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U.S. ATOMIC ENERGY COMMISSION

# REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

## REGULATORY GUIDE 5.26

## SELECTION OF MATERIAL BALANCE AREAS AND ITEM CONTROL AREAS

### A. INTRODUCTION

Proposed (38 FR 26735) Section 70.58, "Fundamental Nuclear Materal Controls," of 10 CFR Part 70, "Special Nuclear Material." would require certain licensees authorized to possess more than one effective kilogram of special nuclear material to establish Material Balance Areas (MBAs) or Item Control Areas (ICAs) for the physical and administrative control of nuclear materials. This section would require that:

1. Each MBA be an identifiable physical area such that the quantity of nuclear material being moved into or out of the MBA can be measured.
2. A sufficient number of MBAs be established so that nuclear material losses, thefts, or diversions can be localized and the mechanisms identified.
3. The custody of all nuclear material within an MBA be the responsibility of a single individual.
4. ICAs be established according to the same criteria as MBAs except that control into and out of such areas would be by item identity and count for previously determined special nuclear material quantities.

This guide describes bases acceptable to the Regulatory staff for the selection of material balance areas and item control areas.

### B. DISCUSSION

The division of a nuclear plant into material balance areas and item control areas can provide improved material control and accounting as follows:

1. A loss or theft of material or of an item or items can be identified as having occurred in a particular part of the plant so that the investigation can be more effective and the loss or theft mechanism more easily identified and corrected or counteracted.
2. The assignment of responsibility to a single designated individual for the control of the material or the items in each area could provide more vigilant and effective control in each area and thus in the total plant.
3. The capability for detecting the loss or theft of material may be improved by taking smaller material balances.

#### Number of MBAs and ICAs

The number of MBAs and ICAs established at a plant will depend on considerations that are specific to the individual plants. Such considerations will have a bearing on the definition of the word "sufficient" in the Part 70 requirement that the number of MBAs and ICAs be sufficient to localize losses or thefts. It is not the number of MBAs or ICAs per se that will be sufficient to localize losses but the division of the plant into MBAs and ICAs using bases for such division which will permit identification and location of losses. Among the most significant considerations for establishing MBAs are detection capability, physical boundaries, and the organizational structure to provide administrative control in each area. Other factors which may pertain include material types, processes and process layout, and functional locations such as laboratories, shipping and receiving areas, or storage areas.

Each of these factors will affect the selection of MBAs and ICAs and the effectiveness of such selection to control material and items and to identify losses within an area. For example, if an MBA is selected to consist of a building in which there are two processes using different material types (such as two different enrichments of uranium), there may be some difficulty in identifying to which enrichment a MUF should be applied. If each process (probably in separate rooms in the building) is established as an MBA, MUFs for each process could be identified, and losses or thefts from each process could be evaluated and investigated as needed. In this case, the process and the material type provided a definition of the MBA. It would not be necessary for different types of material to be used in the two processes for them to be established as separate MBAs. Two parallel processes using the same type of material might be separate MBAs as shown in Cases II and V in Appendix A. Division also might be made within a process to establish MBAs that would improve detection capability for separate parts of the process.

It may be possible to make the conversion step of a fuel fabrication process a separate MBA with a measured balance around it. The remainder of the process steps (the fabrication steps, pelletizing, sphere formation, alloying, and any other) could constitute another MBA up to the point where the nuclear material is sealed in a fuel pin, rod, etc. After sealing, the material could be treated as an identifiable item and sent to another area for storage or for further fabrication such as welding, assembly, or testing. Transfer of the items from the MBA would be based on the material quantities as measured when the items were loaded.

If the final fabrication area or storage area receives fuel from more than one loading MBA or is in a separate building on the plant site, it would be designated as an ICA using item identity and the measured quantitites from the loading MBAs for control.

