Hybrid Low-Power Research Reactor with Separable Core Concept

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Introduction

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New RR Project

New Research Reactor Projects in the World

- **Currently, there are approximately 30 IAEA Member States developing or planning new research reactors.**
- **13 Member States are working on their first ever research reactor project.**

New Customers of RR

- 158 Facilities (including critical and sub-critical facilities) are more than 40 years old. - (RRDB at IAEA)
- Demands of new RR or critical assembly would be expected.
- New customers of RR are expected to be about 30 countries in 20 years.
  - Except Russia, Argentina, China, France, USA, Japan, India
    - These countries are exporting RR or have an abilities to build a RR.

158 Facilities with first criticality more than 40 years ago

Overview | Reactor List

This database contains 158 Research Reactors with first criticality more than 40 years ago distributed over 39 Countries.
Note that this view includes Reactors of the following status: ☐(check this to include all)
OPERATIONAL, TEMPORARY SHUTDOWN

Hybrid Low Power Research Reactor

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H-LPRR(1)

Hybrid Low Power Research Reactor (H-LPRR)

- The KAERI has designed a Hybrid Low Power Research Reactor (H-LPRR), to meet the needs
- Not only for conventional research reactor utilization
- But also for a critical assembly
- H-LPRR can be used for the education of nuclear engineering students at an universities.

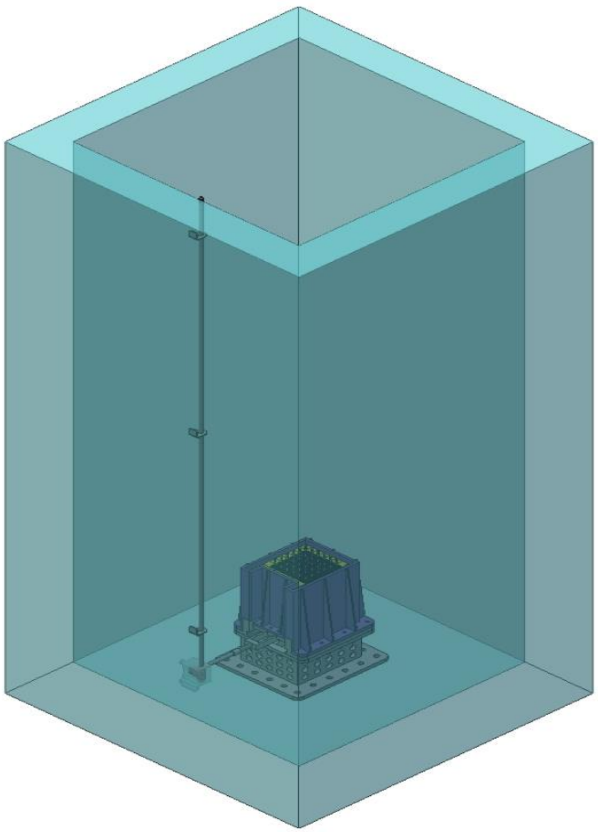
Calculation Codes

- MCNP6.1 & McCARD code and a continuous neutron cross-section data(ENDF/B-VII.1) were used to calculate the core parameters.

H-LPRR(2)

