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Calculation of MUF for the Pyro-processing Facility

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1. Introduction

In order for nuclear power projects, the international society needs to ensure the “Atoms for Peace”. Accordingly, countries that perform nuclear power projects comply with the IAEA safeguards system to prove their peaceful use of the nuclear materials.

The IAEA safeguards system is divided into DIQ (Design Information Questionnaire), nuclear material accountancy, and additional measure such as C/S (Containment and Surveillance). As the detailed requirements for judging the diversion of nuclear materials, the IAEA suggests SQ (Significant Quantity) about SNM (Special Nuclear Materials), such as U and Pu, and the timeliness goal of detection about the diversion of nuclear materials. To operate facilities, it is required to accomplish these goals.

In particular, in the case of the treatment facilities of spent nuclear fuel that has a high Pu content, it is very important to meet the requirements to judge the diversion of nuclear materials.

However, given that item counting is impossible in bulk facilities, MUF (Material Unaccounted For) occurs inevitably in the process of nuclear material accountancy. Therefore, to meet the requirements, it is necessary to make evaluation in advance.

2. Main body

2.1. MUF Calculation Method

MUF is referred to as the materials inventory difference and measurement difference in MBA (Material Balance Area). As explained earlier, it is a factor used to detect a significant quantity in the case of the diversion of nuclear materials.

The MUF calculation is written as follow:

$$MUF = (PB + X - Y) - PE \qquad (1)$$

Where,
PB: the beginning physical inventory
X: the sum of increases to inventory
Y: the sum of decreases from inventory
PE: the ending physical inventory

In bulk facilities, MUF is caused by process and measurement errors, such as bulk error, sampling error, and analytic error.

To calculate MUF, it is required to set the KMPs (Key Measurement Point) first in a facility, and then calculate the measurement error in each KMP with the use of error propagation. [3]

$$\sigma_y^2 = \sum_{i=1}^{k} a_i^2 \sigma_i^2 + 2\sum_{i=1}^{k-1}\sum_{j>i} a_i a_j \sigma_{ij} \qquad (2)$$

where,
σi2 : variance of xi
σij : covariance between xi and xj
xi : value for the i-th random variable

In the way of adding each measurement error of KMP in one MBA, the amount of MUF is calculated.

As the calculation tool, Monte-Carlo Simulation codes named GoldSim was used. The following detailed process and nuclear material flow were simulated.

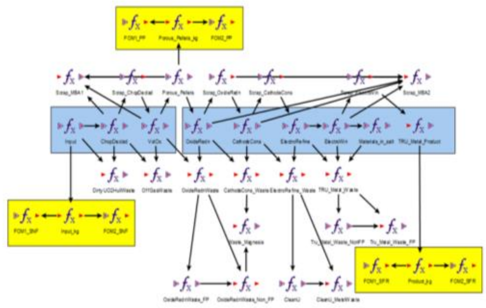

Fig. 1. Simulating the material flow

To calculate the separated MUF in each KMP, process is separated in the unit of MBA. And then the information of each KMP is connected.

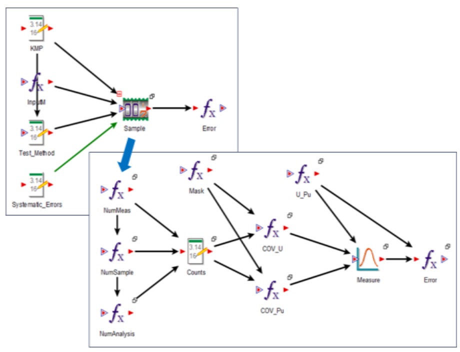

Fig. 2. Calculation process of accounting error at each KMP

In each KMP, measurement error is calculated with the use of error propagation. With the sum of the calculated values, the total amount of MUF is calculated.

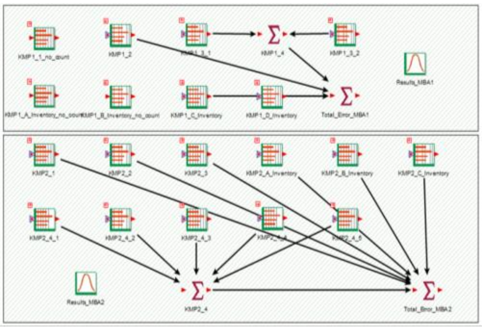

Fig. 3. Information of the MBAs and KMPs about target facility

2.2. Evaluation Facility

As a facility to evaluate MUF, KAPF (Korea Advanced Pyro-processing Facility) was chosen. The basic assumptions are presented as follows:

Here, head-end process cell (MBA-1) and main pyro-processing cell (MBA-2) were mainly analyzed. The facility capacity was 30t/yr, and Material Balance Period (MBP) was set to 1 year.

In addition, for sampling uncertainty and measurement uncertainty, ITV (International Target Values)-based estimation was carried out. [4]

2.3. Results of calculation

In this study, MUF of KAPF was calculated, and the results are presented below. In addition, to analyze correlation with MBA setting, head-end process and main pyro-process were set to one MBA, and each calculation result was compared as table I.

Table I: Results of calculation

SNM	MBA	Total Error (kg)
Pu	MBA-1	5.322
	MBA-2	**8.989**
U^{235}	MBA-1	4.349
	MBA-2	23.783

According to the calculation result, MUF quantity of Pu exceeded 1 SQ (8kg) in the MBP. To meet the target quantity, it is necessary to increase measurement efficiency, reduce facility capacity, or extend MBP. On the assumption of one MBA, a lower MUF quantity was calculated.

3. Conclusion

To reduce such a MUF, the effects on a total MUF were analyzed. As a result, the error arising in a particular process such as U/TRU ingot and Porous Pellets was significant. Therefore, it is necessary to reduce measurement error in the process.

MUF is one of requirements to judge the diversion of nuclear materials, and the requirement should be met. Nevertheless, it is required to come up with additional measures to prevent the exclusive use and reduce MUF, such as containment, surveillance, or multi-channel based processing design.

REFERENCES

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