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Preliminary Core Designs of Two Fluid Molten Salt Reactors

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(Ref.) Paper of the same title in ECOS2009

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Molten Salt Reactor (MSR)

MSR is a liquid fuel nuclear reactor using mixed molten salts.

	LWR	MSR
Fuel type	Solid	Liquid
Outlet temperature	~600K	~1000K
Fuel cycle	U-Pu	Th-^{233}U
Moderator	Water	Graphite

Liquid:
- On-line fuel reprocessing

~1000K:
- High thermal efficiency

Th-^{233}U:
- High proliferation resistance
- Abundance of resources
- Almost no minor actinides (MA)

Graphite:
- Irradiation damage
- Slow but positive reactivity coefficient

→ We chose hard neutron spectrum MSR.

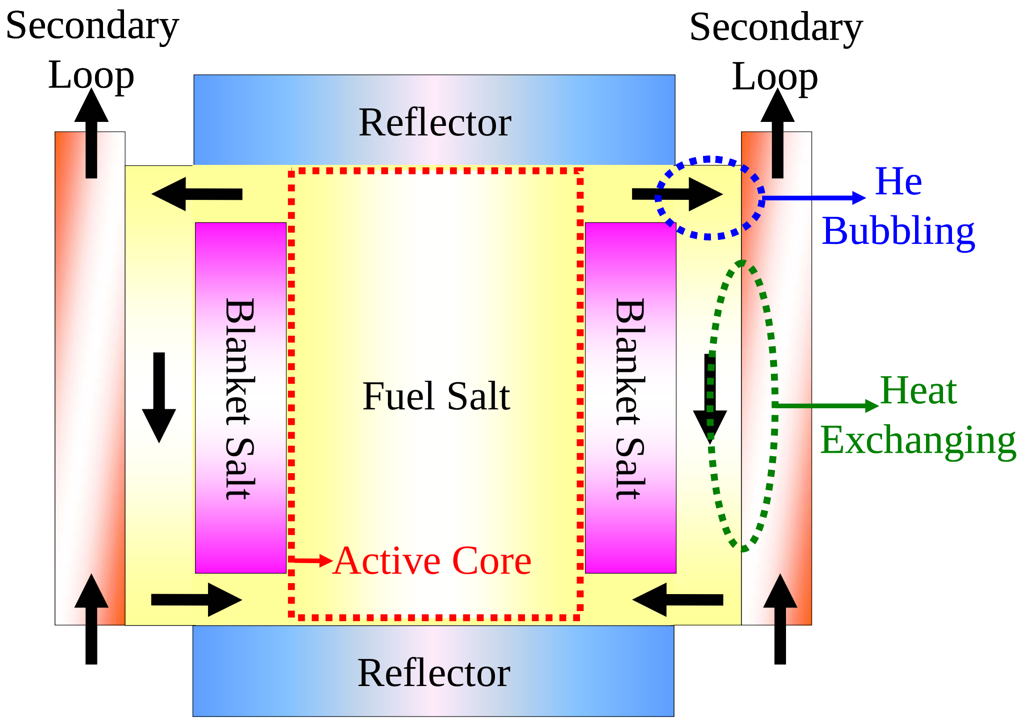
(no graphite moderator)

Hard neutron spectrum MSR - 1

1GWe-MSFR

(Molten Salt Fast Reactor)

- One of the most famous concepts of hard spectrumMSR
- Studied in France
- Large volume of single fluid fuel salt in cylinder core
- The active core is surrounded by radial blanket salt and two axial reflectors



