SESSION 7: Research and Development Required to Deliver an Integrated Approach

Evaluation of Radiation Characteristics of Spent RBMK-1500 Nuclear Fuel Storage Casks during Very Long Term Storage

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2. Dry storage casks for RBMK-1500 SNF
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SNF management strategy in Lithuania

- SNF will be stored at the interim dry storage facility at Ignalina NPP for at least of 50 years.
- Possibilities of further SNF management according to current RW Management Strategy: (1) arrangement of a deep geological repository in Lithuania, (2) a regional deep geological repository of several European Union member states, (3) transfer SNF to the states that own proper installations and take responsibility for the SNF.
- "Development Programme for Radioactive Waste Management" is under preparation according to EU Directive 2011/70/Euratom.
- Possibility to elongate the SNF storage at the storage facilities for a period over 50 years shall be analyzed.

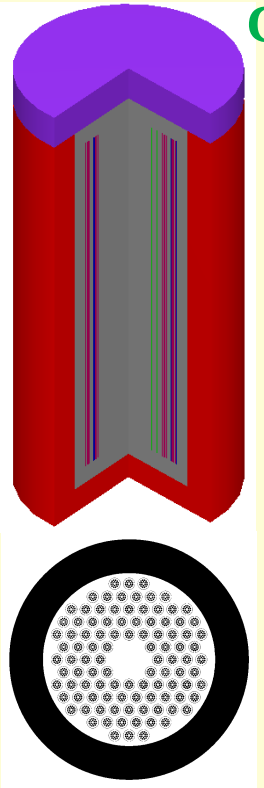
SNF management strategy in Lithuania

main activities and preliminary schedule for deep repository

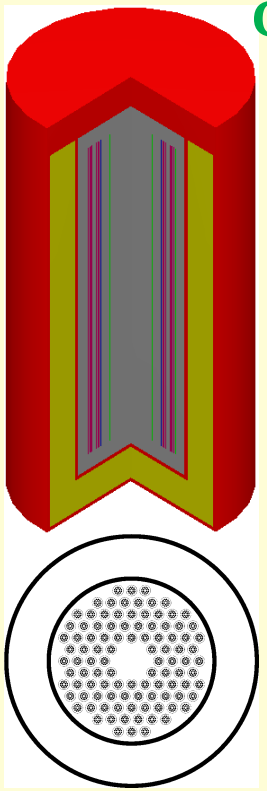
Stage	Start	End
Planning and preliminary investigations	2002	2025
Investigations, designing and safety analysis	2025	2067
Construction of facility for SNF placement into canisters	2035	2064
Selection of site suitable for the repository and comprehensive studies (geological, hydrological, hydrogeological, geochemical, etc.)	2027	2037
Construction of the repository facilities (at surface)	2031	2067
Construction of the repository (underground works)	2036	2066

Dry storage casks for RBMK-1500 SNF

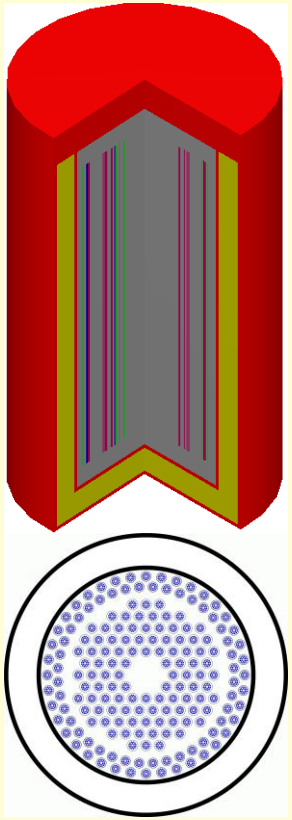
CASTOR®RBMK-1500



CONSTOR® RBMK-1500



CONSTOR®RBMK-1500/M2



- Dual purpose casks
- Storage capacity 51 / 91 FAs
- CASTOR® – ductile cast iron, loaded mass ~75 tons
- CONSTOR® – reinforced heavy concrete, loaded mass ~88 tons; 116 tons (/M2)

