This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

45th INMM Meeting, July 18-22, 2004, Orlando, FL

CONTINUOUS MATERIAL BALANCE RECONCILIATION FOR A MODERN PLUTONIUM PROCESSING FACILITY

Thomas Gary Clark, Westinghouse Savannah River Company
Jerry M. O'Leary, Westinghouse Savannah River Company
Melinda L. Adams, Westinghouse Savannah River Company
Thomas L. Williams, Department of Energy Savannah River

Abstract

This paper describes a safeguards approach that can be deployed at any modern plutonium processing facility to increase the level of safeguards assurance and significantly reduce the impact of safeguards on process operations.

One of the most perplexing problems facing the designers of plutonium processing facilities is the constraint placed upon the limit of error of the inventory difference (LEID). The current manual (DOE M 474.1-1B) constrains the LEID for Category I and II material balance areas to 2% of active inventory up to a Category II quantity of the SNM being processed . For ^{239}Pu (Material Type Code 50) a Category II quantity is two kilograms. Due to the large material throughput anticipated for some of the modern Plutonium facilities, the required LEID cannot be achieved reliably during a nominal two month inventory period, even by using state-of-the-science non-destructive assay (NDA) methods.

The most cost-effective and least disruptive solution appears to be increasing the frequency of material balance closure and thus reducing the throughput being measured during each inventory

period. Current inventory accounting practices and systems can already provide the book inventory values at any point in time. However, closing the material balance with measured values has typically required the process to be cleaned out, and in-process materials packaged and measured. This process requires one to two weeks of facility down time every two months for each inventory, thus significantly reducing productivity. To provide a solution to this problem, a non-traditional approach is proposed that will include using in-line instruments to provide measurement of the process materials on a near real-time basis. A new software component will be developed that will operate with the standard LANMAS application to provide the running material balance reconciliation, including the calculation of the inventory difference and variance propagation. The combined measurement system and software implementation will make it possible for a facility to close material balances on a measured basis in a time period as short as one day.

Introduction

The US Department of Energy is engaged in several initiatives that will necessitate construction of facilities capable of processing a large throughput of nuclear material, specifically Plutonium. Even with state-of-the-science measurement systems deployed in these facilities, a small uncertainty or error will be associated with each measurement performed. These small uncertainties can represent an unacceptably large amount of material when multiplied by the large throughput anticipated to be processed between physical inventories to meet program requirements. In addition to the logical concern that some significant amount of material can be diverted but not detected, the Department of Energy (DOE) has established formal acceptable maximums for the Limit of Error for Inventory Difference (LEID) in the MC&A directives. Modern nuclear facilities will be faced with being good stewards of these national assets and compliance with these DOE directives. This paper documents a conceptual approach for a non-traditional inventory method being investigated for use in DOE's new Plutonium facilities.

Discussion

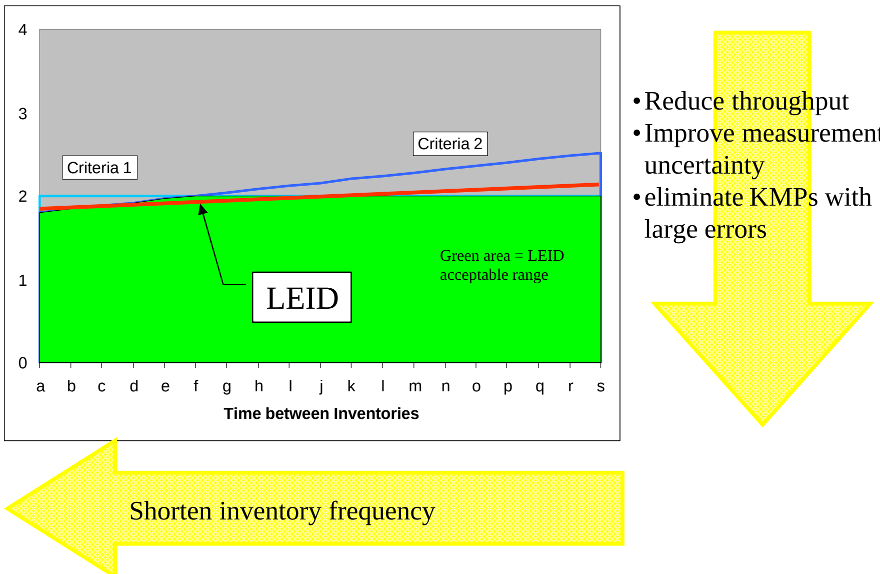
The LEID Driver

The figure below illustrates the relationship of the LEID to the dual DOE acceptance criteria. The LEID is simplified to a sloping straight line for illustration purposes only, but is actually a complex statistical combination of the measurement errors and material quantities being measured. The new DOE high-capacity facilities will face the challenge of operating in the very small acceptable window shown in the figure where the LEID crosses the green area.