Active core radius/height : 1.25/2.85m

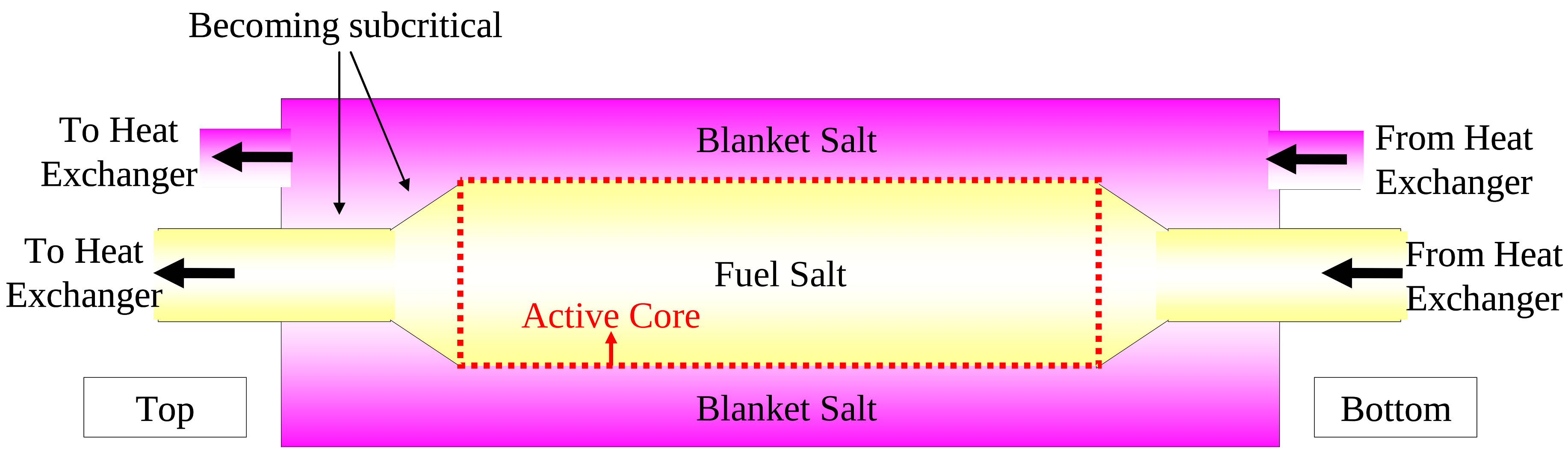
Active/Total fuel volume : 14/20m^3

Width of blanket : 0.40m

Hard neutron spectrum MSR - 2

CyMSR (Cylindrical Molten Salt Reactor)

- New MSR design has been proposed by Dr. David LeBlanc, Canada
- The active core is a simple cylinder, surrounded by radial blanket.
- At top and bottom of the core, the core becomes subcritical state.
- The core size can be freely changed by changing fuel composition, power density and total power.



Objectives of this study

- ***Confirmation of the feasibility of CyMSR concept by nuclear calculation***
- ***Analysis of the potential of CyMSR concept in terms of resource usage***

Fundamental specification of CyMSR

- There is no constraint of the core size of CyMSR.
- In this study we fixed power density and core volume, and we selected the power density and the core volume to the same values of those of MSFR, shown below.

Thermal Power [MWt]	2,500	Active Fuel Core Volume [m^3]	14
Electric Power [MWe]	1,000	Full Fuel Volume [m^3]	20
Thermal Efficiency [%]	40	Width of Blanket [cm]	60
		Thickness of Container [cm]	0.85

- The blanket is binary salt LiF-ThF_4 (72-28mol%).
- The structural material is Hastelloy N.

Fuel types

Three types of fuel for CyMSR

	Two-Fluid MSR (no ThF_4)	FUJI-U2 fuel (typical MSR fuel)	MSFR fuel (no BeF_2)
Fuel [mol%]	$LiF-BeF_2-^{233}UF_4$ 68.5 -31.3- 0.2	$LiF-BeF_2-ThF_4-^{233}UF_4$ 71.76-16 -12.02-0.22	$LiF-ThF_4-^{233}UF_4$ 77.5-20.08-2.42
Temp.	894[K]	900[K]	953[K]
Density	2.03[g/cm^3]	3.33[g/cm^3]	4.43[g/cm^3]
Neutron spectrum	Soft (no thorium)	Hard	Harder (fast)