Core parameters of H-LPRR

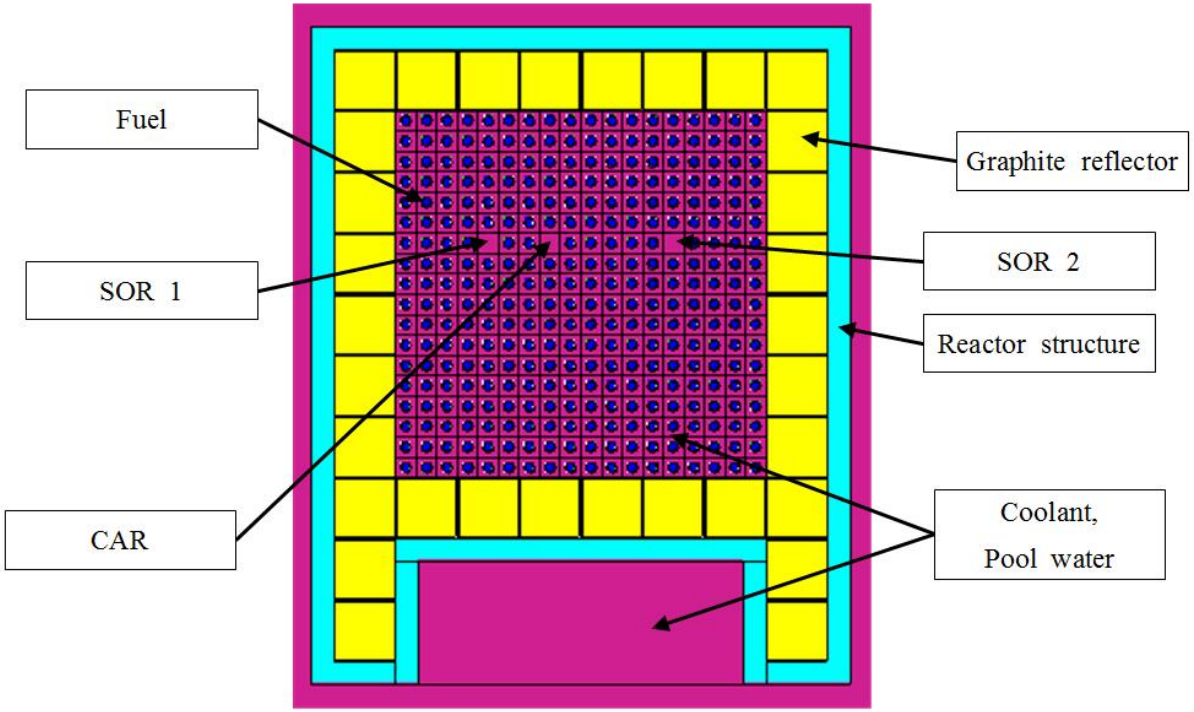
Component	Parameter	Value
Reactor	Type	Open Pool
Core	Thermal Power (kW)	70
	Average thermal neutron flux (#/cm^2.sec)	1 x 10^{12}
	Size of Fuel zone (W x L x H [cm])]	32.4 x 32.4 x 32
Fuel	Type	Rod
	Material	UO_2
	Enrichment	5%
	Clad Material	Zr-4
Coolant	Material	Light Water (H_2O)
	Core cooling	Natural Convection
Moderator	Material	H_2O^* / H_2O, Graphite**
Reflector	Material	None* / Graphite**
Absorber	Material	B_4C
	Use	CAR & SOR
Reactor Structure	Material	Al 6061T6



H-LPRR(3)

Fuel region

- 321 UO_2 fuel rods
- 1 Control rod, 2 Shut-down rods
- Initial Core does not have a graphite reflector.

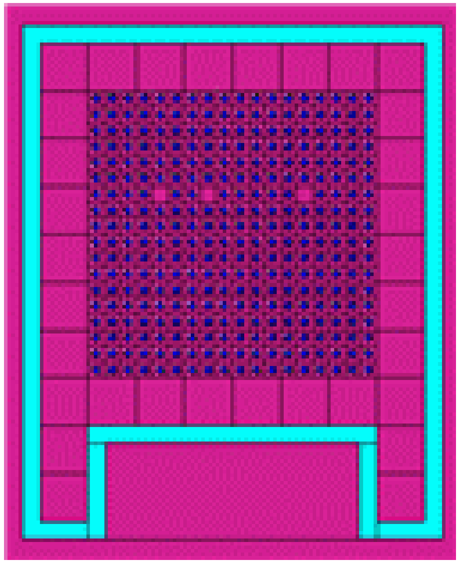


X-Y plane at Z=0

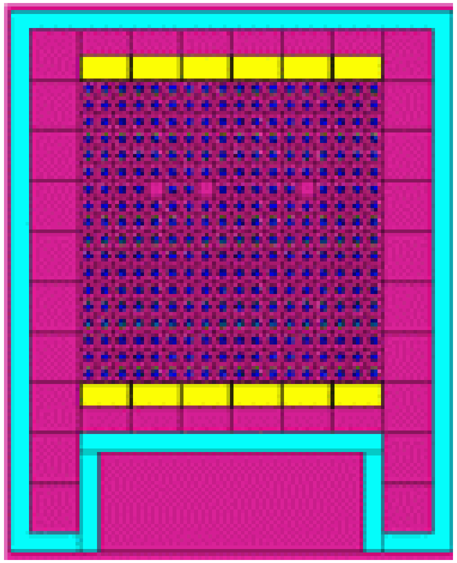
H-LPRR(4)

Reactivity compensation of core

- Initial excess reactivity : 5mk
- U-235 burn-up and the production of long-lived poisons make the core being sub-critical.
- A graphite reflector would be added to compensate the loss of reactivity.



