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NUCLEAR MATERIALS CONTROL AND
ACCOUNTABILITY CRITERIA FOR UPGRADES
MEASURES

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**NUCLEAR MATERIALS CONTROL AND ACCOUNTABILITY CRITERIA
FOR UPGRADES MEASURES**

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MC&A Criteria for Upgrades Measures

1. Introduction

As a result of major political and societal changes in the past several years, methods of nuclear material control may no longer be as effective as in the past in Russia, the Newly Independent States (NIS), and the Baltic States (BS). The objective of the Department of Energy (DOE) Material Protection, Control, and Accounting Program (MPC&A) is to reduce the threat of nuclear proliferation by collaborating with Russia, NIS, and BS governments to promote western-style MPC&A. This cooperation will improve the MPC&A on all weapons useable nuclear materials and will establish a sustainable infrastructure to provide future support and maintenance for these technology-based improvements.

Nuclear materials of proliferation concern include materials of the types and quantities that can be most easily and directly used in a nuclear weapon. Sabotage of nuclear material is an event of great concern and potentially disastrous consequences to both the U.S. and the host country. However, sabotage is currently beyond the scope of program direction and cannot be used to justify U.S.-funded MPC&A upgrades. Judicious MPC&A upgrades designed to protect against insider and outsider theft scenarios would also provide additional, although not comprehensive, protection against saboteurs.

This paper provides some suggestions to establish consistency in prioritizing system-enhancement efforts at nuclear material facilities. The suggestions in this paper are consistent with DOE policy and directions and should be used as a supplement to any policy directives issued by NN-40, DOE Russia/NIS Task Force.

2. Criteria for MC&A Measures in a Nuclear Facility

a. Definitions of MPC&A functions

For purposes of this discussion, we use the following definitions.

Physical Protection consists of measures to prevent the theft of nuclear material by "outsiders," i.e., people who do not have access to the nuclear facility because of their employment. This paper does not deal with physical protection.

Material Control consists of measures to prevent the theft of nuclear material by "insiders", i.e., people who have access to the nuclear facility because of their employment.

Material Accounting consists of measures to detect the loss of nuclear material. Materials accounting may deter the theft of nuclear material by insiders because of the risk of early detection.

There is a need to establish consistent criteria for implementing safeguards of nuclear material inventories in nuclear facilities in the former Soviet Union (FSU). These criteria will be outlined for material accounting and material control. These criteria will be used to evaluate a site for required upgrades in the safeguards system.

b. Criteria for selecting material control measures

Material control criteria should be based on the attractiveness of the nuclear material for theft by an insider. Categories of attractiveness are defined by the DOE and the International Atomic Energy Agency (IAEA). In Table I, a summary of the criteria are presented from the IAEA approach. The DOE approach is shown in Table II.

Table III shows material control measures for different levels of material attractiveness. The material attractiveness categories are taken from Table I.

The Tables are contained on pages 13-17.

Materials Control Measures for Materials in IAEA Category 3

Even the lowest level of material attractiveness defined by the IAEA requires a significant amount of materials control. Of the nine measures listed, five deal with controlling access to nuclear materials. These five measures are relatively inexpensive to implement and should be given high priority.

Portal monitoring should be implemented if employees have access to physically small nuclear material containers that can be concealed on their person. Because portal monitoring is relatively expensive, it should not be implemented in all facilities. Facilities that have low pedestrian traffic may use hand-held instruments rather than portal monitors. An example of low traffic would be less than ten people per hour at peak times.

Screening waste containers should be implemented in processing facilities to prevent the removal of significant amounts of material via waste streams. An example of a monitoring method would be to use a hand-held radiation instrument along with the weight limit of the waste container. The weight limit would deter the use of shielding material to prevent radiation detection.

All facilities should be encouraged to return highly enriched uranium (HEU) and plutonium to a protected vault when the material is not in use and not under personnel surveillance. Material in a vault is generally easier to control and account for than material in use.

Tamper indicating devices (TIDs) deter insider theft and simplify physical inventory procedures. TIDs are most effective when a small number of TIDs can be used on a large amount of material. Examples include use on critical assemblies or on doors to storage vaults.

Nuclear materials less attractive than IAEA Category 3 may require some materials control measures. For example, access control may be desirable for materials that are less attractive than IAEA Category 3. Also, amounts of HEU that are smaller than Category 3 should be returned to a locked vault when not in use.

Materials Control Measures for Materials in IAEA Category 2

For IAEA Category 2 materials, in addition to material control measures for Category 3 materials, the two-man rule is recommended. Vaults are alarmed for unauthorized access by using video monitors or motion sensors. Sensitive access areas are monitored by video surveillance.

