



CRITICALITY AND DOSE RATE MODELLING FOR COPPER DISPOSAL CANISTER WITH SPENT RBMK-1500 NUCLEAR FUEL

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Institute was founded in 1956 as the Institute of Energy and Power Engineering of the Lithuanian Academy of Sciences.

In 1967–1991 it became known among local and foreign scientific society interested in fundamental research in hydrodynamics, thermal physics, material science, simulation and control of power supply systems, hydrology as the Institute for Physical and Engineering Problems of Energy Research.

In January 1992 Government of the Republic of Lithuania granted a state science institution status to the institute, which became independent from the Academy of Sciences and was named the Lithuanian Energy Institute.

Laboratory of Nuclear
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Main research areas:

- experimental investigation of turbulent convection heat transfer regularities in single-phase flows;
- numerical modelling of heat transfer and turbulent transport in single-phase flows in various channels and geological structures;
- management of spent nuclear fuel: modelling of fuel characteristics, safety and environmental impact assessment of storage and disposal facilities, normative and legislative base;
- management of radioactive waste: strategy, safety and environmental impact assessments of treatment technologies and storage and disposal facilities, normative and legislative base;
- evaluation of different factors related to decommissioning of nuclear power plants;
- fire hazard analysis of nuclear power plants and other large facilities.