Step 0



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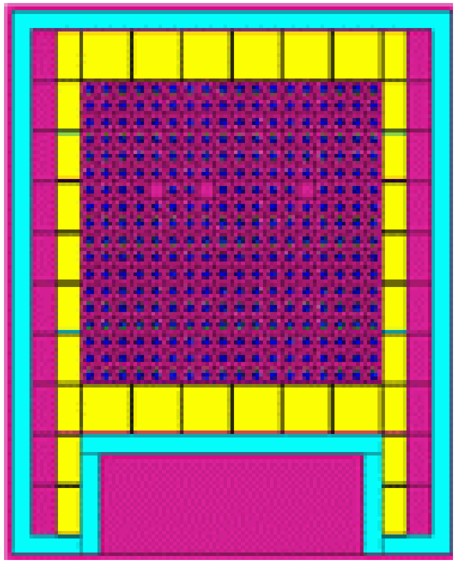
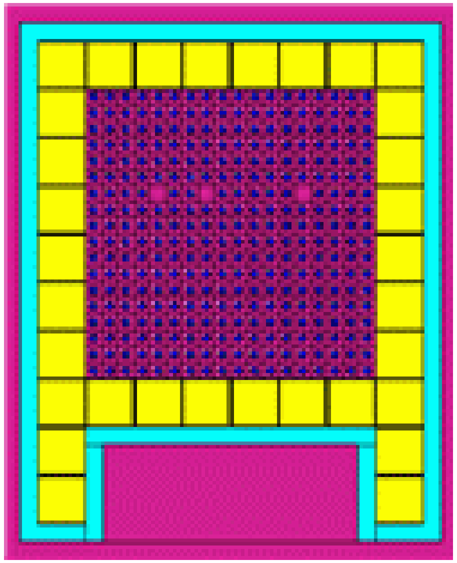


Step 5



Step 6

H-LPRR(5)

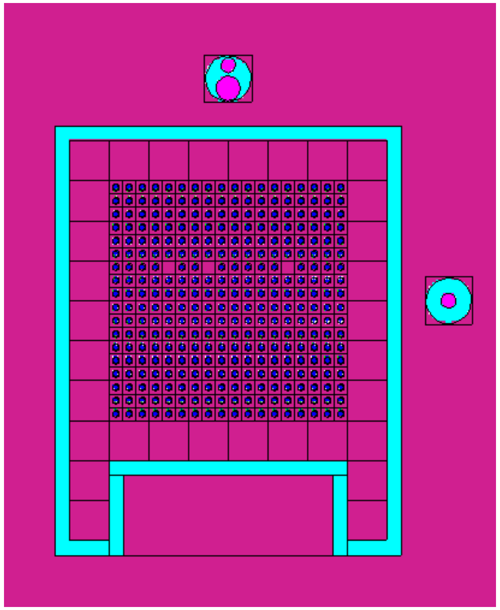
Reactivity compensation plan

- Step 1 to 6, there are 6 actions for the reactivity compensation.
- The core would be had an additional excess reactivity
  - About 3mk ~ 5mk for each step.
- The lifetime of a reactor core is related to the amount of operation time and the amount of excess reactivity.
- Core could be had about 22mk excess reactivity.
- H-LPRR can be operated more than 20 years without refueling.
  - 40 hours a week and 50 weeks a year at its full power.

H-LPRR(6)

Use of H-LPRR

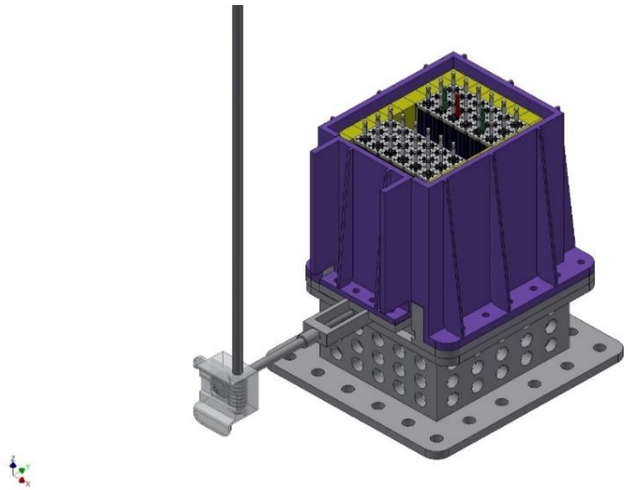
- **H-LPRR would be used for the conventional research reactor utilization**
- **The H-LPRR has two holes for NAA at the north and east side of the core.**
  - **The NAA hole provides 5 x 10^{11} #/cm^2.sec thermal neutron flux for an irradiation of material.**