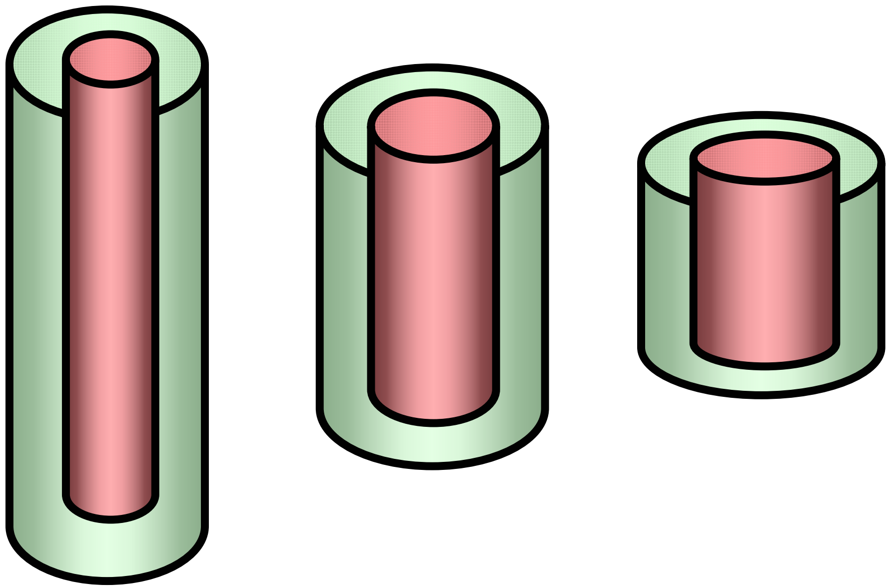
Changing Be and ^{233}U to achieve criticality

Changing Th and ^{233}U to achieve criticality

Core dimensions

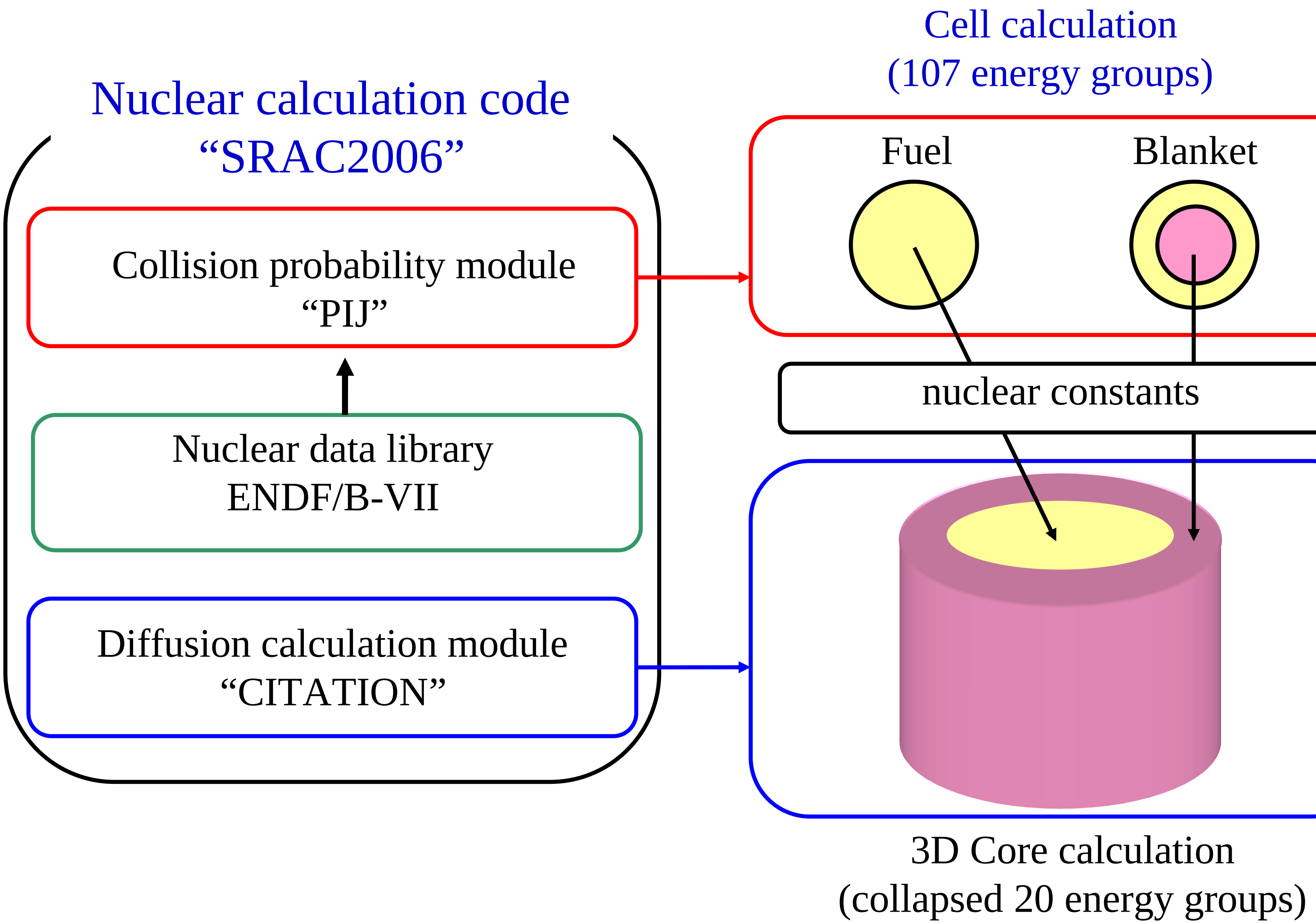
Three cases are studied for the same core volume.

