U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-2159
Revision 1

Acceptable Standard Format and Content for the Fundamental Nuclear Material Control Plan Required for Special Nuclear Material of Moderate Strategic Significance

Draft Report for Comment

Office of Nuclear Material Safety and Safeguards

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ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) regulations governing material control and accounting (MC&A) for licensees authorized to possess and use special nuclear material (SNM) of moderate strategic significance, sometimes referred to as a Category II quantity of material are in Subpart D, “Special Nuclear Material of Moderate Strategic Significance,” of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 74, “Material control and accounting of special nuclear material.”

SNM of moderate strategic significance means either of the following:

(1) less than a formula quantity of strategic special nuclear material but more than 1,000 grams of uranium-235 (contained in uranium enriched to 20 percent or more in the uranium-235 isotope) or more than 500 grams of uranium-233 or plutonium or in a combined quantity of more than 1,000 grams when computed by the equation:

grams = (grams contained uranium-235) + 2(grams uranium-233 + grams plutonium), or

(2) 10,000 grams or more of uranium-235 (contained in uranium enriched to 10 percent of more but less than 20 percent in the uranium-235 isotope)

This document provides a structure and information as one means of facilitating compliance with the following regulations about licensee or applicant preparation and implementation of its fundamental nuclear material control plan and corresponding NRC review and inspection:

- 10 CFR 74.41, “Nuclear material control and accounting for special nuclear material of moderate strategic significance”
- 10 CFR 74.43, “Internal controls, inventory, and records”
- 10 CFR 74.45, “Measurements and measurement control”

Such performance-based MC&A requirements, which cover all Category II quantities of material, replace the prescriptive approach that appeared previously in 10 CFR Part 70, “Domestic licensing of special nuclear material,” before the NRC consolidated these MC&A requirements in 10 CFR Part 74 in 2002 (67 FR 78130). This report presents recommendations for the acceptable format and content for those fundamental nuclear material control plans, which address the following:

- the performance objectives that must be met
- the MC&A system capabilities that must be achieved to meet those objectives
- the incorporation of checks and balances to detect falsification of data and reports that could conceal the theft or diversion of SNM
- basic commitments that should be made

CONTENTS

ABBREVIATIONS AND ACRONYMS

CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EI	ending inventory
FNMC	fundamental nuclear material control
HEU	high-enriched uranium
IAEA	International Atomic Energy Agency
ICA	item control area
ID	inventory difference
LEU	low-enriched uranium
MBA	material balance area
MC&A	material control and accounting
NDA	nondestructive assay
NRC	U.S. Nuclear Regulatory Commission
Pu	plutonium
PuO_2	plutonium dioxide
RSD	relative standard deviation
SEID	standard error of the inventory difference
SNM	special nuclear material
SRD	shipper–receiver difference
SQ	significant quantity
TID	tamper-indicating device
U-233	uranium-233
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
UO_2	uranium dioxide
wt %	weight percent

1 INTRODUCTION

The Atomic Energy Act of 1954, as amended, authorized the U.S. Atomic Energy Commission to regulate the receipt, manufacture, production, transfer, possession, use, import, and export of special nuclear material (SNM) to protect public health and safety and to provide for the common defense and security. The Energy Reorganization Act of 1974 transferred the licensing and related functions of the Atomic Energy Commission to the U.S. Nuclear Regulatory Commission (NRC).

Title 10 of the *Code of Federal Regulations* (10 CFR) Part 70, "Domestic licensing of special nuclear material," and 10 CFR Part 74, "Material control and accounting of special nuclear material," include the principal requirements for SNM licensing. 10 CFR 70.22(b) specifies that a Part 70 license application for specified types of SNM must contain a full description of the applicant's program for the control and accounting of such SNM to show how it will comply with the graded material control and accounting (MC&A) requirements of 10 CFR Part 74, Subparts C–E. This document suggests a standard format and content for use in preparing fundamental nuclear material control (FNMC) plans for facilities authorized to hold SNM of moderate strategic significance.

Licensees that possess SNM of moderate strategic significance are referred to as "Category II" licensees under the three-tier graded approach for MC&A in 10 CFR Part 74. Categories I, II, and III correspond to the three types of material defined in 10 CFR 74.2: formula quantities of strategic SNM, SNM of moderate strategic significance, and SNM of low strategic significance, respectively. The same categorization is used in 10 CFR Part 73, "Physical Protection of Plants and Materials." The graded approach for MC&A applies requirements for possession of SNM that are increasingly stringent from Category III to Category II to Category I. The requirements are risk-informed, considering the increased level of control needed for the types and quantities of material in each defined category. The general requirements in Subparts A and B of 10 CFR Part 74 apply to all SNM licensees. The specific requirements for Category II licensees are in 10 CFR, Subpart D, sections 74.41, 74.43, and 74.45.

Chapter 2 of this document describes the basis of the four general performance objectives of 10 CFR 74.41(a) and the MC&A system capabilities of 10 CFR 74.41(c) needed to meet the objectives. Chapters 3–11 address the system capabilities needed to maintain accurate, current, and reliable information on, and confirm the quantities and locations of, SNM in the licensee's possession. Chapters 12 and 13 address the system capabilities needed to promptly investigate and resolve anomalies indicating a possible loss of SNM and provide information to aid in the investigation and recovery of missing SNM. Chapter 14 addresses recordkeeping requirements. These chapters are intended to provide an outline for an acceptable FNMC plan for facilities authorized to hold SNM of moderate strategic significance.

This document contains guidance to licensees or applicants, and licensees may use this guidance when making changes to their existing approved FNMC plans. Comprehensive criteria are included as examples only. Each licensee or applicant should develop an MC&A system or an MC&A program[1] associated with its FNMC plan that

[1] The terms "MC&A system" and "MC&A program" are used interchangeably in this document.

considers the unique features of its operation. When additional guidance is available on particular topics, the acceptance criteria section includes an appropriate reference.