H-LPRR(7)

Experimental Zone of H-LPRR

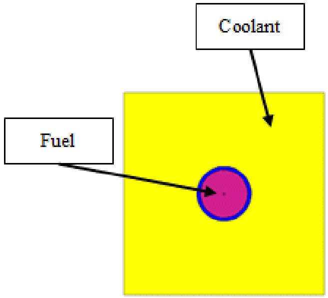
- The core is horizontally separable into two sub-cores.
  - Maximum gap of two sub cores is about 10 cm.
- The central space between sub-cores provides an area.
  - Experiments in critical or subcritical conditions
  - Kinetic parameter measurement
  - Neutron spectrum measurement for a fuel array
  - Use of experimental zone is studying now.



H-LPRR(8)

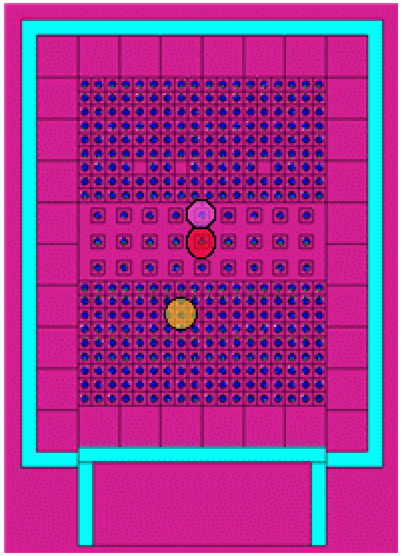
Application of Experimental Zone(1/2)

- Infinite array of fuel with $H2O$ coolant.
  - Same fuel with H-LPRR
  - Fuel pitch is 3.4cm
  - K-inf is approximately 1.



K-inf of infinite array ≈ 1

- Fuels in the experimental zone.
  - Fuel pitch is 3.4cm
  - 9 x 3 fuel batch in the experimental zone
  - K-eff of core is approximately 1.

