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FR09 - International Conference on Fast Reactors and Related Fuel Cycles

Analysis of Core Physics Test Data and Sodium Void Reactivity Worth Calculation for MONJU Core with ARCADIAN-FBR Computer Code System

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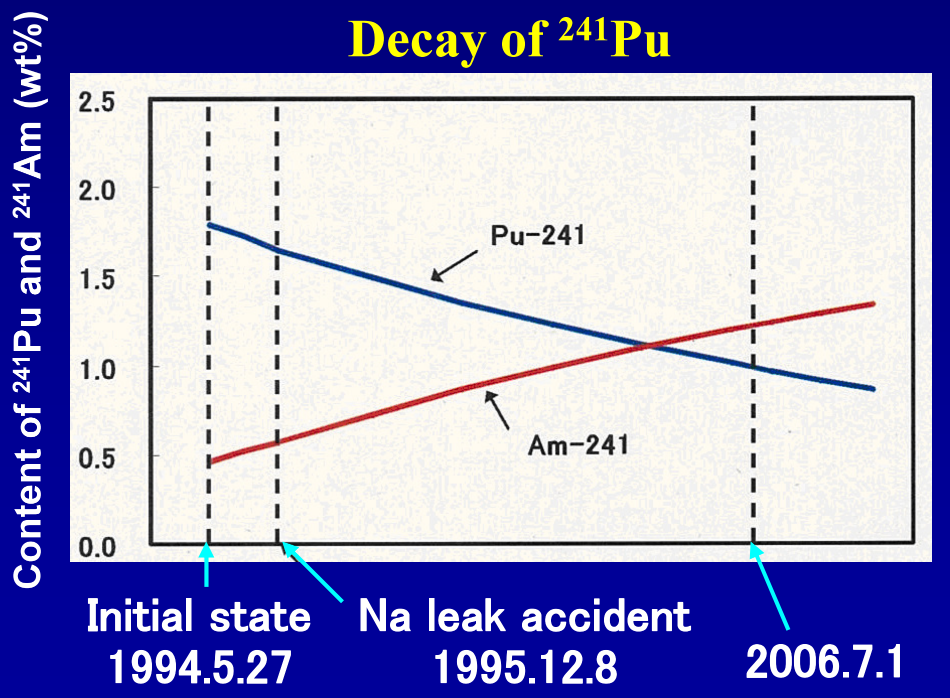
Contents

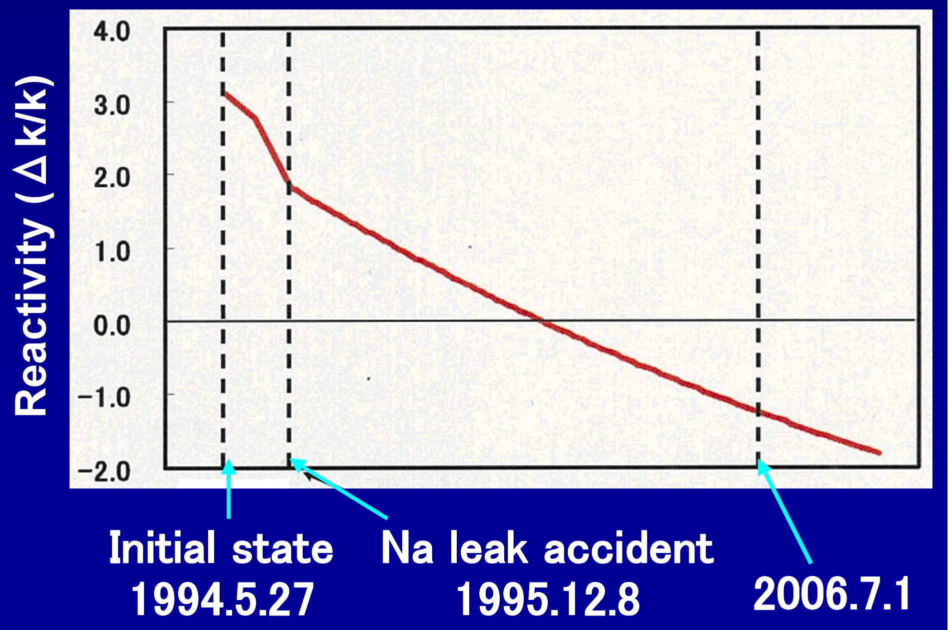
Background

- The operation was suspended over 14 years since 1995.
- ^{241}Pu changed to ^{241}Am and the reactivity of core decreased.
- For the restart of MONJU, a number of initial MOX fuels were replaced by the new MOX fuels which contain higher plutonium enrichment.

