A User requirement2 (UR2) Evaluation of Proliferation Resistance of a 600MWe TRU Burner using ORIGEN2.1

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1. Introduction

Proliferation Resistance (PR) should be assessed during design, operation of innovative nuclear energy system (INS) and management of spent fuel. For developing a TRU burner design an evaluation of PR is necessary to quantitatively evaluate a degree of PR and possibility of misuse and diversion of nuclear material (NM). In this paper, PR is evaluated based on the assessment methodology of the INPRO user manual against a 600MWe class TRU burner. Furthermore, its result is compared with the result of PR assessment of PWR and CANDU. The attractiveness of nuclear material is also assessed by using the ORIGEN2.1 code.

2. Assessment Methodology of Proliferation Resistance and a reference TRU Burner

PR is defined as "characteristic of a nuclear energy system that impedes the undeclared production of nuclear material or diversion, or misuse of technology by States intent on producing nuclear weapons or other nuclear explosive devices." "The degree of proliferation resistance results from a combination of inter alia, technical design features, operational modalities, institutional arrangements and safeguards measures" [1]. These consist of intrinsic features and extrinsic measures.

The objective of a PR assessment is to provide guidance for developing INS that will indicate how the objectives of non-proliferation will be satisfied.

2.1 Intrinsic proliferation resistance features

Intrinsic proliferation resistance features are those features that result from the technical design of nuclear energy systems, including those that facilitate the implementation of extrinsic measures [2]. The intrinsic proliferation resistance feature consists of the four types of technical features of a nuclear energy system:

1st: to reduce the attractiveness NM during production, use, transport, storage and disposal.
2nd: to prevent the diversion of NM.
3rd: to prevent or inhibit the undeclared production of direct-use material.
4th: facilitate verification, including continuity of knowledge.

All four types of intrinsic features should be able to reduce costs and efforts of international safeguards implementation [1].

User requirement 2 (UR2) is one of guidelines which is to be fulfilled by the developer and supplier. UR2 is evaluated quantitatively for the attractiveness of nuclear material in an INS.

Table I: User requirement 2 and criteria for PR [1].

Basic Principle BP	
UR2 Attractiveness of NM and technology	CR2.1 attractiveness of NM quality
	CR2.2 attractiveness of NM quantity
	CR2.3 attractiveness of NM form
	CR2.4 attractiveness of nuclear technology

2.2 Reference Core Description

The reference TRU burner core is a sodium-cooled fast reactor to generate 600MWe and it uses U-TRU-10% Zr metal fuel. The core is operated with a cycle length of 332 EFPD and five batches, and spends 30 days for refueling. The charged TRU enrichment is set to 30.0 wt.%.

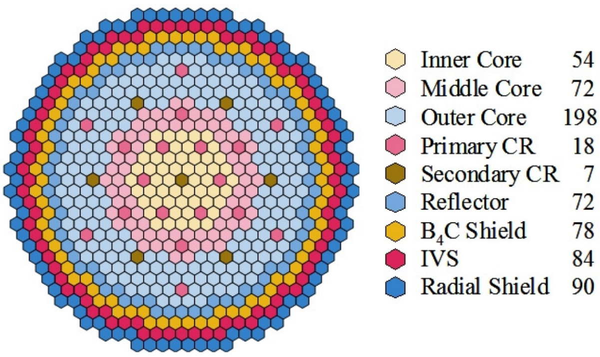

Fig. 1. Core configuration of reference TRU burner [3]

Table II: Characteristic of reference TRU burner

Core Thermal Power (MWt)		1,500
Core Electric Power (MWe)		600.0
Core average flux (BOEC) (10^{15}n/cm^2·s)	Inner	3.78
	Middle	3.71
	Outer	2.52
Core average flux (EOEC) (10^{15}n/cm^2·s)	Inner	3.94
	Middle	3.87
	Outer	2.65

3. UR2 Assessment by using ORIGEN2.1

INPRO is providing the reference values for proliferation resistance assessment, and developing reasonable regulation and safeguard with working group.

