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CONCEPTUAL STUDY OF LOW-POWER RESEARCH REACTOR FOR EDUCATION AND TRAINING

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Contents

Introduction

✓ Over the world,

- Decreasing trends of RRs due to aging and under-utilization
- 60% of 250 RRs in operation are less than 250kW
- Supplier of a low-power RR become fewer
- RR's role will continue as long as nuclear energy is used for peace

✓ In Korea,

- KAERI's experiences on high power RRs :
  HANARO(30MW), JRTR(5MW), KJRR(15MW), PALLAS(80MW)
- Possibility of a low-power RR for education and training for University

➢ A conceptual study to develop a reference model of a low-power RR

- High safety and economy with flexibility in utilization

Basic Requirement

Major top-tier requirements for education/training RRs	
Flexibility	- Core configuration & structure : Simple, Easy change of core structure, Easy access to core & Exp. facilities - Utilization area : Field education, Rx. Exp., Neutron beam & Radiation utilization - Core power : Easily operable from zero to full power including transient
Safety & Security	- Reactivity : Rx. to avoid uncontrolled power transient (limited excess reactivity, limited reactivity insertion rate, negative reactivity feedback) - Cooling : Cooling by natural circulation. No emergency cooling - Radiation safety : ALARA - Security : Physical and Cyber security
Economy	- Low construction cost - Fuel cost : Manufactured with proven technology to secure stable supply (LEU fuel, No cost for spent fuel disposal) - Min. operation and maintenance costs : designed to be easily maintained (Min. operators, Maintenance free design, Use of commercial components)

Preliminary Design Features

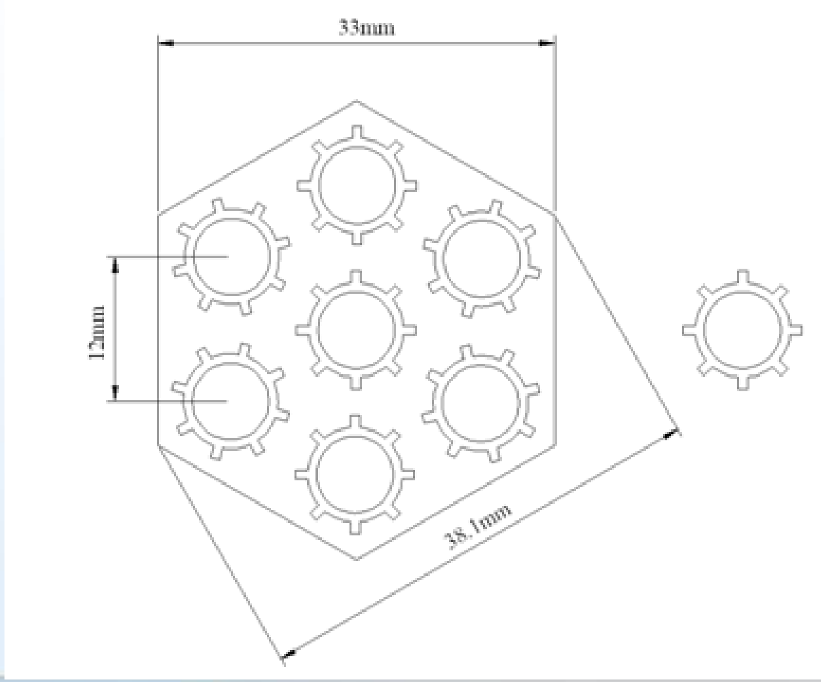
Reactor Type	Open-Tank-In-Pool
Thermal Power (kW)	250
Max. Thermal Neutron Flux ($n/cm^2 \cdot sec$)	$>5.0 \times 10^{12}$ in the core
Fuel Type & Material	Rod type or Plate type U-Mo with 19.75% enrichment (LEU)
Coolant & Cooling Method	H_2O Natural circulation
Moderator/Reflector	H_2O/Graphite
Reactor safety	High negative feedback Inherent & passive characteristics
Reactor Control	Digital technology Control rod - Hf, SUS
Experimental facilities	Vertical holes for RI production, NAA, PTS, HTS etc. 2 Beam tubes for NR, BNCT