Materials Control Measures for Materials in IAEA Category 1

For IAEA Category 1 materials, in addition to Category 2 measures, vaults are alarmed for unauthorized access by video monitors and motion sensors. Access to work areas may be

controlled by biometric sensors. In addition, records may be kept of personnel locations by material balance area (MBA).

Materials Control Measures for Weapons and Weapons Components

Depending on the overall safeguards system design, dual biometric sensors may be used on vaults to insure the two-man rule. This is in addition to material control measures for Category 1 materials.

c. Criteria for choosing material accounting measures

Types of Facilities and Materials Balance Areas

Different materials accounting measures are used for item and bulk nuclear material facilities. For this paper, we define an item facility as a facility in which there are no mechanisms for loss such as processing losses, but in which items may be divided or combined. A bulk facility is defined as a facility in which there are loss mechanisms due to non-recoverable waste, scrap, or holdup. According to these definitions, most reactors and storage vaults are item facilities. Fuel pellet fabrication plants and scrap recovery plants are bulk facilities. These definitions can be applied to both facilities and to materials balance areas. In Appendix 2 guidelines for scaling the accounting system with the size and complexity of the site are given.

Table IV shows material accounting measures that should be applied to all MBAs, to item MBAs, and to bulk MBAs. Note that Table IV describes what material accounting measures should be used, not how the measures should be applied.

Accounting Measures When Material Crosses an MBA Boundary

As shown in Table IV, all off-site shipments and receipts should be recorded for materials accounting purposes. It is common for shipments and receipts to take place via a central storage facility. Verification measurements should be performed soon after receiving materials. Table V outlines recommended methods and instruments for performing verification measurements. Confirmation measurements are less rigorous measurements that measure some attribute such as weight or radiation signature but not actual quantity. Verification measurements are more rigorous and provide an assay or quantity of nuclear material in the item measured.

All internal transfers in and out of MBAs should be recorded. Generally, material is in the form of items when it is moved from one MBA to another, i.e., nuclear material is not usually piped from one MBA to another.

When nuclear material moves across an MBA boundary, custody of the material changes, and two different nuclear materials custodians should approve the transfer. When an item moves across an MBA boundary (including shipments and receipts), the item's unique identification number or bar code is checked, the item is weighed, and either the net weight or container weight is recorded.

For item MBAs, when an item crosses the MBA boundary, either a confirmatory measurement (such as enrichment) or a verification measurement (mass and isotopic content) should be made. Generally, it will be easier to make a confirmatory measurement. For most storage facilities, it is not necessary to perform verification measurements.

For bulk MBAs, when an item crosses the MBA boundary, a verification measurement is required.

Measures Performed as Needed

The most important measure listed in Table IV is the first one listed under measures performed as needed. It involves setting up the MBA structure, defining key measurement points, and appointing nuclear materials custodians for each MBA. For simplicity in this document, item accountability areas are called item MBAs. Other accounting measures for both item and bulk MBAs include physical inventory taking, measurement control, internal audits, and reporting to the national system.

For item MBAs, frequent inventories should be taken of items not in a vault or not protected by other means. Items protected by high radiation fields (e.g., >100R/h at one meter), locks, or seals (such as items in a critical assembly protected by TIDs) need not be inventoried as frequently. For item MBAs in which items may be divided or combined, it is desirable to perform verification measurements on the new items. If this is not practical, weighing and confirmatory measurements should be used.

For bulk MBAs, bulk material should be converted to items, sealed with a TID, assayed, and returned to a vault whenever possible. It is desirable to perform verification measurements on bulk material that has undergone significant processing changes in order to identify process losses. For some bulk MBAs, it will be necessary to perform holdup measurements or to clean out processing equipment in order to "close the material balance." A material balance is closed at the end of an accounting period when all material transactions into or out of the MBA are accounted for. A statistical analysis of verification measurements must be made to determine if material has been removed from the process stream.

Threshold Amounts and Conversion Times

Appendix 1 shows threshold amounts (also called significant quantities) and conversion times (also called detection times) for different types and amounts of nuclear materials, as defined in the IAEA Safeguards Glossary, IAEA/SG/INF/1, 1980. IAEA, Euratom, and many national system inspections are designed to detect a missing threshold quantity of nuclear material within the conversion time. A threshold amount is defined in the Glossary as "the approximate quantity of special fissionable material required for a single nuclear explosive device." Conversion time is defined as "the time required to convert different forms of nuclear material to the metallic components of a nuclear explosive device."