Dry storage casks for RBMK-1500 SNF

Evaluation of radiation characteristics

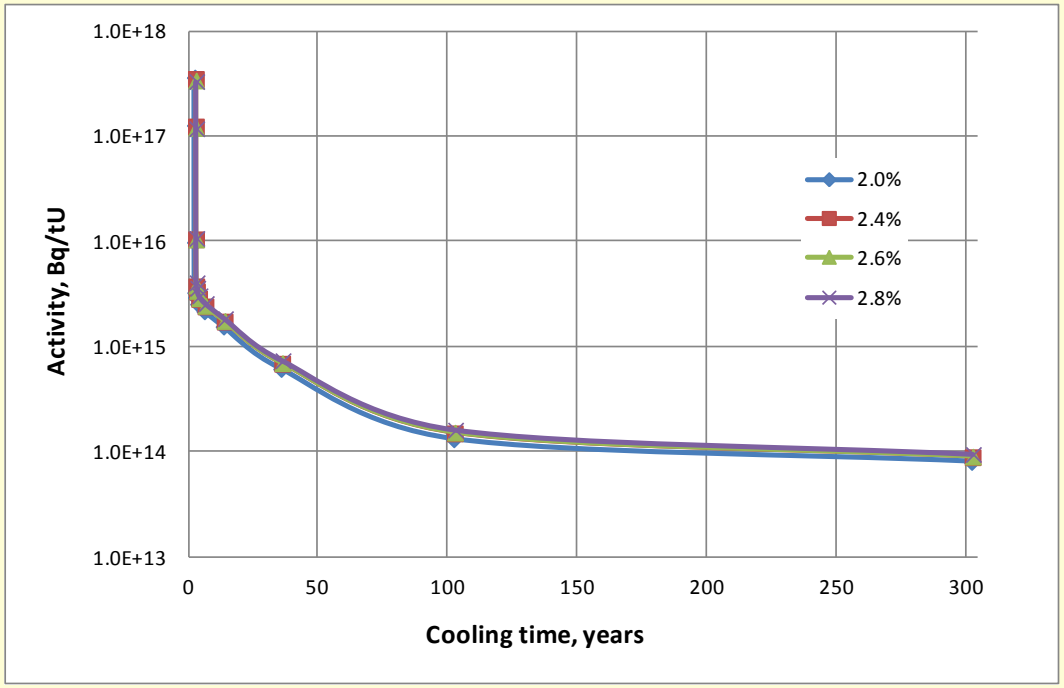
- Two tasks:
  - **Task No. 1**: estimation of the characteristics (concentrations of fission products, actinides, neutron and gamma source emissions, etc.) of an irradiated fuel assembly during a very long term storage period;
  - **Task No. 2**: when characteristics of SFA are obtained, dose rate calculations on the surface and at some distance from the casks are performed.

Evaluation of radiation characteristics

- **Task No. 1**:
  - Modelling of RBMK-1500 SNF characteristics was performed using TRITON module
  - Results are comprehensively presented in "*ŠMAIŽYS, A., POŠKAS, P., NARKŪNAS, E., BARTKUS, G. Numerical modelling of radionuclide inventory for RBMK irradiated nuclear fuel, Nuclear Engineering and Design Vol. 277 (2014) 28–35.*"
  - Relatively rapid decrease of gamma emissions in different energy groups is observed during a 50 year period; for neutron emission this period is 100 years.
  - After 300 years of storage, low energy gammas are dominant in the emissions and, contrary, for the neutrons – higher energy neutrons are dominant.