Decay of ^{241}Pu



Decrease of Reactivity



Background (Continued)

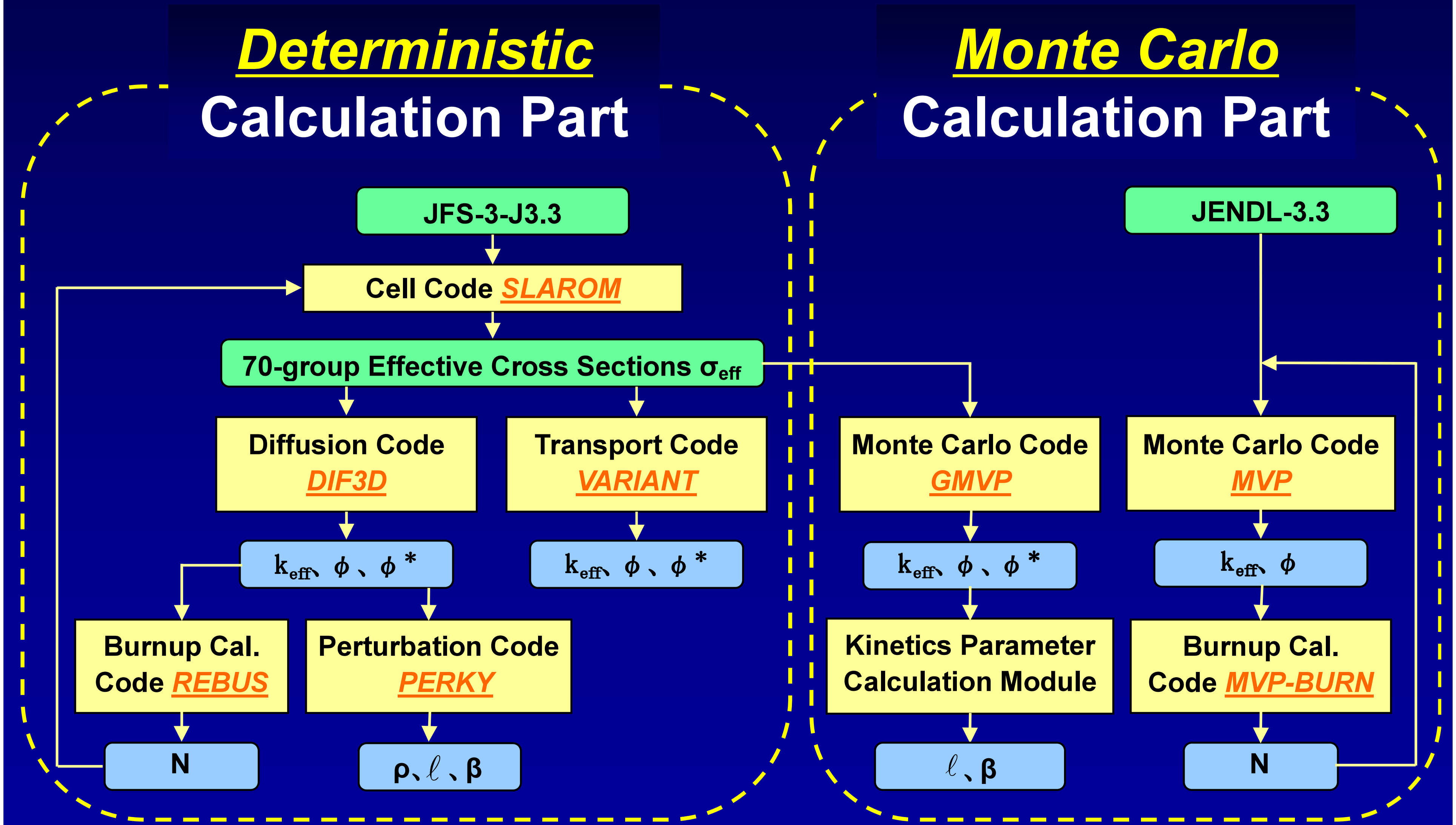
- MONJU core characteristics are affected due to the change of enrichment and composition of plutonium.