It also may be that the conversion step of the process is not administratively separated from the rest of the process so that it could not be considered a separate MBA. This would not preclude a measured balance around that step if the product from the step were measurable before it went into the subsequent step of the process. With proper control of the material to assure that all is measured once and only once as it moves from process step to process step, measured internal material balances can be taken around process segments whose inputs and outputs are measurable even though separate MBAs may not be established.

### Detection Capability

The basic objectives of material balance accounting for special nuclear material are to detect the occurrence of missing material whether it be lost or stolen, and conversely to provide assurance with a stated degree of confidence that if any material is missing it is less than a threshold quantity. A prime indicator for attaining these objectives is Material Unaccounted For (MUF). The base for evaluation of a MUF value is the Limits of Error of the Material Unaccounted For (LEMUF). If a MUF value is within the LEMUF value, it can be stated with a specified probability that the MUF is due to uncertainties of the measurement system. The validity of this statement depends on a number of factors, a major one of which is the validity of the LEMUF itself. The LEMUF provides the limits which define the threshold quantity for a detectable loss or theft. A LEMUF that has been inflated, either intentionally or inadvertently, can mask a loss or theft by indicating that a MUF is not statistically significant, i.e., the MUF is the result only of the measurement error of the system, when in fact the MUF includes a significant loss or theft. The ramifications of the evaluation of MUF and the generation of data for MUF and LEMUF are the subjects of other regulatory guides. It is sufficient for the purpose of this guide to know that the combination of a properly generated MUF and LEMUF provides a loss detection mechanism.

In general, the detection capability of MUF and LEMUF varies directly with the quality of the material balance measurements and inversely with the quantity of material in a given balance. In this context, detection capability means the threshold quantity of material that the system can detect as being missing with some stated probability. This capability is represented by a LEMUF value stated in terms of quantity, e.g., grams or kilograms. This detection capability based on a measured material balance is associated with MBAs rather than ICAs, since ICAs are controlled on an item basis. In an ICA either all items are accounted for or they are not. If they are not, one or more missing items are indicated, and an investigation is required.

The selection of MBAs can affect detection capability by lowering the quantity of material in a material balance, thereby lowering the absolute LEMUF, since with less material there could be a smaller LEMUF and a greater sensitivity. This assumes that only the quantity of material is changed and not measurement quality.

Examples showing the effect of this quantity change using this assumption are presented in Appendix A of this guide. The examples obviously are simplified greatly. In real situations there would be complicating factors such as discard streams, scrap removals from MBAs, recycle that might cross MBA boundaries, or uneven distribution of inventory or throughput between MBAs, in addition to changes in measurement quality. Each of these could affect the selection of MBA boundaries.

### Physical Boundaries

The physical boundaries of MBAs and ICAs are not specified in the proposed regulations except that they must be "identifiable physical areas." The boundaries could be no more than lines painted on the floor around certain parts of the process. However, if MBA or ICA boundaries do not minimize the possibility of intermixing of materials or items from different areas, either intentionally or inadvertently, the balance of such an area or the item control for such an area could become meaningless, and the location of a loss or theft of material or items might not be identifiable. Further, with boundaries that do not provide physical separation of materials it is more difficult to discharge the custodial responsibility for a given area. It is too easy for material to be moved without the proper documentation and appropriate transfer of custodial responsibility in such cases. Areas bound by walls, such as separate buildings or rooms within a building, or by grids, such as a storage crib or a room divider, are well defined and the materials and items can be kept within the areas more easily.

The critical factor is not the physical boundary, but the identification of an area which can be administratively controlled as a separate area around which either measured material balance control or item control can be maintained. This control would be related to the three aspects of improved material control and accounting noted in the beginning of the Discussion section of this guide, i.e., loss location, responsibility assignment, and detection capability. The boundaries selected will depend on combinations of considerations of these three items.