	case-1	case-2	case-3
Core diameter (m)	1.5	2.0	2,5
Core height (m)	7.9	4,5	2.9

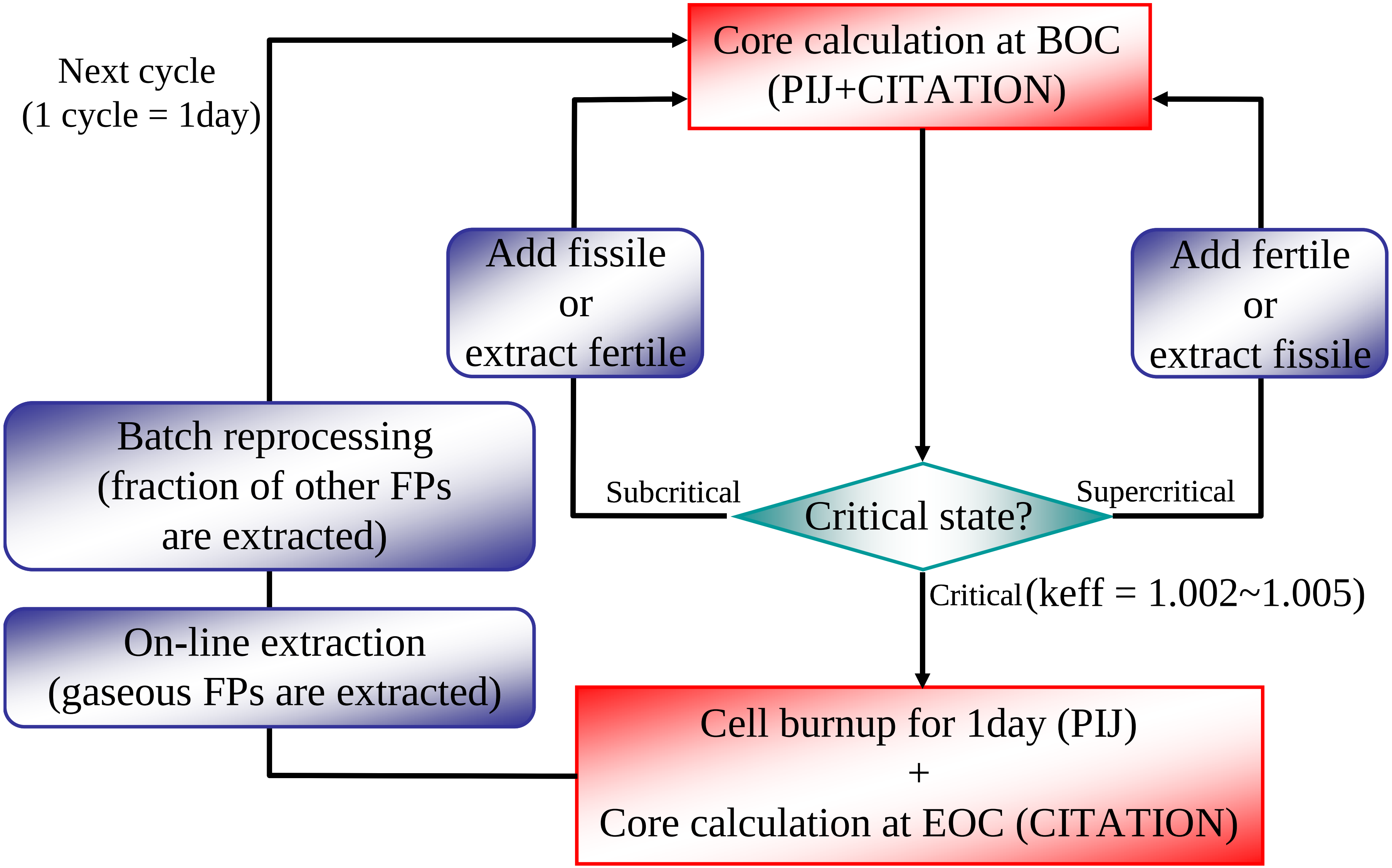


Blanket width is fixed.