Although numbers selected by the IAEA for threshold amounts and conversion times can be questioned, the concepts have proven useful for quantitatively describing the performance of materials accounting systems. The concepts can be used to establish physical inventory intervals, physical inventory sampling plans, and measurement accuracy. The performance of proposed Russian materials accounting systems should be evaluated using these concepts, and the facility operator (and the national system) should judge whether or not the performance is adequate.

Resource and financial considerations at large bulk facilities sometimes make it impossible to detect missing threshold amounts within the conversion times shown in Appendix 1. In particular, it would be cost prohibitive to install process monitoring systems in Russian production facilities.

3. A Process for Determining Upgrade Requirements

A team of Material Control and Accounting (MC&A) specialists would be established to implement the process for determining upgrade requirements for a candidate facility or site. Before upgrade requirements can be determined the pre-upgraded state of MC&A at the facility needs to be determined using the MC&A measures criteria presented in Section 2 of this document. The candidate facility needs to choose a facility team to work with the U.S. team on the survey. Fig. 1 describes the process for determining the upgrades requirements. The details of this process are described below.

a. Perform initial survey of facilities and operations with nuclear materials.

The first step in the process for determining upgrade requirements is to determine and identify all candidate nuclear material inventories that qualify under the DOE MPC&A program. All information that has been acquired under any site surveys performed by physical protection teams should be shared with the team performing the MC&A survey. The category and attractiveness of the target nuclear materials will determine not only the level of physical protection required to secure the material but will also determine the level of material control and accounting that is required to track and control the material inventories. The required elements of the site MC&A program may be defined in Russian requirements and may depend on the category of the material inventories. Note any inventories that do not qualify under this program. Make use of the criteria for attractiveness in Section 2 above.

b. Categorize the facility and nuclear material holdings.

Identify the process operations that occur. In this step, determine the primary functions of the facility being surveyed. In general, a facility can be categorized as one of two types: either an item facility or a bulk handling facility, or some of both. If it is determined that the facility is primarily an item facility, decisions can be made regarding requirements for accountability measurements and accounting as outlined in Section 2.b. In general, confirmation measurements may be adequate to confirm the presence of nuclear material in

Fig. 1
Outline of Process for Determining Upgrades

the items in the inventory. It may not be practical to require strict assay measurements to validate the quantities in all of the items whereas bulk facilities require stricter measurement standards and practices.

c. Determine the required elements of the site MC&A program.

After the facility is categorized, a determination of the required MC&A elements for the facility needs to be made. Guidelines from federal requirements and site-specific requirements should be used in making this determination. The important issues here are to identify missing or weak elements in the site program if possible and determine required upgrades to meet requirements. The upgrade options described in Section 5 below should be reviewed early in the process to identify any quick fixes. Simple identified upgrades may be implemented early on to improve the MC&A program.

d. Draft an MC&A framework or guide for the site.

This guide would include site responsibilities and authorities. This guide is a high-level document that describes in some detail what the site or facility is required to implement for the functions of nuclear material control and accounting at the site. This document does not describe how these functions are implemented. A procedures document will describe how in a later step of the process. The drafting of the MC&A framework will require some coordination between the U.S. side and the Russian/NIS side. If formal federal requirements for MC&A are available, this will address all of these requirements. Essentially this document describes what the facility or site has implemented or is going to implement to be in compliance with these requirements. During the process of drafting the document, a determination of missing elements of the MC&A program and necessary upgrades at the site is made.

e. Draft a site implementation guide for site authority approval.

After the site MC&A framework is drafted and approved, an implementation guide needs to be formulated. This implementation guide will describe in detail the priorities, the schedule, and the budget of all the identified MC&A elements that are to be added or upgraded. The DOE will be involved in the selection of upgrade options.

f. Implementation Phase—Draft of operational procedures for the site.

This is the implementation phase of the process. After agreements have been reached and task statements written, the actual work of upgrading the various elements of the MC&A program begins. During the implementation phase of the process, it is strongly recommended that the facility begin drafting the procedures manual or document that describes in some detail how the various MC&A functions are implemented to provide all the elements of an MC&A program for the site. This document describes the site-specific elements of the program and how they comply with the requirements. Details such as accountability measurement systems and measurements, inventory programs, TID programs, accounting systems, and surveillance systems should be included in this document. Performance tests and internal audit programs should also be addressed.

g. Audit and review the status of all upgrades and performance of the MC&A elements that are implemented.

Finally, the status of the program is determined with an internal audit, and the performance of the MC&A program, as upgraded, can be determined. Major deficiencies need to be

documented and corrective actions must be formulated and implemented. Periodic reviews and internal audits will be conducted to determine the performance of the program.