Evaluation of radiation characteristics / Task No. 1

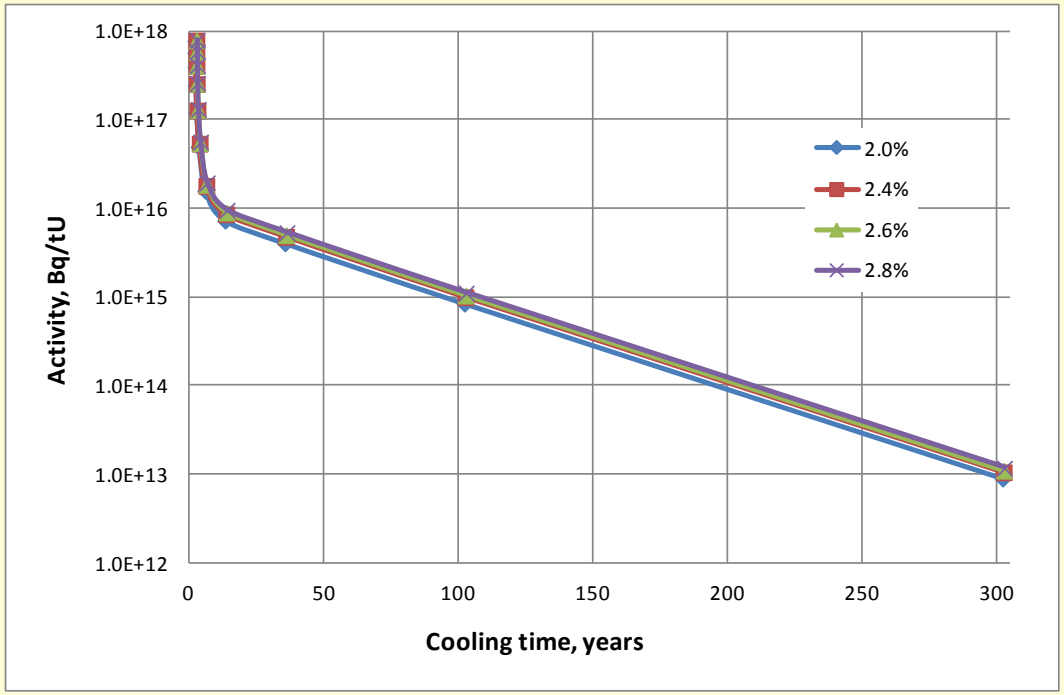
- The activity of actinides decreases by two orders of magnitude during a 5 year storage period;
- Afterwards, the activity decreases by one order of magnitude after a 100 year period, and after that the activity decrease is insignificant.
- The main actinides with the highest activity values: Np-239, U-237, Np-238, Pu-241, Am-242, Cm-242, Cm-244, Pu-238 and Pu-240.



- The differences between actinides activities for fuel with 2.0% and 2.8% enrichments are about 15%.

Evaluation of radiation characteristics / Task No. 1

- Activity of fission products rapidly decreases approximately by two orders of magnitude during a 10 year storage time.
- Afterwards the activity decreases gradually also by two orders of magnitude during a 10–300 year period.
- Cs-137, Ba-137m, Pm-147, Sr-90, Y-90, Kr-85, Sb-125, Sn-121 and Eu-154 have the highest activity values.



- The differences between fission products' activities for fuel with 2.0% and 2.8% enrichments are about 20%.

Evaluation of radiation characteristics / Task No. 2

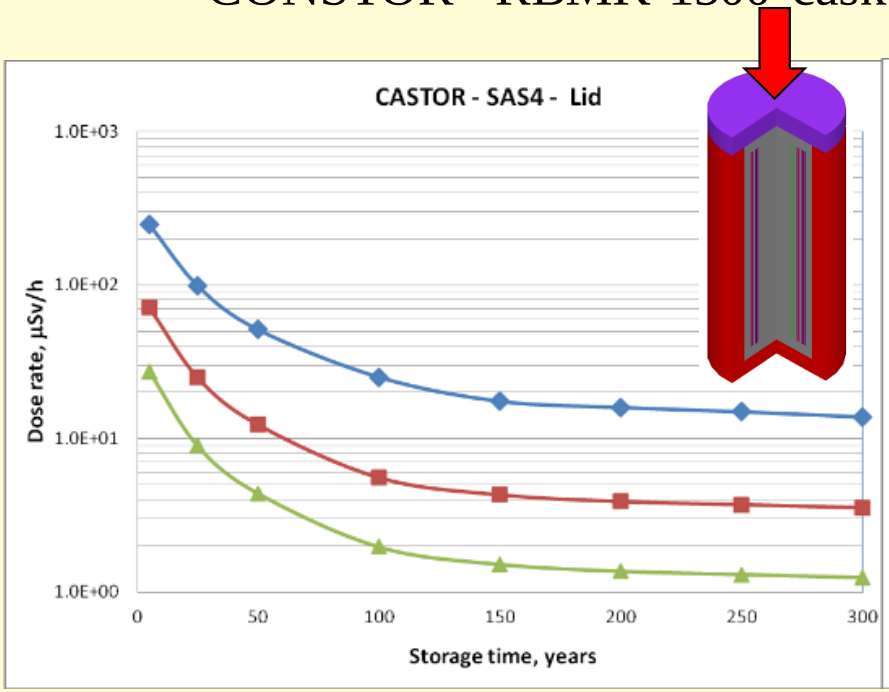
- Sequence SAS4 from SCALE computer code system was used;
- Dose rates and how these doses change during a very long term storage period were calculated on the surface and at some distance from the casks;
- SAS4 calculates radiation doses exterior to a cask using a three-dimensional Monte Carlo method.
- SAS4 input data are nuclide composition of an irradiated and cooled fuel assembly; material composition and geometry of a storage cask; temperatures; radiation source characteristics; locations of radiation dose detectors.