- Especially, the sodium void reactivity worth, which is an important parameter in the safety analysis of fast reactors, is strongly affected due to the accumulation of ^{241}Am.

- In order to evaluate the core characteristics of fast reactors, a computer code system ARCADIAN-FBR has been developed by utilizing the developed core analysis codes and the latest nuclear data library JENDL-3.3.

- Considering the ^{241}Am accumulation in the core fuel, the sodium void reactivity worth was analysed for MONJU core by ARCADIAN-FBR code system.

Structure of *ARCADIAN-FBR*



Analysis of MONJU Core Physics Test Data by MVP Code

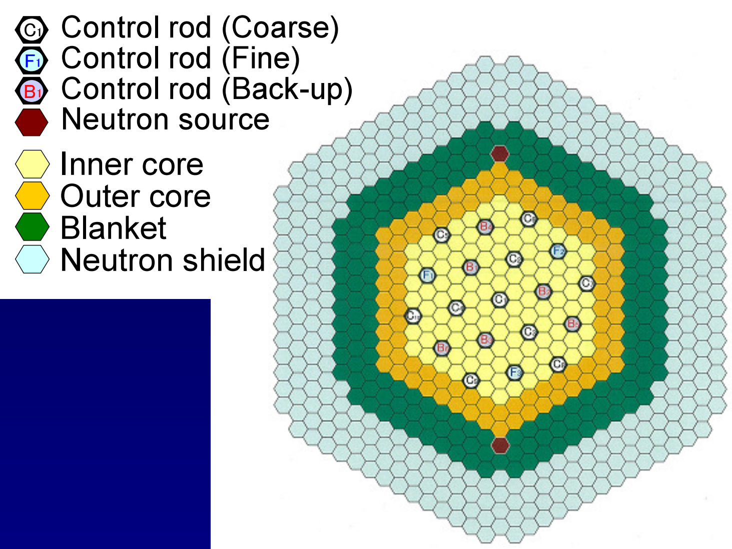
MONJU core physics test data were analyzed to confirm the applicability of the continuous-energy Monte Carlo code MVP and nuclear data library JENDL-3.3 used in ARCADIAN-FBR code system.

- **Description of MONJU Core**
- **Calculation Method of MVP**
- **Results of MVP Calculations**

Description of MONJU Core

Main specification of MONJU

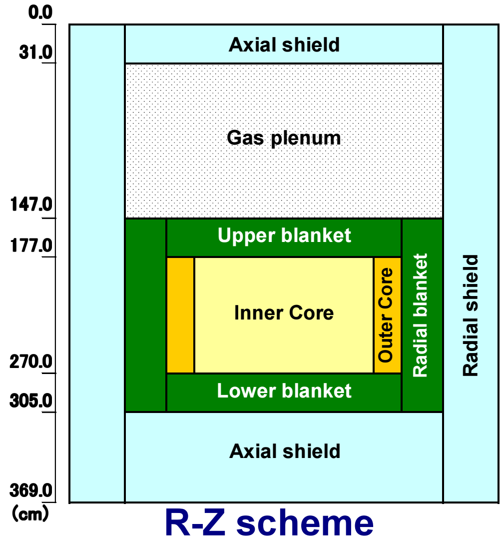
Specifications \ Core	Normal operation	During system start-up tests	
	Equilibrium core	Initial critical core	First start-up core
Thermal output (MW)	714	0	0 - 321
Core height (m)	0.93	0.93	0.93
Core equivalent diameter (m)	1.79	1.66	1.79
Pu fissile fraction [Inner/Outer cores] (wt%)	16 / 21	15 / 20	15 / 20
Blanket thickness [Upper/Lower/Radial] (m)	0.30 / 0.35 / 0.30	0.30 / 0.35 / 0.30	0.30 / 0.35 / 0.30
Number of fuel assemblies [Inner/Outer cores]	108 / 90	108 / 60	108 / 90
Number of control rods	19	19	19