### Item Control Areas (ICAs)

ICAs are differentiated from MBAs to simplify and improve the control and accountability of identifiable items. Control into and out of ICAs is required to be by item identity and count and previously determined special nuclear material quantities. This excludes items that do not have an identity that will differentiate them from other similar items, e.g., loose fuel pellets or unsealed, unlabeled containers of SNM. Such items could be substituted for other similar items of different SNM content or the SNM content changed so that control of the material would not be maintained. Loaded and sealed fuel rods or tamper-safed sealed containers of SNM that have been numbered or in some way uniquely identified provide assurance that the quantity of contained SNM remains as previously measured. ICAs for the handling and storage of such items provide control without the need for making additional measurements for material balances. Storage areas for finished fuel rods or assemblies, process intermediates, or irradiated fuel assemblies could be ICAs. Shipping and receiving areas could be considered ICAs if item integrity is maintained in those areas.

## C. REGULATORY POSITION

A variety of factors that are specific for individual plants and processes pertain to the establishment of MBAs and ICAs. The effectiveness of the MBAs and ICAs in enhancing nuclear material control should be evaluated for each situation. The factors presented below should be considered in the selection and establishment of MBAs and ICAs.

### Physical Boundaries

Physical boundaries of MBAs and ICAs should be established so that control of the material moving into, out of, and within the area can be maintained to the extent that material assigned to a given area is kept separate from material assigned to any other area. The boundaries of the MBAs must be established so that the quantity of material moving into or out of an area can be represented by a measured value. The boundaries of ICAs must be established so that items moving into or out of an area can be controlled by identity, count, and a previously measured valid special nuclear material content.

### Detection Capability

Material flows and inventories and the quality of the measurement of such flows and inventories should be given primary consideration in establishing material balance areas. Model material balances similar to those of Appendix A should be prepared to evaluate the effects of the selection of various MBAs. Such model balances should include all of the material flow, inventory, and measurement factors that will affect the balance. Such factors would include recycle, discards, scrap inventory, random and systematic error effects, common measurements and their covariant effect, and changes in measurement or inventory quality as a result of division of flows or inventories.

Material balance areas should provide the maximum practicable detection capability consistent with other factors such as physical boundaries or process operation and layout. To improve detection capability, consideration should be given to changes in such things as process layout or process operations, physical boundaries, measurement techniques, and inventory techniques. Consideration also should be given to establishing procedures for material balances around process segments internal to MBAs.

### Number of MBAs and ICAs

The number of MBAs and ICAs established in a specific plant should be based on considerations of detection capability and the physical and functional aspects of the plant and material that would assist in identifying and localizing material losses or thefts.

Different material should be processed in separate MBAs.

The establishment of separate processes as separate MBAs should be considered. Although detection capability may not thereby be improved, the identification and location of losses or thefts would be. Even when separate processes are not maintained as separate MBAs, separate material balances should be taken around each process to identify and locate losses and possibly to enhance detection capability.

Functional areas such as laboratories, receiving and shipping areas, and warehouses or storage vaults should with boundaries that do not provide physical separation of materials it is more difficult to discharge the custodial responsibility for a given area. It is too easy for material to be moved without the proper documentation and appropriate transfer of custodial responsibility in such cases. Areas bound by walls, such as separate buildings or rooms within a building, or by grids, such as a storage crib or a room divider, are well defined and the materials and items can be kept within the areas more easily.

The critical factor is not the physical boundary, but the identification of an area which can be administratively controlled as a separate area around which either measured material balance control or item control can be maintained. This control would be related to the three aspects of improved material control and accounting noted in the beginning of the Discussion section of this guide, i.e., loss location, responsibility assignment, and detection capability. The boundaries selected will depend on combinations of considerations of these three items.