Evaluation of radiation characteristics / Task No. 2

- According to calculation results, dose rate values for a CONSTOR® RBMK-1500 cask in all directions are less than for a CASTOR® RBMK-1500 cask.
- This is also affirmed by the existing operational experience. For instance:
  - the mean individual dose for the personnel performing cask loading and handling activities at the Ignalina NPP reactor unit was **0.65 mSv** per one CASTOR® RBMK-1500 cask and **0.86 mSv** per cask for personnel working at the dry storage facility.
  - In case of a CONSTOR® RBMK-1500 cask, the mean individual dose was **0.20 mSv** and **0.26 mSv** per cask for the personnel at the reactor unit and the dry storage facility, respectively.

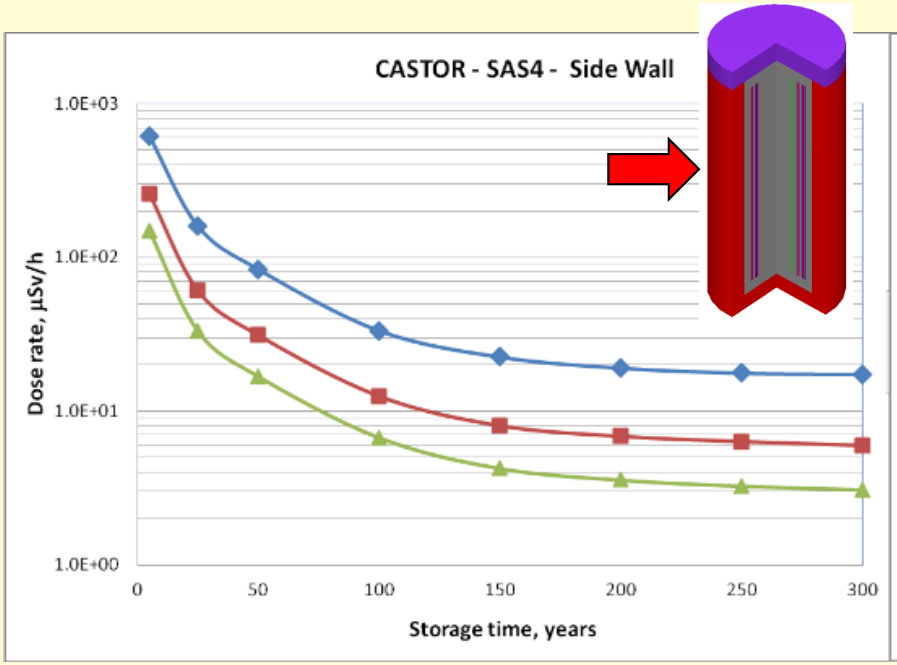
Evaluation of radiation characteristics / Task No. 2

