Study on Neutronics and Thermohydraulics of water cooled SMR with Uranium Oxide Fuel

Final Project SH2611 VT23 Small Reactors

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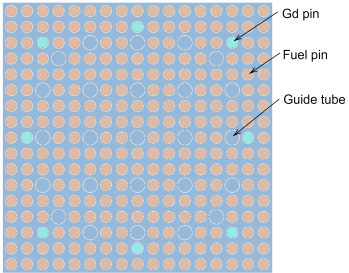
Task Description

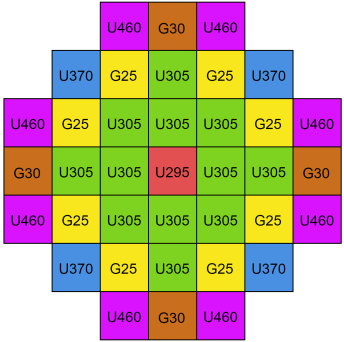
- Design a small reactor unit with an electrical power of 100 MW and enriched uranium oxide.
- Calculate reactivity swing for a fuel average burn-up of 50 GWd/ton and determine the control rod configuration so that the maximum control rod worth is less than 0.5 $. Reactivity losses are to be minimized by use of a burnable poison.
- Calculate the fuel Doppler coefficient and moderator/coolant temperature coefficient.
- Determine the radius of the emergency planning zone, assuming 100% release of xenon and 0.1% release of iodine in a severe accident occurring for a core average burn-up of 50 GWd/ton. The dose acceptance criterion is 20 mSv.
- Estimate the capital and operational costs for a plant with 8 units, based on scaling from literature data. Estimate the LCOE for this 8-unit plant assuming an economic life of 25 years and 90% availability

Reactor Design



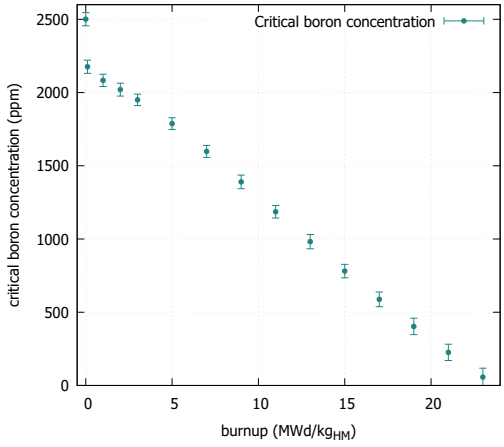
Parameter (Unit)	Value
Thermal power (MW_t)	270
Electrical power (MW_e)	100
Active fuel length (cm)	200
Fuel assembly type (-)	17x17
Number of fuel assemblies (-)	37
Number of fuel rods per assembly (-)	264
Number of control rod assemblies (-)	4
Number of shutdown rod assemblies (-)	12
Fuel mass UO_2 (kg)	9250
Cladding material (-)	M5[1]
Fuel cycle length (months)	24

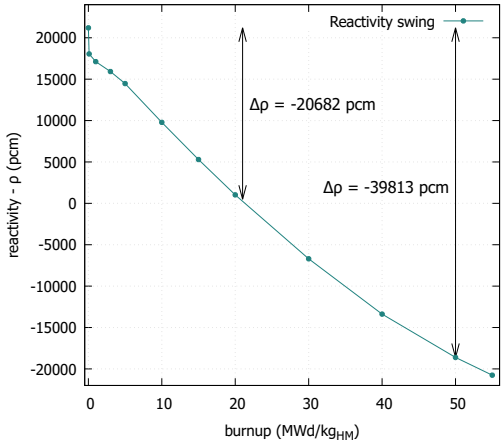
[1]Composition of the cladding in wt.% (bal.Zr-1Nb-0.14O)



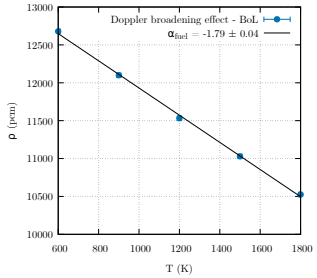
Parameter (Unit)	Value
Fuel pellet radius (mm)	4.05765
Fuel pin outer radius (mm)	4.7498
Cladding thickness (mm)	0.6096
Fuel rod pitch (mm)	12.59
Lattice pitch (cm)	21.5
Chanel flow area (m^2)	0.02753
Active core diameter (m)	1.51
Pressure vessel dimensions (m)	4.6 × 23