Calculation code

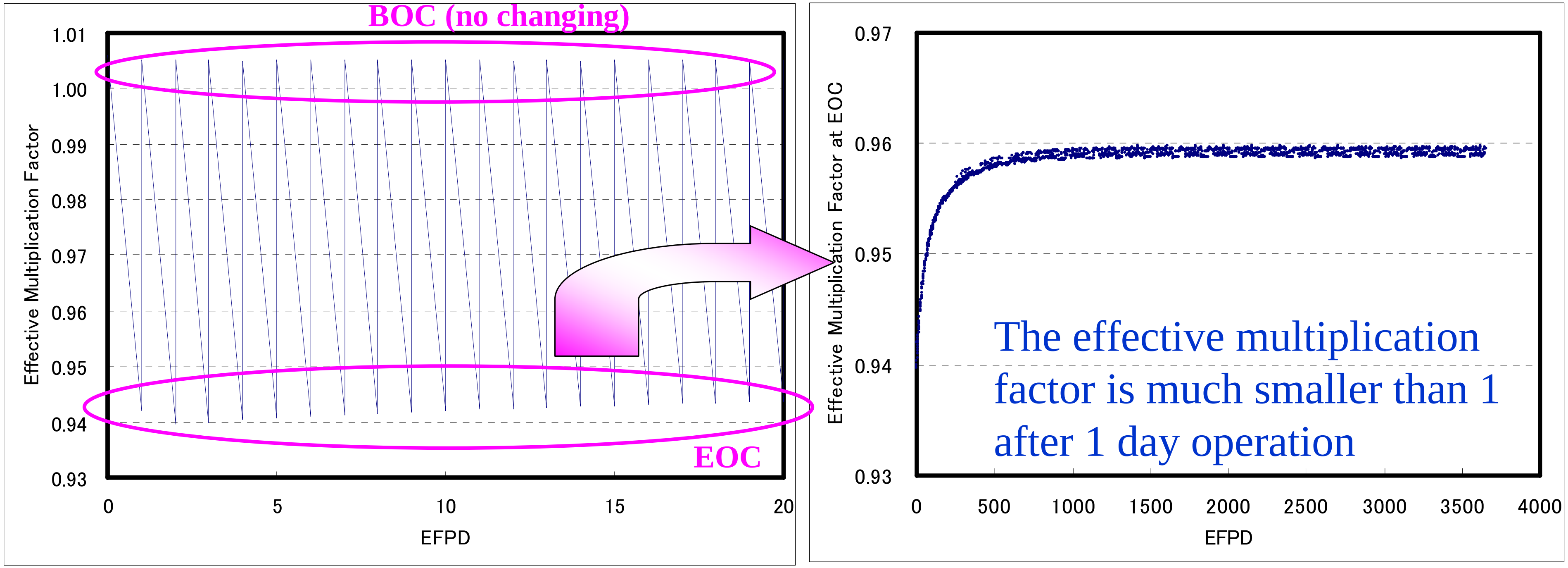


Flow chart of burnup calculation



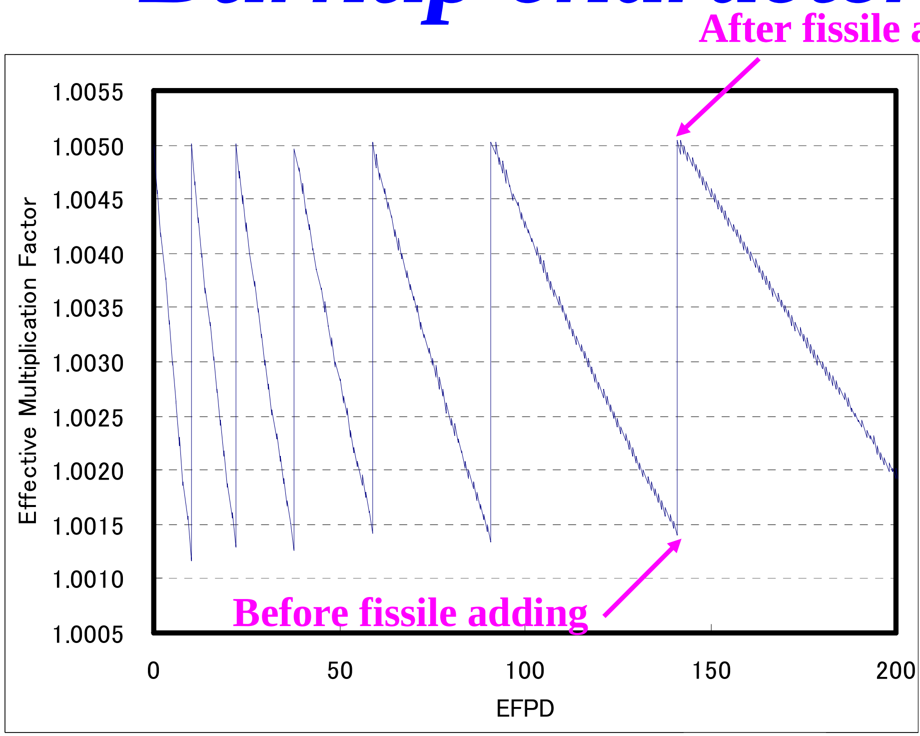