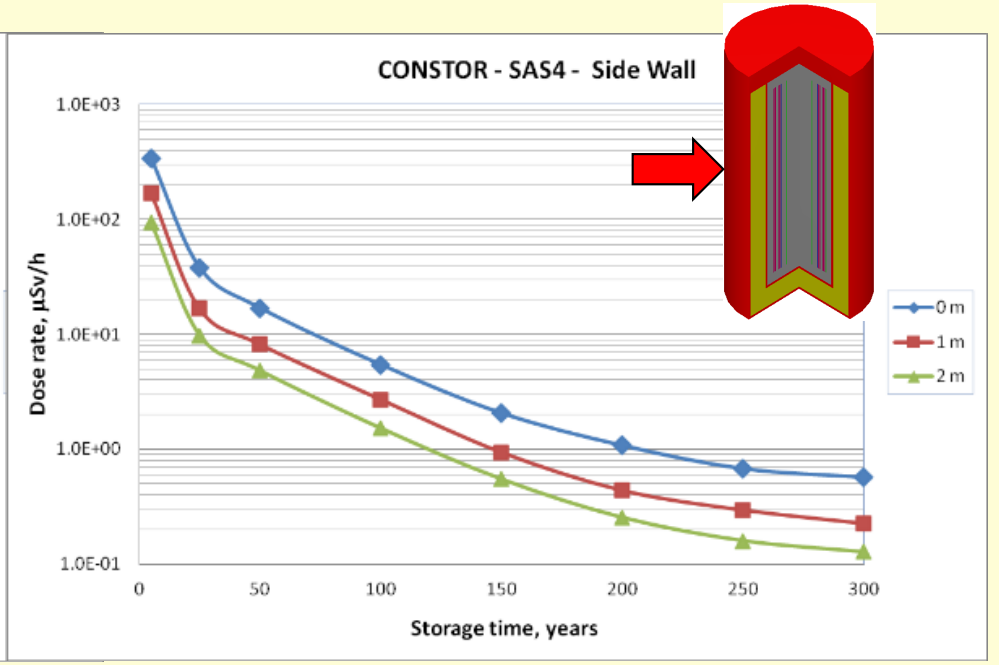
- The smallest difference of total equivalent dose rate for different storage casks is at the lid points. This is because the lid systems are made from the same material for both casks. Only total thickness of the lid system for a CONSTOR® RBMK-1500 cask is a little bigger.



Evaluation of radiation characteristics / Task No. 2

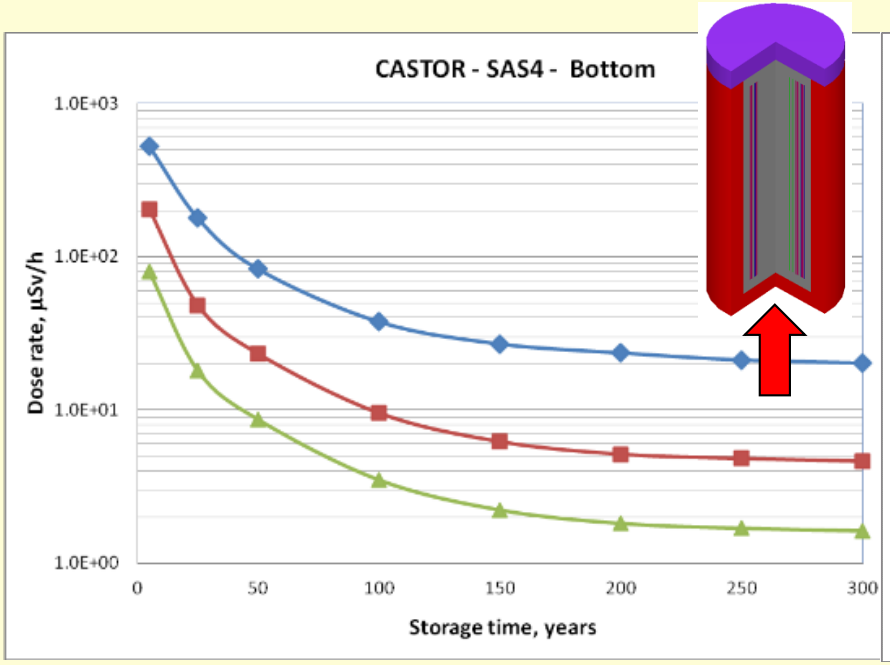
- Material composition and thickness of the casks side walls and bottoms are different, therefore total equivalent dose rates at cask side walls and bottoms differ from 2 to 7 times during storage periods up to 50 years