Several factors affect the LEID calculation. Some of these can be manipulated to improve the situation and others are relatively fixed. Below is a short list of some adjustments for the major factors:

- Shortening the inventory period
- Reducing processing throughput
- Selecting instruments with low measurement uncertainties
- Manipulating subMBA boundaries and Key Measurement Points

Factors Affecting the LEID



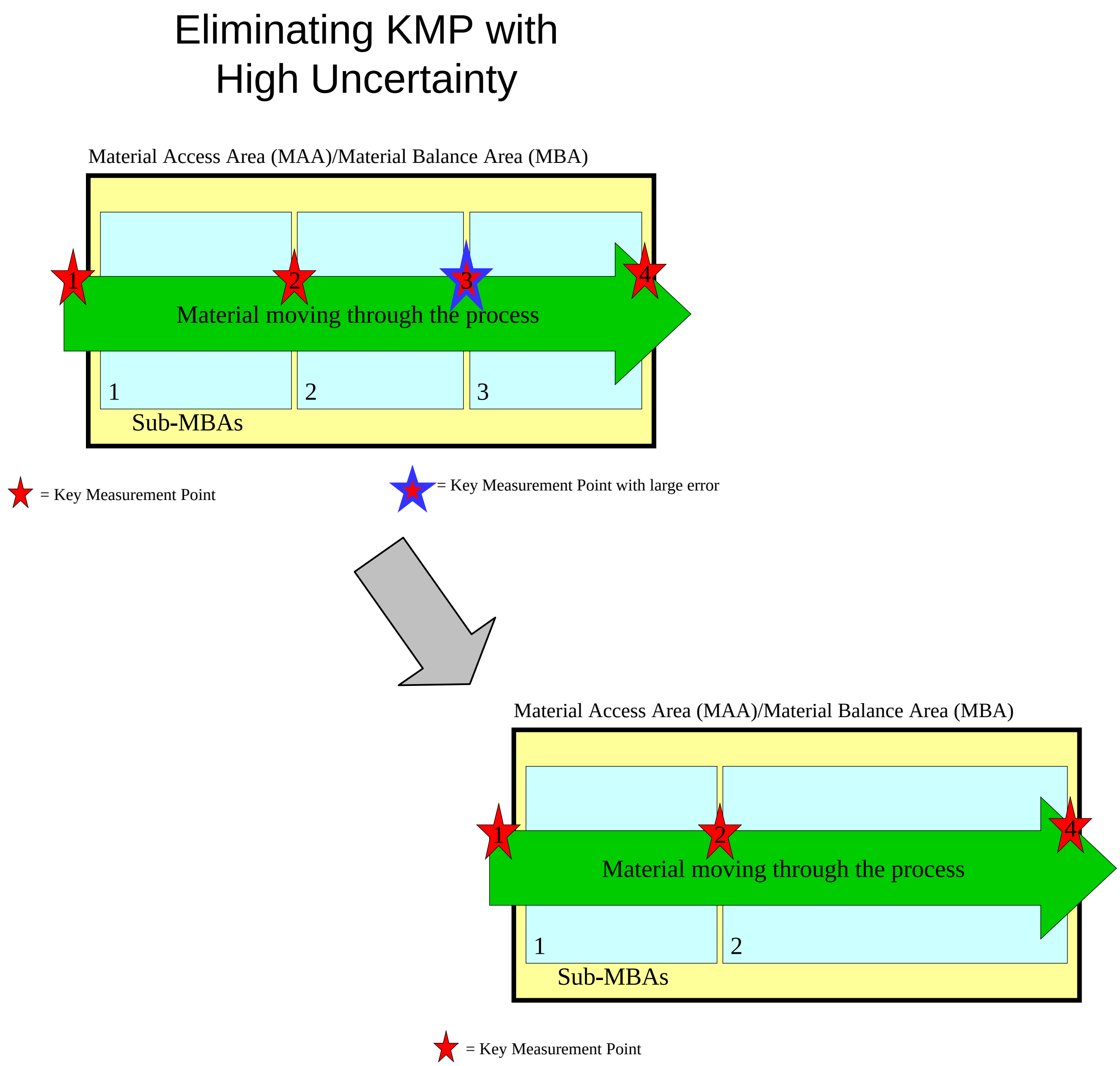
<u>Inventory Frequency</u>
Considering a "generic" modern nuclear material facility, it becomes clear that some of these factors are more "adjustable" than others. For example, performing inventories more frequently affects the LEID calculation by reducing the active inventory to be considered. A more frequent inventory also reduces the number of measurements performed and, therefore, the number of times an uncertainty must be applied to the propagated error. Theoretically reducing the inventory period is relatively easy. Practically, a significant reduction in the inventory period has far reaching impacts to the facility and can, in extreme cases, jeopardize its ability to meet its production goals.