In preparing FNMC plans, licensees or applicants should consider the system capabilities specified in 10 CFR 74.41, "Nuclear material control and accounting for special nuclear material of moderate strategic significance"; 10 CFR 74.43, "Internal controls, inventory, and records"; and 10 CFR 74.45, "Measurements and measurement control." They should also consider the general performance objectives specified in 10 CFR 74.41(a). Because 10 CFR 74.41, 10 CFR 74.43, and 10 CFR 74.45 are performance-oriented regulations, they do not contain a detailed set of technical specifications. With this flexibility, licensees or applicants have many alternatives for how their overall MC&A system is designed, managed, and operated, which permits a risk-informed, performance-based approach that focuses on those MC&A activities most important to safeguards. Accordingly, this document does not cover all possible methods that a licensee or applicant might use to meet the MC&A requirements. Instead, it provides examples of acceptable MC&A approaches that may be used.

This guidance is intended for use by licensees, applicants, and the NRC safeguards licensing reviewers. Users should not regard acceptance criteria as rigid, fixed standards. That is, a lower effectiveness of one capability relative to a particular aspect is acceptable if there is a compensating system feature, or combination of features, that provides an overall effective safeguards system. In the final analysis, an NRC reviewer must find that the licensee's or applicant's FNMC plan provides reasonable assurance that it meets all applicable regulatory requirements.

Chapters 3–14 below discuss the contents of an FNMC plan. A typical FNMC plan consists of the main text (the body of the plan) and one or more annexes (or appendices). The contents of an approved FNMC plan will be made a condition of license in accordance with 10 CFR 70.32(c), and compliance with the FNMC plan commitments and pertinent procedures will be inspectable. In practice, adherence to its FNMC plan is set as a condition of the facility license. Commitments in the FNMC plan are therefore binding on the licensee. Explanations and discussions appearing in the body of the plan should be sufficiently detailed and precise so that NRC licensing reviewers, NRC inspectors, and licensee personnel responsible for developing and implementing the plan have a clear and common understanding of what the FNMC plan requires.

The annex (or appendix) of an FNMC plan should provide supplementary and general information about the facility and the MC&A system or MC&A program and subsystems (e.g., copies of blank record forms, site map, process diagrams, an example standard error of the inventory difference calculation). The annex will not be incorporated as a condition of license and will not be the basis for inspection. Thus, descriptions presented by the licensee or applicant to meet regulatory requirements must be in the plan itself, rather than the annex, and must provide adequate detail so as not to be largely dependent on examples or supplementary information in the annex for proper understanding. Procedures detailed in the annex may be changed without NRC approval or notification, provided that the changes do not degrade plan commitments and capabilities.

Preparation of an FNMC plan with this standard format will assist the NRC in evaluating the plan and in standardizing the licensing and review process. However, the NRC does not require conformance with the standard format. A licensee or applicant may use a different format if it provides an equal level of completeness and detail.

2 GENERAL PERFORMANCE OBJECTIVES, RELATED REQUIREMENTS, COMMITMENTS, AND ACCEPTANCE CRITERIA

General Performance Objectives

The general material control and accounting (MC&A) performance objectives applicable to all U.S. Nuclear Regulatory Commission (NRC) licensees authorized to hold special nuclear material (SNM) of moderate strategic significance are set forth in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 74, "Material control and accounting of special nuclear material," specifically in 10 CFR 74.41(a). The following information discusses the basis of these general performance objectives and the related requirements in Subpart D, "Special Nuclear Material of Moderate Strategic Significance," of 10 CFR Part 74.

1. Maintain accurate, current, and reliable information on, and confirm the quantities and locations of, SNM in the licensee's possession.

The purpose of this objective in 10 CFR 74.41(a)(1) is to verify the presence of all SNM held by the licensee and to detect the occurrence of any significant loss, including possible theft or diversion. To maintain current information on all such SNM, licensees should have in place a program that provides timely, accurate, and reliable information about the quantity and location of SNM in their possession. Accurate information means that quantities for plutonium, the element uranium, and the isotopes uranium-235 (U-235) and uranium-233 (U-233) are based on measured values or on reliable information. Reliable information means that the quantity and location of all SNM is known, except for items that can be exempt from the item control program as specified in 10 CFR 74.43(b)(6). The location designations must be specific enough to provide for the retrieval of items in a prompt manner. Reliable information also means that the quantities and locations of all nonexempt SNM material, and items listed in the accounting records, are correct and verifiable.

The licensee or applicant should accurately account for all SNM that is received and shipped by maintaining reliable records based on accurate measurements. When a shipment is received, the licensee or applicant should begin monitoring the movement and location of the material within the facility using item control procedures (1) to monitor the location and integrity of items until they are processed, and (2) to ensure all SNM quantities of record associated with receipts, shipments, discards, and ending inventory are based on measurements. Chapter 8 of this document includes recommendations for meeting the requirements for the item control program, and Chapters 4 and 5 describe measurements and measurement control programs, respectively. Monitoring the material in process may involve the use of process or material control data. Licensees and applicants should maintain a detailed and accurate recordkeeping system for the generated data that provide knowledge of the material's location in a timely manner.

The licensee or applicant must conduct total plant physical inventories at intervals not to exceed 9 calendar months, in accordance with 10 CFR 74.43(c)(7). It must conduct each physical inventory in a manner such that the detection of any actual significant loss, including possible theft or diversion, would be assured by evaluating each inventory difference (ID) using a standard error of the ID that is less than 0.125 percent of the active inventory. As a result, the investigation and reporting of any ID that exceeds three times the standard error of the ID is equivalent to a

hypothesis test that provides 90-percent power for detecting a discrepancy as small as 0.4 percent of active inventory at a 5-percent false alarm rate.

