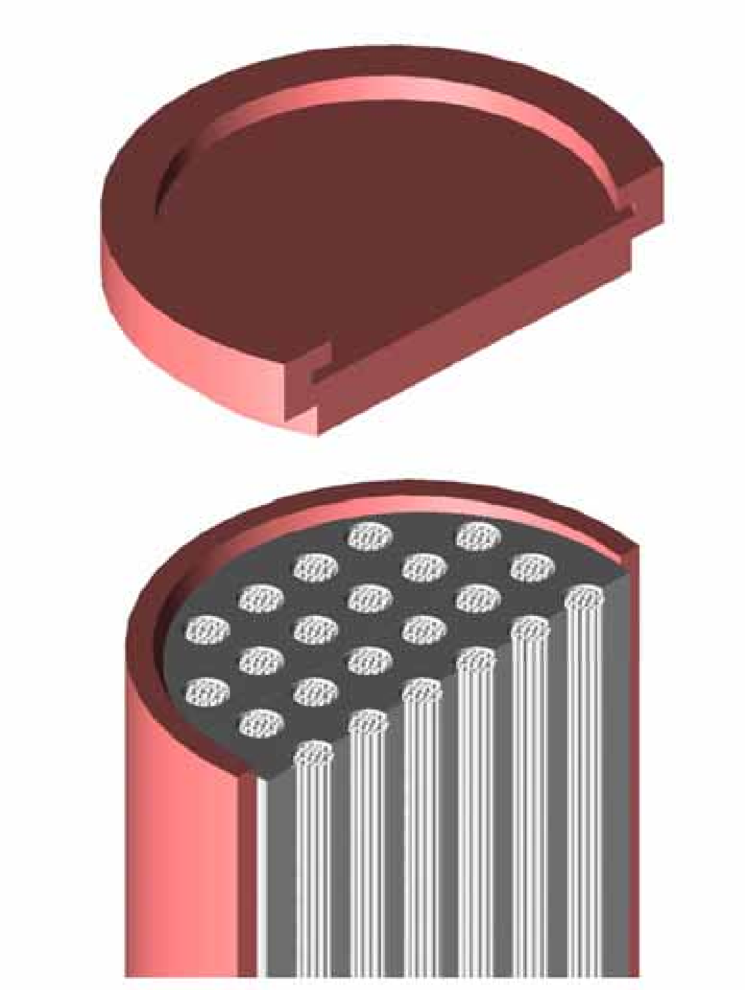


Emplacement tunnels for SNF

- ✓ The diameter and length of horizontal SNF emplacement tunnels is 1.85 m and 250 m
- ✓ The distance between the emplacement tunnels is 40 m and 1.2 m (justified by thermal calculations) between the canisters



Disposal canister for SNF



- ✓ Copper canister
- ✓ Canister insert contains 32 for RBMK-1500 SNF fuel half-assemblies
- ✓ Diameter of copper shell - 1050 mm, height - 4070 mm, wall thickness of copper canister - 50 mm
- ✓ For Lithuanian SNF disposal purposes ~1400 canisters would be required

Criticality

✓ Criticality analysis for copper disposal canister with (2.8% ^{235}U RBMK-1500 SNF was performed using SCALE 4.3 computer codes system.