<u>Throughput</u>
Throughput is probably not adjustable since most of the DOE facilities have a required throughput which the facility must meet in order to accomplish its intended mission. Reducing the throughput enough to alleviate the LEID issue would almost certainly impact the ability of the facility to meet its mission requirements. Presumably, the throughput for a new facility has already been carefully scrutinized to ensure that facilities are not designed and constructed with excess capacity which increases the cost without adequate justification.

<u>Instrument Uncertainty</u>
Selecting the best instrument to measure the specific type and form of nuclear material is certainly achievable even if perhaps it is more expensive than an instrument with higher measurement uncertainties. In some cases this additional cost can be an issue if multiple processing lines require suites of exotic NDA equipment. Sometimes this situation can be improved by re-mapping the subMBA[i] boundaries to eliminate or relocate measurement points, reducing the number of expensive instruments required.

Eliminating Key Measurement Points with large errors

Rearranging the subMBA boundaries may also provide some relief at locations in the process where material is difficult to measure with low uncertainty. See the figure below. However, this alternative is not without its disadvantages. Elimination of a subMBA makes isolation and evaluation of inventory differences much more difficult. Recognize that re-mapping subMBA boundaries and providing instruments with low uncertainty for these transfers is relatively easy while the facility is in the design phase. Retrofitting these capabilities and adjusting the boundaries after-the-fact is, at best, expensive and can be near impossible especially when structural changes are necessary. Therefore, in order to provide the most flexibility and to assure the highest chance of success, an MC&A strategy and a scoping LEID calculation should be performed early in detailed design to identify and address any problem areas.



This technique of adjusting the facility subMBA structure to improve the error propagation calculation has been the subject of other INMM presentations so this facet of the approach will not be discussed further in this paper.

In addition, experience with these designs has revealed that many times adjustment of more than one of the LEID affecting factors is needed to ensure compliance. In fact, one of the most difficult adjustments to accommodate may be to shorten the inventory period which we will consider in more detail below.

Inventory using a Non-Traditional Approach

After optimizing a modern nuclear material processing facility design for measurement considerations, it may be necessary to also adjust the inventory frequency to achieve compliance with the DOE requirements on LEID. By increasing the inventory frequency (i.e., performing an inventory more often than DOE requires), the LEID can often be improved. The DOE requirements stipulate that for Category I and II material balance areas in which processing occurs, physical inventories must be conducted at least bi-monthly (every two months) or at completion of the material campaign. A traditional inventory involves shutting down the process and moving "in process" material to locations where it can be physically measured as part of the physical inventory. Both items and bulk material in storage must also be measured. These measured values are compared to the official measured values recorded in the accountability records for the MBA and an "inventory difference" or ID is calculated. In addition, an evaluation of the combined measurement error is also performed. The ID and error are compared to control limits to ensure that no significant amount of material is uncontrolled or missing and that the measurement strategy will detect diversion of sufficiently small amounts of material.

Inventories of large facilities, including preparation time, movement of material to measurement points, actual performance of the physical inventory, resolution of outliers, calculation of the ID, and reconciliation are expected to take approximately a week to complete. It becomes immediately clear that shortening of the inventory period to much below 60 days and planning for a week's outage causes a significant impact to available processing time. In fact, scoping calculations done for one large new plutonium facility currently in design indicates that the inventory frequency would have to be reduced to bi-weekly to achieve compliance with the LEID requirements. If each inventory also includes approximately a week of down time, the result is that the facility is available to process material only 1 in every 2 weeks. This is an untenable situation.