### Item Control Areas (ICAs)

ICAs are differentiated from MBAs to simplify and improve the control and accountability of identifiable items. Control into and out of ICAs is required to be by item identity and count and previously determined special nuclear material quantities. This excludes items that do not have an identity that will differentiate them from other similar items, e.g., loose fuel pellets or unsealed, unlabeled containers of SNM. Such items could be substituted for other similar items of different SNM content or the SNM content changed so that control of the material would not be maintained. Loaded and sealed fuel rods or tamper-safed sealed containers of SNM that have been numbered or in some way uniquely identified provide assurance that the quantity of contained SNM remains as previously measured. ICAs for the handling and storage of such items provide control without the need for making additional measurements for material balances. Storage areas for finished fuel rods or assemblies, process intermediates, or irradiated fuel assemblies could be ICAs. Shipping and receiving areas could be considered ICAs if item integrity is maintained in those areas.

## C. REGULATORY POSITION

A variety of factors that are specific for individual plants and processes pertain to the establishment of MBAs and ICAs. The effectiveness of the MBAs and ICAs in enhancing nuclear material control should be evaluated for each situation. The factors presented below should be considered in the selection and establishment of MBAs and ICAs.

### Physical Boundaries

Physical boundaries of MBAs and ICAs should be established so that control of the material moving into, out of, and within the area can be maintained to the extent that material assigned to a given area is kept separate from material assigned to any other area. The boundaries of the MBAs must be established so that the quantity of material moving into or out of an area can be represented by a measured value. The boundaries of ICAs must be established so that items moving into or out of an area can be controlled by identity, count, and a previously measured valid special nuclear material content.

### Detection Capability

Material flows and inventories and the quality of the measurement of such flows and inventories should be given primary consideration in establishing material balance areas. Model material balances similar to those of Appendix A should be prepared to evaluate the effects of the selection of various MBAs. Such model balances should include all of the material flow, inventory, and measurement factors that will affect the balance. Such factors would include recycle, discards, scrap inventory, random and systematic error effects, common measurements and their covariant effect, and changes in measurement or inventory quality as a result of division of flows or inventories.

Material balance areas should provide the maximum practicable detection capability consistent with other factors such as physical boundaries or process operation and layout. To improve detection capability, consideration should be given to changes in such things as process layout or process operations, physical boundaries, measurement techniques, and inventory techniques. Consideration also should be given to establishing procedures for material balances around process segments internal to MBAs.

### Number of MBAs and ICAs

The number of MBAs and ICAs established in a specific plant should be based on considerations of detection capability and the physical and functional aspects of the plant and material that would assist in identifying and localizing material losses or thefts.

Different material should be processed in separate MBAs.

The establishment of separate processes as separate MBAs should be considered. Although detection capability may not thereby be improved, the identification and location of losses or thefts would be. Even when separate processes are not maintained as separate MBAs, separate material balances should be taken around each process to identify and locate losses and possibly to enhance detection capability.

Functional areas such as laboratories, receiving and shipping areas, and warehouses or storage vaults should be separate MBAs or ICAs. Receiving and shipping areas may be established as ICAs provided the material is not processed or subdivided and is identifiable by item and in a sealed, tamper-safed condition. Warehouses and storage vaults should be considered ICAs since all material in storage should be identifiable by item and in a sealed, tamper-safed condition.

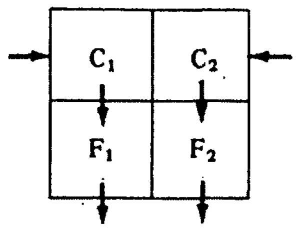
**Item Control Areas**

Areas designated as ICAs should contain only items that are identified to differentiate them from other similar items and are in a sealed tamper-safed condition that assures the integrity of prior measurements. Such items as loose fuel pellets or unsealed, unlabeled containers of SNM do not have identities that will differentiate them from other similar items and are therefore not acceptable for control in ICAs.