The licensee or applicant should verify the presence of all SNM held under license, as documented in its accounting records. This verification is normally accomplished by the following means:

- a shutdown and cleanout of processing equipment

- measurement of cleanout materials and measurement of any materials not previously measured in their existing form

- visual verification (on a 100-percent basis) of the presence of all possessed SNM items(by means of unique item identities)

- confirming the SNM quantities associated with unencapsulated and unsealed items on ending inventory

However, a dynamic (i.e., nonshutdown) inventory of some or all processing equipment, and in particular for uranium enrichment facilities, may be used if the measurement uncertainty associated with the total material balance (for the inventory period) is within the 0.125 percent of active inventory constraint specified in 10 CFR 74.43(c)(8)(iii) and 10 CFR 74.45(c)(4).

Chapter 7 of this document details recommendations for physical inventories. In summary, a total plant physical inventory involves the following:

- verifying the presence, on a 100-percent basis, of all uniquely identified SNM items listed in the accounting records

- measuring (by direct measurement or, if direct measurement is not feasible, by indirect measurement) all bulk SNM quantities on hand (i.e., all SNM not in item form)

- measuring any items not previously measured

- verifying the identity and integrity of all encapsulated items and items affixed with tamper-indicating devices

The physical inventory program should be managed and maintained independent of the production or operations organization, but it should not be excluded from using process monitoring and production control data.

2. Conduct investigations and resolve any anomalies indicating a possible loss of SNM.

3. Permit rapid determination of whether an actual loss of a significant quantity of SNM has occurred, with significant quantity being either—

i. more than one formula kilogram of strategic SNM; or

ii. 10,000 grams or more of uranium-235 contained in uranium enriched up to 20.00 percent.

As discussed further in Chapter 12, to meet the requirements of 10 CFR 74.41(a)(2) and (3), the licensee or applicant should have a formalized program to promptly investigate and resolve any anomaly that may indicate a possible loss of SNM. Resolution of such anomalies means that the licensee or applicant has made a rapid determination of whether an actual loss of a significant quantity of SNM has occurred, including possible theft or diversion. An anomaly detected during a material balance closure needs to be investigated and resolved in accordance with 10 CFR 74.43(c)(8)(iii).

Resolution of an anomaly depends on the type of indicator. Various types of anomalies at plants could occur from a wide range of possible underlying scenarios (e.g., from unidentified or inadequately monitored loss mechanisms, simple theft, or complex diversions). The investigation and resolution process should begin with a thorough review of the MC&A records to locate obvious errors. These might include omissions of entire items, incorrect entries to computer programs or records, transcription errors, incorrect estimates of the amount of holdup in equipment, or calculation errors. A detailed examination of the MC&A records for each material type should identify gross errors. The next stage in the resolution process would be to isolate the process or storage area that appears to be causing the anomaly. Once this is done, all of the information that contributed to the SNM quantities for that location should be verified. If resolution still is not accomplished, the licensee should remeasure and sample material in the process or storage areas to verify quantities. If the investigation of an indicator results in a determination that an actual loss or theft has occurred, the loss or theft must be reported to the NRC in accordance with 10 CFR 74.11, “Reports of loss or theft or attempted theft or unauthorized production of special nuclear material.”

To achieve these objectives with regard to uranium enrichment facilities, a licensee’s or applicant’s program should include monitoring process operations and personnel and process-related activities to detect the unauthorized production of enriched uranium. The monitoring program is to ensure that licensees or applicants establish an adequate detection program, independent of production, that provides assurance of detecting (1) the unauthorized production of SNM of moderate strategic significance, to the extent of uranium enriched to more than 20 percent of U-235, and (2) the unauthorized production of uranium of low strategic significance. The overall design of this monitoring program should include an analysis of potentially credible means by which unauthorized production could occur; that is, for each conceivable and credible scenario for unauthorized production, a surveillance or an enrichment monitoring system for the timely detection of that scenario should exist.

4. Generate information to aid in the investigation and recovery of missing SNM in the event of an actual loss.

If the NRC or other government agency deems it necessary to conduct an investigation of actual (or highly suspected) events concerning missing material, the licensee or applicant should provide any information it deems relevant to the recovery of material involved in a loss, theft, or diversion, in accordance with 10 CFR 74.41(a)(4). The burden shall be on the licensee or applicant to provide all information that it recognizes as being relevant, as opposed to providing only information that the investigators request. Chapter 13 provides additional information and recommendations concerning the provision of information to aid in investigations.

Incorporating Checks and Balances

In addition to the 10 CFR 74.41(a) general performance objectives, which focus on the prevention of material loss or theft, licensees or applicants authorized to hold SNM of moderate strategic significance must, in accordance with 10 CFR 74.41(c), be able to detect the falsification of data and reports that could conceal the diversion of SNM by (1) a single individual, including an employee in any position, or (2) collusion between two individuals, one or both of whom have authorized access to SNM. The MC&A program needs to protect against a single insider, providing that such an individual does not have authority within the physical protection system that would permit him or her to participate in a conspiracy aimed at defeating the safeguards system. If an MC&A individual does have authority within the physical protection system, the MC&A program is required to protect against the coverup of a collusion of that individual with any other individual having MC&A authority. To address collusion concerns, the licensee or applicant would need to protect an MC&A function performed by a worker without physical protection system authority against a single insider. This approach should allow licensees or applicants to provide adequate controls without requiring a totally redundant system while still maintaining the ability of the MC&A program to provide an extra level of independent protection and an added measure of assurance that the safeguards system as a whole has not been compromised.