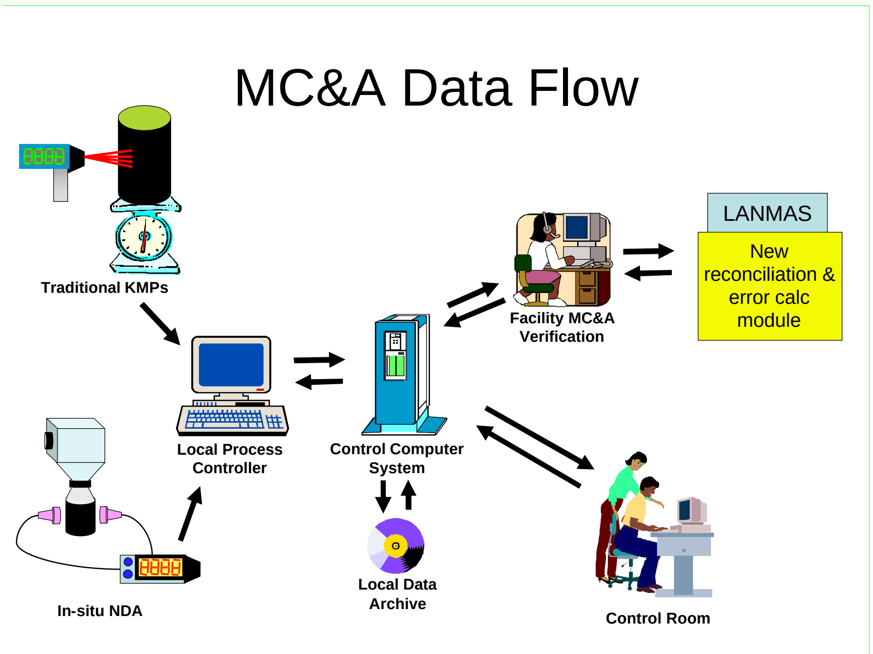
"In Process" Material Measured In-situ

Efforts to engineer a solution to this dilemma start with an analysis of the physical inventory process and what can be done to shorten the time required to perform and reconcile an inventory. Most of the preparation time is spent shutting down the process, relocating or packaging material so that it can be measured, and performing the measurements. In order to shorten this time, a proposal is being developed to measure accountable material in-situ. Inventory preparation time could be cut significantly if practical instrumentation can be designed to assay nuclear material in the process at those points where shutdown and clean out are very time consuming. The selection process of these in-situ measurement locations carefully considers the expense and difficulty of installation of assay equipment against the anticipated savings in terms of the impact to the facility operations. Efforts have been made in the new facility designs to limit the amount of additional instrumentation required to perform this task. Every effort has been made to design subMBA boundaries and measurement locations to take full advantage of instrumentation already in the design. For in-situ process measurements, some additional instrumentation may be needed. An earnest effort has been undertaken during design to limit these specialized instruments as much as possible and to fully utilize them. For example, in-situ instruments for some process modules can do double duty by monitoring for inventory buildup that may approach criticality limits or some instruments may be used for process control or monitoring in addition to performing their MC&A function.

Surprisingly, careful review of the LEID calculation reveals that some in-situ measurements with a relatively high uncertainty do not aversely affect the resultant overall facility error significantly. The "in process" material is measured according to requirements, but the measurement can be performed with less sophisticated, more reliable, less costly instrumentation without compromising the overall facility LEID.

Handling Inventory Data

Traditional approaches for data collection involve entering measurement data manually onto procedures and then transmitting the procedures to clerks for entry into the accountability system. This method takes a significant amount of time to complete for each transaction and injects an opportunity for keying errors that lead to delays during the inventory performance (i.e., outliers that must be resolved in conjunction with the inventory). This process must be automated in order to significantly reduce the overall time to complete an inventory. Data collection and reporting must be performed electronically so that instrumentation information is available almost immediately for the accountability system to use. Further, calculations currently done by hand must also be automated. New software modules will need to be developed to allow the accounting system to gather all the pertinent data and calculate the ID and LEID virtually immediately when the physical inventory measurement data becomes available. These software modules are planned to be developed as components of the site MC&A accountability system.



Segmented Inventory

Traditionally, facilities are shutdown for physical inventory and the entire facility is inventoried "wall to wall" within the inventory duration. Frequently, process lines are released to restart following inventory at staggered times as the reconciliation of each subMBA is completed. To further reduce the impact of inventory on the facility processing, the proposed non-traditional approach would inventory and reconcile modules individually while they continue to run. Any movements between modules would be carefully controlled during this time and movements between subMBAs would be extremely limited. This on-the-fly inventory technique coupled with rapid data collection and automatic reconciliation should allow a compliant inventory to be performed while minimizing the adverse impact to the facility processing schedule.

Conclusion

IF:

- Inventory preparation time is significantly reduced by measuring selected "in process" material in situ so that it is not necessary to shutdown the process and relocate accountable material to measurement locations, AND
- Process modules can be inventoried while they continue to run, AND
- Data collected from facility measurement systems are reported very rapidly to the site MC&A system, AND
- Reconciliation and closing of the inventory process are automated in the accounting system software,

THEN:

- Inventories can be performed almost at will in the new DOE facilities with very little impact to the facility processing.

This approach has the side benefit of greatly expediting the resolution of any MC&A control element alarms. Book values and expected mass balances around process modules can be verified very quickly. This lets the facility MC&A staff rapidly investigate and resolve any out-of-limit condition.

Therefore, employing this non-traditional approach to the new DOE plutonium facilities should increase process availability by greatly reducing the burden of performing routine inventories and also improve the nuclear material safeguards by providing a system that approaches continuous inventory monitoring.

---

[i] The term "subMBA" is used to refer to an accounting structure internal to a material balance area (MBA) that is used for localization of inventory differences. Some sites use the terms "control account" or "unit process account."