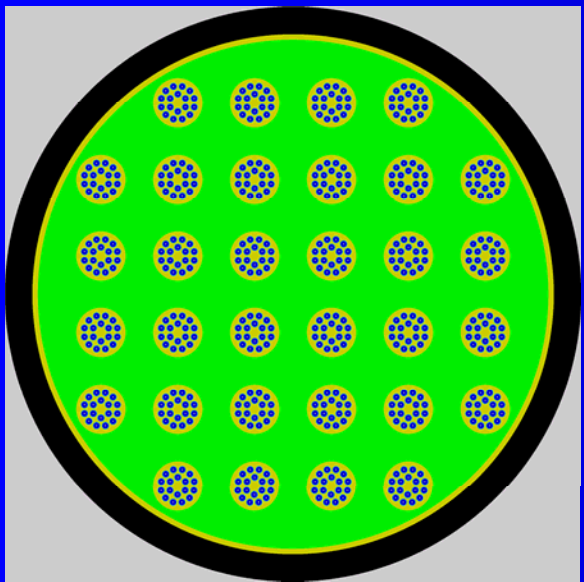


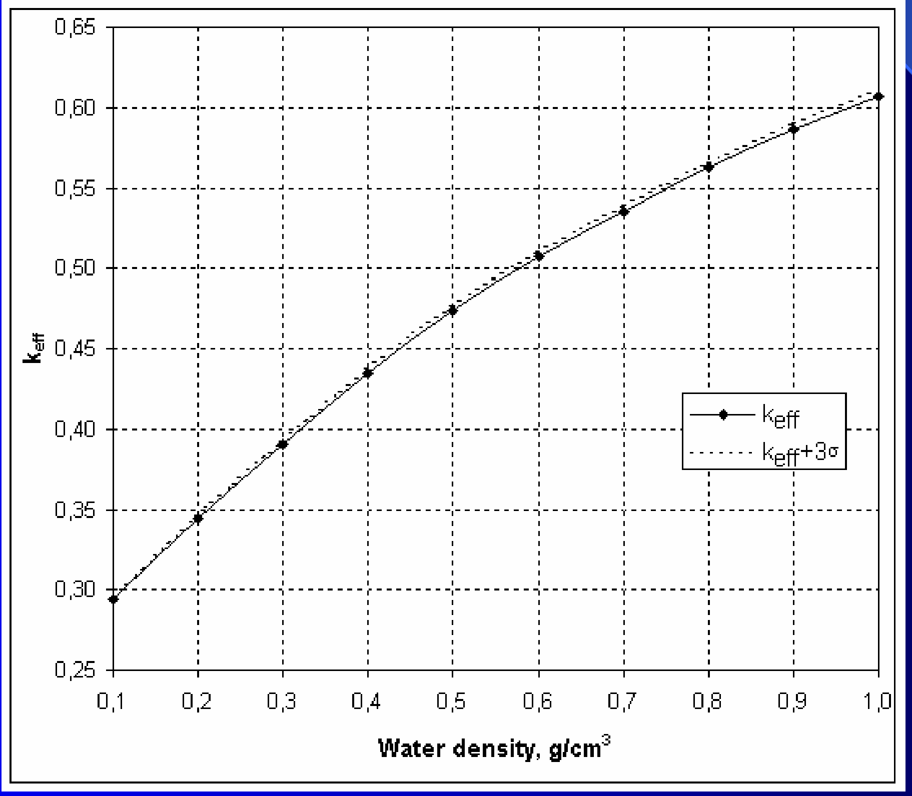
Fig. Radial cross-section of the copper disposal canister (plotted with KENO-V.a)

✓ The main conditions and assumptions accepted for the criticality calculations:

- Maximum loading of the canister, i.e. insert of the canister contains 32 cylindrical holes each with fuel half-assembly (18 fuel rods in each) inside
- No credit for burnup. The fuel half-assemblies contain only fresh, undepleted fuel with 2.8% ^{235}U enrichment
- There are no structural damages in fuel rods, half-assemblies, insert and canister body

Criticality (cont.)

- ✓ Estimated effective neutron multiplication factor k_{eff} is less than 0.95 (as it is required for criticality safety).



Dose rate assessment

- ✓ Sequences SAS2H and SAS4 from SCALE 4.3 computer code were used.

- ✓ The main assumptions for the modelling of fuel assembly irradiation and equivalent dose rate calculations were following:

  - RBMK-1500 fuel assembly that consists of 18 fuel rods was homogenized and in the reactor's fuel channel was described as an element of 5 concentric cylinders (Fig.)

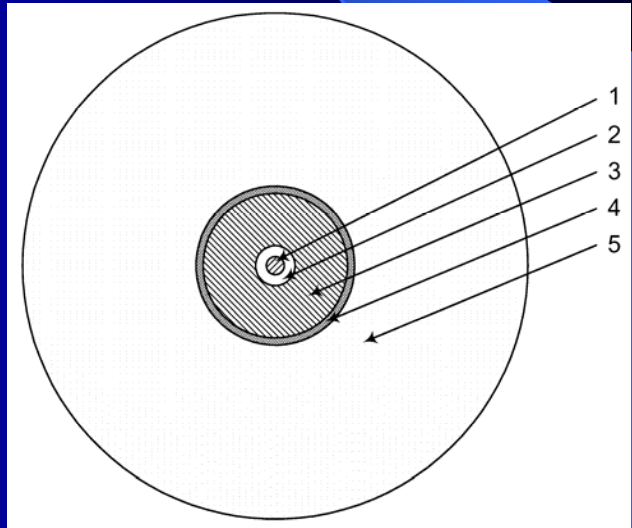


Fig. 1-carrier rod, 2-coolant, 3-homogeneous mixture of UO_2 and H_2O, 4-fuel channel tube, 5-moderator

Dose rate assessment (cont.)

