Denaturation of Pu by Transmutation of MA

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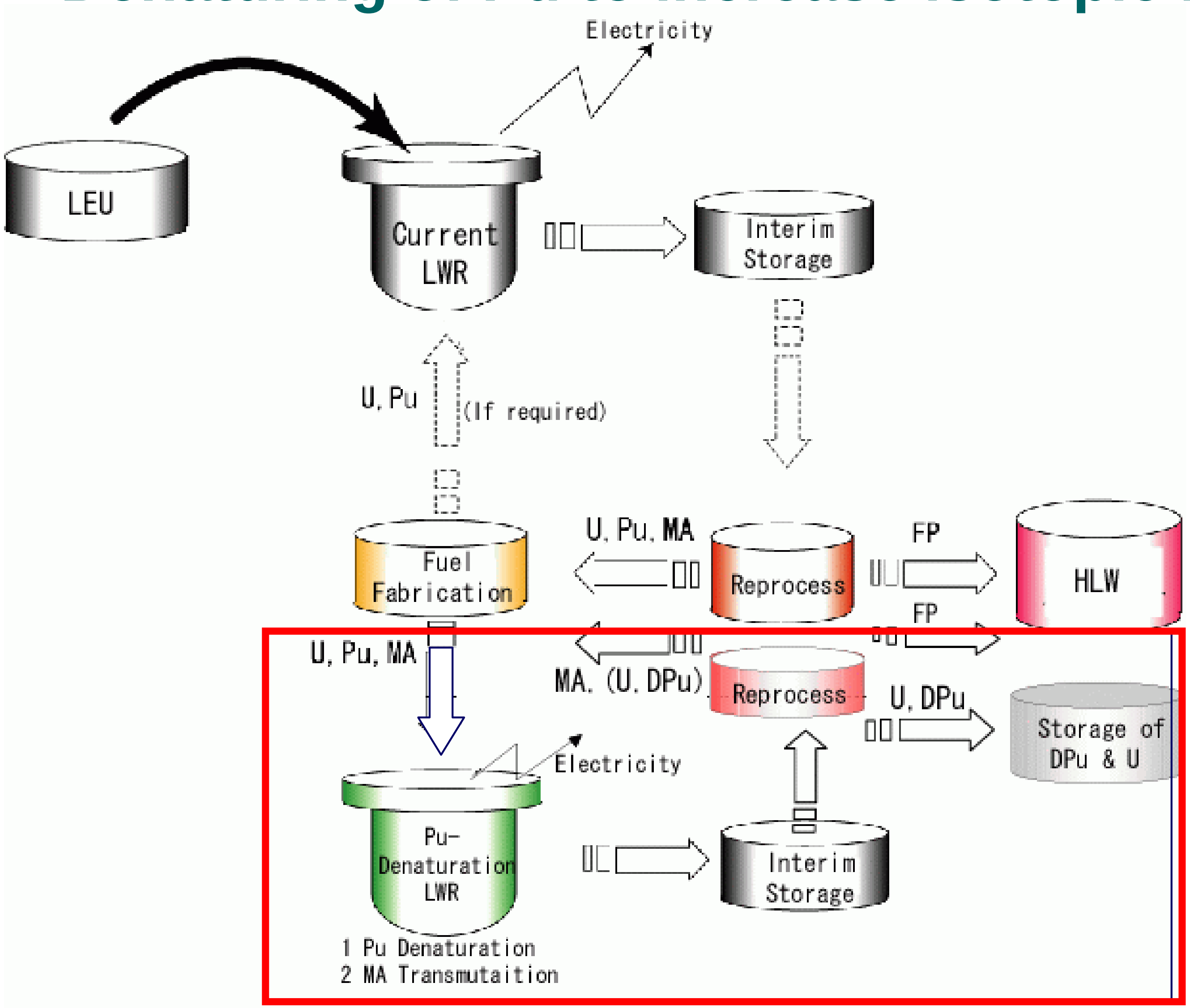
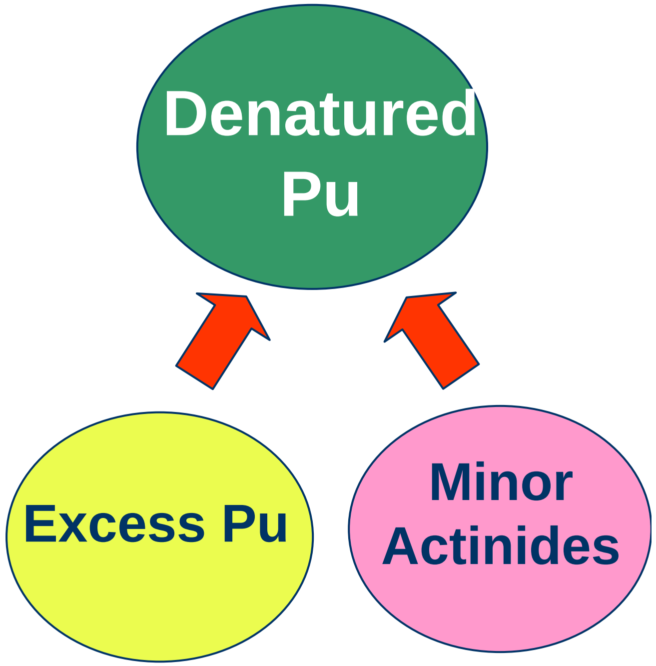
Denaturing of Pu to increase isotopic barrier for civil Pu