Commitments and Acceptance Criteria Pertaining to General Performance Objectives

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria for the general performance objectives and corresponding system capabilities. The FNMC plan should state these commitments.

Chapters 3–14 list the commitments and acceptance criteria. The following chapters of this document incorporate and expand on the performance objectives specified in 10 CFR 74.41(a) and the system capabilities specified in 10 CFR 74.41(c). The chapters are arranged in a format and sequence to provide licensees and applicants an outline for the required FNMC plan.

3 MANAGEMENT STRUCTURE

3.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(b)(1) through (4) is to require licensees or applicants to implement a management structure that permits effective functioning of the material control and accounting (MC&A) system or program and assures that the MC&A program performance will not be adversely affected by the plant management structure. Documentation, review, and approval of critical MC&A procedures, and the assignment of the key functions to specific positions, eliminate ambiguities about what is to be done by whom. The management structure is meant to separate key MC&A functions from each other to incorporate checks and balances that increase MC&A system reliability and make the theft or diversion of special nuclear material (SNM) less likely. It is also meant to free MC&A management personnel from conflicts of interest with other major functions, such as production.

3.1 Corporate Organization

Licensees or applicants should describe the corporate structure and should identify all corporate organization positions that have responsibilities related to MC&A at the licensee's or applicant's site. This should include a description of the corporate-level functions, responsibilities, and authorities for MC&A program oversight and assessments. At least one corporate official should have responsibility for the control and accounting of all SNM possessed by the licensee or applicant.

3.2 Plant or Site Organization

Licensees or applicants should describe the site's management structure, emphasizing MC&A. Regulations in 10 CFR 74.43(b)(2) require that a single individual be responsible for the overall planning, coordination, and administration of MC&A functions. The site management structure should be described to the extent that it can be clearly shown that the MC&A organization is independent of potentially conflicting responsibilities. This description should also indicate how responsibilities are assigned for the following functions:

- overall MC&A program
- SNM custodianship
- receiving and shipping of SNM
- analytical laboratories
- bulk and nondestructive assay measurements
- sampling operations
- measurement control program
- physical inventories
- onsite SNM handling operations

Licensees or applicants should briefly describe each site-level position, outside of the MC&A organization, that has responsibilities for MC&A activities (e.g., sampling, mass measurements, analytical measurements, and measurement control). For each position, licensees or applicants should clearly describe the functions, responsibilities, and authorities.

3.3 Material Control and Accounting Organization

Licensees or applicants should provide an organizational chart and position-by-position description of the entire MC&A organization. Licensees or applicants should designate an individual as the overall manager of the MC&A program, and the FNMC plan must demonstrate the assurance of independence of action and objectivity of decision for the MC&A manager. Two options for meeting the organizational independence are for the MC&A manager to (1) report directly to the plant or site manager, or (2) report to an individual who reports to the plant or site manager through a management chain with no production responsibilities.

3.3.1 Responsibilities and Authority

Licensees or applicants should clearly indicate the responsibilities and authority of each supervisor and manager for the various functions within the MC&A organization. The description should indicate how the activities of one functional unit or individual serve as a control over, or checks on, the activities of other units or individuals. The FNMC plan should explain how coordination is achieved and maintained between the MC&A organization and other plant organizational groups that perform MC&A-related activities. Licensees or applicants should make a definitive statement specifying how the MC&A manager assures appropriate review and approval for all written procedures pertaining to MC&A-related activities and to any future revisions thereto, which are issued both within and outside of the MC&A organization. In addition to the MC&A manager function, the plan should address, at a minimum, the following functions:

- nuclear material accounting
- measurement control program
- item control program
- physical inventory
- statistical applications

Whenever more than one key MC&A function is assigned to the same person, the FNMC plan should clearly describe the checks and balances that prevent the following:

- performance of accounting or record control functions by individuals who also generate source data

- assignment of sole authority to any individual to overcheck, evaluate, or audit information for which he or she is responsible

For individuals in management or supervisory positions, some modifications to procedures, such as restricting unescorted access to some areas, may be necessary to provide sufficient assurance that the system cannot be compromised.

3.3.2 Material Control and Accounting Procedures

Licensees or applicants are required by 10 CFR 74.43(b)(3) to provide for the review, approval, and use of written MC&A procedures that are critical to the effectiveness of the MC&A system and identify such procedures in the FNMC plan. Critical MC&A procedures are those written procedures that, if not performed correctly, could result in a failure to achieve one or more of the performance objectives of 10 CFR 74.41(a), and the system capabilities of 10 CFR 74.41(c). A

licensee's or applicant's development of its critical MC&A procedures, and any changes later made to them, should involve technical review by cognizant personnel, be approved by line management directly affected, and be approved by a level of management above the level responsible for executing the procedures. The FNMC plan should contain a definitive statement that the procedures will be followed. This set of critical MC&A procedures should, at a minimum, include those addressing the following topics, regardless of which facility organizational group is responsible for the particular topic:

- accountability record system
- sampling and measurements
- measurement control program
- item control program
- physical inventories
- tamper-safing
- investigation and resolution of loss indicators
- determining standard error of inventory difference (ID), active inventory, and ID
- shipments and receipts
- shipper–receiver comparisons
- providing information to aid in investigations
- MC&A recordkeeping
- independent assessment of the effectiveness of the MC&A program

3.4 <u>Training and Qualification Requirements</u>

This section of the FNMC plan should describe the training programs to be established and maintained to provide both qualified personnel and the continuing level of qualification with respect to personnel assigned to MC&A responsibilities.