Preliminary neutronic analysis -1

❖ Numerical analysis method

- MCNP-5 : Criticality, Neutron flux
- TRITON-NEWT : Burn-up estimation
- ENDF/B-VII library

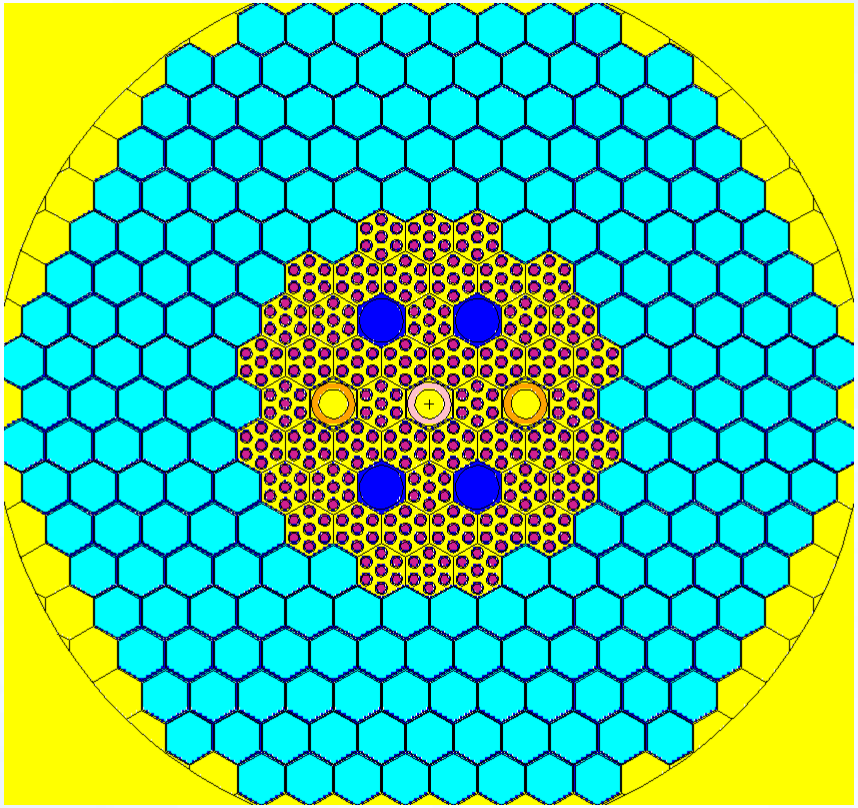
❖ Rod type fuel assemblies



- Remove outer-most ring of HANARO 36-rods standard fuel assembly
- 7 Fuel rods (no tie rod)
- Ass. Dimension : 36 X 570 (mm)

Preliminary neutronic analysis -2

❖ 250kW – Rod type core



✓ Core : 48 fuel assemblies
Total 336 fuel rods
4-incore irradiation holes
2-shim rod (Hf)
1-regulating rod (SUS)
D=27cm
H=50cm

✓Fuel : U-7Mo
5gU/cc, 6gU/cc,
7 rods/assembly

✓ Avg. linear power :
1.5 kW/m at 250 kW

✓ 5gU/cc

Keff = 1.04341 (ARO)
= 0.91044 (ARI, SUS)
= 0.93009 (SRI)