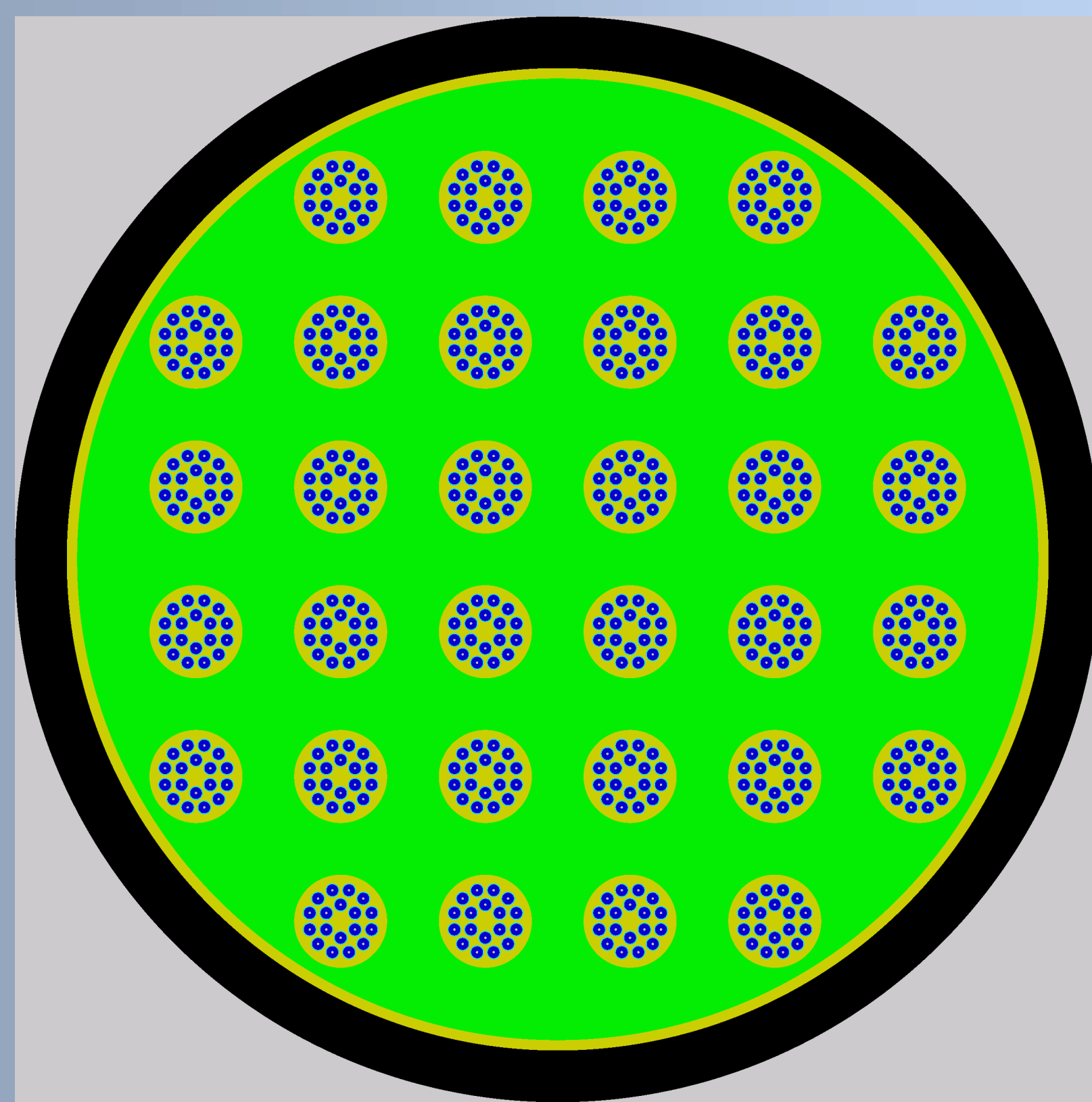
1. Introduction

Presently there is only one nuclear power plant in Lithuania – Ignalina NPP (INPP). After final shutdown of INPP Unit 1 in 2004 and Unit 2 in 2009 total amount of spent nuclear fuel (SNF) will be approximately 22 thousands of fuel assemblies. All these assemblies should be stored about 50 years and after that disposed of. Extended studies on selecting of suitable geological formation had led to the conclusion that crystalline rock and argillaceous rocks are the primary candidates for disposal of SNF in Lithuania. Disposal concept for RBMK-1500 SNF in crystalline rocks in Lithuania is based on Swedish KBS-3 concept with SNF emplacement into the copper canister with cast iron insert. The bentonite and its mixture with crushed rock are also foreseen as buffer and backfill material.

Modelling results on criticality and dose rate for RBMK-1500 SNF fuel emplaced in copper canisters performed using SCALE computer codes system are presented in this poster.

2. Criticality

- Criticality safety analysis for a repository differs from conventional analysis of criticality.
- For conventional criticality safety analysis the events are primarily attributed to short-term equipment failure or accidents and human errors.
- The events in the repository that may lead to a criticality are related to long-term processes that take place over hundreds and thousands of years.
- There are also additional considerations, for example, misloading of waste must be considered if burnup credit is used.
- The analysis must also consider the effect on criticality of natural events (e.g., earthquakes) that may deform or change the relative position of the disposal container or waste package



Radial cross-section of the copper disposal canister loaded with RBMK-1500 fuel (plotted with KENO-V.a)

3. Shielding

- Calculated dose rate level indicates what measures should be introduced (for example, remote handling, additional shielding) to meet radiation safety requirements during SNF emplacement in canisters and transfer to the repository.
- The γ dose rate outside the canister is important for radiolytic disintegration of water also.
- According SKB Technical Report, 1999 “Deep repository for spent nuclear fuel”, the canister design criteria require that the γ dose rate not exceed 1 Gy/h (1 Sv/h if only β , γ radiation).