Cross sectional view

Measured data in Start-up Tests

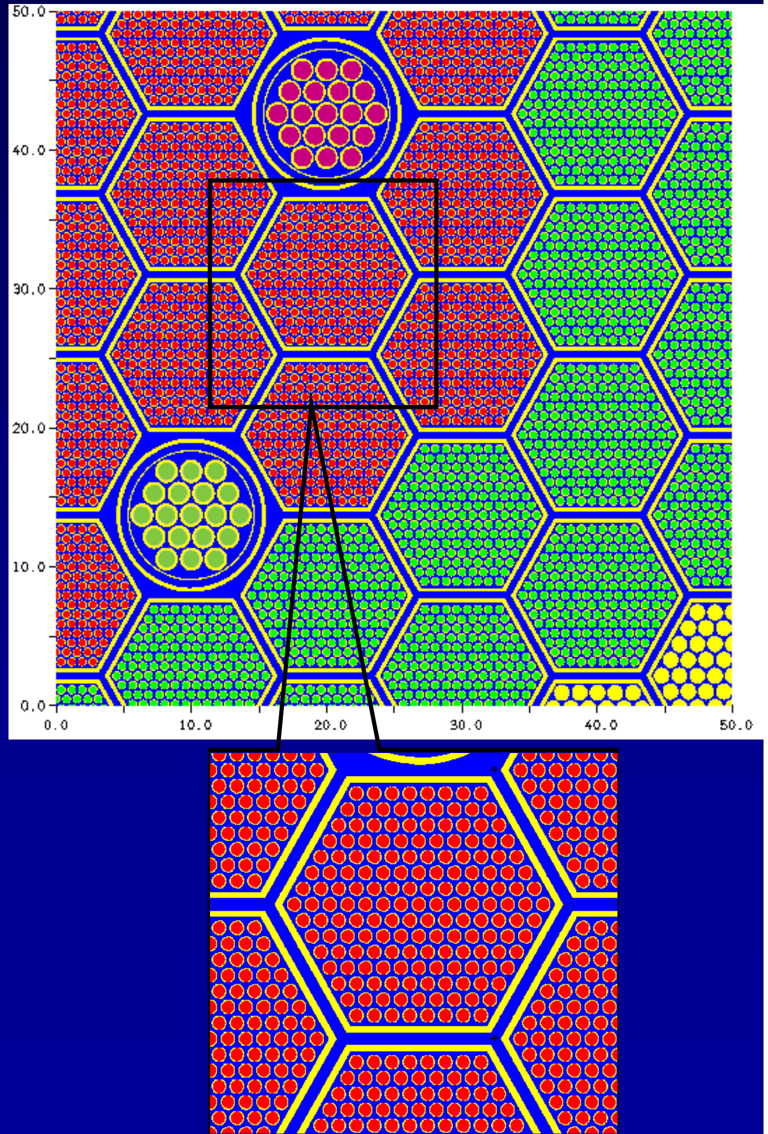
– Criticality
– Excess reactivity
– Control rod reactivity worth
– Isothermal temperature coefficient, etc.



R-Z scheme

Calculation Method of MVP

Item	Condition
Code	MVP
Method	Continuous-energy Monte Carlo
Library	JENDL-3.3
Core model	3-D pin by pin model
Number of neutron histories	1,000,000 10,000,000



- Calculated parameters by MVP code
  - Criticality
  - Excess reactivity
  - Control rod reactivity worth
  - Isothermal temperature coefficient

Results of MVP Calculations for MONJU Core Physics Test Data

Parameter		Measurement	Calculation	C/E
Criticality (k_{eff})	Initial critical core	1.00	1.0004	1.000
	First start-up core	1.00	1.0007	1.001
Excess reactivity (%Δk/k)		2.8	2.8	1.00
Control rod reactivity worth (%Δk/k)	Main control rod (Central one rod)	0.974	0.982	1.011
	Main control rod (12 rods)	8.49	8.49	1.000
	Back-up control rod (6 rods)	7.42	7.29	0.983
Isothermal temperature coefficient (10^{-5}Δk/k/°C)		–3.0	–2.96	0.987