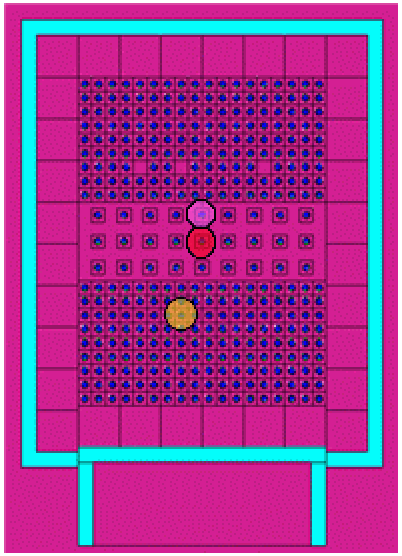


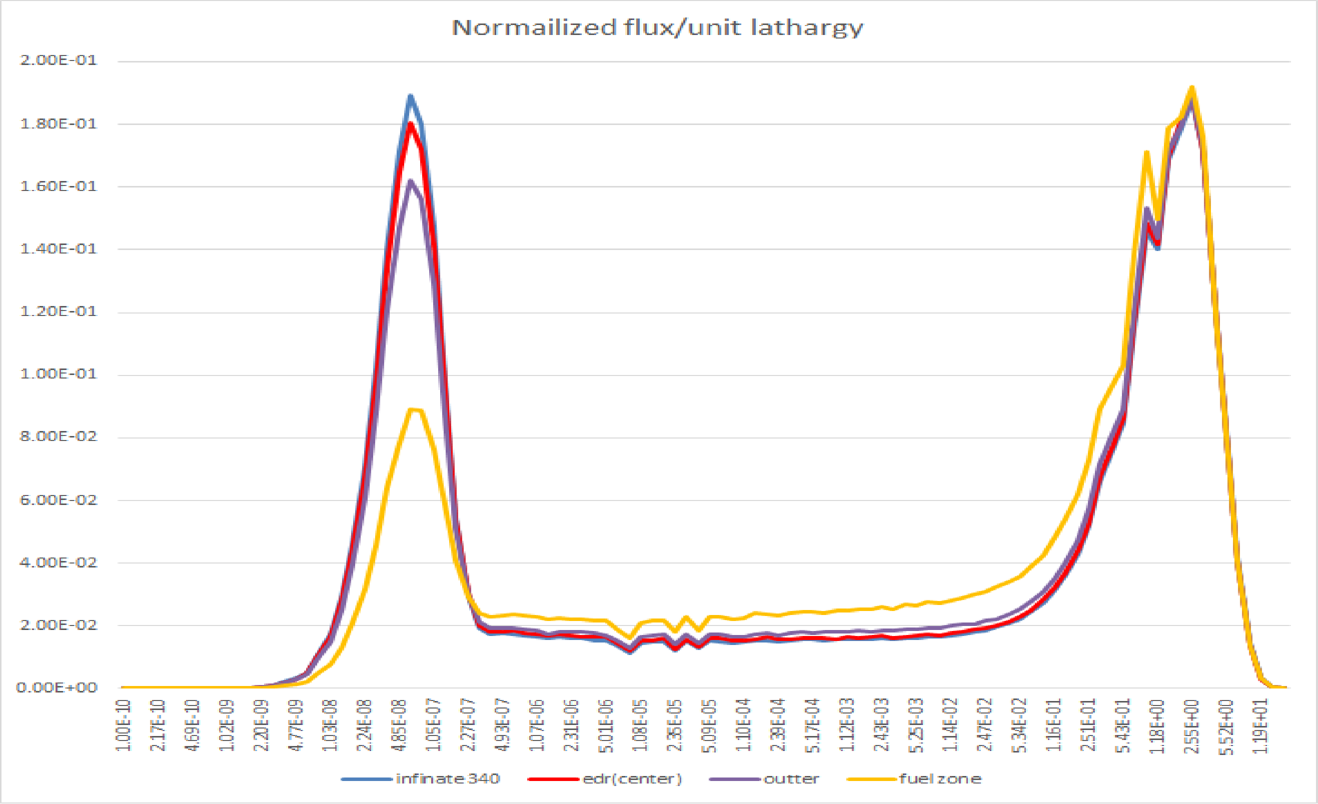
K-eff of H-LPRR ≈ 1

H-LPRR(9)

Application of Experimental Zone(1/2)

- The neutron spectrums of each test fuels are very close.

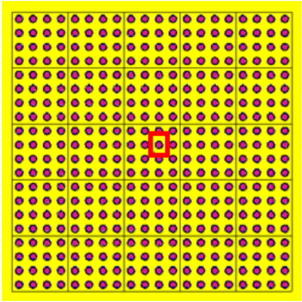




H-LPRR(10)

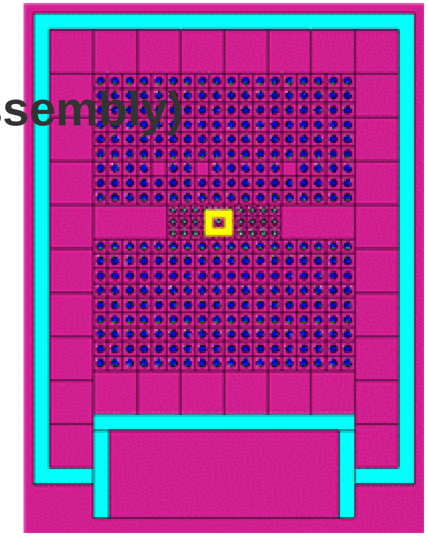
Application of Experimental Zone(2/2)

- **Critical assembly of HANARO fuel.**
  - Use 19.75% enriched HANARO fuel
  - 400 fuel rods used for critical.
  - K-eff is approximately 1.



K-eff of critical assembly ≈ 1

- **Fuels in the experimental zone.**
  - Fuel pitch is 1.4 cm (same to the critical assembly)
  - 10 x 3 fuel batch in the experimental zone
  - K-eff of core is approximately 1.