4. Site Description

The objective of the facility or site MC&A program/system is to control access to and movements of the inventories of nuclear materials and to verify that the physical protection system and the material control system are adequate to protect the materials. A comprehensive description of the site is essential when evaluating the material control systems that are in place. The understanding of operations with nuclear materials and an understanding of the physical facilities that contain the inventories of nuclear materials are necessary to understand all control features that have been implemented at the site. The site description should include details of access controls to buildings, nuclear material records and record systems, locations of storage facilities, and locations of measurement and accountability systems. Information that has been acquired during any physical protection surveys should be available to the MC&A survey team.

5. MC&A Upgrade Options

After the survey has been completed, the MC&A survey team will evaluate the findings and review the upgrade options that are appropriate. This will be a preliminary review before the other steps in the process have been completed. This early review may identify quick fixes that will provide cost-effective upgrades for early system enhancements. An example of this early review is to look at the potential for consolidating inventories of nuclear materials in order to minimize the complexity and expense of implementing MC&A upgrades. After the MC&A framework is drafted and an analysis of the existing MC&A system is completed, a comprehensive list of upgrades will be developed to address all deficiencies in the system. Upgrade options should include an understanding of available resources and obvious fixes that can improve the effectiveness of the system with the least cost. Prioritizing the upgrades should include evaluating the costs of the upgrades. The following is a list of options that need to be reviewed for possible upgrades at the site.

- Portal Monitors—includes radiation and metal detectors
- MC&A Organization—provides oversight of MC&A functions
- NDA Measurement and Survey Instruments—it is necessary for all material in the accounting system to be accurately measured
- Computerized Accounting Systems—see criteria in Section 2 above
- Physical Inventory Program—specifies frequency of inventories
- Material Surveillance—specifies methods for surveillance

After the upgrades are completed and U.S. funding diminishes, the site must be trained and committed to operate and maintain the upgraded system. Project teams should keep this in mind when designing and selecting system upgrades. Training in the use, maintenance, and operation of the installed upgrades should be included as part of the selection of the upgrades.

There can be some overlap between the physical protection and material control measures at a nuclear facility. The proposed upgrades in these two areas need to be coordinated to eliminate duplication or redundancy. For example, material surveillance may be appropriate for material control and also may be planned for physical protection systems. With proper coordination, each element of the facility MPC&A system can benefit from the proposed upgrades.

6. System Performance Testing

During the upgrade selection process and the preliminary evaluation of the MC&A system as upgraded, some thought needs to go into system performance testing. The performance of some elements of the system will be easier to quantify than others. For example, nondestructive assay equipment will be tested and evaluated as a part of their installation into the system. Portal radiation monitors will also be tested frequently. Other elements of the MC&A system such as the physical inventory program will require developed procedures for testing their effectiveness. These procedures should be a part of the process to develop the procedures manual for the site. Once these procedures are organized and implemented, it should be a routine matter to do the performance testing of the system.

7. Preliminary MC&A System Survey Checklist Questions

MC&A Management Structure

- Is there a site MC&A management organization with clear responsibility for MC&A functions independent from operations organizations?
- Is there an organization chart showing responsibilities and authorities?
- Is there a training and qualification program for the responsible MC&A organization?

Administrative Functions

- Is there a documented qualification/certification program for MC&A specialists?
- Are there required documents in the MC&A program?
- Are there documented procedures for all MC&A functions?
- Is there periodic review and revision of written MC&A procedures (documented)?
- Is there an independent assessment of facility MC&A program?
- Are there documented process descriptions and process flows?
- Are there documented material forms for all processes?
- Are all quantities of nuclear materials in all processes and storage areas documented?
- Is there a documented MBA and item control area structure for the site?
- Is there an MBA custodian system/organization in the facility?

Assay Measurement Functions

- Are there details of the documented accountability measurements program?
- Are qualifications and responsibilities of measurements personnel documented?
- Are authorized measurement methods and procedures at the facility documented?
- Is there a documented measurement control program for all measurement instruments?
- Is there a certification program for measurement instruments?
- Is there a calibration program for measurement instruments?
- Is there a standards program for measurement systems?
- Is there a training program for personnel involved in measurements and the measurement control program?

- Is there a facility audit program for measurements and the measurement control program?