✓ The main assumptions for the modelling of fuel assembly irradiation and equivalent dose rate calculations were following (cont.):

- Fuel enrichment 2.8% ^{235}U, burn-up 30 MWd/kgU, irradiation time 3 years, cooling (interim storage) time of SNF is 50 years;
- For dose rate calculations axial burn-up distribution of fuel assembly was not taken into account.

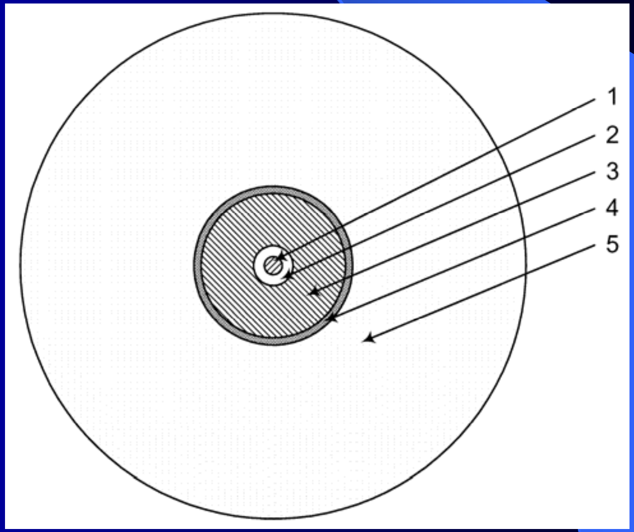
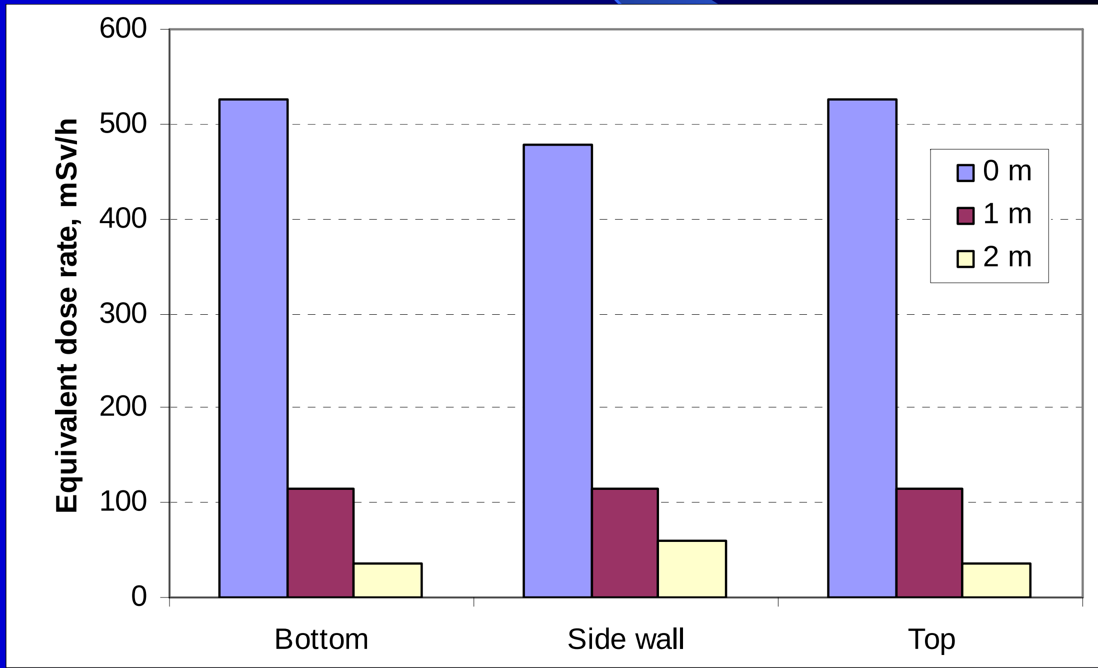


Fig. 1-carrier rod, 2-coolant, 3-homogeneous mixture of UO_2 and H_2O, 4-fuel channel tube, 5-moderator

Dose rate assessment (cont.)

- ✓ Total equivalent dose rate for 50 years stored RBMK-1500 SNF is app. 500 mSv/h on the surface of the canister.