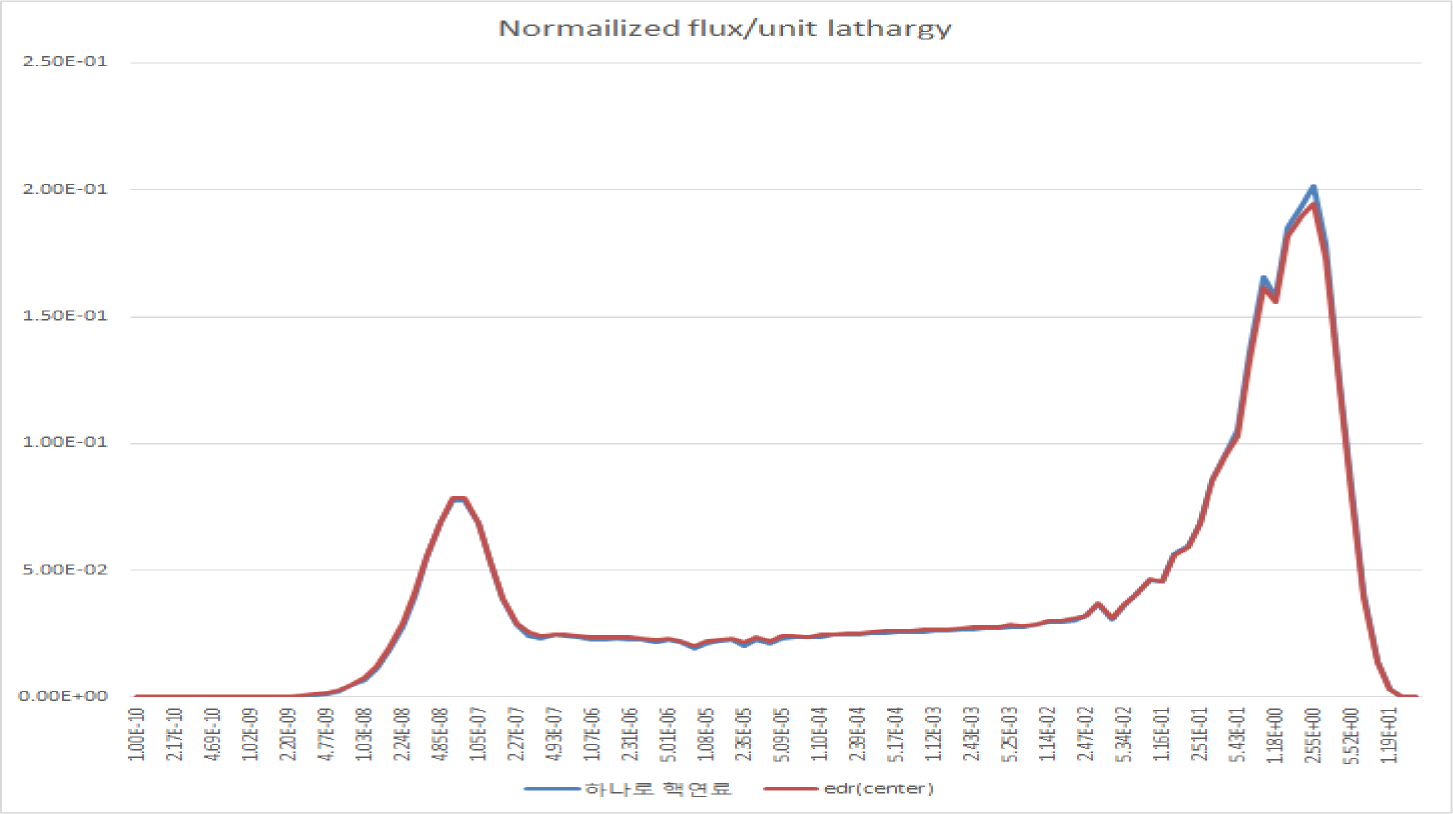


K-eff of H-LPRR ≈ 1

H-LPRR(11)

Application of Experimental Zone(2/2)

- **The neutron spectrums of each test fuels are very close.**



Safety of the H-LPRR

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Safety of the H-LPRR(1)

- The priority in design is given to safety.
  - Core cooling
    - The reactor core is submerged in a pool.
    - 70kW thermal power is cooled by natural convection.
  - Temperature coefficient of Core
    - A strong negative fuel and coolant temperature coefficient lead to core has it's inherent safe.
  - 20 years without refueling
    - Easy to maintenance
    - Graphite reflector handling is easier than refueling.