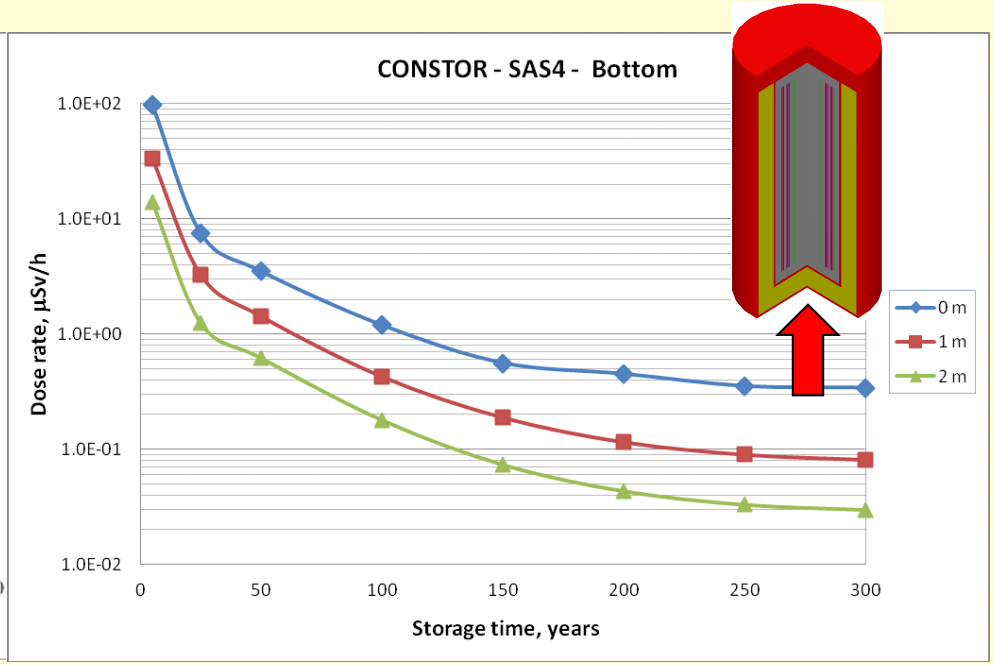




Evaluation of radiation characteristics / Task No. 2

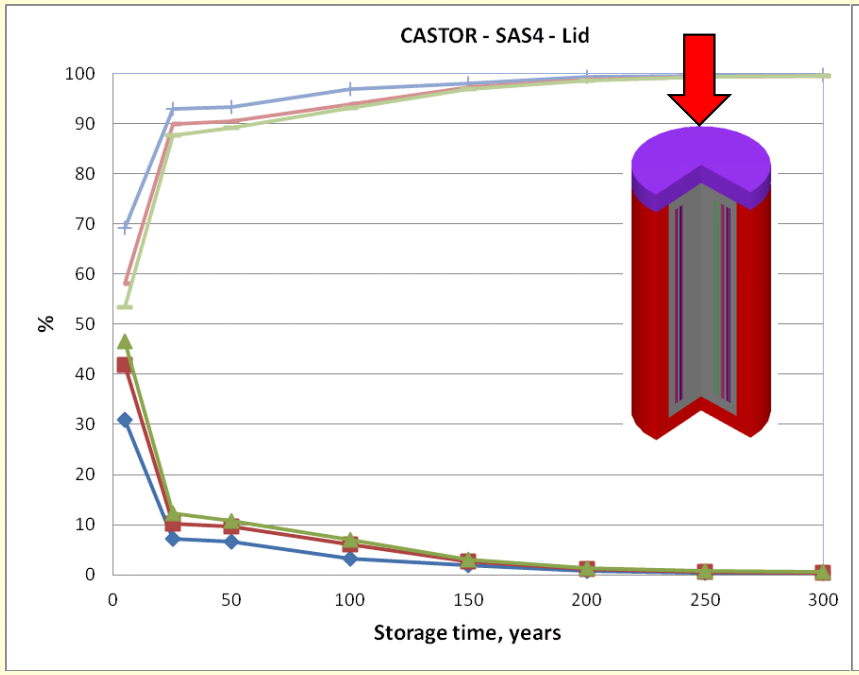
- Afterwards the difference of dose rates for different casks is increasing up to 60 times. This is determined by material composition of side walls and bottoms of a CONSTOR® RBMK-1500 cask, which is effectively absorbing the neutrons.