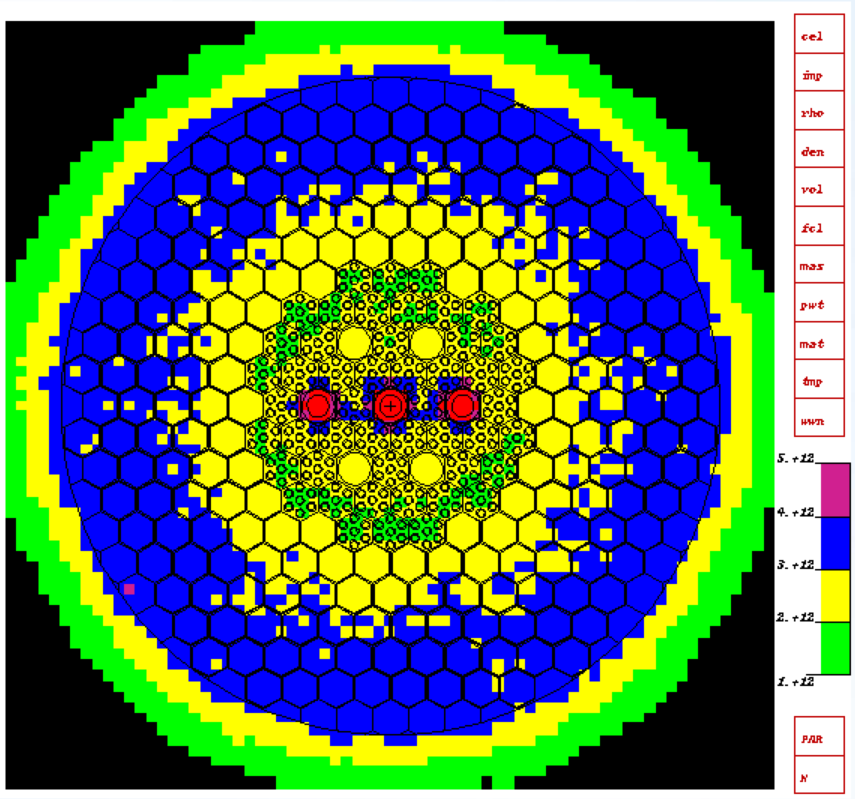
✓ 6gU/cc

Keff = 1.05515 (ARO)
= 0.92799 (ARI, SUS)
= 0.94599 (SRI)

Preliminary neutronic analysis -3

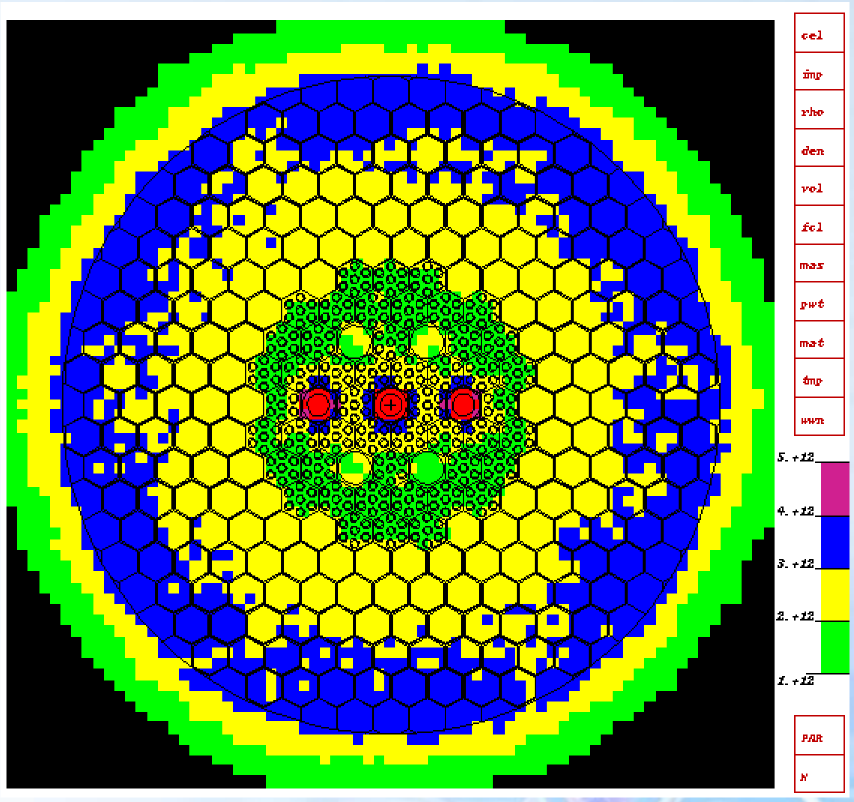
✓ Thermal neutron flux Dist.