Control Functions

- Is there a facility shipper-receiver evaluation program?
- Is there a facility material control program?
- Is there a formal physical inventory program for accountable nuclear material?
- Is there a documented statistical sampling plan for the physical inventory program?
- Is there a documented plan for managing holdup of nuclear material in the processes?
- Are there documented and approved procedures for physical inventory activities?
- Are there documented material control limits used for acceptance/rejection of the results of the physical inventory?
- Are there required actions if the physical inventory fails?
- Are there procedures for emergency inventory programs?
- Is there an independent audit program for the physical inventories?
- Are there documented accounting procedures and auditing of those procedures?
- Are there backup copies of critical records?
- Are there procedures for required reports generated/available from the accounting system?
- Is there a documented TID program?

Table I: INFCIRC/225/Rev. 3 Categorization of Nuclear Material for Protection Against Theft/Diversion

MATERIAL	FORM	CATEGORY 1	CATEGORY 2	CATEGORY 3 ³
Plutonium ¹	Unirradiated ²	≥ 2 kg	< 2 kg, ≥ 500 g	< 500 g
Uranium-235	Unirradiated ² -enriched $\geq 20\%$ ^{235}U -enriched $\geq 10\%$, $< 20\%$ ^{235}U -enriched, but $< 10\%$ ^{235}U	≥ 5 kg	< 5 kg, ≥ 1 kg ≥ 10 kg	< 1 kg, > 15 g < 10 kg, ≥ 1 kg ≥ 10 kg
Uranium-233	Unirradiated ²	≥ 2 kg	< 2 kg, ≥ 500 g	< 500 g, ≥ 15 g
Irradiated fuel*			Depleted or natural uranium, thorium, or low enriched fuel $\leq 10\%$ fissile content ^{4,5}	

* Based upon international transport considerations. The State may assign a different category for domestic use, storage, and transport taking into account all relevant factors.

1. All plutonium except that with isotopic concentration exceeding 80% in plutonium-238.
2. Material not irradiated in a reactor or material irradiated in a reactor but with a radiation level equal to or less than 1 Gy/h (100 rads/h) at one meter unshielded.
3. Quantities not falling in Category 3 and natural uranium, depleted uranium and thorium should be protected at least in accordance with prudent management practice.
4. Although this level of protection is recommended, it would be up to the States, upon evaluation of the specific circumstances, to assign a different category of physical protection.
5. Other fuel which by virtue of its original fissile material content is classified as Category 1 or 2 before irradiation may be reduced one category level while the radiation level from the fuel exceeds 1 Gy/h (100 rads/h) at one meter unshielded.

Table II: DOE Nuclear Materials Safeguards Categories

	Attrac- tiveness Level	PU/U-233 Category (Quantities in Kg)				Contained U-235 Category (Quantities in Kg)				All E Materials Category IV
		I	II	III	IV	I	II	III	IV	
Weapons Assembled weapons and test devices	A	All Quantities	N/A	N/A	N/A	All Quantities	N/A	N/A	N/A	
Pure Products Pits, major components, buttons, ingots recastable metal, directly convertible materials	B	≥ 2	$\geq 4 < 2$	$\geq 2 < 4$	< 2	≥ 5	$\geq 1 < 5$	$\geq 4 < 1$	< 4	
High-Grade Materials Carbides, oxides, solutions ($\geq 25\text{g/L}$), nitrates, etc.: fuel elements, and assemblies, alloys, and mixtures; UF4 or UF6 ($\geq 50\%$ enriched)	C	≥ 6	$\geq 2 < 6$	$\geq 4 < 2$	< 4	≥ 20	$\geq 6 < 20$	$\geq 2 < 6$	< 2	
Low grade Materials Solutions (1 to 25g/L), process residues requiring extensive reprocessing, moderately irradiated material, PU-238 (except waste), UF4 or UF6 ($\geq 20\%$ $< 50\%$ enriched)	D	N/A	≥ 16	$\geq 3 < 16$	< 3	N/A	≥ 50	$\geq 8 < 50$	< 8	
All other materials Highly irradiated forms, solutions ($\leq 1\text{ g/L}$), uranium containing $< 20\%$ U-235 (any form any quantity)	E									Reportable Quantities

Table III: Materials Control Measures for Different Levels of Material Attractiveness