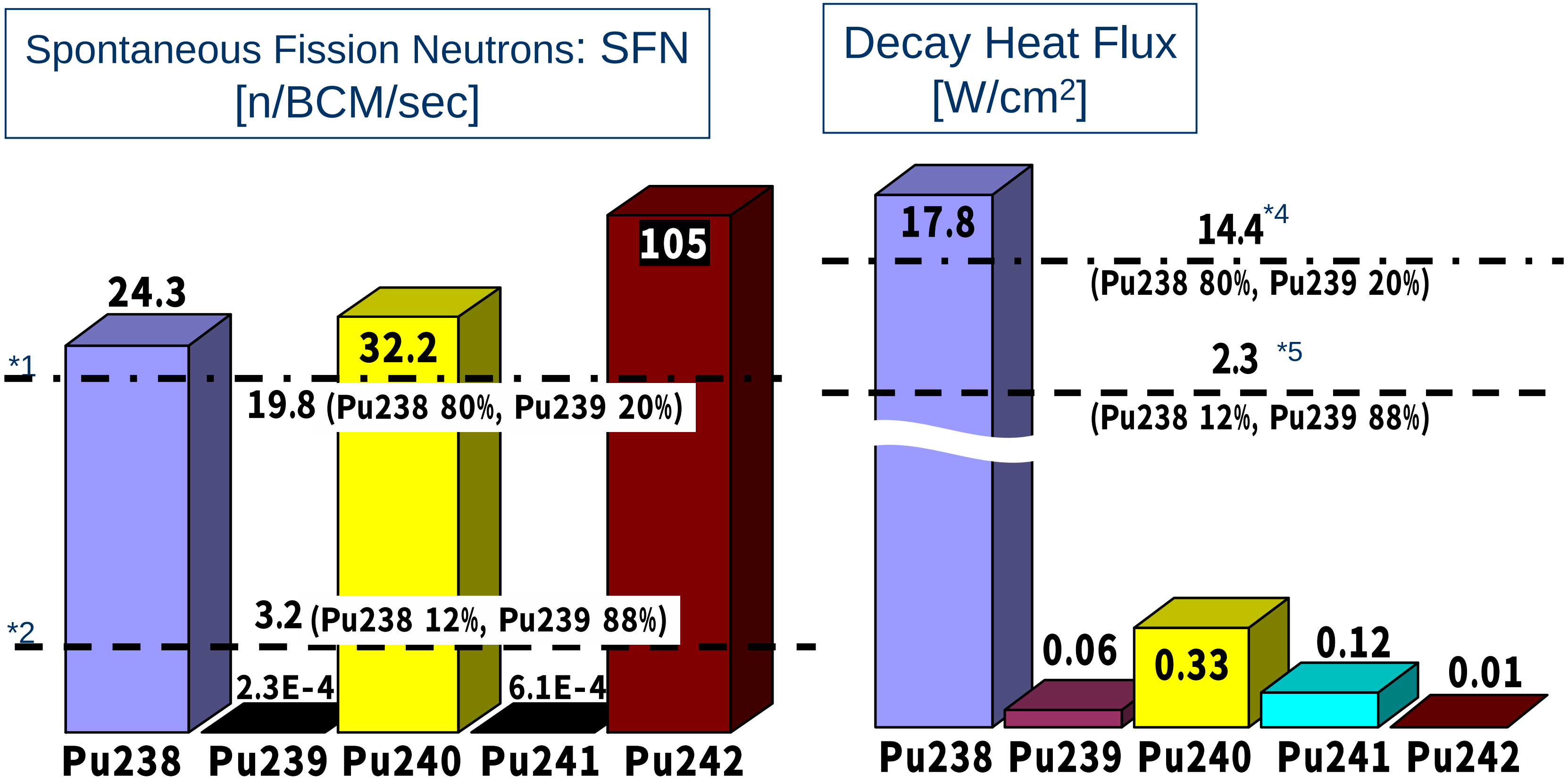
Pu Denaturation system



Objectives

- ***To identify*** the characteristics of Pu denatruring by irradiation and transmutation of MA in LWR for the enhancement of the proliferation resistance

Decay Heat and Spontaneous Fission of Pu Isotopes



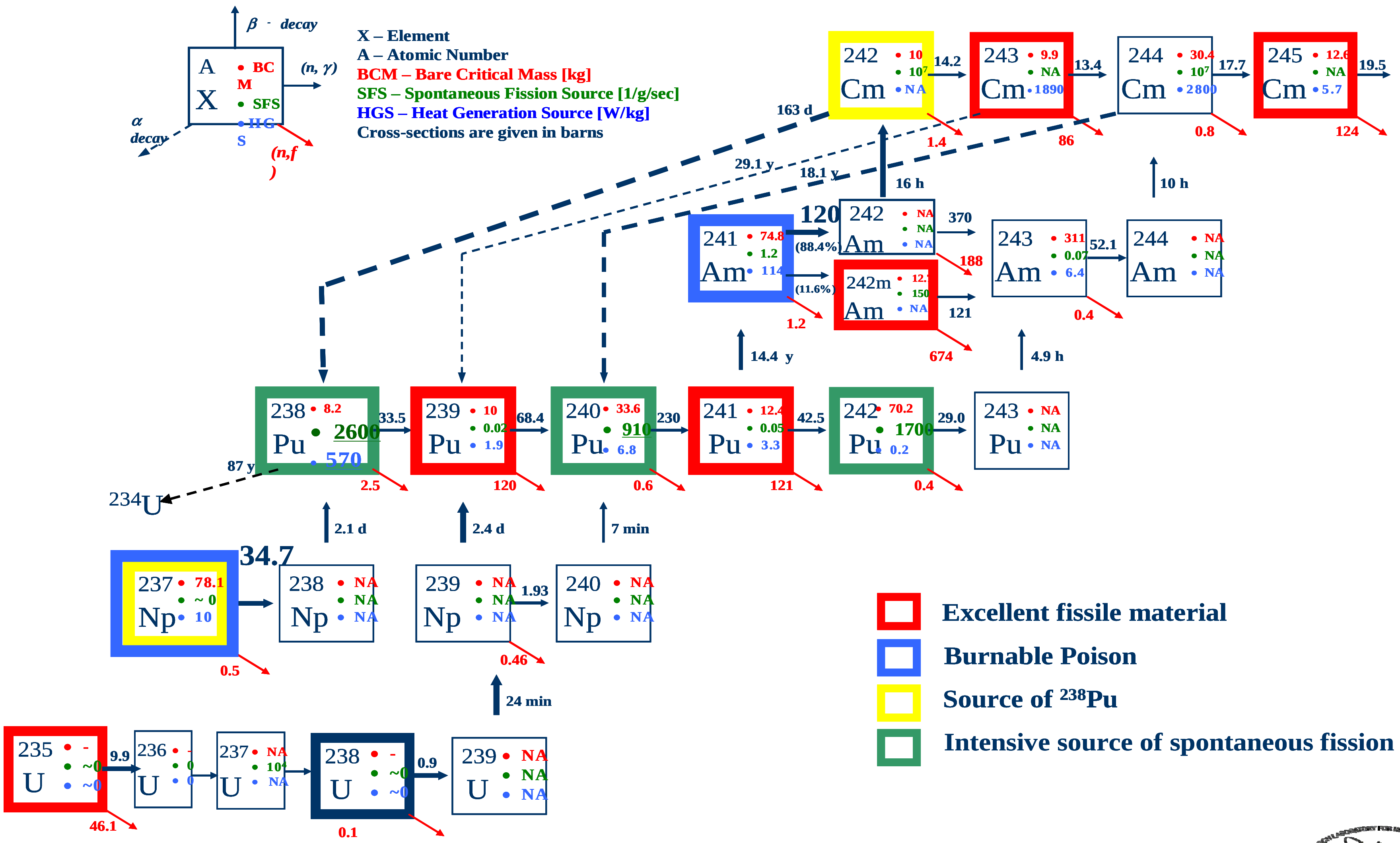
*4: IAEA's criterion (Pu238=80%, Pu239=20%), *5: Kessler's criterion (Pu238=12%, Pu239=88%)

International Atomic Energy Agency, Information Circular, INFCIRC/153, (1972).

G. Kessler, "Plutonium Denaturing by Pu-238," *The First International Science and Technology Forum on Protected Plutonium Utilization for Peace and Sustainable Prosperity*, Mar. 1 – 3, Tokyo, Japan, (2004).

Fig Decay Heat and SFN of Pu isotopes

Main Transmutation in LWR



Methodology

Fuel： MOX Fuel $(U,Pu,MA)O_2$, U-Free-Matrix-Fuel $(Pu,MA,Zr)O_2$

Evaluation index of property of proliferation resistance of Pu:

- Decay Heat (DH)
- Bare Critical Mass (BCM)
- Spontaneous Fission Neutron rate (SFN)

DH + BCM → Heat Flux from the surface of BCM of Pu

BCM + SFN → SFN in BCM of Pu

Criteria :

- IAEA's criteria(Pu^{238}>80%)*, Kessler's criteria(Pu^{238}>12%)

International Atomic Energy Agency, Information Circular, INFCIRC/153, (1972).

G. Kessler, "Plutonium Denaturing by Pu-238," *The First International Science and Technology Forum on Protected Plutonium Utilization for Peace and Sustainable Prosperity*, Mar. 1 – 3, Tokyo, Japan, (2004).