Analysis of Sodium Void Reactivity Worth for MONJU Core

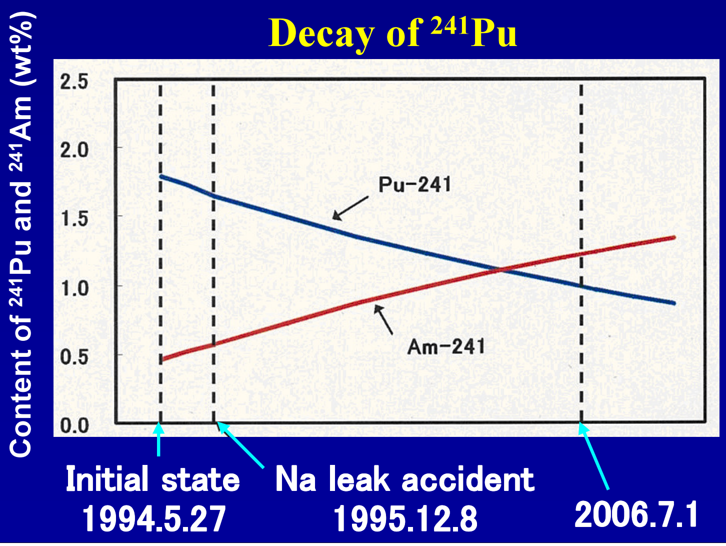
Using the Monte Carlo code MVP with JENDL-3.3 library, the sodium void reactivity worth was calculated for the two MONJU equilibrium cores and the effect of ^{241}Am accumulation on the sodium void reactivity worth was evaluated.

- **MONJU Equilibrium Core**
- **Calculation Method of MVP**
- **Results of MVP Calculations**

MONJU Equilibrium Core

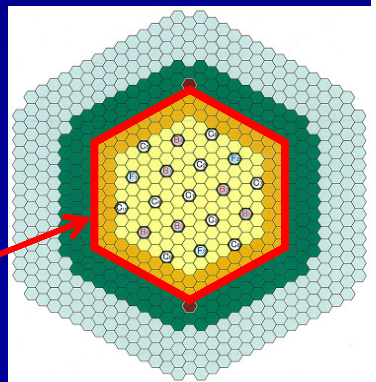
Item	Reference equilibrium core	Alternative equilibrium core
Pu fissile fraction [Inner/Outer cores] (wt%)	16 / 21	16 / 21
Content of ^{241}Am	^{241}Am is neglected	Accumulation of ^{241}Am is considered