In this paper, the results of UR2 assessment are compared those of PWR and CANDU with a TRU burner to analyze a degree of proliferation resistance. PWR considered in this study is fuelled with 4.5 wt.% uranium enriched and its discharge burnup is 45,000 MWD/tHM. In case of CANDU fuelled with natural uranium (NU), the discharge burnup is 7,500 MWD/tHM.

Table Ⅲ: Evaluation of the attractiveness of NM quality after cooling 10 years

Indicator IN	Evaluation Parameter EP	Evaluation scale				
		VW	**W**	**M**	**S**	**VS**
IN2.1: Material quality	EP2.1.1: Material type	UDU	IDU 3)	LEU 1)	NU 2)	DU
	EP2.1.2: $^{239}Pu/Pu$ (wt.%)	**W**			**S**	
		> 50 1)59.18, 2)69.39			< 50 3)45.20	
	EP2.1.4: $^{238}Pu/Pu$ (wt.%)	< 20 1)3.00, 2)0.09, 3)3.78			> 20	
	EP2.1.5: $(^{240}Pu+^{242}Pu)/Pu$ (wt.%)	< 30 1)25.52, 2)27.27			> 30 3)47.21	

1) PWR 45,000MWD/tU 4.5w/o UO_2 10years Cooling
2) CANDU 7,500MWD/tU NU 10years Cooling
3) Reference TRU burner 10years Cooling
UDU: Un-irradiated Direct Use material
IDU: Irradiated Direct Use material
VW: Very Weak, **W**: Weak, **M**: Moderate, **S**: Strong, **VS**: Very Strong

One group neutron cross section and neutron flux were prepared from the results of a REBUS code run. These are used in the ORIGEN2.1 code in case of the reference TRU burner.

^{239}Pu, High Enrichment Uranium (HEU) and pure ^{233}U are the most attractive NM. In the discharged fuel after cooling 10 years, $^{239}Pu/Pu$ is 59.18 wt.%, 69.39 wt.% and 45.20 wt.% in PWR, CANDU and the reference TRU burner, respectively because the result depends on the fuel inventory and type of a reactor. In addition, the spontaneous neutron generation rate (EP2.1.5) can affect the design and reliability of a nuclear weapon. It means that the attractiveness of NM decreases with a higher spontaneous neutron generation rate and a lower weapon grade plutonium (EP2.1.2).

Heat generation (EP2.1.4) is a significant barrier to accessibility because high decay heat makes the access to the nuclear material more difficult in a strong radiation field. Therefore, in this study, decay heat is evaluated as a parameter of accessibility for spent fuel of PWR, CANDU and the reference TRU burner. As shown in figure 1, the decay heat of the reference TRU burner is higher than those of PWR and CANDU because of higher content of Pu, Cm and Cs.

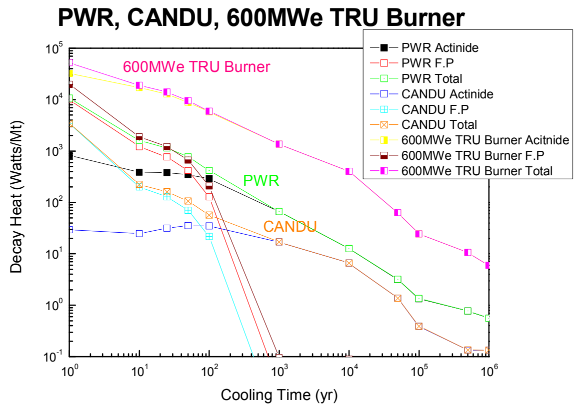

Fig. 2. Decay heat of spent fuel during 10^6 years.

4. Conclusions

Proliferation resistance assessment using ORIGEN2.1 can be useful to evaluate the attractiveness of nuclear material which is defined in the user requirement 2 of the INPRO user manual. In this paper, the user requirement 2 of the proliferation resistance assessment is evaluated quantitatively and accessibility is assessed by evaluating decay heat. Plutonium of poor quality is contained in the reference TRU burner than those of PWR and CANDU. The attractiveness of nuclear material decreases due to a higher spontaneous neutron generation rate. Consequently, the attractiveness of nuclear material of the reference TRU burner is lower than those of currently operating commercial plants in Korea.

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