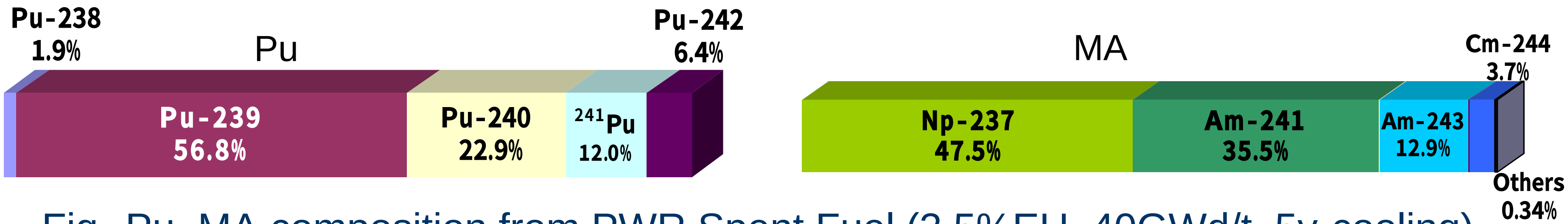
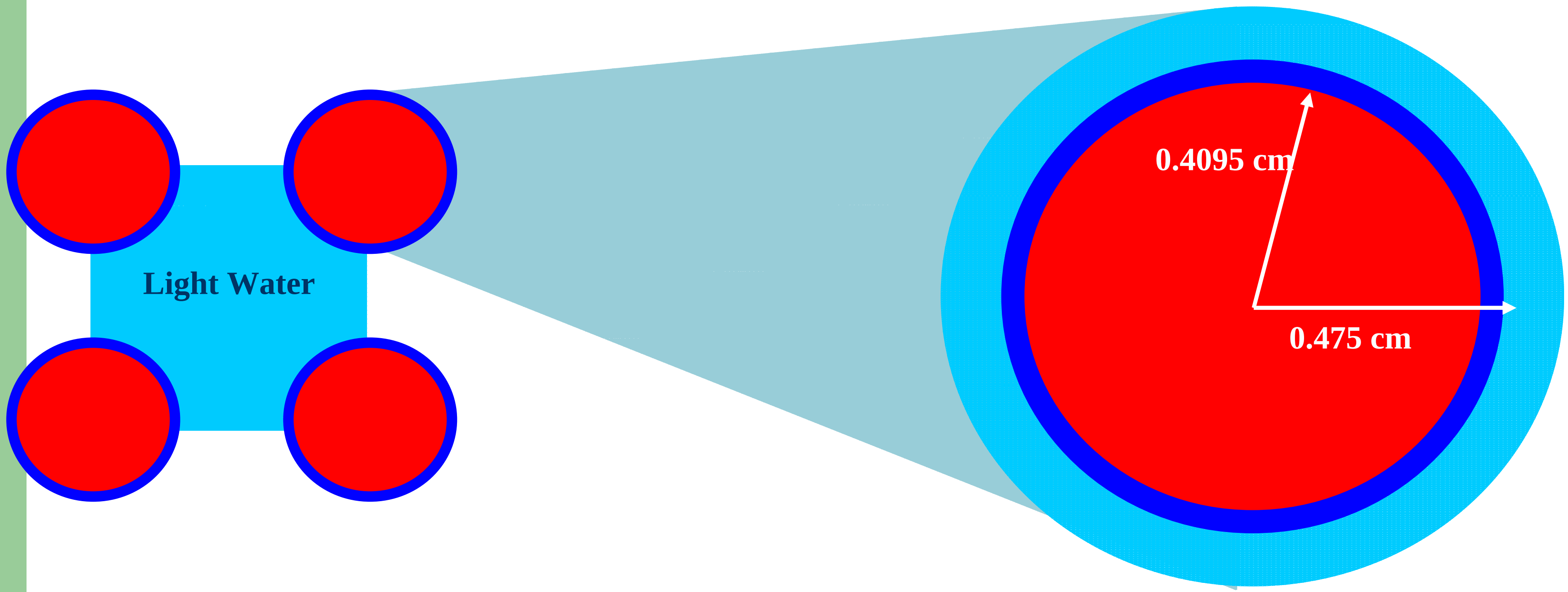


Fig Pu, MA composition from PWR Spent Fuel (3.5%EU, 40GWd/t, 5y-cooling)

Method of Calculation

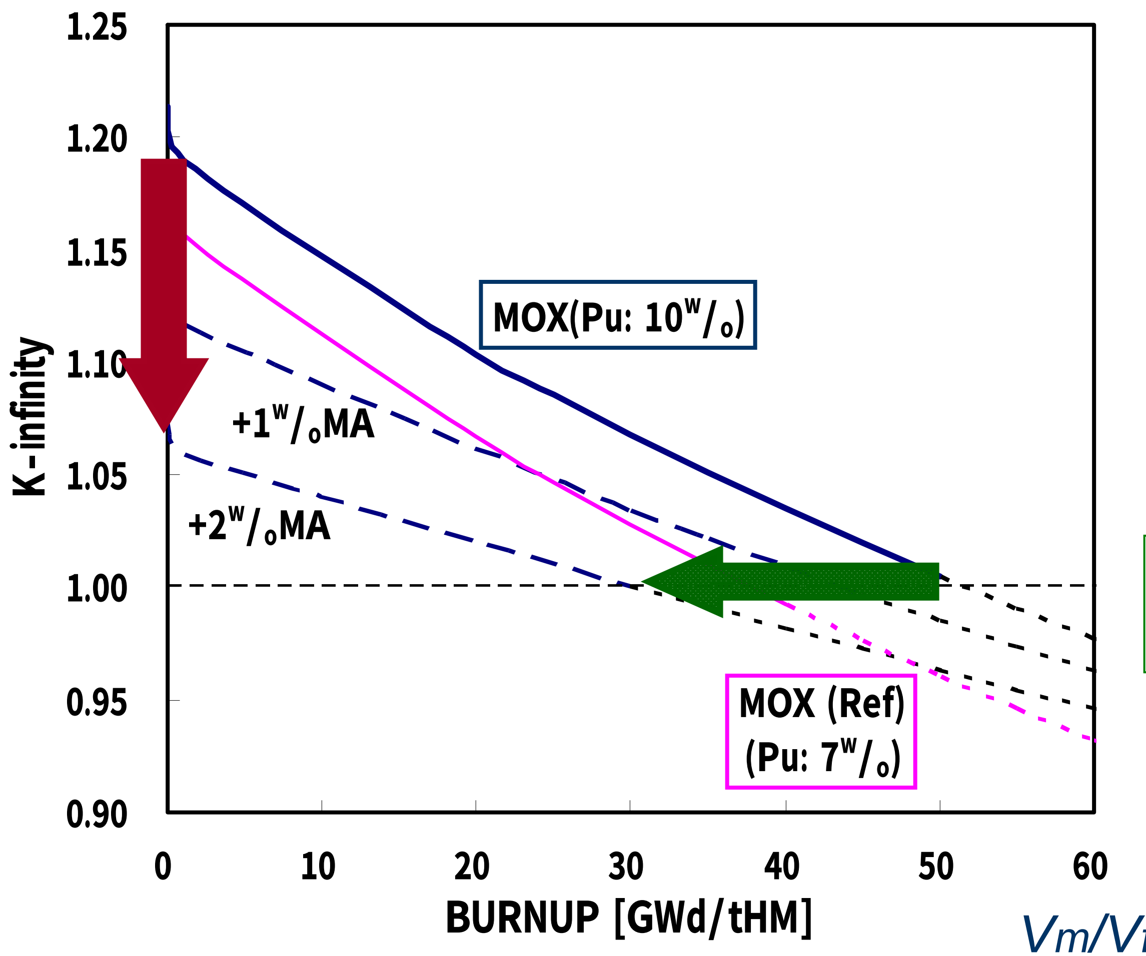
- Infinite cell model



- Computer code used: SRAC(VER.2002) coupled with 107 groups neutron cross section library derived from JENDL3.3