4. Modeling assumptions

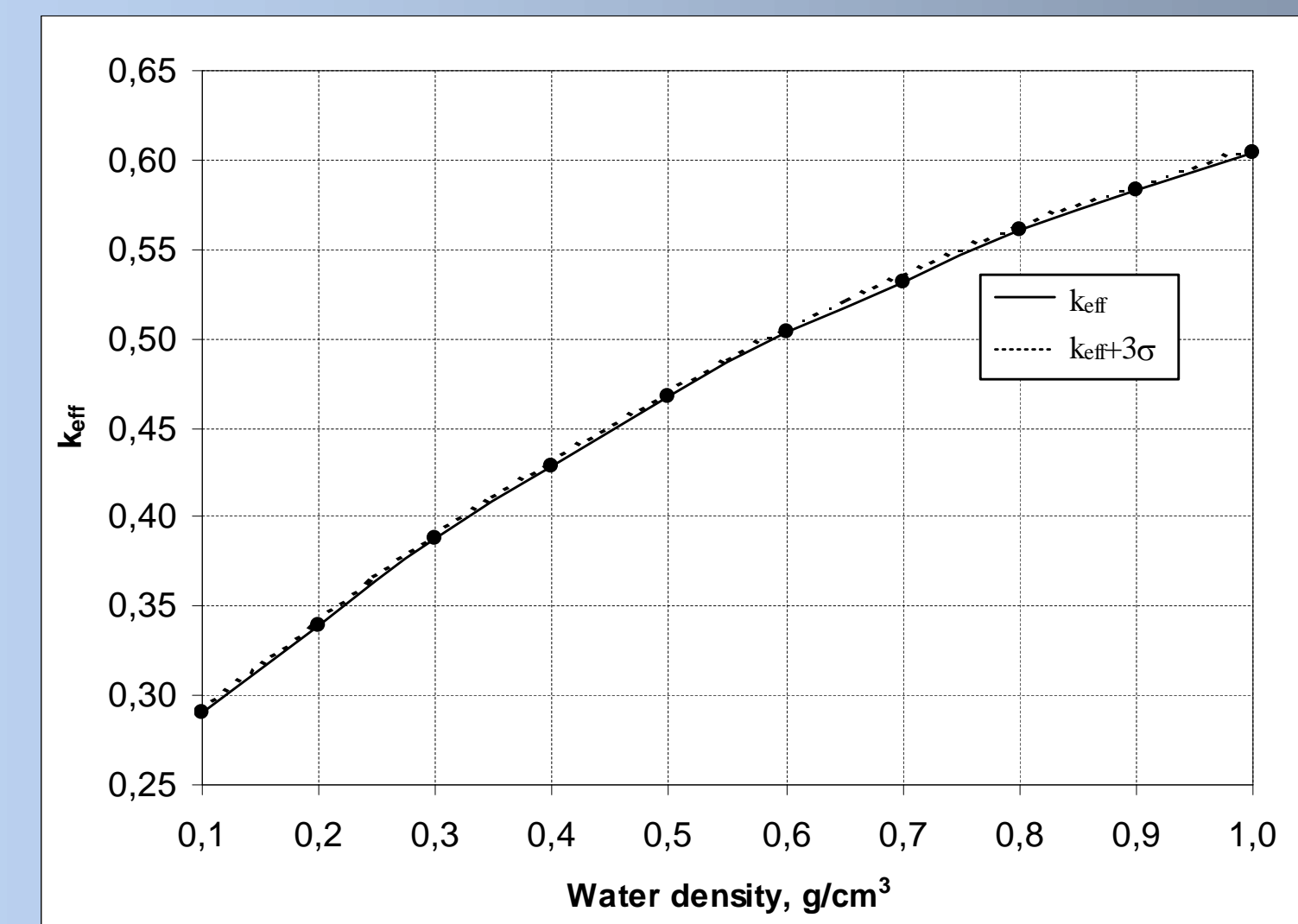
Criticality calculations:

- Maximum loading of the canister, i.e. insert of the canister contains 32 cylindrical holes each with fuel half-assembly inside;
- Discrete representation of the fuel rods is used in the geometry description. This means that each half-assembly consists of 18 fuel rods;
- Insert holes and inner region between insert and canister body are homogeneously filled with water. A water density varies from 0.1 g/cm³ to 1.0 g/cm³. Variation of water density allows to model the most reactive state of the fuel-insert-canister body system;
- The fuel half-assemblies contain only fresh, undepleted fuel (no credit for burnup) with 2.8% ²³⁵U enrichment.