Core element	temperature coefficient (mk/℃)	temperature range (℃)
Fuel	-0.014	20 ~ 100
Coolant	-0.17	20 ~ 100
Reflector	+0.0026	20 ~ 100

Safety of the H-LPRR(2)

Reactivity Insertion Accident analysis of the H-LPRR

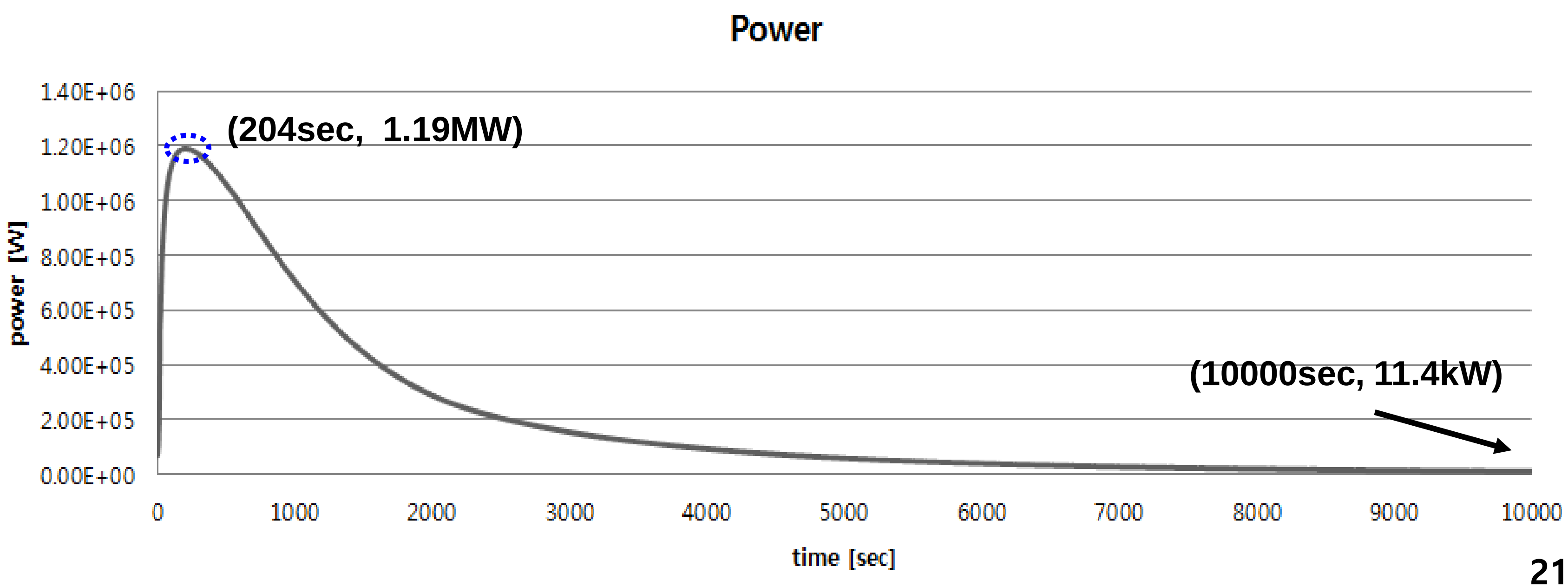
- Some reactor parameters were calculated by McCARD & MCNP6
  - Axial power distribution, power peaking factor, temperature coefficient - MCNP6
  - Kinetic parameters (beta, neutron generation time) – McCARD

- Total inserted reactivity is 5 mk.
  - equal to initial excess reactivity

Safety of the H-LPRR(3)

Reactivity Insertion Accident analysis of the H-LPRR

- **Result**
  - **Maximum thermal power would be 1.19MW at 3minute later**
  - **Maximum fuel centerline temperature is about 580 ℃.**
  - **Hot channel coolant temperature is under the 75 ℃.**
- **The result of RIA analysis shows the core is inherently safe.**



Conclusion

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Conclusion

Conclusion

- Demands of new RR or critical assembly would be expected.
- The KAERI has designed a Hybrid Low Power Research Reactor(H-LPRR).
  - It will meet the needs not only conventional RR & but also for a Critical assembly.
  - The experimental zone of H-LPRR would be provided more versatile experimental programs for students.
- Safe & easy to maintenance

Future work

- Develop the experimental programs using the experimental zone of H-LPRR.
- Fine the optimized position of NAA hole

Thank you.

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