## APPENDIX A

# EFFECT OF MBA SELECTION ON LEMUF AND DETECTION CAPABILITY

To show the effect of MBA selection on the LEMUF and the detection capability, several examples are presented. The examples are given for a simplified plant consisting of two conversion lines and two fabrication lines. The plant may be represented by the following diagram:




where:

$C_1$ & $C_2$ = Conversion lines 1 and 2
$F_1$ & $F_2$ = Fabrication lines 1 and 2

The MBAs used in the example will be:

Total Plant - All lines in one MBA

Parallel MBAs - MBA 1 = $C_1 + F_1$
- MBA 2 = $C_2 + F_2$

Series MBAs - MBA 1 = $C_1 + C_2$
- MBA 2 = $F_1 + F_2$

The examples will consider these configurations for both inventory-dominated and throughput-dominated processes. The following parameters are common to all examples:

1. Throughput is in 2-kg batches (Cases I, II, and III) or 20-kg batches (Cases IV, V, and VI) each of which is measured to ±0.25% (±5 grams and ±50 grams, respectively).
2. For simplification it is assumed that there are no discards and that there is 100% yield in the form of product batches equal in size to the input batches and measured to ±0.25%.
3. The inventory interval is two months.
4. Beginning and ending inventories are the same size but do not contain any common items or material.
5. The total plant inventory is measured to ±0.2% and distributed so that when one-half is measured in a single MBA, it is measured to about ±0.28%.
6. For simplification, only random errors have been considered. In a real situation both systematic and random errors would need to be considered.
7. For simplification it has been assumed that there are no common measurements contributing covariance effects. In real situations such covariance effects would need to be considered.

Case I—Inventory-Dominated Process, Total Plant MBA

Beginning and Ending Inventories each:
250 kg ± 500 g
Input and Output each:
30 batches @ 2 kg ± 5 g = 60 kg ± 27.4 g

$$\text{LEMUF} = \sqrt{2(27.4)^2 + 2(500)^2} = \pm 708 \text{ g}$$

The single total plant MBA detection capability is therefore ±708 grams.

Case II—Inventory-Dominated Process, Parallel MBAs.

For each MBA:
Beginning and Ending Inventories each:
125 kg ± 354 g
Input and Output each:
15 batches @ 2 kg ± 5 g = 30 kg ± 19.5 g

$$\text{LEMUF} = \sqrt{2(19.5)^2 + 2(354)^2} = \pm 501$$

The detection capability has been improved from 708 grams for the single total plant MBA to 501 grams for each MBA. That is, a loss or theft of 501 grams in either MBA would have the same probability of being detected as a loss of 708 grams in the single total plant MBA.

The total plant LEMUF for the two parallel MBAs would be ±501 $\sqrt{2}$ = ±708 grams, the same as the single total plant MBA LEMUF. This is because no additional measurements were made, none of the measurements were improved by dividing the plant into two MBAs, and there were no common transfers between the MBAs.

Case III—Inventory-Dominated Process, Series MBAs.

For each MBA:
Beginning and Ending Inventories each:
125 kg ±354 g
Input and Output each:
30 batches @ 2 kg ± 5 g = 60 kg ± 27.4 g

$$\text{LEMUF} = \sqrt{2(27.4)^2 + 2(354)^2} = 502 \text{ g}$$

The detection capability for Case III is essentially the same as for the individual parallel MBAs (Case II). This would be expected because the inventory dominates and it is divided in half in each case. The total plant LEMUF does not change, even though there have been additional measurements made, i.e., for the transfer between MBAs. This transfer measurement is assumed to be the same for both MBAs. That is, the output measurement of MBA 1 is the input measurement of MBA 2. When the uncertainties of the two MBAs are combined to obtain the total plant MBA uncertainty, this transfer measurement is common and drops out of the equation for the total plant.

The assumption in this case was that the transfer measurement is as good as the input and product measurements. To the extent that this is not true, the individual MBA LEMUF is increased and the detection capability decreased. This effect becomes more pronounced as the absolute uncertainty of the transfer measurement increases. For example, if the uncertainty of the transfer measurement were the same as that of the inventory, i.e., 60 kg ± 354 grams (3% instead of the previously used 0.25%) the LEMUF of the individual MBAs would be ±614 grams. There would still be some advantage in dividing the plant into the series MBAs but not as much as when the transfers between MBAs could be measured with a precision approaching that of the input and product measurements.