Effect of MA doping to reactivity change (MOX case)

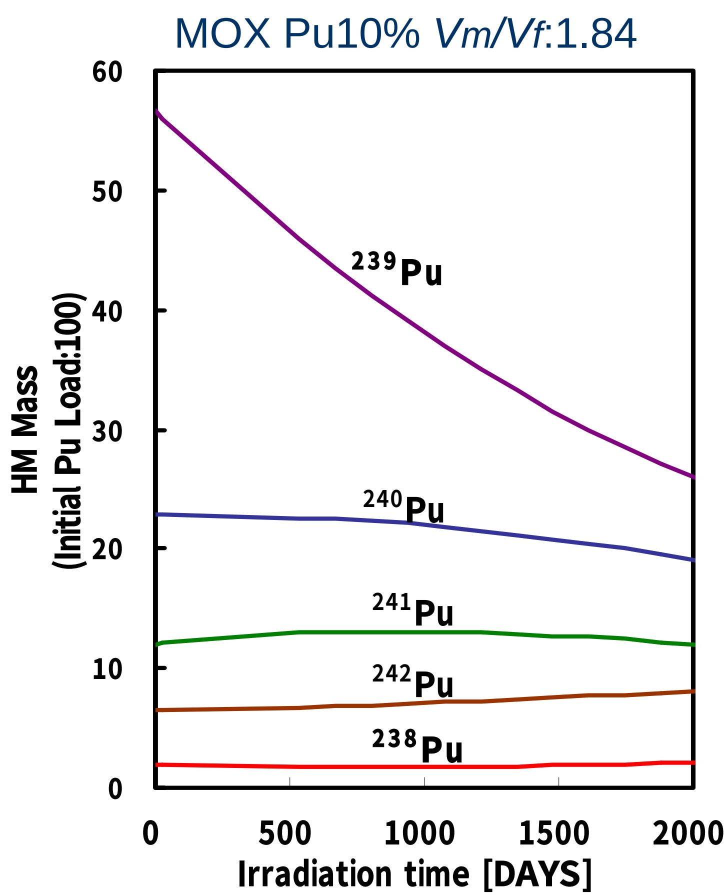
Reducing Initial Reactivity

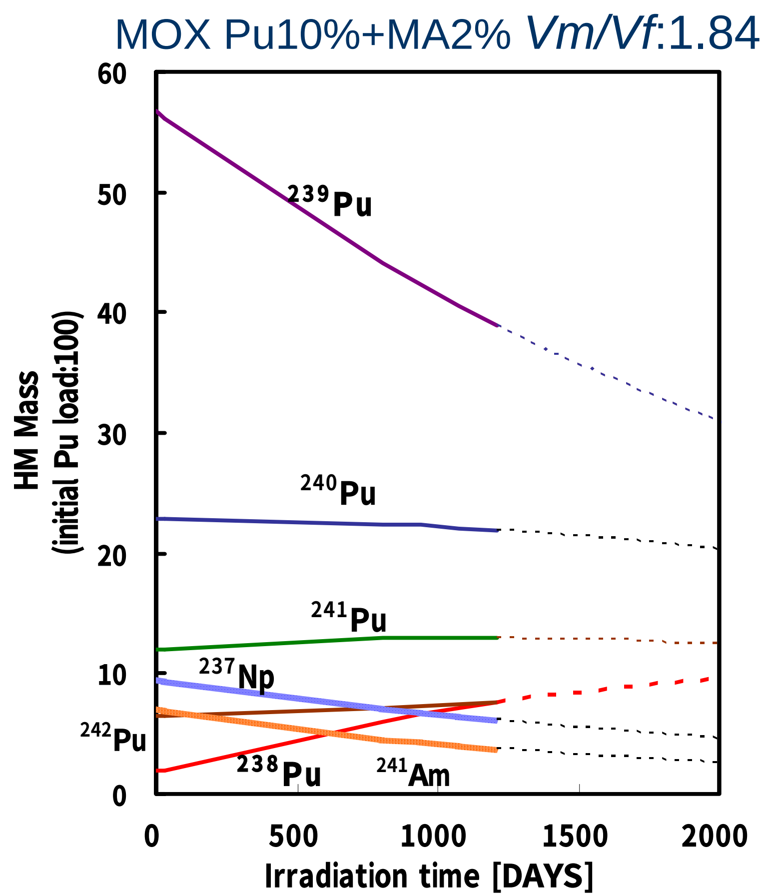


Shortening Max Burnup

V_m/V_f = 1.84

Effect of MA doping to Pu mass (MOX case)





Effect of changing mod-to-fuel ratio (MOX case)