Repeated for 10 years.

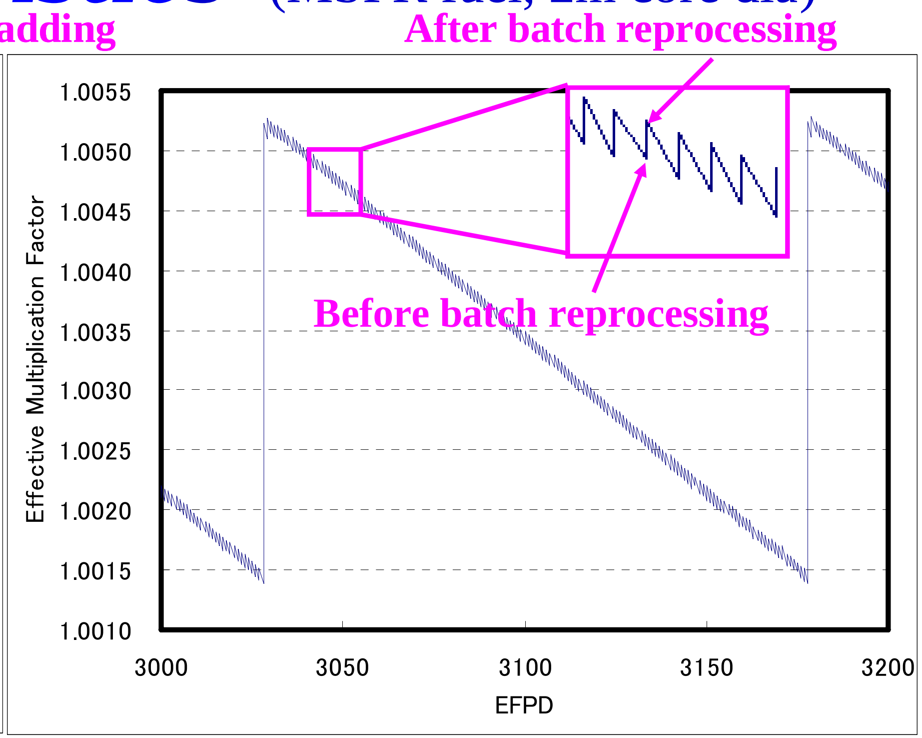
Burnup characteristics (Two-Fluid MSR fuel, 2m-dia)