The training program should ensure that the individuals assigned key MC&A positions (i.e., those involving tasks for which mistakes could directly degrade the safeguards capabilities of the MC&A system) are trained to maintain a high level of safeguards awareness and are adequately prepared to perform their functions correctly with a minimum of errors in accordance with 10 CFR 74.43(b)(4). The list of key positions or functions should include all those for which errors or faulty performance could directly degrade SNM control and accounting. These include MC&A management positions and individual contributor positions having responsibility for key measurements, data analysis, preparation of accountability source documents, and collecting or recording of other data having a direct impact on loss detection, alarm response, and quality assurance functions.

The training program should be structured to define job requirements, establish minimum qualifications for candidates, train and qualify the candidates, and define requalification criteria. The description of the program should identify the training program structure, source of instructional material, and general training objectives. The description should discuss training procedures and qualification criteria in definitive statements. It should state the minimum qualification requirements for each key MC&A position.

3.5 Material Control and Accounting Program Description

The length of this section and its level of detail will depend on the information provided in the previous sections of this chapter. The overall MC&A organization should be described in a way that explains how the general performance objectives of 10 CFR 74.41(a) and the system capabilities of 10 CFR 74.41(c) will be effectively achieved.

The individual who has responsibility for each of the following MC&A-related functions should be specified by title:

- overall MC&A program management (note that this individual should have no major responsibilities not related to MC&A)
- measurements (note that responsibility may be divided based on type of measurements (e.g., analytical laboratory measurements, nondestructive assay measurements, bulk measurements, and sampling)
- measurement control
- statistics
- accountability records
- item control
- physical inventories
- custodial responsibilities (e.g., SNM storage and movement controls)
- investigation and resolution of indicators that suggest possible loss of SNM
- receiving and shipping of SNM
- analytical laboratories
- MC&A recordkeeping system and controls

The MC&A program description should include the policies, instructions, procedures, duties, responsibilities, and delegation of authority in sufficient detail to demonstrate the separation of duties or overchecks built into the program.

3.6 Material Control Boundaries

This section of the FNMC plan should describe how the licensee or applicant establishes various material control boundaries to minimize the occurrence, and facilitate resolution, of MC&A anomalies, such as IDs, missing items of SNM, and potential theft or diversion of SNM.

The FNMC plan should describe the establishment of the facility’s internal control areas, because they are the basis for the control and accounting for all nuclear material in the facility. For example, an internal control area may be designated a material balance area (MBA) or item

control area (ICA). (The Glossary contains definitions of these terms.) An MBA or ICA should correlate to physical or administrative boundaries and monitored locations. The MBA or ICA should be designed to limit losses to a specific area (i.e., the MBA should not be so large that it cannot localize inventory or process differences to a manageable level). Materials transferred between internal control areas must have quantitative measurements.

The FNMC plan should also describe roles and responsibilities of nuclear material custodians for the internal control areas (the Glossary defines “custodian”). The material custodian should have direct interaction with the MC&A organization and should be located within the physical operations area. Custodians who are responsible for more than one internal control area should not have the ability to make material transfers between internal control areas under their direct control.

3.7 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to management structure. The staff’s regulatory finding that the licensee’s or applicant’s FNMC plan for management structure is acceptable and in accordance with the internal control requirements of 10 CFR 74.43(b)(1) through (4) will be informed by the following acceptance criteria:

- The authorship, approval authorizations, and effective dates of MC&A policies and procedures will be documented and will involve appropriate management and technical staff.

- The responsibilities and authorities for each position assigned a function having a significant impact on SNM control and accounting (including all positions authorized to control SNM movement, generate source data, define or implement measurement control requirements, and conduct data analysis) are clearly defined in a written position description that spells out the responsibilities for that position.

- The qualifications and experience required for each position assigned an SNM control and accounting function will be sufficient to permit adequate performance of the duties required of that position.

- The description of training and qualification shows that individuals who work in key positions where mistakes could degrade the effectiveness of the MC&A system are trained to a high level of safeguards awareness.

- The descriptions of the management structure and assignment of duties and authorities show that those responsible for each MC&A function will have sufficient authority to perform the function in the intended manner.

- The MC&A organization is separate from the production organization and also separate from organizations that generate source data, if practical; otherwise, independence of the functions is attained by suitable controls and overchecks.

- The responsibility for MC&A program management is designated to an individual at an organizational level sufficient to assure independence of action and objectiveness of decisions.

- No two key MC&A functions are assigned to the same person unless sufficient checks and balances are provided. To satisfy this criterion:

  - Individuals who generate source data, such as those performing measurements or performing shipping and receiving activities, do not perform any accounting or record control functions unless suitable overchecks are provided to prevent falsification of both source data and accounting records.

  - No individual has the sole authority to overcheck, evaluate performance, or audit information for which he or she is responsible.

- The responsibility for each MC&A function is assigned to a specific position in the organization, and the organization is structured in a way that the key functions are separated or overcheck one another. The position descriptions are available in writing to the personnel affected.

- All current critical MC&A procedures are made easily accessible to all affected individuals and are maintained to show the following for each procedure:

  - revision number
  - date issued
  - person who prepared the procedure
  - person who approved the procedure (as indicated by signature and date signed)

- Management policies are established, documented, and maintained to ensure that all critical MC&A procedures are adhered to, including measurement procedures used for accountability purposes.

4 MEASUREMENTS

4.0 Regulatory Intent

The intent of the measurement capability requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) 74.45(b) is to ensure licensees or applicants establish, maintain, and use a program for the measurement of all special nuclear material (SNM) received; produced; transferred between internal control areas; on inventory; or shipped, discarded, or otherwise removed from inventory, except as specified in 10 CFR 74.45(b)(1). The requirements ensure that all quantities of SNM (both element and fissile isotope) in the licensee's or applicant's accounting records are based on reliable measurements.