MOX Pu10%

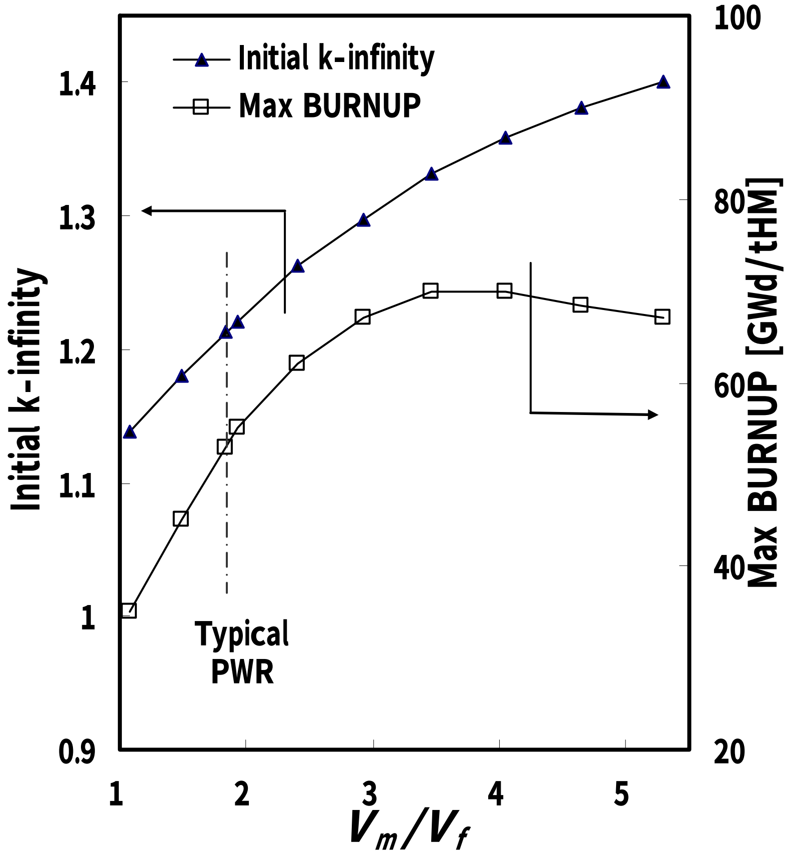


Fig. Initial reactivity and Max Burnup with a function of Mod-to-fuel ratio

MOX Pu10%+MA2%

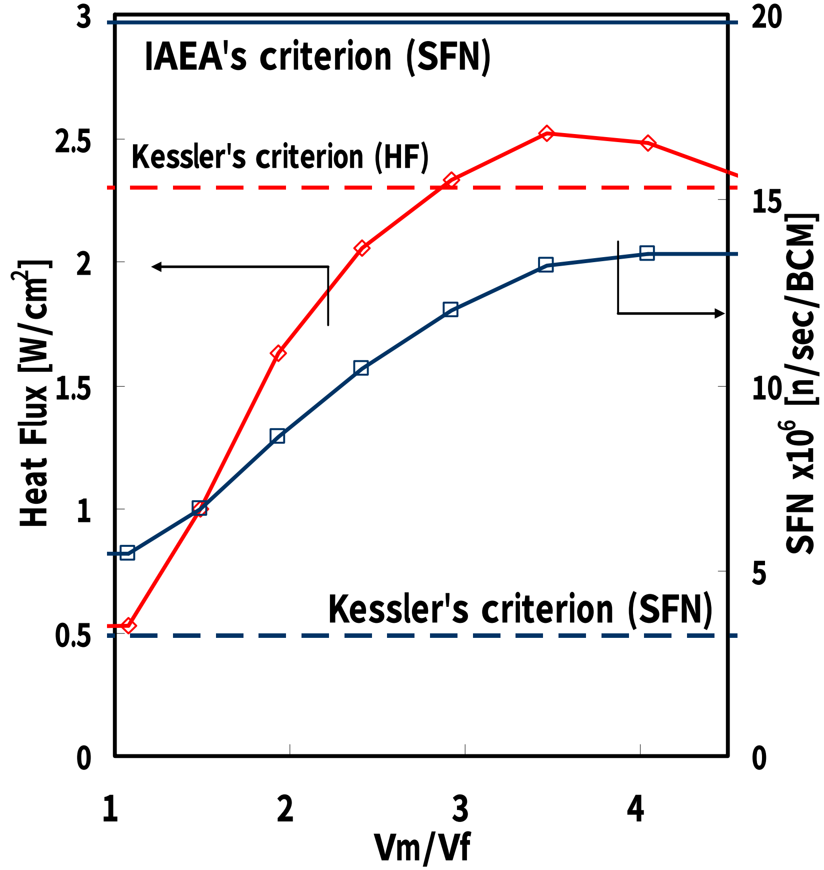
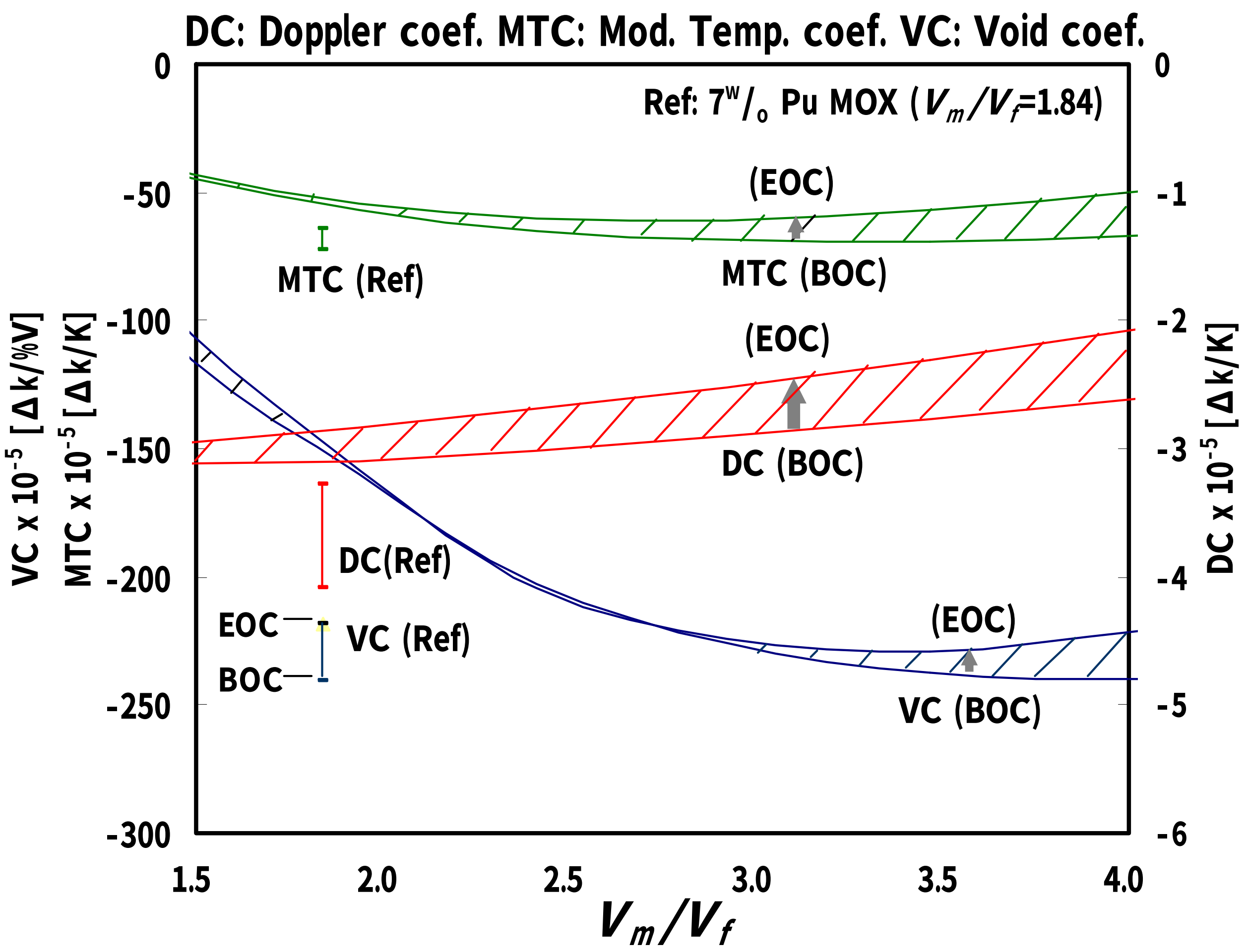


Fig. Intrinsic feature of proliferation resistance of Pu (EOC)

Safety characteristics (MOX case)