- Because cycle lifetime is very short, continuous addition of fissile material is required in the case of Two-Fluid MSR.
- We confirmed the feasibility of CyMSR for Two-Fluid MSR fuel.

Burnup characteristics (MSFR fuel, 2m core dia)





- It is possible for CyMSR to be operated with full power for 10 years.
- Time period between one fissile addition and next becomes longer as burnup.
- The core didn’t achieve equilibrium state in 10 years operation.
- FUJI-U2 fuel case is similar (not shown here).
- We confirmed the feasibility of CyMSR for FUJI-U2 fuel and MSFR fuel.

Burnup characteristics (Summary)

•The interval between one fissile addition and next fissile addition

	Average time period between one fissile addition and next fissile addition		
Core diameter	Two-Fluid MSR	FUJI-U2 fuel	MSFR fuel
1.5m	2.2hour	36days	81days
2m	1.9hour	40days	106days
2.5m	1.8hour	45days	114days

•In the case of Two-Fluid MSR fuel, the larger core diameter is, the shorter time period is because of the difference of fissile inventory.

•In the case of FUJI-U2 fuel and MSFR fuel, the larger core diameter is, the longer refueling interval is, because of difference of conversion ability.

Fissile material balance (1/2)

The amount of ^{233}U for 10 years operation [kg]

Fuel type	Two-Fluid MSR			FUJI-U2 fuel			MSFR fuel		
Core diameter [m]	1.5	2.0	2.5	1.5	2.0	2.5	1.5	2.0	2.5
Initial	64	42	36	3675	3305	3174	6225	5792	5642
Total addition	9374	9341	9334	4128	3553	3318	3126	2689	2404
From ^{233}Pa	0	0	0	1760	1919	1979	1990	2132	2186
From blanket	468	352	284	351	264	216	326	242	195
Net usage	8970	9031	9086	5692	4675	4297	7035	6107	5665
Estimated CR	0.05	0.04	0.03	0.51	0.61	0.66	0.74	0.88	0.99

- Total addition : summation of added ^{233}U
- From 233Pa : summation of extracted 233Pa from core by batch reprocessing
- From blanket : summation of extracted 233U and 233Pa from blanket
- Net usage : Initial + Total adding - From 233Pa - From blanket
- CR(Conversion Ratio) is estimated as .(From 233Pa + From blanket)/ (Total addition)

Fissile material balance (2/2)

•"Net usage" is the amount of 233U required to operate CyMSR for 10 years.

In the case of Two-Fluid MSR, the initial inventory is very small, but "Net usage" is quite large.

•In the case of FUJI-U2 fuel, the value of "Net usage" is smallest. That means the amount of ^{233}U, required for 10 years operation of CyMSR, is smallest.

•In the case of MSFR, Conversion Ratio is estimated as highest.

Summary of the study

- We have studied the feasibility of CyMSR concept.
- If we do not use thorium in the core fuel (Two-fluid MSR fuel case) we have to reduce core diameter than this study. Then, neutron leakage to blanket becomes larger, and Conversion Ratio will be improved .
- If we use thorium in the core fuel too, Conversion Ratio becomes higher, especially, if the neutron spectrum becomes harder by removing BeF_2, Conversion Ratio becomes close to 1.0.
- For FUJI-U2 fuel, the amount of 233U, required for 10 years operation of CyMSR, is smallest among 3 fuel types.

Thank you for the attention!
Any questions/comments?