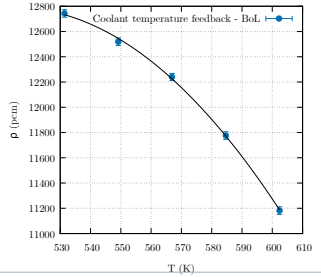
Reactor Burn-up

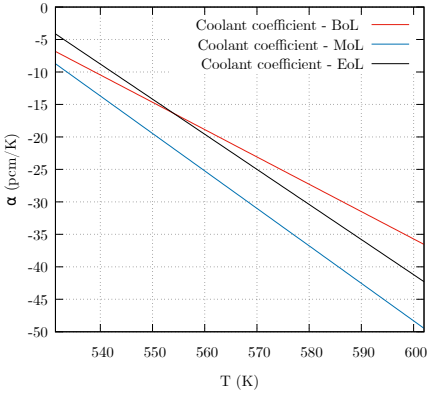




Safety Parameters



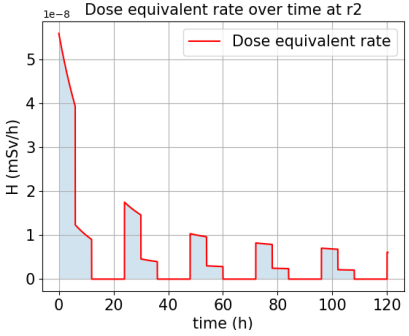




Burnup (MWd/kg$_{HM}$)	α_{fuel}[1] (pcm/K)	α_{cool} (pcm/K)
0 (BoL)	-1.79 ± 0.04	-17.61 ± 0.21
11 (MoL)	-1.80 ± 0.07	-23.50 ± 0.33
21 (EoL)	-1.08 ± 0.02	-17.97 ± 0.19

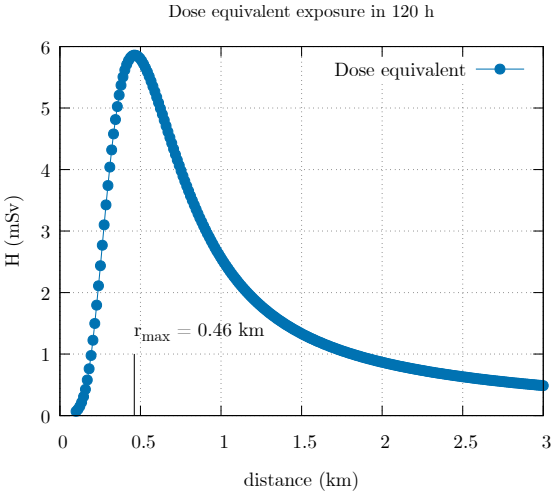
[1] For coolant temperature 557 K

Release of Radionuclides

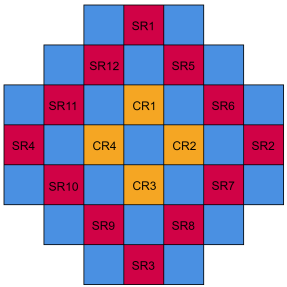


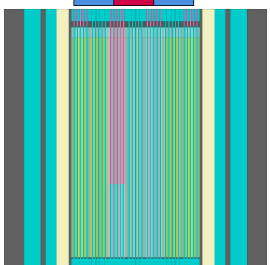
Fission product inventory at EoL

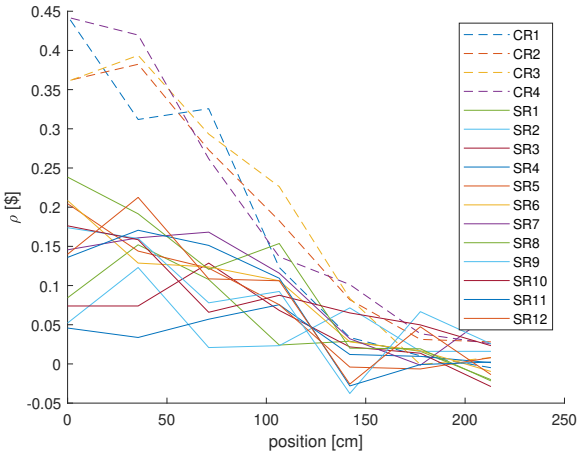
Nuclide	m (g)	A (PBq)	$T_{1/2}$	ε
^{133}Xe	78.4	543.5	5 d	0.1 nSv/(dBq/m^3)
^{135}Xe	2.1	194.7	9 h	1 nSv/(dBq/m^3)
^{131}I	57.1	262.8	8 d	20 nSv/Bq
^{133}I	13.0	543.2	21 h	4 nSv/Bq



Control Rods Design







Cost Estimate

- Economic life: 25 years
- Availability: 90%
- Industry risk factor (β): 7.3%
- Rate of return for risk-free government bond: 3.72%
- 5-year average rate of return for SP500: 8.7%
- Cost of debt for renewable energy: 6.5%
- Assuming an even mix of debt and equity, the plant has a WACC of 6.9%. This results in a CAPEX of 3,357 million USD for an 8-unit plant.

8 module plant	Cost (USD)
Construction cost	2200 million USD/unit
Operational cost	17.3 USD/MWh
LCOE	133 USD/MWh

Thanks for your attention!