Investigation of Design Requirements and Potential Sampling Methods for Engineering-scale Pyroprocessing Safeguards

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1. Introduction

For safeguards of pyroprocessing, destructive analysis (DA) is required for nuclear material accountancy (NMA) and sampling is essential for DA measurement. However, study of sampling approach has not been performed and there are several technical issues due to the high radiation and temperature of pyroprocessing. In this study, design requirements of sampling system and potential sampling methods for various types if sample were investigated.

2. Design requirements of sampling system

The sampling system is covered from a taking a sample to transfer the sample to the analytical laboratory (AL). The design requirements of a sampling system for NMA, such as sampling positions, uncertainty, sample amount and sampling period, are developed based on the conceptual safeguards system of an engineering-scale pyroprocess facility [1]. In other words, sampling uncertainty and sample amount were decided through the feedback with MUF evaluation results. Moreover, sampling position and step were decided by considering representativeness. After taking a sample, it is transferred from the main process cell to the AL through a pneumatic transfer tube. Moreover, all the process is required to be an automated system.

3. Sampling methods

3.1 Input material

The form of input material is SF oxide powder and samples are taken from homogenization mixer during the pre-treatment process. KAERI developed the double stage homogenization concept and the tests were performed with metal oxide powders [2].

Table 1. Design requirements of sampling system

Type	Requirements	
SF oxide powder [Input material]	Positions	2nd homogenization mixer
	Uncertainty & amount	2%, 1g/ea.
	Period	twice /SF assembly
	Weight	Powder inserted into 1st mixer, powder inserted into 2nd mixer, DA sample
Electro-recovery (ER[4] & EW[5]) molten salt [In-process material]	Positions	Electro-recovery vessels (sample: molten phase)
	Uncertainty & amount	1.4%, 1g/ea.
	Period	once/NRTA[1] & RE DD[2] period, twice/WIP[3]& distillation
	Weight	DA sample, total salt weight in vessel (volume x density)
U&U/TRU ingot [Products]	Positions	Ingot manufacture equipment (sample: molten phase)
	Uncertainty & amount	1.4%, 1g/ea.
	Period	U product: 3 times/ three months, 1ea/ingot U/TRU product: 1ea/ingot
	Weight	Ingot, DA sample

1)NRTA: Near-Real Time Accountancy, 2)RE DD: Rare Earth Drawdown, 3)WIP: Work In Process, 4)ER: Electro-Refining, 5)EW: Electro-Winning

For the double stage homogenization, two types of mixer are needed. The concept of double stage homogenization is shown in Fig. 1. The oxidized SF powder from an assembly was charged and homogenized by 3 of 1st mixers with 75 kg/mixer capacity. After mixing, several kg of powder is taken from each 1st mixer and charged into the 2nd mixer. The 2nd mixer has higher performance than 1st mixer and 1 g of DA samples are taken from 2nd mixer after mixing. By this concept, sampling uncertainty and number of DA sample can be reduced. However, specific sampling method is not fully developed yet. The MOX fuel fabrication facility has an automated powder sampling system and KAERI will develop sampling techniques for input accountancy based on the precedent experience in detail.

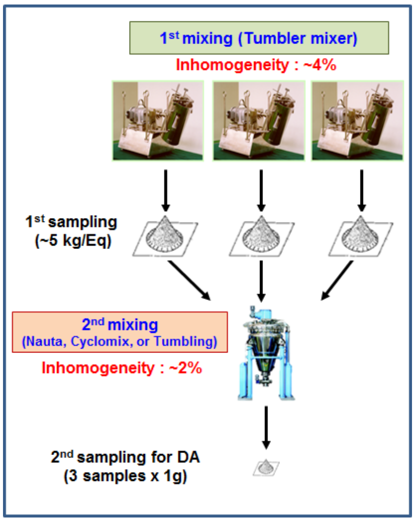

Fig. 1. Concept of double stage homogenization process [2].

3.2 In-process material

The operating temperature of ER/EW process is 500°C. For that reason, temperature is main issue of molten salt sampling. The micro-fluidic and dipstick methods are considered as a salt sampling under the high temperature condition. The microfluidic techniques enable production of uniform micro-samples of molten salt automatically by utilizing sampling line, pump, and droplet generator [3]. For the dipstick method, molten salt is taken by inserting the STS or Ta rod into the electro-recovery vessel and take it out. According to this procedure, molten salt is covered the rod surface and the salt sample can be obtained. This method has been applied at PRIDE and INL. The microfluidic method is valuable but technology readiness level is low and more feasibility study is needed in the future. Therefore, dipstick is considered as a primary salt sampling method for the pyroprocessing.

3.3 Products

The final form of product is U and U/TRU metal ingot. To manufacture the ingot, U and U/TRU metal, recovered by ER and EW process, are melted. Molten phase is proper to take a sample due to the representativeness. According to the melting point of U and U/TRU metal, the temperature is the most difficult obstacle as like salt sampling. The counter-gravity casting process is one of the potential sampling methods. This approach is utilized to cast components of machine and fabricate metal fuel of fast reactor. The counter-gravity casting is that the molten metal is forced to fill mold cavity against gravity under the pressure difference and solidified [4]. This method is expected to be applied for molten metal sampling by optimizing the operation conditions and quartz tube is considered as a mold.

4. Conclusion

The design requirements of the sampling system and potential sampling methods were investigated. However, this study is a fundamental research and further research on developing the sampling methods for various forms of waste and specific conceptual design of automated sampling devices will be performed.

REFERENCES

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