- 5gU/cc



Neutron flux > 3.0E12

- 6gU/cc

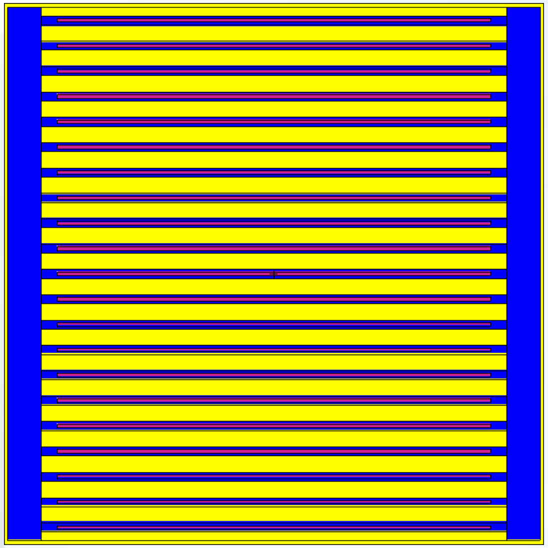


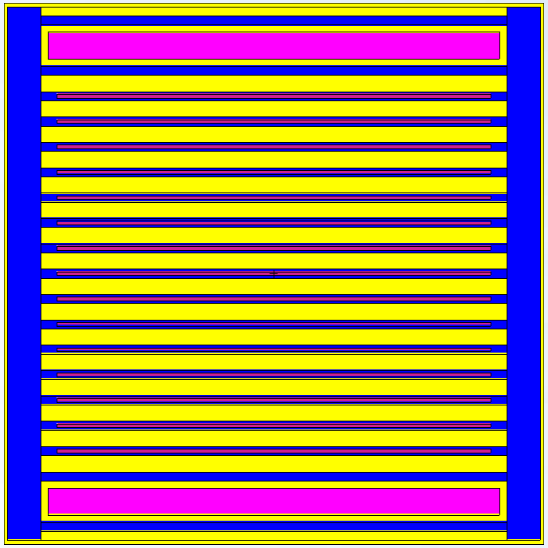
Neutron flux > 3.0E12

❖ F/M ratio adjusting

Preliminary neutronic analysis -4

❖ Plate type fuel assemblies





- Ass. Dimension : 76.2 X 76.2 (mm)
- Meat Dimension : 62.0 X 0.51 X 450 (mm)
- Clad/water thick. : 0.38 / 2.35 (mm)
- 21/15 Fuel plates
- Hf Dimension : 64.6 X 3.97 X 450 (mm)
- 2 Hf plates

