An Evaluation of the Proliferation Resistance of Nuclear Fuel Cycle Options in Korea

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1. Introduction

The Republic of Korea is has yet to decide its policy on the back end of the fuel cycle for spent fuel management. The wet processing of spent fuel is not an option for Korea due to its proliferation risks. The Direct Use of PWR Spent fuel in CANDU Reactors (DUPIC) had been developed in the 1990s in consideration of the unique mix of PWR and CANDU reactors in Korea. The Advanced Spent Fuel Conditioning Process (ACP), proposed as an alternative to the DUPIC fuel cycle in the mid-1990s, was to change the spent fuel from the oxides form into metallic form so as to reduce the volume (1/2~1/4) and heat load (1/4) which will increase the capacity of a final repository. Then, in the early 2000s, pyroprocessing of spent fuel of which the objective was to produce transuranic fuel for sodium-cooled fast reactors (SFR) was seen as one of the most viable R&D options for spent fuel and resource management in Korea.

Since the proliferationresistance is one of the key issues in the fuel cycle option studies, the proliferation resistance of the pyroprocessing of spent fuel was evaluated and compared with those of other fuel cycle options.

2. Evaluation of Proliferation Resistance of Pyroprocessing

The proliferation resistance characteristics of the DUPIC fuel cycle had been examined during Phase 1 and 2 of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) of the IAEA. [1]. Proliferation resistance of the conceptually designed ACP facility was also examined by using the TOPS attributes methodology [2], which assesses proliferation resistance by defining and applying three objective barriers (material, technical and institutional) to key stages (diversion, conversion and weapon fabrication), unit operations, or components of a processing system [3].

KAERI is currently developing full pyroprocessing technology that recovers valuable resources such as uranium from the spent fuels of nuclear power plants. The recovered resources are recycled into fuel for next generation sodium-cooled fast reactors. The main motive for the decision was that, unlike wet reprocessing which enables the separation of plutonium, the transuranic impurities from pyroprocessing such as neptunium, americium, curium and plutonium together render the material far too hot while generating many spontaneous neutrons to make it at all feasible for making a bomb without further separation. The ACP technology can also be used as the front-end part of pyroprocessing. This aspect makes pyroprocessing a promising nuclear fuel cycle for Korea with reasonable proliferation resistance characteristics.

The Multi-Attribute Utility Theory (MAUT) [4] was applied to compare the level of proliferation resistance of the four nuclear fuel cycle options of (1) direct disposal, (2) thermal MOX fuel cycle, (3) DUPIC fuel cycle, and (4) pyroprocessing-SFR fuel cycle [5]. A condition of MAUT is that each attribute must be "utility independent"of all the others, which means that if all other attributes are held constant, regardless of their value, an increase (or decrease) in the value of an attribute will cause an increase (or decrease) in the overall utility value.

Target material was assumed to be spent fuel assemblies for the direct disposal, PuO_2 powder for the thermal MOXfuel cycle, fresh DUPIC fuel bundles for the DUPIC fuel cycle, and TRU ingots for pyroprocessing-SFR cycle, respectively. Table 1 shows the plutonium concentration and dose rate of target materials at 1 meter distance, and Fig. 1 shows the physical geometry of the target materials assumed for the calculation of dose rates.

Table 1. Pu Concentration and Radiation Level of Target Materials

NFC	Target material	Pu concent-ration (wt%)	Dose rate at 1 meter distance (rem/hr)	1 SQ (kg)	Need of shielding/ remote operation
Direct disposal	Spent fuel assembly	1.1451	1,140.0	69.9	Yes
Thermal MOX fuel cycle	PuO_2 powder (8kg)	100.0	0.00036	9.07	No
DUPIC fuel cycle	Fresh DUPIC fuel bundle	0.9	26.5	888.9	Yes
Pyro-processing -SFR	TRU ingot	55.58	106.9	14.40	Yes

A utility function was created for each attribute of material, technical and institutional barriers, based on the technical data and expert opinions, where technical data was not available. The weighting factor of each attribute was determined by using the Analytic Hierarchical Process (AHP) to achieve consistency of expert judgments [6]. The proliferation resistance indices based on the MAUT analysis were 0.810 for direct disposal, 0.399 for the thermal MOX fuel cycle, 0.729 for the DUPIC fuel cycle, and 0.708 for the pyroprocessing-SFR fuel cycle, respectively, indicating that pyroprocessing has better proliferation resistance than PUREX, but lower than the DUPIC fuel cycle.

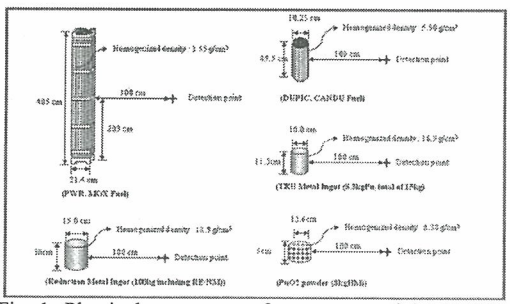

Fig. 1. Physical geometry of target materials for the calculation of dose rate

Considering the current activities related to the development of pyroprocessing technology and the existing plans to construct pyroprocessing facilities in Korea, a Member State Support Program (MSSP) for the IAEA has been initiated in 2008 to prepare for the development of safeguards approaches for pyroprocessing facilities. The main objective of the MSSP is to determine the concept of a reference pyroprocessing facility which can be used to develop a model safeguards approach for all the pyroprocessing concepts worldwide. An assessment of the safeguardability is planned to be performed to determine the optimum combination of available and potential safeguards techniques and methods. Proposals for design features supporting the safeguards implementation will be made based on the project.

3. Conclusion

The preliminary analysis on the proliferation resistance of the pyroprocessing-SFR fuel cycle indicates that pyroprocessing could be a feasible option of Korea for the spent fuel and resource management. Since a detailed vulnerability assessment of pyroprocessing can only be made when sufficient process and design information is available in the future, KAERI is currently performing an MSSP program with the IAEA which will identify the gaps that need to be addressed.

4. REFERENCES

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