- ✓ Total equivalent dose rate is defined mainly by the γ radiation (more than 99.9%); neutrons form only insignificant part of total dose rate



Thermal evolution

- ✓ Temperature evolution in SNF tunnels was assessed using FLUENT 6.1 code.
- ✓ The main assumptions for thermal calculations:
  - It was assumed that heat transport occurs only by conduction
  - The gap between the bentonite and host rock is assumed to disappear because of bentonite swelling within very short period after emplacement and is not taken into account

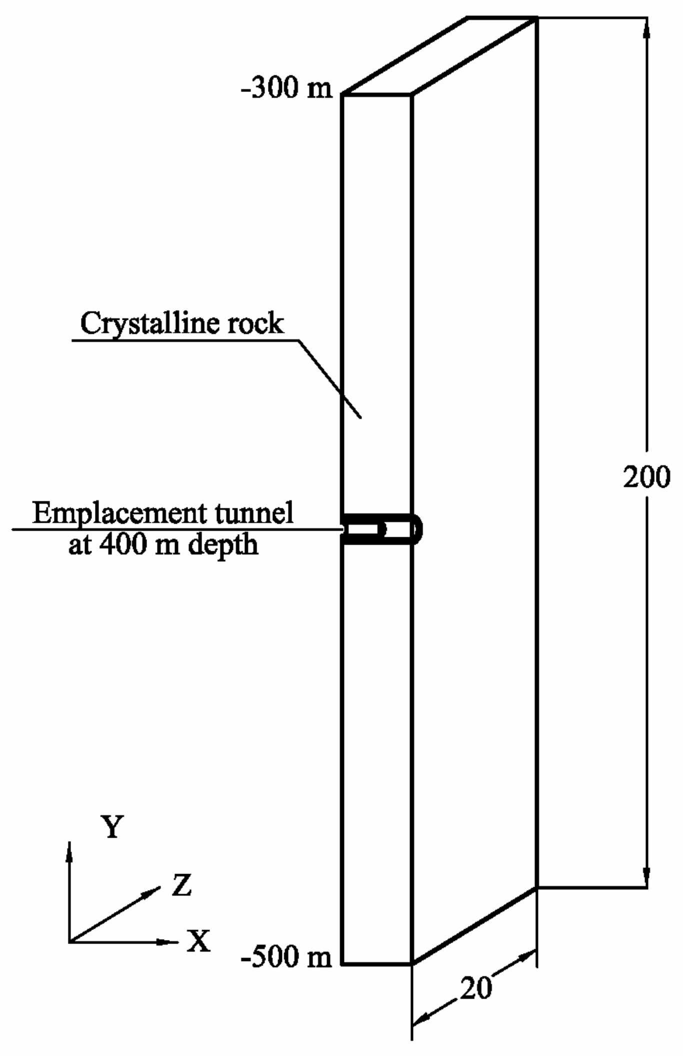


Fig. Schematic three-dimensional view of the analyzed domain

Thermal evolution (cont.)

✓ The main assumptions for thermal calculations (cont.):

- The distance between SNF disposal canisters is 1.2 m, the disatnce between emplacement tunnels – 40 m
- Two cases were analysed when the bentonite thermal conductivity is 1) low (partly saturated) and 2) higher (fully saturated)