The measurement requirements in 10 CFR 74.45(b)(1) apply to all SNM of moderate strategic significance subject to the following four exceptions:

(1) sealed sources that have each been determined by other means to contain less than 10 grams of uranium-235 (U-235), uranium-233 (U-233), or plutonium

(2) samples received, transferred between internal control areas, or on inventory that have each been determined by other means to contain less than 10 grams of U-235, U-233, or plutonium

(3) receipt of sealed sources, of any quantity, that were previously manufactured and shipped by the licensee, and that are returned to the licensee, provided the unique identity and encapsulation integrity have not been compromised and the booked receipt quantity equals the previously shipped quantity for the sealed sources in question

(4) heterogeneous scrap that cannot be accurately measured in its as-received form, provided such scrap is measured after dissolution within 18 months of receipt, and the after-dissolution measurement must include measurement of both the resulting solution and any undissolved residues before any comingling with other scrap solutions or residues

Further, 10 CFR 74.45(b)(2) requires licensees or applicants to maintain and follow a program for the development and use of written measurement procedures, including the documented review and approval of such procedures, and any revisions thereof, before use. The provisions of 10 CFR 74.45(b)(2) specify that these procedures must cover (1) preparing or acquiring, maintaining, storing, and using reference standards, (2) calibrating measurement systems, performing bulk mass and volume measurements, conducting nondestructive assay (NDA) measurements, obtaining samples, and performing laboratory analyses for element concentration and fissile isotope abundance, and (3) recording, reviewing, and reporting measurements. Section 4.4 provides guidance on the measurement procedures below.

4.1 Measurement Points

The FNMC plan should identify and describe each measurement that is used for accounting purposes. Measurements (1) establish the quantities in each internal control area, material balance area (MBA), or item control area (ICA) and in the facility, and (2) contribute to the desired capability to localize losses and to generate and assess alarms. Measurement points or

sampling stations should be selected to provide quantitative information about material flows and inventories that will permit detection and localization of any loss or diversion or to confirm that no theft or diversion has occurred.

Typically, three functional types of internal control areas such as designated MBAs and ICAs are present: (1) processing, (2) storage, and (3) receiving and shipping. Typical processing MBAs include (1) processing areas, (2) decontamination and recovery areas, (3) laboratory areas, and (4) feed and product sampling and transfer areas. The licensee or applicant should identify and define the measurement points for processing MBAs because of the physical or chemical changes of the nuclear materials that occur in these MBAs. The storage and the receiving and shipping areas are typically ICAs.

4.2 Measurement Systems

The FNMC plan should describe in detail each measurement system used for nuclear material accounting purposes. The principal elements and operations involved in the measurement systems for MC&A encompass mass (or weight) or volume determination, sampling, chemical analyses for elements and isotopes, and NDA. Each measurement system also should be defined or identified by its unique set of the following parameters: (1) measurement device or equipment used, (2) standards used for calibration, and (3) standards used for control. Additionally, for analytical laboratory measurements, the following should be identified, as well: (1) sampling technique and equipment used, (2) sample aliquoting technique, and (3) sample pretreatment methodology. Chapter 5 describes elements of the measurement control program (e.g., standards traceable to a national system) used for validating and determining control limits, precision, and accuracy levels for each measurement system used for accountability.

The FNMC plan should describe each measurement system associated with bulk, analytical, and NDA measurements and should identify, where applicable, any other measurement systems used for accounting purposes that do not fall within these categories. These descriptions should provide sufficient information to demonstrate how the systems are implemented to ensure the licensee's or applicant's capability to meet the precision and accuracy limits. The following sections provide examples of the types of information necessary for selected measurement systems.

4.2.1 Bulk Measurement Systems

For each weighing system, the licensee or applicant should specify the type of weighing device, the type of container(s) weighed, material within the containers being weighed, capacity of the weighing device (e.g., capacity not to exceed X kilograms), range to be used, sensitivity of the device (e.g., sensitivity is +/- Y grams), and the calibration frequency.

For each volume measurement system, the FNMC plan should identify the vessel (e.g., tank, column), capacity of the vessel to which the measurement applies (e.g., capacity not to exceed X liters), the material being measured, the volume measuring device and instrumentation, the sensitivity of each device and system (e.g., sensitivity is +/- Y milliliters), the range of operation or calibration (or both), and the calibration frequency.

4.2.2 Analytical Measurement Systems

For each analytical measurement system, the FNMC plan should specify the following:

- type of material or chemical compound (e.g., plutonium oxide (PuO_2), plutonium metal or alloy, uranium dioxide (UO_2), mixed UO_2 and PuO_2 oxides, uranium hexafluoride, uranium alloy, uranyl nitrate solution) being sampled and measured
- sampling technique(s)
- sample handling (i.e., preanalysis sample storage and treatment)
- analytical method used
- characteristics measured (e.g., grams of uranium or plutonium per gram sample, or U-235 or U-233 isotopic content)
- measurement interferences
- expected measurement uncertainty
- types of calibration standard(s) and calibration frequency

4.2.3 Nondestructive Assay Measurement Systems

For each NDA measurement system, the FNMC plan should identify the following:

- the NDA equipment package (i.e., type and size of detector and type of associated electronics and computer interface, as appropriate)
- the type of container measured
- SNM material type within container
- sampling technique(s), if applicable
- attribute measured
- measurement configuration (including source to detector distance)
- calculation method
- expected measurement uncertainties

4.2.4 Other Measurement Systems

If applicable, the FNMC plan also should identify any other measurement systems used for accounting purposes that do not fall within the three categories covered by Sections 4.2.1, 4.2.2, and 4.2.3.

