Current Issues for the Material Balance Evaluation in NFFP

Won-Woo Na, Wan-Sou Park, Seung -Ho Ahn
Korea Atomic Energy Research Institute, 150 Dukjin-dong, Yusong-gu, Daejon, 305-353

1. Introduction

The Korean nuclear fuel fabrication plant started to manufacture the nuclear fuels at the end of 1988 and has been supplying all the domestic needs of the LWR fuels since then. A new CANDU fuel fabrication plant was also built in 1997. These plants were classified as a bulk facility by the Agency's safeguards criteria, the Agency has been applying the inspection procedure designed to meet the purpose of safeguarding these. It requires that one physical inventory verification and two interim inspections should be carried out under the zone approach, which has been applied for LEU and NU fresh fuels. In order to evaluate the material balance during each material balance period, the Material Unaccounted For (MUF) must be accurately declared by the facility operators and properly evaluated by the Agency.

2. Material Balance Evaluation

Material Balance Evaluation is one of the tools used to assess the validity of operator's declarations of nuclear material amounts and verify the operator's compliance with safeguards agreement. The conceptual view of material balance evaluation and associated safeguards activities is that they provide the framework through which an inspector can detect diversion accomplished through the creation of defects as small as bias defects, that is, a diversion accomplished through the removal of small amounts of material from each of many items. The specific diversion strategies that material balance evaluation is designed to detect are refereed to as "diversion into MUF", "diversion into D" and "diversion into SRD".

2.1 Operator MUF

According to an agreement between the ROK and the Agency for the application of safeguards, the facility operators declare nuclear material amounts in three periodic reports required by the Agency. These reports are the Material Balance Report (MBR), the detailed Physical Inventory Listing (PIL), which is attached to the MBR, and the detailed Inventory Change Reports (ICR), which are sent within 30 days of every receipt, shipment and other changes. The relationship between the reported amounts is expressed in the following simple equation, which is generally referred to as the material balance equation or the MUF equation.

$$MUF = PB + X - Y - PE$$

PB represents the material on inventory at the beginning of the accounting period, X represents the material received during the accounting period, Y represents the material shipped or discarded during same period, and PE represents material on inventory at the end of the accounting period. MUF is material unaccounted for, that is the balance of material that the other terms of the equation fail to account for.

2.2 Operator-Inspector Difference

Because of measurement uncertainty, there is usually a difference between the inspector's measured value and value declared by the operators. This random variable is referred to as the operator-inspector difference. The four components are combined in the following equation to calculate D for the overall material balance.

$$PB_O - PB_I = D_{PB}$$
$$X_O - X_I = D_X$$
$$Y_O - Y_I = D_Y$$
$$PE_O - PE_I = D_{PE}$$
$$D_{PB} + D_X - D_Y - D_{PE} = D$$

Evaluating the significance of D requires estimating the measurement uncertainty associated with both inspector and operator. When it is applied well, MUF-D is capable of detecting both diversion into MUF and diversion into D.

2.3 SRD evaluation

A Shipper-Receiver Difference (SRD) is the difference between the quantity of nuclear materials stated by the shipper and the quantity of nuclear materials measured by the receiver. In the simplest case, the shipper's diversion strategy would be to overstate the amount shipped and to keep the overstated amount of materials for diversion. The receiver's strategy would be to understate the amount of materials received and to put aside the undeclared materials for diversion. However, both diversion strategies can be detected by SRD evaluation, but only when the receiver measures the materials received and the inspector performs verification on receipts.

3. Current Issues

In order to meet the purpose of inspecting the plants, the inspectors have applied three methods (H, F, D) using the nondestructive assay (NDA) and chemical analysis (DA). And the Agency should examine the measurements uncertainties, measurement bias and diversion of nuclear materials to perform the Material Balance Evaluation. But, several pending items mentioned below have been issued now, which should be solved to meet the purpose of the Agency's safeguards.

3.1 MUF History

The facility has reported the MUF during each of all material balance periods to the Agency since the first physical inventory taking in 1989. Since then, the Agency has always calculated its Cumulative MUF. Generally the MUF has been tended to be positive except two times of negative MUFs. The operators

explained that these negative MUFs were caused by the work cleaning the filters in process lines and gathering nuclear materials.

3.2 Observation on Historical Analytical Data

Measurement uncertainty estimates are split into two components, random and systematic. Random error can be controlled by replicating measurements. Systematic error may be caused by such factors as faulty calibration of the measuring instrument and other conditions. A measurement uncertainty is an estimate of the intrinsic error associated with measuring a stratum of material by a given method. It can be expressed as a percent relative standard deviation. Measurement uncertainties are specified on the basis of MBA, material type, stratum and measurement system. Table 1 shows a measurement uncertainty that was applied for PIV 2004. It is also used to do sample calculation and confirm the verification results to evaluate the material balance.

Table 1 Delta - Values (Relative Standard Deviation)

Gross Defect		Partial Defect		Bias Defect	
Stratum	RSD	Stratum	RSD	Stratum	RSD
FF-	0.150	FF-	0.114		
FF1	0.150	FF1	0.147		
FR-	0.150	FR-	0.057		
MP-	0.200	MP-	0.180	MP-	0.112
PD-	0.150	PD-	0.060	PD-	0.005
PL-	0.150	PL-	0.074	PL-	0.005
PL-		PL-	0.061		
SC-	0.150	SC-	0.088	SC-	0.025
SC1	0.150	SC1	0.088		
SC2	0.150	SC2	0.082		
SD-	0.150	SD-	0.140	SD-	0.100
UF-	0.150	UF-	0.053		
				PM-	0.028
				WS-	0.100

3.3 SRD reports

The plants have received UF_6 and Gd pellets and natural UO_2 from foreign suppliers and began to report the SRD for UF_6 to the Agency in 2003 and for UO_2 in 2004. It has been reported based on just only weighing items. On the other hand, the plant requested the contracted laboratory (Ledoux) to analyze the enrichment of UF_6 receipts from the suppliers. The differences between the shipper's and Ledoux's enrichment values are showed in Table 2.

Table 2 Differences between the Shipper's and Ledoux's Enrichment values

Shipper	Difference	Items
Russia	+0.00215 wt%	20
USEC	+0.00140 wt%	10
Urenco	+0.00196 wt%	28

3.4 Other Issues

Possible sources for the observed Cumulative MUF and the large positive MUFs in ^{235}U could not be clearly identified until now. However, it is recommended to continue monitoring the biases in the enrichment measurement of the product pellets to see whether these biases can be one possible source for the MUF. Regarding the facility' measurement system for U-concentration and enrichment in powders and pellets, the Agency suggested that the facility have to improve its measurement procedure including preparation of the reference samples and other things. And the amounts contained in the retained waste (TW) in recent years are lower than earlier. This can be explained by the fact that UF_6 is now converted by a dry process.

4. Summary

As the plants are classified as a bulk facility by the Agency's safeguards criteria, the Material Balance Evaluation is a good tool to timely detect diversion that will be accomplished through the creation of defects as small as bias defects. Through all evaluations made by the Agency, it is strongly recommended to report SRD based on both weight and enrichment, maintain the reliable MUF declaration and improve the gamma spectrometry measurement procedure. These recommendations have been now applied and are going on.

References

[1] IAEA "IAEA Safeguards Criteria", 2004-09-09.
[2] M.Williams, "Material Balance Evaluation", 1999.
[3] B.D.Lee, "Analysis on the Material Balance Evaluation Methods using Paired Data", 2000 KNS.