It can be seen from Cases I, II, and III that striking a balance around portions of the inventory will increase the detection capability for each portion, but not for the total plant.

In Case I, if an actual loss of 708 grams had occurred, it would be expected that the MUF would exceed the LEMUF of ±708 grams part of the time. The probability of the MUF exceeding the LEMUF in this case could be calculated. When the MUF exceeds the LEMUF, an alarm is sounded and the high MUF is investigated as occurring somewhere in the total plant.

In Cases II and III the balance is taken around smaller areas so that the detection capability is improved to 502 grams for each area. If a loss or theft of 708 grams were to occur in either area, it would have a higher probability of detection since the LEMUF is only ±501 grams. In addition, if such a loss did occur, the area in which it occurred would be shown by the high MUF in that MBA so that the investigation could be confined to the smaller area. In order for a person to steal 708 grams of material with the same probability of success, i.e., being undetected, as in a single total plant MBA, portions of the material would have to be removed from two different MBAs or over a longer period of time in the same MBA. This would expose the thief to an increased probability of detection by the physical protection surveillance and alarm systems.

If a person were to steal 501 grams from each MBA of Case II or III the detection capability would be the same for each MBA as for theft of the 708 grams from the single total plant MBA. The total quantity stolen, however, would be so large that the total theft would have a higher probability of detection upon calculation of the balance for the entire plant. In the example, the combined LEMUF for the two MBAs would be ±708 grams but the MUF (i.e., material stolen) would be 1002 grams and probably would trigger an investigation. The location of the loss within the plant in this case may not be known because the MUF of the individual MBAs may not have exceeded the LEMUF.

Case IV--Throughput-Dominated Process, Total Plant MBA

Beginning and Ending Inventory each:
50 kg ± 100 g
Input and Output each:
30 batches @ 20 kg ± 50 g = 600 kg ± 274 g

$$\text{LEMUF} = \sqrt{2(274)^2 + 2(100)^2} = \pm 413 \text{ g}$$

Case V--Throughput-Dominated Process, Parallel MBAs

For each MBA:
Beginning and Ending Inventories each:
25 kg ± 71 g
Input and Output each:
15 batches @ 20 kg ± 50 g = 300 kg ± 194 g

$$\text{LEMUF} = \sqrt{2(194)^2 + 2(71)^2} = \pm 292 \text{ g}$$

The individual MBA detection capability has been improved from 412 grams to 292 grams. The total plant LEMUF will not change ($\pm 292\sqrt{2} = \pm 413$) because no additional measurements were made nor were any improvements made in the measurement of any of the balance components.

Case VI–Throughput-Dominated Process, Series MBAs

For each MBA:
Beginning and Ending Inventories each:
25 kg ± 71 g
Input and Output each:
30 batches @ 20 kg ± 50 g = 600 kg ± 274 g

$$\text{LEMUF} = \sqrt{2(274)^2 + 2(71)^2} = \pm 400 \text{ g}$$

There has been little gain in the detection capability over a total plant MBA because the throughput is the same for each of the two series MBAs as for a single total plant MBA. The little gain that is realized is due to the gain obtained by dividing the inventory in half. In addition, if the transfer measurement between MGAs in Case VI is not as good as the input and product measurements there may be a loss of detection capability. For example, if the precision of the transfer measurement for each batch is ±0.5% instead of ±0.25%, the uncertainty of this total transfer measurement becomes 600 kg ± 547 grams and the LEMUF for each MBA becomes ±780 grams. This is a poorer detection capability than the 412 grams for the single total plant MBA. The effect of this transfer measurement is more pronounced here than in Case III where the inventory dominated.