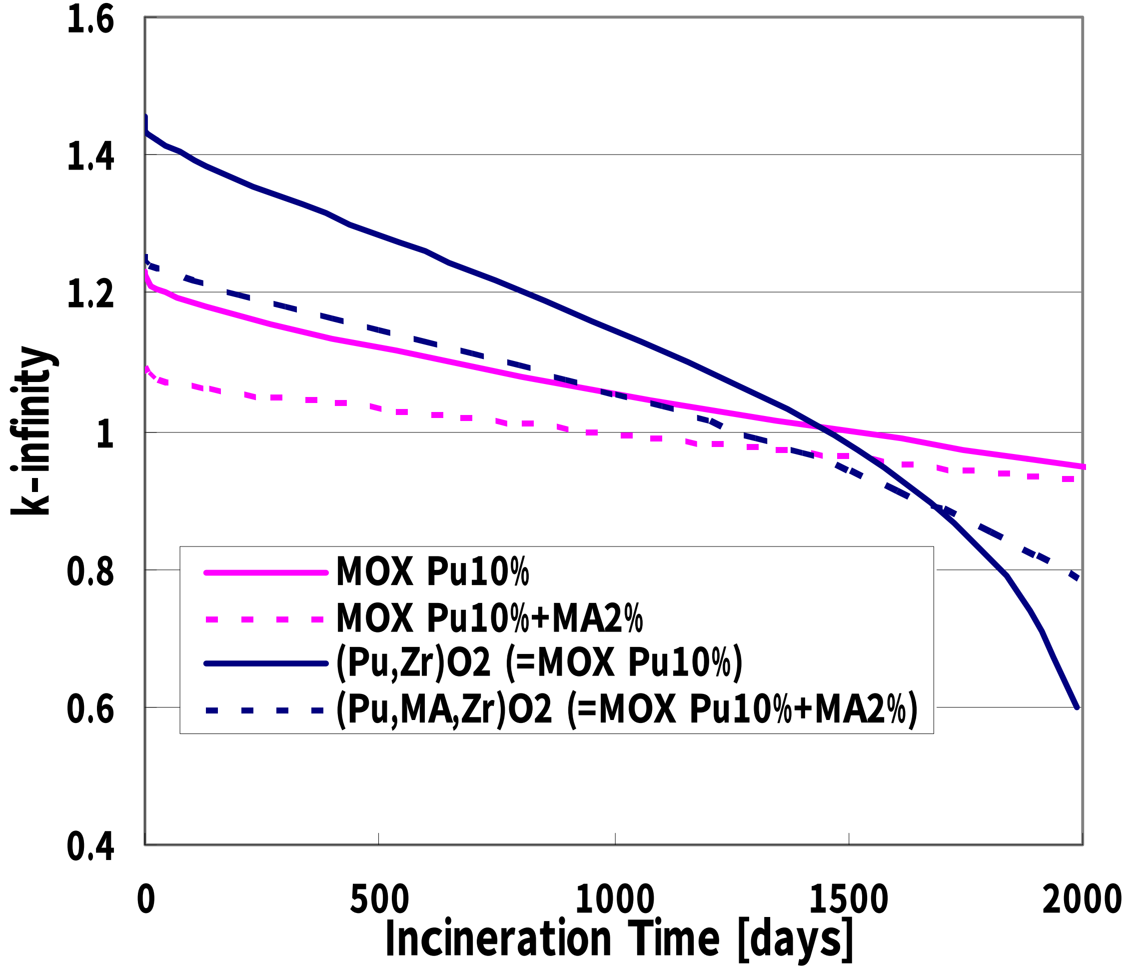
Summary of MOX case

- By irradiation of Pu and transumutation of MA in LWR, the property of proliferation resistance of Pu is enhanced dramatically

- With a little MA doping (~2%) and a little modification of V_m/V_f (2.5~3), Pu can be denatured to satisfy the proliferation resistance criterion proposed by G. Kessler but not to be sufficient for IAEA's criterion

- Safety coefficients take negative values throughout irradiation

Effect of MA doping to reactivity change (U-free fuel case)

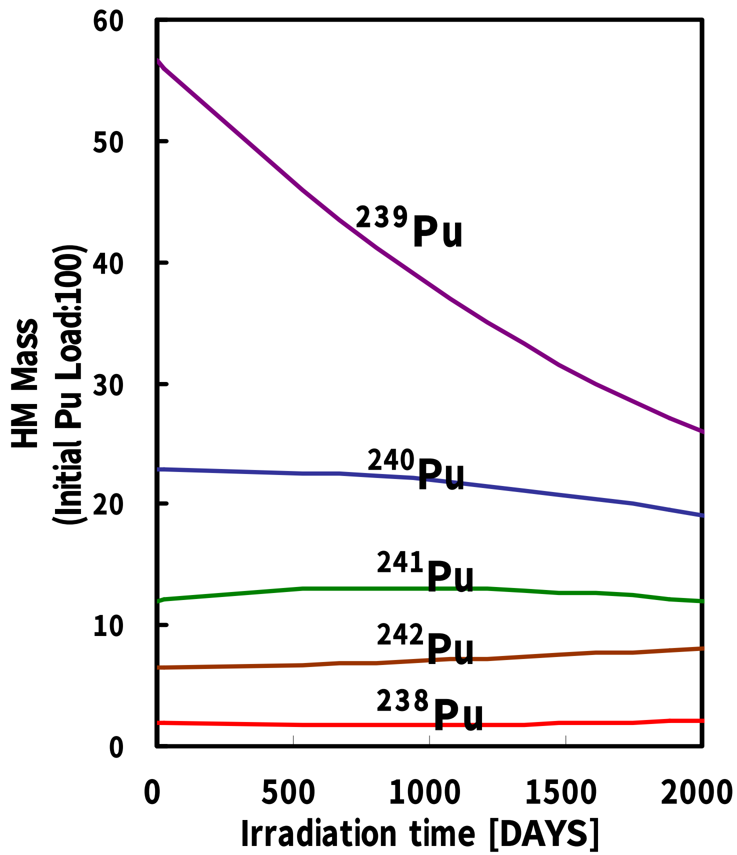


U-Free Fuel:
$(Pu_x, MA_y, Zr_z)O_2$

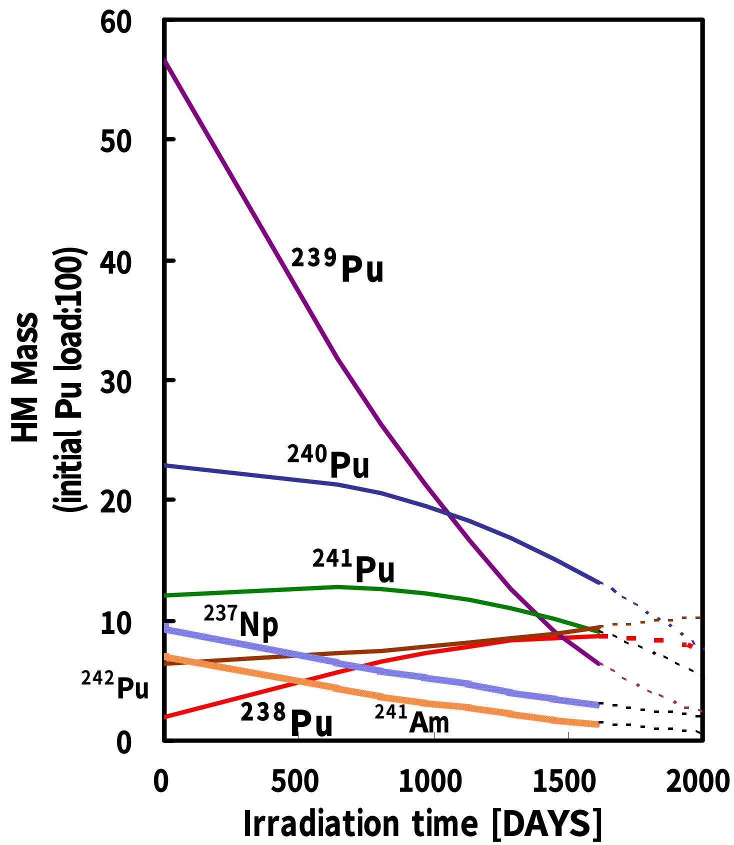
$V_m/V_f = 1.84$

Effect of MA doping to Pu mass (U-free fuel case)