Material Type	Foot- notes	Materials Control Measures
IAEA Category 3	p a p p,a a	<p>Portal monitors for radiation and metal detection.</p> <p>Waste containers screened for radiation and metal before discard.</p> <p>Locks on all areas where nuclear materials are located.</p> <p>Keys and combinations limited to those who have work-related responsibility in the area.</p> <p>Unescorted access limited to employees who have work-related responsibility in the area.</p> <p>Cleared escorts for all personnel who do not have work-related responsibility in the area.</p> <p>Return all HEU and Pu that is not in use and under personnel surveillance to a locked vault.</p> <p>Keys and combinations to vaults limited to a subset of employees who have work-related responsibility in the area.</p> <p>Apply TIDs to infrequently opened vault doors and nuclear material containers.</p>
IAEA Category 2	p p	<p>Add:</p> <p>Two-man rule applied for all material removed from vaults.</p> <p>Dual locks installed on vault doors to enforce two-man rule.</p> <p>Vaults alarmed for unauthorized access by using video monitors or motion sensors.</p> <p>Sensitive work areas monitored by video.</p> <p>Cranes alarmed or locked out to prevent unauthorized movement of fresh or spent fuel assemblies.</p> <p>Radiation monitors used to detect unauthorized movement of spent fuel.</p>
IAEA Category 1	p p	<p>Add:</p> <p>Vaults alarmed for unauthorized access by using video monitors <u>and</u> motion sensors.</p> <p>Access to work areas and vaults controlled by biometric sensors.</p> <p>*Records kept of personnel locations by MBA (these records may be based on biometric data, magnetic strip data, etc.).</p>
Weapons and weapons components		<p>Add:</p> <p>*Dual biometric sensors installed on vaults to insure two-man rule.</p>

Footnotes

- p These measures serve both materials control and physical protection objectives.
- a These measures serve both materials control and materials accounting objectives.
- * Optional measures that depend on overall safeguards system design.

Table IV: Materials Accounting Measures for Item and Bulk MBAs

Type of MBA	Measures performed when material crosses MBA boundary	Measures performed as needed
Either Item or Bulk MBA	<p>Check and record:</p> <ul style="list-style-type: none"> Item identification number or barcode TID Gross weight net weight and/or container weight Location Custodian <p>For shipments and receipts, also check and record</p> <ul style="list-style-type: none"> Receiving information or shipping information Passport data 	<p>Define item and bulk MBAs, key measurement points, and nuclear materials custodians for each MBA.</p> <p>Conduct periodic physical inventory verification.</p> <p>Maintain measurement control program.</p> <p>Perform internal audit of MC&A functions.</p> <p>Report to national system as required.</p>
Item MBA (no processing losses, but items may be divided or combined).	<p>Make and record either confirmatory** measurement(s) or verification** measurement.</p>	<p>Conduct frequent inventories of items not in vault or not protected by other means.</p>
Bulk MBA (possible processing losses)	<p>Make and record verification measurement of feed, product, and significant scrap and waste.</p>	<p>Make and record confirmatory or verification measurements when items are divided or combined.</p> <p>Convert bulk material to items and return items to vault when possible.</p> <p>Perform verification measurement before and after changes to material due to processing and when bulk material is converted to items.</p> <p>Perform process holdup measurements.</p> <p>Close materials balance and perform statistical analysis.</p>

*Shipments and receipts are treated as items.

**Confirmatory measurements determine an attribute of the material, such as enrichment.

Verification measurements determine mass and isotopic content used for materials accounting.

Table V: Verification Measurements Guidelines -- NDA Techniques

Nuclear Material	Isotope Measured	Measurement Approach
Pu metal and oxide	All Pu	Calorimetry-Gamma Isotopics
Pu metal and oxide	Pu-240	Neutron Coincidence Counter Neutron Multiplicity Counter
Pu metal and oxide scrap and waste	Pu-239	Segmented Gamma Scanner
	Pu-240	Neutron Coincidence Counter
Pu metal and oxide	Pu-239	Active Neutron Well Counter
HEU metal and oxide	U-235	Active Neutron Coincidence Counter Californium Shuffler Transmission-corrected Gamma
	% U-235	Enrichment Meter
HEU fuel pellets	U-235	Random Driver - Neutron
HEU fuel assemblies	U-235	Active Neutron Coincidence Collar
HEU scrap/waste	U-235	Californium Shuffler
UF-6 gas	U-235	Transmission-corrected Gamma
	% U-235	Enrichment Meter
UF-6 solid	U-235	Active Neutron Coincidence
LEU metal	U-238	Neutron Totals Well Counter
LEU metal and oxide	U-235	Active Neutron Coincidence
	% U-235	Enrichment Meter
LEU fuel rods	U-235	Active Fuel-Rod Scanner
LEU scrap/waste	U-235	Californium Shuffler

Appendix 1

Taken from IAEA Safeguards Glossary, IAEA/SG/INF/1

Material	Threshold Amount
Pu [Pu-239 > 95%]	8 kg Pu-239
U [U-235 > 90 - 95%]	25 kg U
U-233	8 kg U-233