4.3 Measurement Uncertainties

Licensees or applicants should provide the expected measurement uncertainties of the described measurement systems. Variance components for calibration, sampling, random, and systematic error for each measurement system should be stated. Licensees or applicants should clearly identify the units in which the errors are expressed. Chapter 6 of this document contains further information on measurement uncertainties.

4.4 Measurement Procedures

The licensee or applicant should define how it ensures that it establishes, approves, and maintains measurement procedures (i.e., methods). It can accomplish this by (1) making a definitive statement that it establishes and maintains an approved measurement procedures (i.e., methods) manual, or a set of approved manuals, (2) stating which organizational units are responsible for the preparation, revision, and approval of measurement procedures, and (3) defining the requirements for periodic review of the procedures.

Licensees and applicants should make a clear statement defining how their facilities ensure that a measurement procedure cannot be used for accountability purposes without documented approval. Each procedure should be approved by the overall MC&A manager and by the manager of the organizational unit responsible for performing the measurement. The measurement control program manager should also approve measurement procedures.

The FNMC plan should provide a definitive statement that all SNM quantities in the material accounting records are based on measured values and that measurement systems are maintained for the measurement of SNM associated with the following:

- additions to inventory (e.g., receipts)
- removals from inventory (e.g., shipments and measured discards)
- material on ending inventory

For receipt of material, the licensee or applicant may use the shipper's measured values rather than its own measurements, provided that (1) a shipper–receiver comparison, based on attributes or confirmatory measurements, shows no significant shipper–receiver difference (as defined by 10 CFR 74.43(b)(7)), (2) in the case of a significant difference between shipper and receiver, no significant difference exists between the shipper's value and the umpire value used to resolve the difference, or (3) the material in question is exempted from shipper–receiver comparison requirements (e.g., sealed sources and samples). However, when booking shipper's values, a licensee or applicant should use the shipper's measurement uncertainty when determining the standard error of the inventory differences.

4.5 Scrap Control

Heterogeneous scrap that cannot be accurately measured in its received form need not be measured until after dissolution within 18 calendar months of receipt. In accordance with regulations in 10 CFR 74.45(b)(1)(iv), the after-dissolution measurement must include both the resulting solution and any undissolved residues before any comingling with other scrap solutions or residues. In the meantime, a licensee or applicant should use the shipper's value or an appropriate factor-based value for inventory purposes.

4.6 <u>Commitments and Acceptance Criteria</u>

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to measurements. The following are acceptance criteria for assuring that all quantities of SNM are based on reliable measurements and in accordance with 10 CFR 74.45(b):

- A program of measurement procedures and methods is maintained for all SNM receipts, movements, removals, and inventory items, and the licensee or applicant has based all quantities of SNM in the material accounting records on measured values.

- A list of measurement systems that are the key contributors to the total measurement standard error is maintained. These are considered key measurement systems, and the measurement control program should monitor and control their standard deviations. The licensee or applicant should review annually and update the list of measurement systems as necessary.

- A basic description or summary of all measurement systems used to generate SNM values for accountability purposes is provided. A measurement system is defined as any instrument or device, or combination of devices, used to derive (1) an element concentration, (2) an isotope quantity, (3) a U-235 enrichment or isotopic distribution, (4) a bulk material mass (weight), or (5) a bulk material volume. This measurement system can be characterized by its random and systematic error components.

- For accounting practices, the set of key measurement systems, based on recent (or anticipated) measurement control data and modes of process operations, is expected to account for at least 90 percent of the total measurement uncertainty contribution to the standard error of the inventory difference.

When determining an SNM quantity by weighing, sampling, and analyses, the net weight of material in each item within a uniform material batch (or lot), such as blended PuO_2 or UO_2 powder, plutonium metal, or sintered UO_2 pellets must be determined by direct mass measurement. However, the element or isotope concentrations for the batch need not be determined for each container but instead may be derived by sampling procedures, including the following:

- analysis of composite samples or measurements of representative items, objects, or samples selected by statistical sampling

- use of concentration or enrichment factors determined from historical averages, controlled input specifications values, or empirical relationships where such values or relationships are periodically tested, their uncertainties or bounds have been determined to be within 2 percent of the factor value, and diversions with material substitution are improbable.

5 MEASUREMENT CONTROL PROGRAM

5.0 Regulatory Intent

The intent of the measurement control requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) 74.45(c) is to ensure that a formal measurement control program controls measurement systems (described in Chapter 4) used to establish special nuclear material (SNM) accountability quantities. A measurement control program for material control and accounting (MC&A) monitors and controls the quality of measurements of SNM. Quality is monitored by collecting data from which the current precision and accuracy of measurements (and consequently, the systematic and random errors) can be evaluated. Quality control is ensured by evaluations, reviews, and other administrative measures for control of selection of design of facilities, equipment, and measurement methods and the training and qualification of personnel who perform SNM measurements. Close control of SNM measurement quality is needed to ensure that a loss, theft, or diversion of SNM will not be masked by either a bias or excessive random error in the measurement data.

5.1 Organization and Management

The organization and management of the measurement control program should be described in sufficient detail to show how licensees assign the measurement quality assurance function and how independence from the analytical laboratory and other units performing either sample taking or measurements is maintained. The measurement control program manager should be at a sufficiently high management level to ensure objectivity and independence of action in accordance with 10 CFR 74.45(c)(1). The individual assigned the responsibility for planning, developing, coordinating, and administering the measurement control program should have no direct responsibility for performing measurements or for SNM processing and handling. Thus, the measurement control program manager could either report directly to the overall MC&A manager or, if in a different organizational unit, be on the same level as the MC&A manager.

The licensee’s or applicant’s measurement control program should be properly managed to ensure adequate calibration frequencies, sufficient control of biases, and sufficient measurement precision to achieve the capabilities required by 10 CFR 74.45(c).