Decay of ^{241}Pu

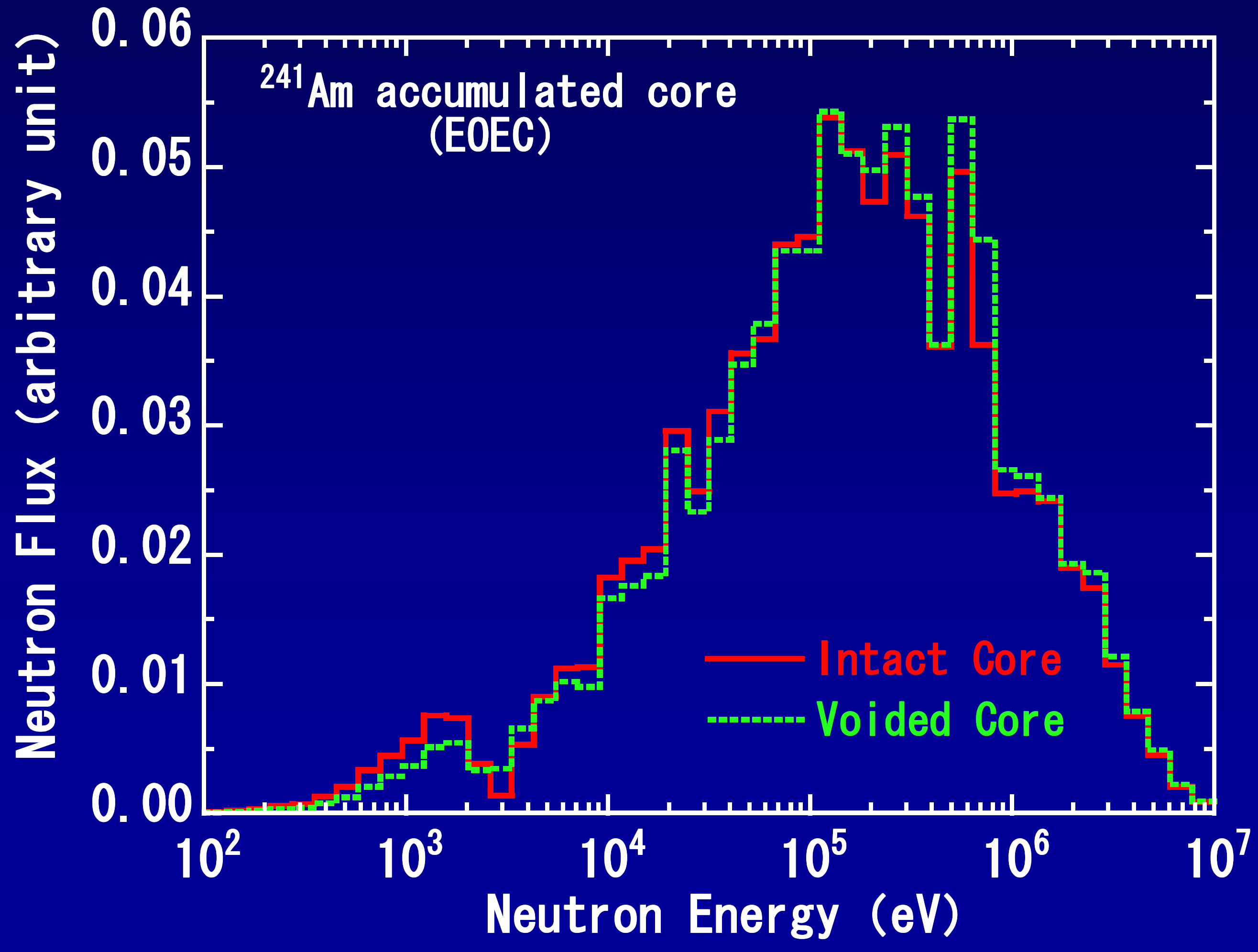


Calculation Method of MVP for Sodium Void Reactivity Worth

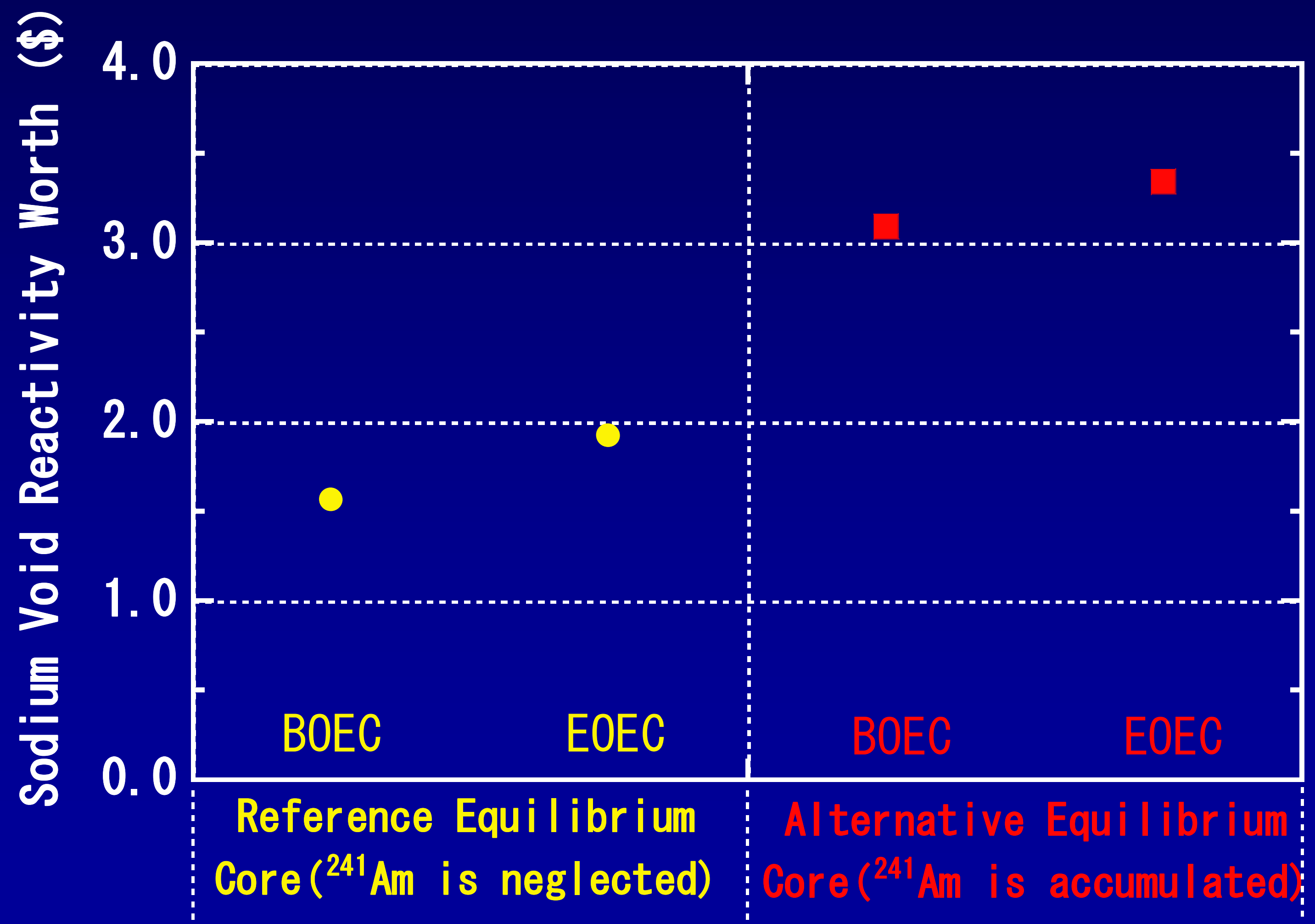
Item \ Core	Reference equilibrium core		Alternative equilibrium core	
	BOEC	EOEC	BOEC	EOEC
Method	Continuous-energy Monte Carlo code MVP & JENDL-3.3			
Core model	Three dimensional pin by pin model			
Pu fissile fraction [Inner/Outer cores] (wt%)	16 / 21		16 / 21	
Content of ^{241}Am	^{241}Am is neglected		Accumulation of ^{241}Am is considered	
Control rod condition	Nominal insertion	All rods out	Nominal insertion	All rods out
Reactor power condition	Rated power		Rated power	
Voided region	Within the wrapper tube in the active core		Within the wrapper tube in the active core	