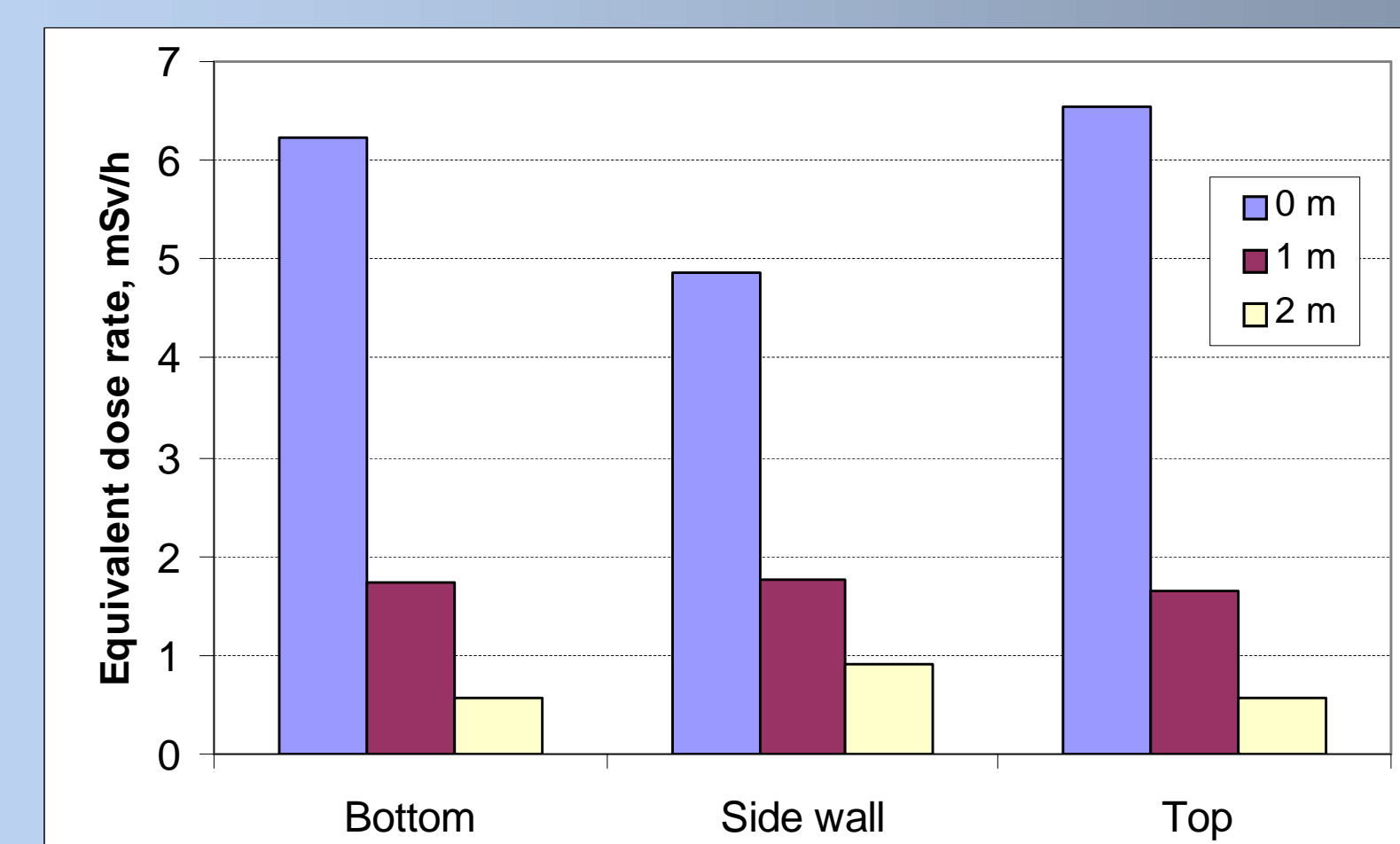
Shielding calculations:

- Fuel enrichment 2.8% ²³⁵U, burn-up 30 MWd/kgU, irradiation time 3 years, cooling time 50 years;
- 3-D description of canister geometry;
- Radiation source was modeled as homogenous cylindrical body which contains 32 spent nuclear fuel half-assemblies and insert of the canister;
- Locations of point detectors were at a middle of sidelong surface, at a center of the top and the bottom of canister. Location distances – 0, 1 and 2 meters.

5. Results and discussion



k_{eff} values continuously increasing when water density is increasing and maximal k_{eff} value of approximately 0.60 is reached when water density is 1.0 g/cm³. The main requirement of the criticality safety is that effective neutron multiplication of the system containing fissile material must be less than 0.95. For disposal canister when long-term processes (corrosion, degradation, etc.) are not taken into account, k_{eff} values are less than allowable value of 0.95.



Total equivalent dose rate at the surface of the canister varies from 5 mSv/h (at side wall) to 6.5 mSv/h (at top).

Total equivalent dose rate is formed mainly by the γ radiation (more than 99.9%); neutrons forms only insignificant part of total dose rate.

6. Conclusions

Criticality analysis of the disposal canister has demonstrated the influence of the moderator (water) on the value of effective neutron multiplication factor, but k_{eff} is less than allowable value 0.95.

Further studies should be performed for evaluation of the long-term processes such as corrosion, degradation and their effects on criticality.

Dose rate calculations have shown that dose rate values on the surface of the disposal canister are rather high in comparison to storage casks.

Additional measures such as remote handling, additional shielding, etc. could be necessary to reduce exposure on operating personnel.