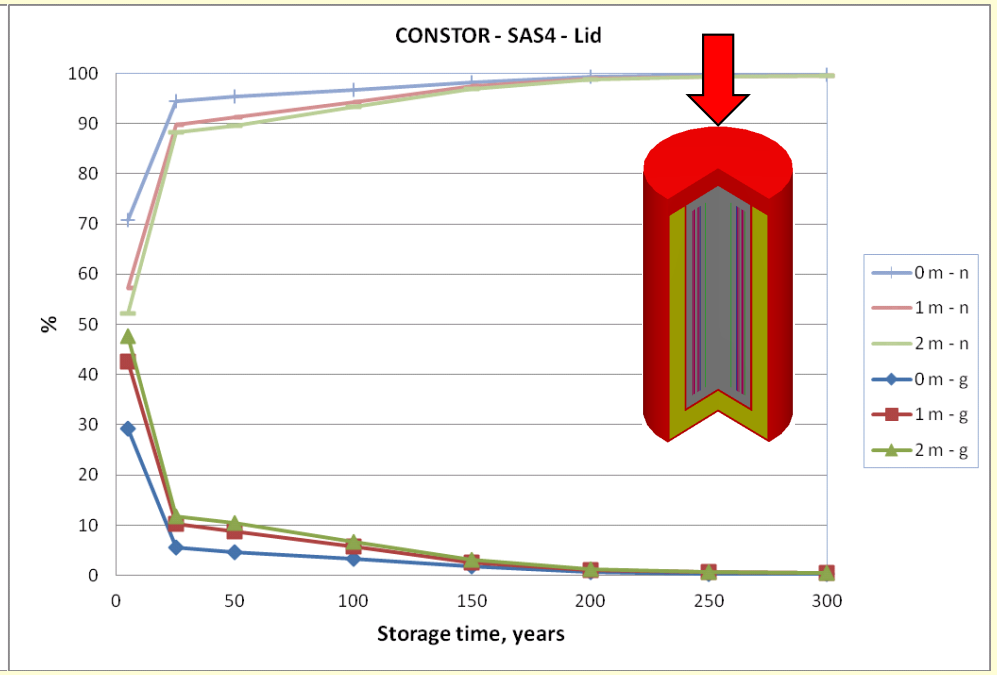




Evaluation of radiation characteristics / Task No. 2

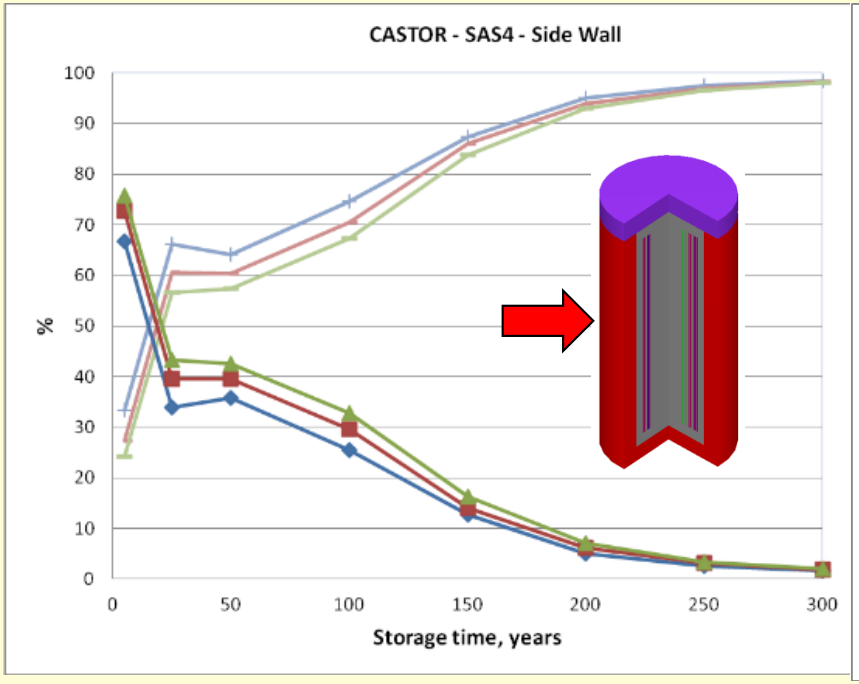
- The total equivalent dose rate is formed by neutrons and gamma radiation. Influence of neutrons on total equivalent dose rate for both casks is the same at the lid points, but completely different at the side walls and the bottoms.