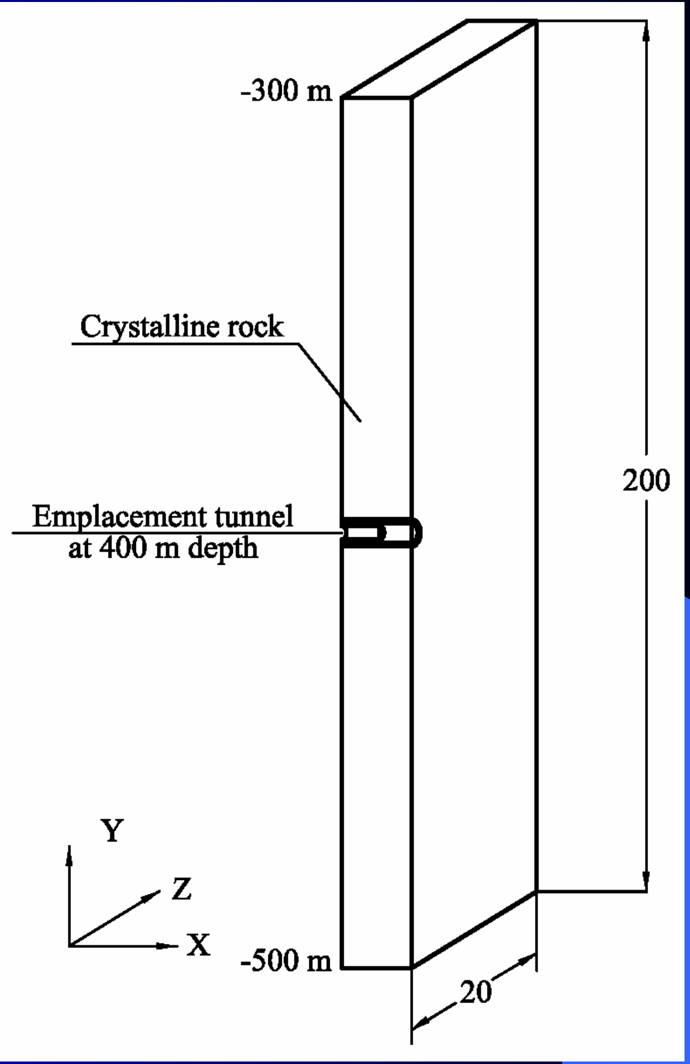
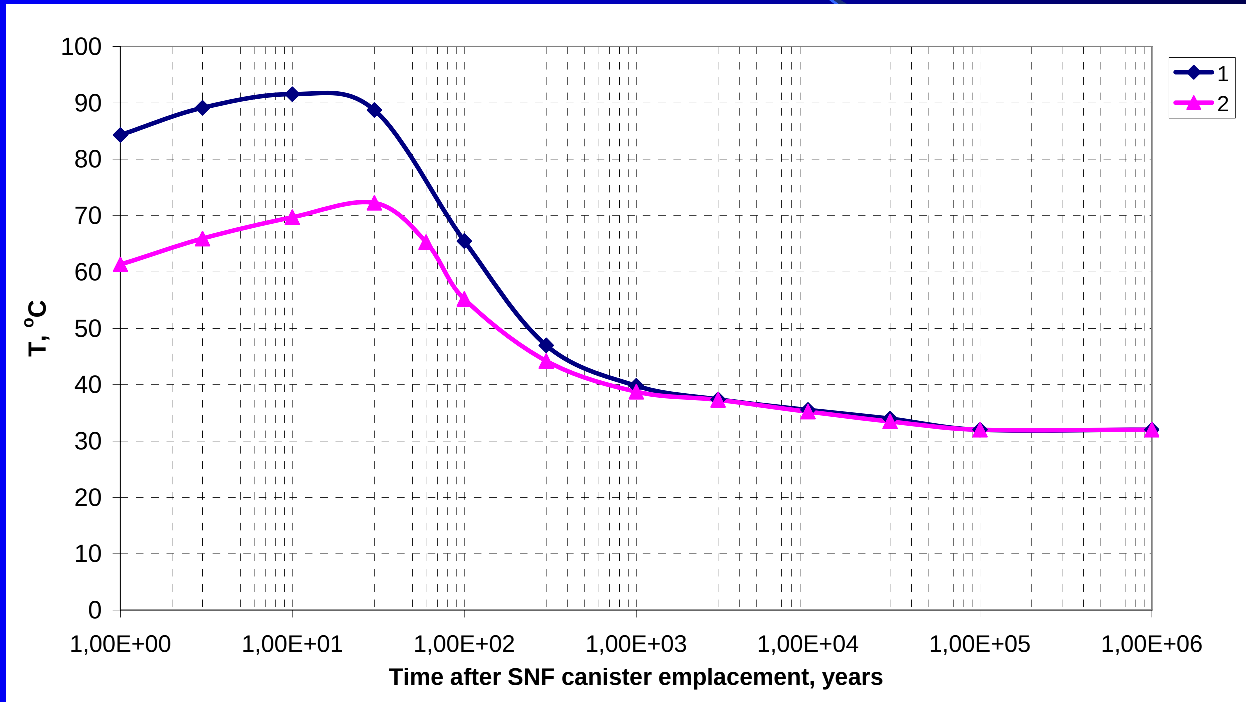


Fig. Schematic three-dimensional view of the analyzed domain

Thermal evolution (cont.)



✓ Maximum temperatures on the surface of SNF disposal canister:

- in case of partly saturated bentonite T_{max} ≈92°C (curve 1);
- in case of fully saturated bentonite T_{max} ≈72°C (curve 2).

Thermal evolution (cont.)

- ✓ The results of temperature assessment around the canisters loaded with 32 RBMK-1500 SNF half-assemblies show that a maximum heat output of app. 784 W per canister at the time of waste emplacement will satisfy the temperature constrain (<100 °C).
- ✓ Calculation results justify the chosen distance between canisters 1.2 m.

Conclusions

- ✓ Generic repository concept for disposal of RBMK-1500 SNF in the crystalline rocks in Lithuania was developed based on Swedish KBS-3
- ✓ 1400 disposal canisters would be required for disposal of all RBMK-1500 SNF from Ignalina NPP
- ✓ Preliminary results on modelling of the criticality, dose rate and thermal evolution are also presented.

THANK YOU