Beginning material form

Conversion Time

Pu, HEU or U-233 Metal

Order of days
(7-10)

PuO₂, Pu(NO₃)₄, or other pure Pu compounds;
HEU or U-233 oxide or other pure compounds;
MOX or other non-irradiated pure mixtures containing
Pu, U [(U-233 + U-235) >= 20%]; Pu, HEU and/or
U-233 in scrap or other misc. impure compounds

Order of weeks
(1-3)*

Pu, HEU or U-233 in irradiated fuel**

Order of months
(1-3)

U containing < 20% U-235 and U-233, Th

Order of one year

* This range is not determined by any single factor, but the pure Pu and U compounds will tend to be at the lower end of the range and the mixtures and scrap at the higher end.

** Criteria for establishing the irradiation to which this classification refers are under review.

Appendix 2

Scaling the NM Accounting System with the Nuclear Facility

Introduction

Nuclear facilities that handle and process nuclear materials (NM) are required to track the NM holdings and keep adequate records to manage and control the inventory of those holdings. The complexity of the systems to do this job is related to the complexity of the operations with the NM. Accounting systems range from simple paper logs to complex computerized database management systems. Also the more complex the operations, the more complex the inventory of NM. In this discussion, there is an attempt to identify the minimum system that will provide the required functions with various types of facilities.

The NM operations being considered range from small storage facilities to highly complex NM processing facilities. The number of different facilities in this discussion will be limited to the following five types:

Type 1: This is a small storage facility with a small inventory of NM (<50 items). There are no complex operations in this facility. The inventory in this facility is very static with items remaining in storage for long periods of time. The facility has one MBA. The MBA is limited to ~1000 square feet of space (<10 moves per month).

Type 2: This is a moderate nuclear facility with a moderate inventory of NM but no processing or complex operations (<500 items). The facility serves a storage function with some moderate activity. The facility has one or two MBAs. The inventory is mainly static (<100 moves per month).

Type 3: This is a large storage facility with a large inventory of NM (>500 items but <10,000 items). There may be considerable measurement and inspection activity in this facility. There are no mechanisms for loss of material. The facility has several MBAs. The inventory is pretty static especially after it is filled. Material moves are restricted to the interior of the facility (<1000 moves per month).

Type 4: This facility is a modest processing facility with a large inventory and considerable activity (>10,000 items and <20,000 items). There could be several buildings in this facility. The inventory is not static. The operations with NM are complex. The facility has many MBAs. There are several mechanisms for loss of material (<10,000 moves per month).

Type 5: This is a large, complex processing facility with a large inventory and considerable activity with the materials (>20,000 items and <100,000 items). The inventory is very dynamic. The facility may have more than 100 MBAs. There are many mechanisms for loss of material (<50,000 moves per month). Examples of Type 5 facilities are Rocky Flats and Savannah River.

Requirements for facilities operating with inventories of NM

In the U.S. Department of Energy (DOE) complex there are DOE requirements that must be met before a contractor can engage in operations with NM such as plutonium and enriched uranium. These requirements include good control and accounting of all NM holdings at the contractor site. One such requirement states that "each facility shall have a system that

provides for tracking NM inventories, documenting NM transactions, issuing periodic reports, and assisting with the detection of unauthorized system access, data falsification, and material gains or losses. The accounting system shall provide a complete audit trail on all NM from receipt through disposition."

Discussion

The type 1 facility has no processing of material so items are not changed in form or content. With few items and little activity it is not difficult to track the inventory of items. A very simple accounting system using paper records or log books would be adequate for this operation. The function of the accounting system would be to track the few items that are stored in the MBA. Information relating to the contents of the items and the location of the items would be in the records. There is no need for complicated reports or retrieval of information. One custodian would be responsible for the inventory in the facility. This is the simplest operation with an inventory of NM that you could imagine.

The Type 2 facility contains a very static inventory without any processing. There may be a need to move items into an area for nondestructive assay measurements, but most of the time the items are in storage. There may be a few moves into and out of the facility. The operation is very simple and requires a simple accounting system to track the items in the inventory. A paper record system may be adequate, but a simple computerized filing/record-keeping system would be desirable. There would be little need for a sophisticated database management system. A simple database design with the capability to generate reports sorting the material by location and material type would be helpful. There may be enough complexity in the inventory items to make management of material forms and types difficult on a paper system. The function of the accounting system would be similar to the type 1 facility. One custodian would perform all the necessary record keeping functions for this facility. If the facility had two MBAs it could be desirable to have two custodians to manage the inventory.