✓ Standard fuel assembly

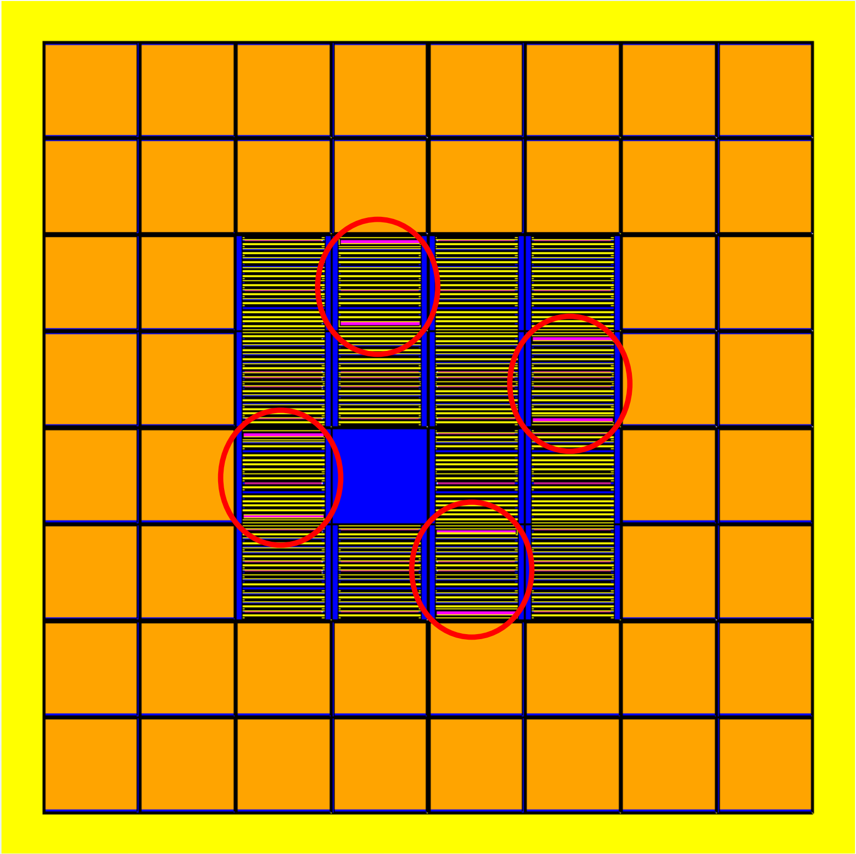
U-235 loading (g)	
5gU/cc	295
6gU/cc	354
7gU/cc	413
8gU/cc	472

✓ Control fuel assembly

U-235 loading (g)	
5gU/cc	211
6gU/cc	253
7gU/cc	295
8gU/cc	337

Preliminary neutronic analysis -5

❖ 250kW – Plate type core



	U-235 loading (kg)
5gU/cc	4.09
6gU/cc	4.91
7gU/cc	5.73
8gU/cc	6.54

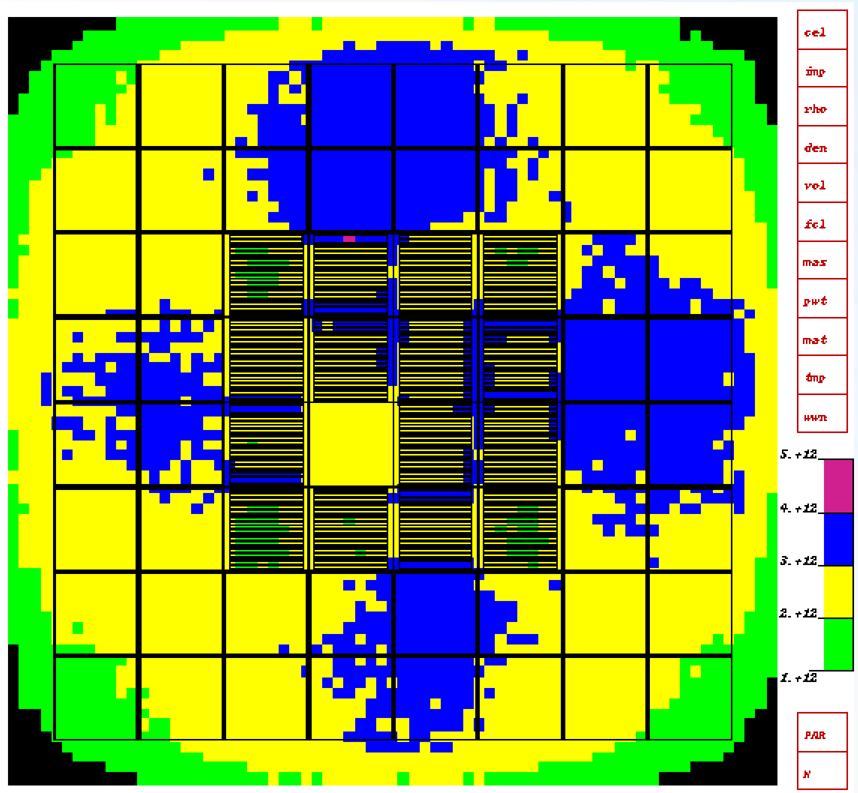
	Keff	
	ARO	ARI
5gU/cc	1.06745 (0.00036)	0.86832 (0.00039)
6gU/cc	1.08671 (0.00037)	0.89365 (0.00038)
7gU/cc	1.09954 (0.00038)	0.91277 (0.00038)
8gU/cc	1.11085 (0.00039)	0.92772 (0.00038)