Neutron Spectra for Intact and Voided Cores

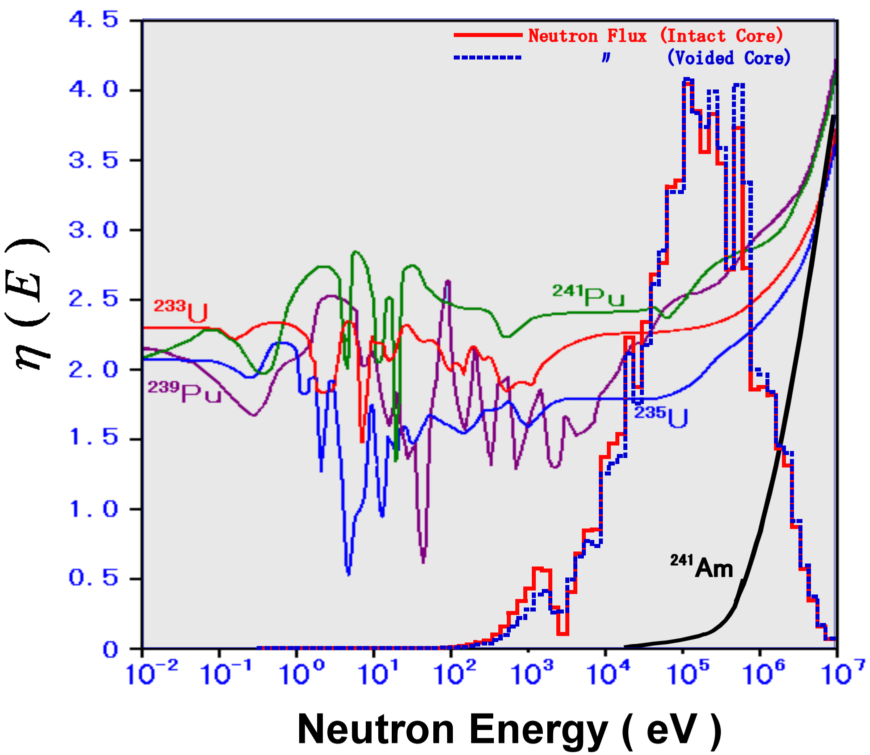


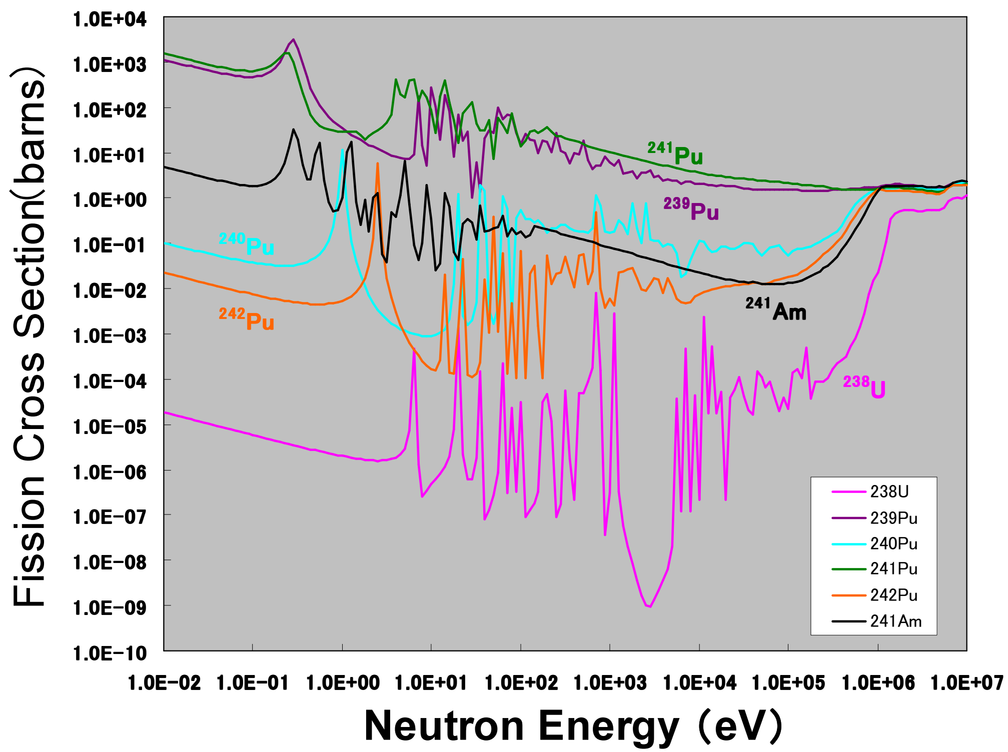
Results of Sodium Void Reactivity Worth for MONJU Cores



η value and Fission Cross Section of ^{241}Am

- The η value and threshold fission cross section of ^{241}Am significantly increase in the energy region over 100 keV.
- The spectral effect due to voiding is much larger in ^{241}Am accumulated core compared to no ^{241}Am accumulated core.





Summary

- The core characteristics of MONJU are affected due to the change of enrichment and composition of plutonium in the core fuel. Especially, the sodium void reactivity worth is strongly affected due to the accumulation of ^{241}Am.
- Considering the ^{241}Am accumulation in the core fuel, the sodium void reactivity worth was analysed for MONJU core by the Monte Carlo code MVP in the ARCADIAN-FBR code system.
- As a result of calculation, it was confirmed that the accumulation of ^{241}Am influences on the sodium void reactivity worth and hence on the safety analysis of sodium-cooled fast reactors.

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Results of Sodium Void Reactivity Worth for MONJU Cores

		Voided regions	k_{eff}	Void reactivity (%Δk/kk')	Void reactivity ($)	Remarks
Reference equilibrium core (^{241}Am is neglected)	BOEC	None (Intact)	1.0125	—	—	1σ: ±14pcm
		Within wrapper tube in active core	1.0175	0.487	1.56	1σ: ±13pcm
	EOEC	None (Intact)	1.0118	—	—	1σ: ±13pcm
		Within wrapper tube in active core	1.0179	0.598	1.92	1σ: ±13pcm
Alternative equilibrium core (^{241}Am is included)	BOEC	None (Intact)	1.0065	—	—	1σ: ±14pcm
		Within wrapper tube in active core	1.0164	0.963	3.09	1σ: ±15pcm
	EOEC	None (Intact)	1.0120	—	—	1σ: ±13pcm
		Within wrapper tube in active core	1.0228	1.041	3.34	1σ: ±14pcm