The Type 3 facility has a considerable inventory of NM items (up to 10,000 items). It has a modest number of items, but is certainly more than a manual system can manage without some challenges. Operations in the facility include storage, measurements, physical inventories, and inspections of items. Most of the inventory is static but with such a number of items in the inventory there will be considerable movement of items throughout the facility. Tracking this size of inventory is an application for a modest computerized system. Using a database management system will eliminate excessive manpower to track and record movements and storage of this inventory. Also generating reports would be very difficult with a manual system. It is very time consuming to sort information manually when you are dealing with thousands of items in several MBAs. A computerized system with one to three work stations would be adequate for this facility. The functions of the accounting system include updating assay values for items, tracking, report generation, and searching for specific items. The report generation includes sorting items by material type, container type, location, and program codes. The accounting system should be able to handle information regarding other materials that may be in the items such as contaminants and nonaccountable materials of interest. The inventory is contained in a single building with several rooms and could have three or four MBAs. The database would be on one of the computers with a network connecting any other workstations to this central computer. Most of the computer transactions would be performed by one or at the most two people. There would probably be two or more custodians in this facility.

The Type 4 facility has a fairly large number of items to track and a number of complex operations including processing activities. This is not a static inventory. The processing operations are not on a production scale but rather on a research and development scale.

There may be more than one building in the facilities. Each building could have several MBAs. Movement of material would be between MBAs and/or between buildings. Tracking activities would be difficult with a manual accounting system. This type of facility would have one custodian per MBA and each custodian would have access to a computer work station. The accounting system would consist of a central database server and several work stations to accommodate the activities that would be required to update the database in a timely manner. A sophisticated database management system would be appropriate here, and a well-designed database to manage the information in the inventory would enhance the tracking, accounting functions, and reporting requirements of such a facility. The functions of the accounting system for this facility would include the functions for the Type 3 facility plus functions related to the complex processing of material. The new functions would include splitting and combining items, modifying an item's administrative data, and tracking chemical changes to the materials in the processing operations. Bulk handling of material would also have to be managed by the accounting system. There would be as many as 800 or so moves or transactions per day, and tracking all that activity would require a well-designed system. All of this transaction activity could be handled by the custodians and assistants to the custodians. One could easily imagine this being a full-time job for several people. The computerized system would be required to generate the various reports that would be needed by the custodians and the NM operations staff. An information system of this size becomes very valuable for NM operations staff in addition to NM accounting staff. Material management staff could also have a need for information in the system, and various NM management reports could be available too.

Type 5 facilities have a complex inventory of items and a complex number of production-scale operations. These facilities can range from a few buildings to a complex of buildings performing different operations with the NM. There would be a large number of MBAs and a large number of custodians. Each custodian would have one or more work stations available to accountability staff for the tasks of updating the database required for the site. It is still desirable to have a single central database on a single database server. This would eliminate the need for reconciling two or more databases. It is also desirable to have a near real-time accounting capability and this is easier to attain with a single central database. The magnitude of the job is greater than for Type 4 facilities but similar in function. The design of the database would be practically the same and the functions of the computerized system would be very similar. There would just be a much larger quantity of items to track and record. The more complex the operation, the more requirements there could be for reporting information, but the general design of the system would be similar to the design for the Type 4 facility. The computerized system would have to accommodate all of the different functions that are a part of the operation of a large complex facility. With a very large database and a large number of transactions taking place, it is very desirable to have a backup server available in the event of any failures in the primary system (There could be 1000-2000 transactions per day). This would be a modest investment to maintain availability of the accounting system under severe failure conditions. There would be enough work stations in the facility to provide backup in case of a work station failure. It would not be difficult for a custodian or assistant to use a backup work station in substitute of their normal work station.

Summary of Facility and Accounting System Criteria

Facility	#MBAs	# Inventory Items	#Moves per Month	Operations	Type of AS
Type 1	1	<50	<10	Storage	Manual Paper
Type 2	1-3	<500	<100	Storage	Automated Files
Type 3	3-10	>500;<10,000	<1,000	Storage, Measmts	Computer Database
Type 4	>10	>10,000;<20,000	<10,000	Storage, Processing	Advanced Computer DBMS
Type 5	>100	>20,000;<100,000	<50,000	Storage, Processing	Advanced Computer DBMS

Type of Accounting System	Hardware	Software
Manual paper system	None required	None required
Simple computer files	Modest personal computer	Simple file management system
Computerized DBMS	Small client-server system 1-3 clients	Simple DBMS
Advanced DBMS	Advanced client-server system 10-100 clients	Advanced relational DBMS