✓ Avg. heat flux = 15.40 kw/m^2

Preliminary neutronic analysis -6

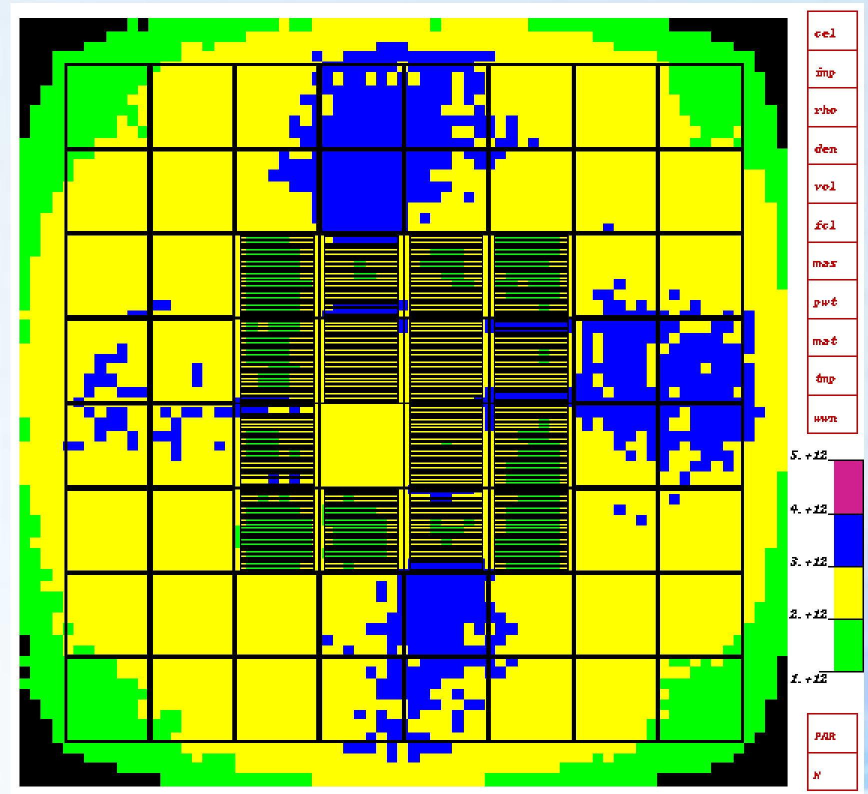
✓ Thermal neutron flux Dist.