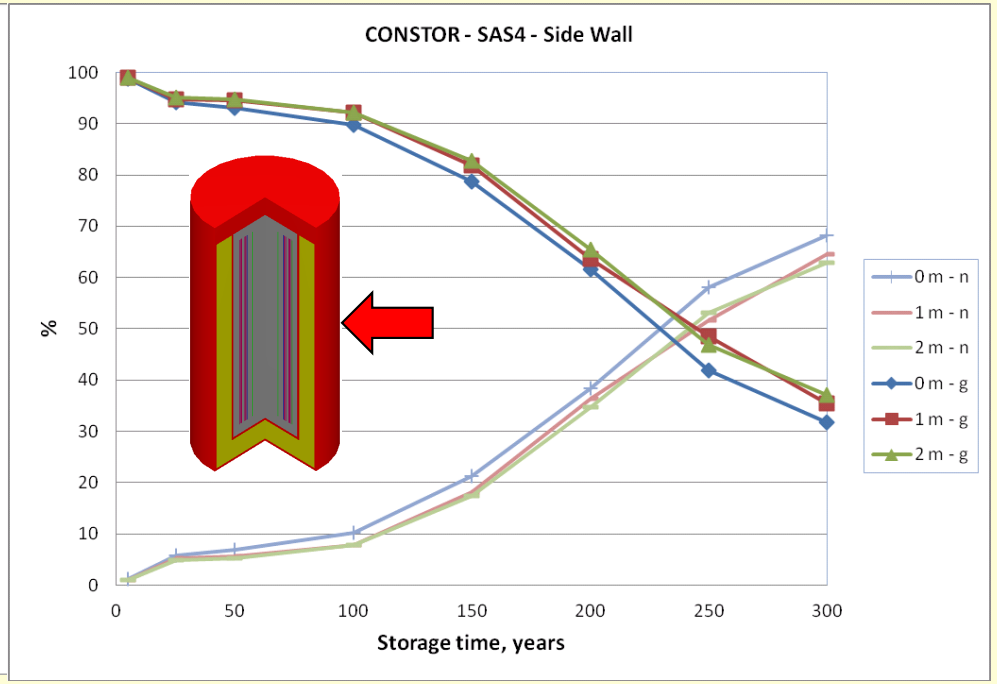




Evaluation of radiation characteristics / Task No. 2

- At the beginning of storage gamma radiation is the dominating component at the side walls and bottoms for both casks. However, during 300 years of interim storage, the total equivalent dose rate is significantly decreasing and after such period dose rate caused by neutrons is becoming dominant.





Conclusions

- Dose rates on the surface and at some distance for the ductile cast iron CASTOR® RBMK-1500 and heavy concrete CONSTOR® RBMK-1500 casks loaded with RBMK-1500 spent nuclear fuel were calculated using SAS4 sequence of SCALE computer code system.
- The dose rate calculations were performed at the beginning of SNF storage and after 300 years of very long term storage.
- The obtained results show that dose rate values on the surface of both casks are less than the design criteria value 1000 μSv/h. Calculations and existing operational experience revealed that a CONSTOR® RBMK-1500 cask has better shielding properties than a CASTOR® RBMK-1500 cask.
- During 300 years of interim storage, the total equivalent dose rate is significantly decreasing and after such period dose rate caused by neutrons is becoming dominant.

Acknowledgements

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Thank you for your attention.