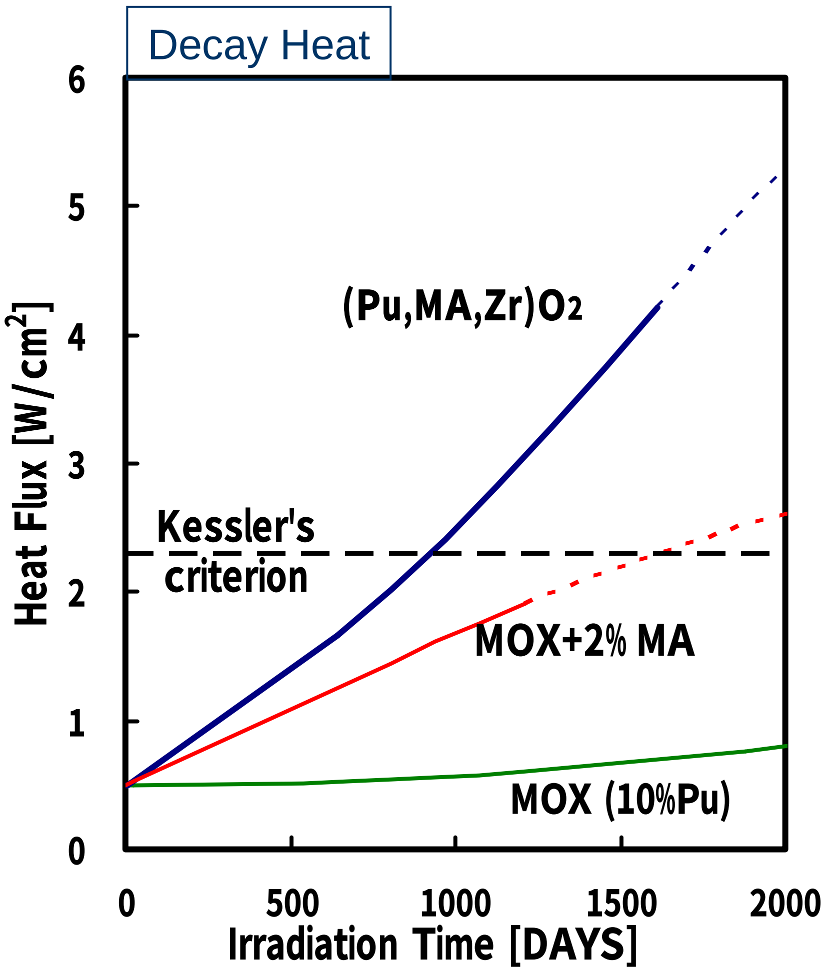
MOX Pu10%

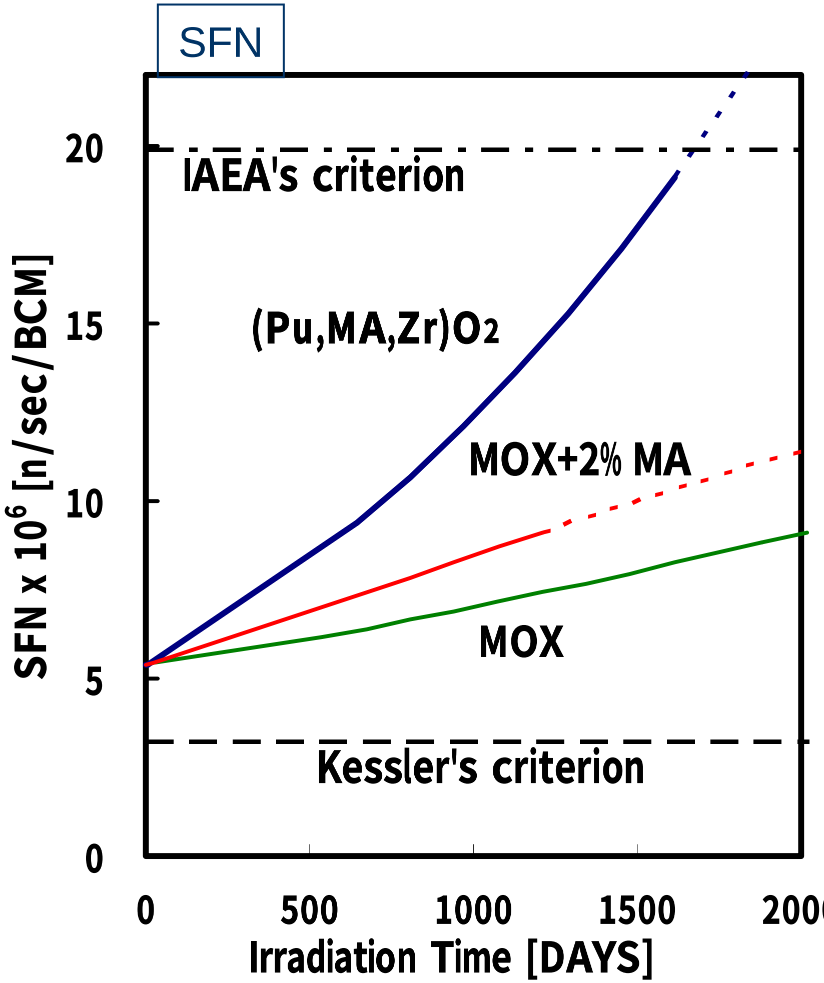


(Pu,MA,Zr)O2 (=MOX Pu10%MA2%)

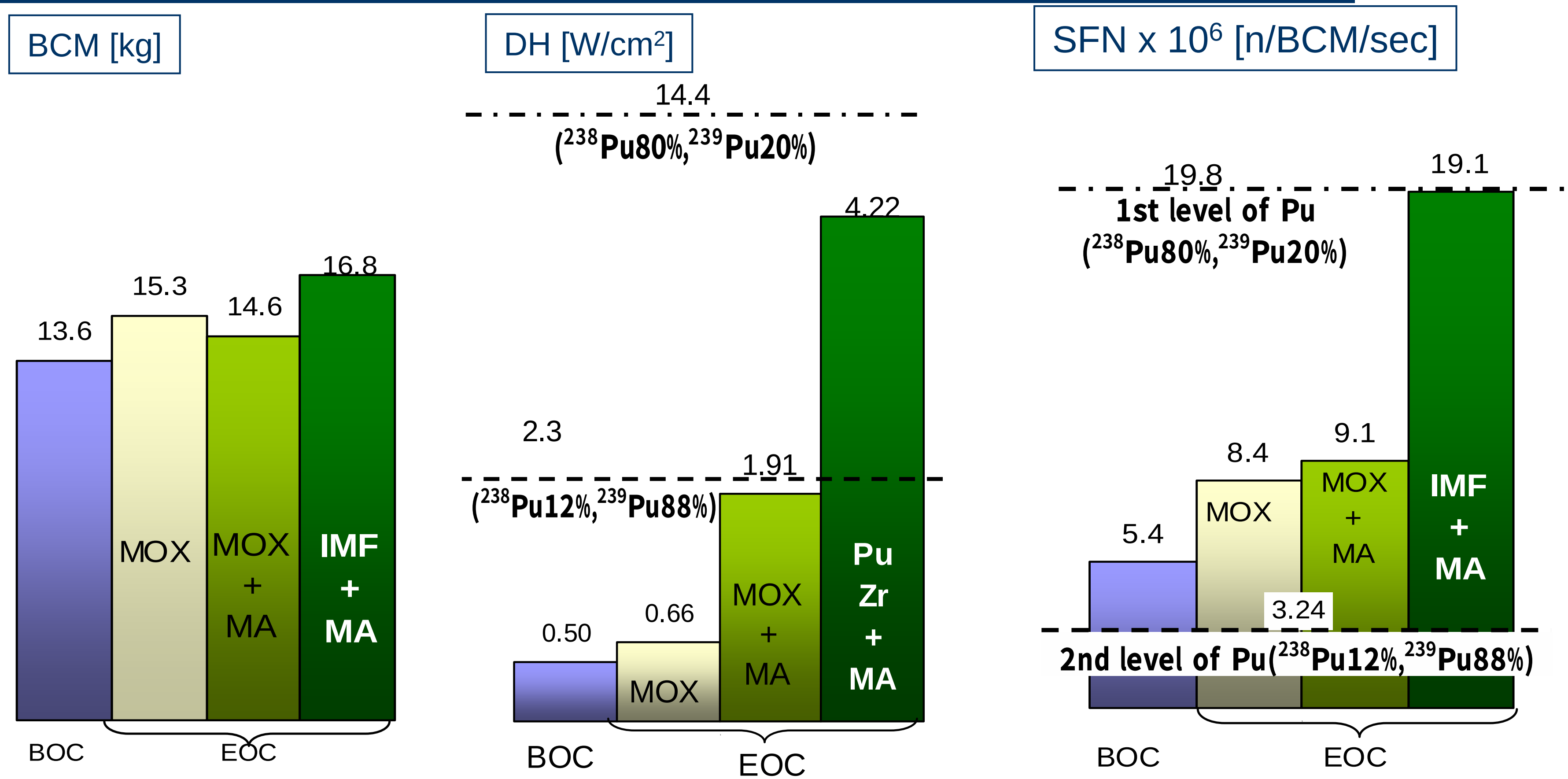


Effect of MA doping to intrinsic feature of proliferation resistance of Pu





Summary of the Enhancement of Proliferation Resistance of Pu



Fuel Type	Irradiation Time [FPD: Full Power Days]
MOX: Pu7%	1340FPD
MOX+MA:Pu10%+MA2%	1210FPD
IMF+MA:(=MOXPu10%+MA2%)	1610FPD