- 5gU/cc



Neutron flux > 5.0E12

- 6gU/cc



Neutron flux > 5.0E12

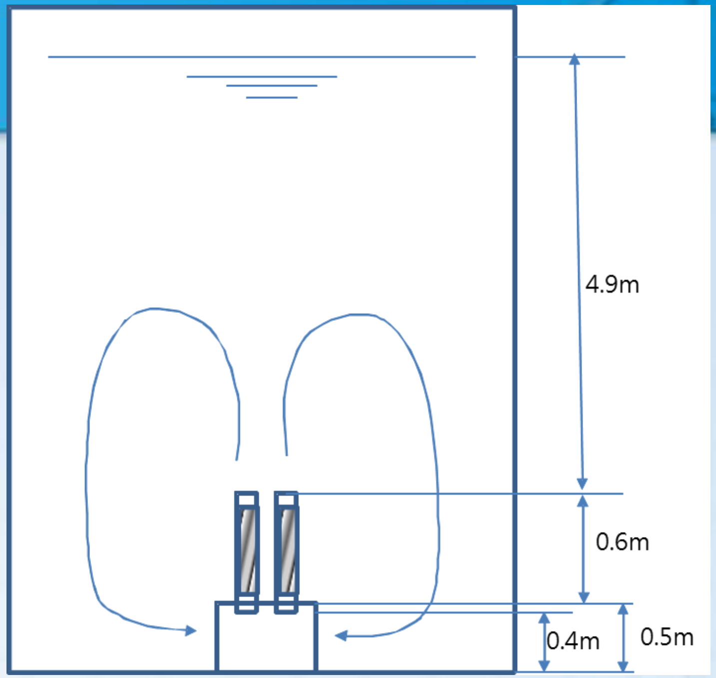
Preliminary neutronic analysis -7

✓ Rod fuel vs. Plate fuel core

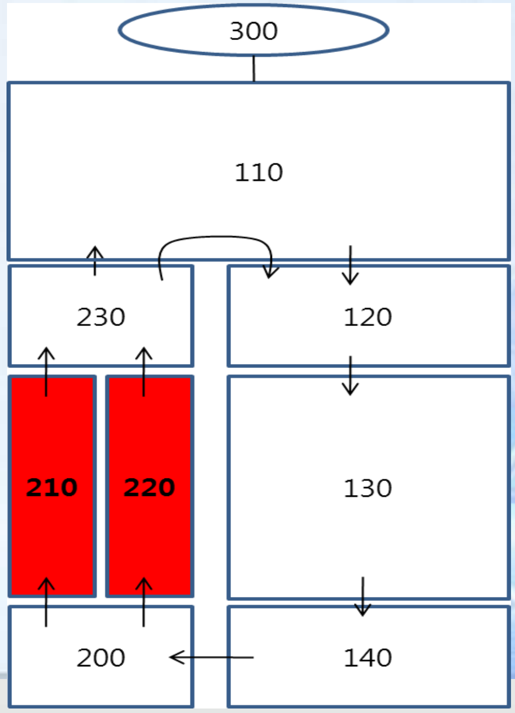
CORE	Mass of U-235 (kg)		Criticality / Cycle length			
			Rod		Plate	
	Rod	Plate	ARO	Days	ARO	Days
5gU/cc	5.25	4.09	1.04341	3950	1.06745	4050
6gU/cc	6.31	4.91	1.05515	6100	1.08671	6500
7gU/cc	7.36	5.73	-	-	1.09954	8700
8gU/cc	8.41	6.54	-	-	1.11085	11000

Preliminary T/H analysis -1

- ✓ Parameters of interest
  - Max. ONB temperature
  - Min. CHFR
- ✓ By using MARS code
- ✓ Assumptions
  - Pool temperature : 35°C
  - Total & axial peaking factor : 3.0 & 1.34
  - Elevations :



- ✓ Nodalization for MARS calculations
  - Quasi-steady state calculation
  - ONB temp. : 120°C



Preliminary T/H analysis -2

✓ Calculation Results : Coolable by natural circulation

	Power (kW)	Coolant vel. (m/s)	Coolant temp. (°C)	Fuel temp. (°C)	CHFR
Rod	500	0.27*/0.23**	86*/66**	132*/109**	8.7*/-
	250	0.19*/0.15**	59*/50**	120*/95**	13.0*/-
	100	0.12*/0.09**	49*/43**	103*/70**	-/-
Plate	1000	0.25*/0.21**	83*/57**	117*/80**	35.7/-
	750	0.23*/0.18**	74*/55**	110*/74**	- / -
	500	0.20*/0.14**	66*/52**	94*/67**	- / -
	250	0.13*/0.093**	58*/48**	78*/54**	- / -
	100	0.076*/0.052**	51*/44**	63*/51**	- / -

Hot channel*/ Avg.**

Concluding Remarks

- ✓ A conceptual study to develop a reference model of a low power RR is being performed to prepare for future needs

  - Fundamental requirements
  - Preliminary analysis for rod type and plate type cores

    → controlable, coolable, and feasible

- ✓ A reference model will have high safety and economics together with high flexibility in use