Thorium Energy Conference THEC13

October 27 – 31, 2013, Globe of Science and Innovation, CERN, Geneva, Switzerland

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

HIGH CONVERSION Th-U233 FUEL CYCLE FOR CURRENT GENERATION OF PWRs

D. Baldova, E. Fridman

BACKGROUND

- Th is a good fertile material → can be converted into U233
- U233 is the best fissile material in thermal neutron spectrum
- Th-U233 can achieve high conversion (HC) in thermal spectrum
- HC fuel cycle in PWRs can improve utilization of natural resources

OBJECTIVES

- To develop HC Th-U233 fuel cycle for existing PWRs
- To maximize the Fissile Inventory Ratio (FIR)
  - Via the use of heterogeneous seed-blanket (SB) fuel assembly
  - In closed fuel cycle

METHODOLOGY

- Neutronic calculations on 2D assembly level
  - Performed using the HELIOS code
  - Selection of SB fuel assembly designs for full core analysis
  - Cross section generation (SPH method used for correction)
- 3D full core burnup calculations with T-H feedback
  - Performed using the DYN3D code
  - Estimation of maximum achievable power density
  - Estimation of maximum inlet coolant temperature

LIMITING PARAMETERS

- DNBR > 1.3
- Only subcooled boiling is allowed
- T_{CL} < 2635°C

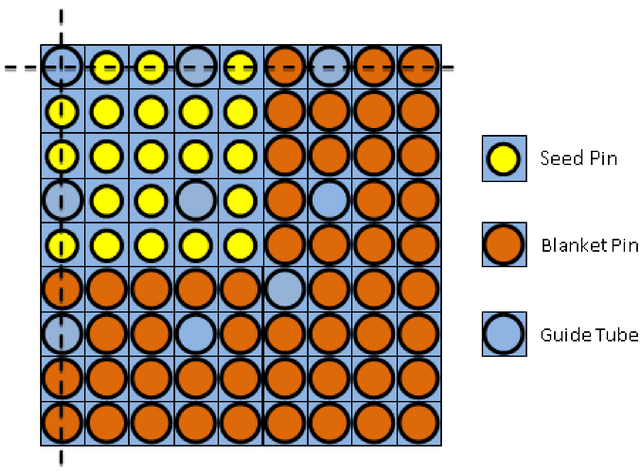
CONSTRAINS

- Retrofittable into the standard PWR core
- Fixed pumping power
- Fuel cycle length equal to 1 year
  - 90% of capacity factor
  - 3 batch fuel management

SELECTED SB FUEL ASSEMBLY DESIGNS

- 72 seed and 192 blanket pins
- Enlarged blanket radius
  - To improve the conversion performance
- Reduced power density
  - Due to the high power peaking in seed

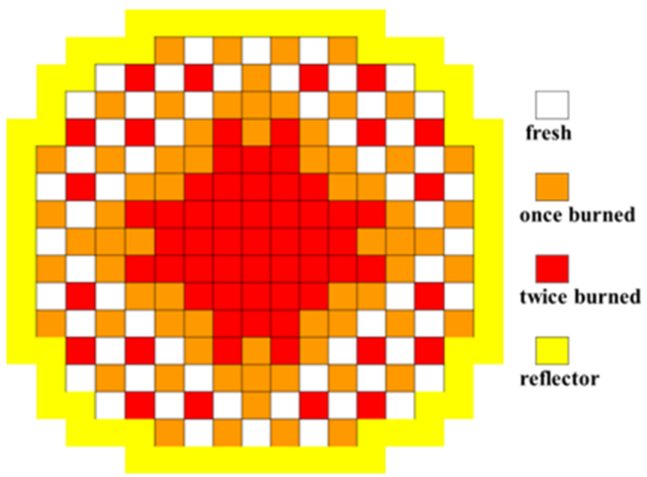
Case No.	Power density, W/cm³	Tinlet, °C	U233 content, w/o	
			Seed	Blanket
1	70	265	9.25	0.5
2	65	265	9.01	0.5
3	60	275	8.86	0.5
4	55	289	8.83	0.5



REFERENCE PWR CORE TO HC Th-U233 CORE

- Typical Westinghouse PWR core
- The core is fully loaded with Th-U233 SB fuel assemblies

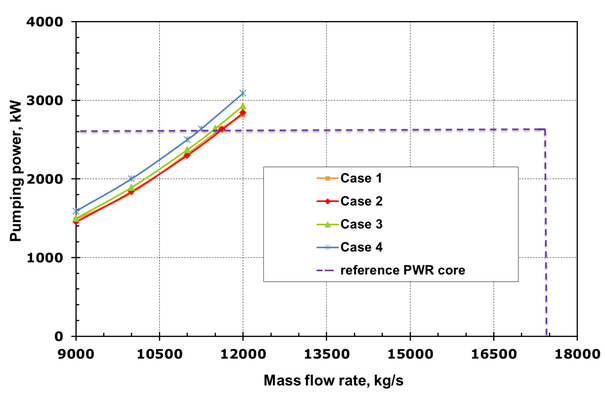
Parameters	Reference PWR core	HC PWR core
Total thermal output, MW	3359	?
Number of fuel assembly	193	193
Core power density, W/cm³	104	?
Core active length, cm	366	366
Inlet pressure, bar	155	155
Inlet water temperature, °C	265.5	?
Total mass flow rate, kg/s	17368	?
Pressure drop (active core), kPa	115	?



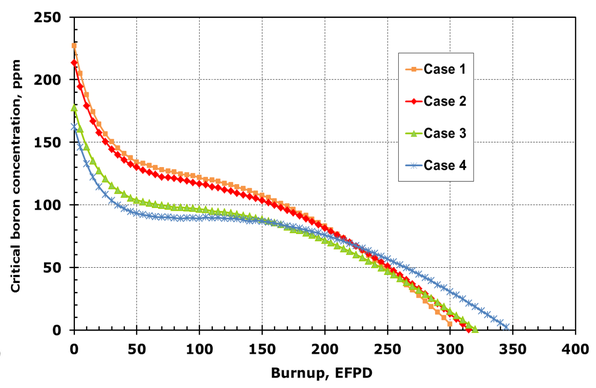
HC Th-U233 PWR Core

Three-batch loading pattern

RESULTS OF 3D FULL CORE ANALYSIS



Pumping power vs. mass flow rate



Critical boron concentration

Case No.	T_{CL}, °C	Min DNBR	Max. void fraction, %	FIR at discharged	Pressure drop, kPa
1	2110	1.46	0.6	0.98	168
2	1957	1.54	0.3	0.99	170
3	1870	1.52	0.7	1.00	170
4	1774	1.51	8.0	1.01	170

CONCLUSION

- The HC Th-U233 core can be potentially operated
  - At power density = 70 W/cm³ and T_{inlet} = 265°C
- The sustainable fuel cycle can be achieved
  - At power density = 60 W/cm³ and T_{inlet} = 275°C
  - At power density = 55 W/cm³ and T_{inlet} = 265°C

Daniela Baldova | Department of Reactor Safety | d.baldova@hzdr.de | www.hzdr.de