Safety Characteristics (U-Free Fuel case)

DC: Doppler Coef. (ΔT_f=200K) , unit: $10^{-5}[\Delta k/\Delta T_f]$
MTC: Moderator Temp. Coef. (ΔT_m=15K), unit: $10^{-5}[\Delta k/\Delta T_m]$
VC: Void Coef.(30%Void) unit: $10^{-5}[\Delta k/\Delta V\%]$

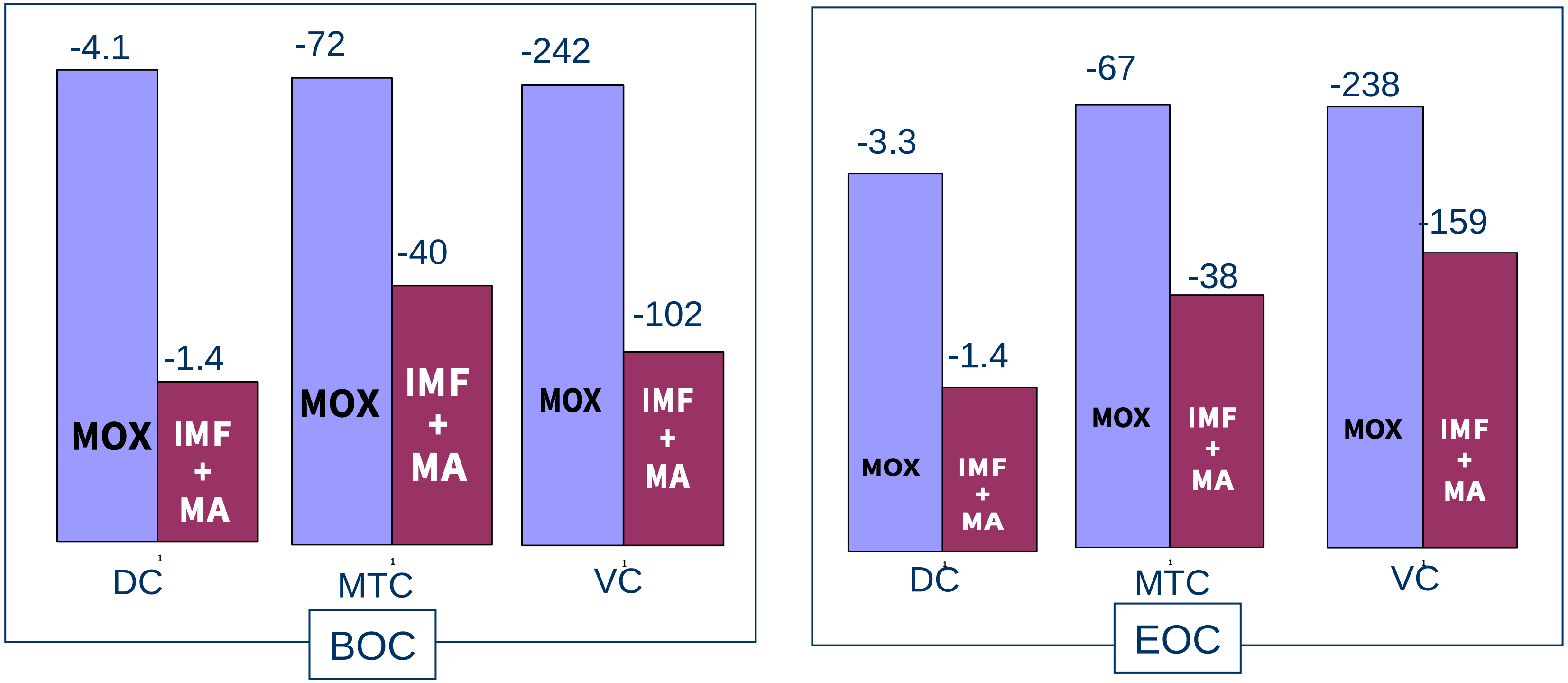


Fig Comparison of safety characteristics with conventional MOX(7%Pu)

Lack of U worse all the safety characteristics

Summary of U-Free Fuel case

- By irradiation of Pu and transumutation of MA in LWR, the property of proliferation resistance of Pu is more enhanced than MOX case because of no additional Pu production
- With a little MA doping, Pu can be denatured to satisfy the proliferation resistance criterion proposed by G. Kessler (SFN is enhanced comparably with IAEA's criterion)
- Safety coefficients take negative values throughout irradiation

Terminology

IAEA

Proliferation Resistance Fundamentals for Future Nuclear Energy Systems

Department of safeguards, International Technical Meeting, Como, Italy, October 2002.

Proliferation resistance is that characteristic of a nuclear energy system that impedes the diversion or undeclared production of nuclear material or misuse of technology by States in order to acquire nuclear weapons or other nuclear explosive devices.

Intrinsic proliferation resistance features are those features that result from technical design of nuclear energy systems including those that facilitate the implementation of extrinsic measures.

Extrinsic proliferation resistance measures are those measures that result from States' decisions and undertakings related to nuclear energy systems.

Terminology

US
Department of Energy
Nuclear Energy
Research Advisory Committee

Technological Opportunities To Increase The Proliferation Resistance Of Global Civilian Nuclear Power Systems

January 2001

Material qualities*, *technical impediments and institutional arrangements present **barriers** that make it difficult for proliferators to exploit civilian nuclear power systems.

Material barriers include
- the isotopic composition (percentage and type),
- the chemical processing required to separate a weapons-usable substance,
- the radiation hazard and signature associated with the material at each step in the civilian system and in any process to generate a weapons-usable material,
- the difficulty of moving the mass/or bulk of the material,
- the inherent detectability of the material.

"Isotopic barrier" incorporates issues and attributes including critical mass, spontaneous neutron generation and heat generation rate, radiation and so on.

Sources Currently Used for Assessment
of Proliferation Resistant Properties for Plutonium

IAEA Information Circular
(Unofficial electronic edition)

INFCIRC/153 (Corrected)
June 1972 GENERAL Distr.
Original: ENGLISH

The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons

PART II

EXEMPTIONS FROM SAFEGUARDS

The Agreement should provide that the Agency shall, at the request of the State, exempt *nuclear material* from safeguards, as follows:

- Special fissionable material, when it is used in gram quantities or less as a sensing component in instruments;
- *nuclear material*, when it is used in non-nuclear activities in accordance with paragraph 13 above, if such nuclear material is recoverable;
- **Plutonium with an isotopic concentration of plutonium-238 exceeding 80%.**