5.1.1 Functional Relationships

The relationship and coordination between the measurement control program manager, the analytical laboratory, and other measurement performing groups need to be clearly defined. Adequate assurance should be provided so that the measurement control program manager has the authority to enforce all applicable measurement control requirements.

5.1.2 Procedures

The measurement control program procedures should be established, maintained, and kept current and readily available. The licensee or applicant should specify who has responsibility for preparation, revision, and approval of the measurement control and measurement quality assurance procedures. Individual measurement control procedures should have documented approval by the measurement control program manager. The procedures should address the following:

- calibration frequencies and methods
- standards used for calibration (i.e., description and storage controls)
- standards used for control (i.e., method of obtaining or preparation, and traceability)
- control standard measurements
- replicate sampling and replicate measurements
- verification of process control instrumentation through comparison with other process instruments
- generation and collection of control data
- control limits and responses
- recordkeeping controls and requirements

5.1.3 Contractor Program Audits and Reviews

If an outside contractor (i.e., an offsite laboratory) provides measurement services using measurement systems that are not under the licensee's measurement control program, the review program used to monitor the offsite measurements should be described. The licensee or applicant should ensure that the contractor or offsite laboratory performing such measurement services has an acceptable measurement control program to the extent that use of the contractor's measurements will not compromise the licensee's or applicant's ability to meet any measurement or measurement control requirement in its fundamental nuclear material control (FNMC) plan. In accordance with 10 CFR 74.45(c)(2), the licensee or applicant must ensure that the contractor or offsite laboratory conforms with applicable requirements in 10 CFR 74.45(c)(5), (6), (7), (10), and (11). Conformance must include reporting by the contractor or offsite laboratory of sufficient measurement control data to enable the licensee or applicant to calculate bias corrections and measurement uncertainties.

The licensee should conduct an initial review of the applicable measurement control program before using measurements performed by the contractor or offsite laboratory. All contractor or offsite laboratory assessment findings and recommendations should be documented and submitted to both the measurement control program manager and the overall MC&A manager within 30 days of completion of the review. The two managers should agree on any necessary corrective actions to take based on their evaluation of the report, and they should transmit these findings to the contractor or offsite laboratory in writing. The licensee or applicant should not use measurements performed by such contractors or offsite laboratories until it has verified that the corrective actions have been instituted.

The persons who conduct a contractor review need not be employed by the licensee; however, they should not be employed by, or in any way be associated with, the contractor or offsite laboratory so that the independence of the conclusions may be maintained.

5.2 Replicate Sampling

The licensee or applicant is required by 10 CFR 74.45(c)(7) to conduct control measurements to provide current data for the determination of random error behavior. Random error is determined by evaluating current data generated during each material balance period from replicate analyses of samples. The FNMC plan should describe the replicate sampling program, which must include the following, as appropriate:

- replicate analyses of individual samples
- analysis of replicate process samples
- replicate volume measurements of bulk process batches
- replicate weight measurements of process items and bulk batches, or alternatively, the use of data generated from the replicate measurements of nondestructive assay (NDA) control standards as derived from the control standard program

The licensee or applicant should ensure that replicate samples are independent of one another. The number of replicate samples measured for each analytical measurement system should be described. The number of replicate samples measured for each analytical measurement system during an inventory period should be equal to at least one of the following:

(1) 100 percent of the accountability batches sampled (when less than 15 batches)

(2) the greater of 15 samples or 15 percent of the accountability batches sampled

(3) 50 samples (when 15 percent of the batches is greater than 50)

For nonkey analytical measurement systems, the minimum number of replicate samples to be measured during an inventory period should be equal to one of the following:

(4) 100 percent of the accountability batches sampled (when less than eight batches)

(5) the greater of eight samples or 10 percent of the accountability batches sampled

(6) 25 samples (when 10 percent of the batches is greater than 25)

For each measurement system involving sampling and analysis, the FNMC plan should indicate (1) how many samples are taken and measured for each accountability batch measurement, and (2) how many analyses are performed on each accountability sample. If two or more samples are used and the licensee performs one or more analyses per sample for each accountability batch measurement, replicate requirements are automatically met. If, however, one sample per batch is normally used for accountability purposes, the replicate program should include a periodic taking of a second (i.e., replicate) sample.

For NDA and mass (weight) measurement systems, replicate data can be obtained either from the repeat measurements on production items or by using the data generated from the control standard program. That is, each consecutive pair of control standard measurements (for a given NDA or mass system) can be regarded as a replicate pair. The minimum number of replicate

measurements performed during an inventory period for a given key NDA or mass system should be as given in items (1), (2), or (3), above, except that the numbers or percentages are in terms of items measured, rather than batches sampled. Likewise, for nonkey NDA and mass measurement systems, the minimum number of replicate measurements should be as given in items (4), (5), or (6) above.

The scatter in the repeat measurements is used to estimate the random error variance using a statistical technique known as the one-way analysis of variance.[2] Replication not only improves the precision of results obtained from the statistical analysis of the measurement data, it also can detect gross errors in the data.

5.3 Current Data

The measurement control program must produce current data on the performance of each measurement system used during each material balance period, as required by 10 CFR 74.45(c)(5). The program data are used to establish measured values and estimated measurement uncertainties, including estimates of bias, variance components for calibration, sampling, and repeated measurements. The program data must reflect the current process and measurement conditions existing at the time the control measurements are made.

5.3.1 Calibrations

The FNMC plan should summarize the licensee's or applicant's calibration program and confirm that the licensee or applicant has written procedures covering the following topics:

- calibration frequency for each measurement device or system

- identification of the standards used to calibrate each measurement device or system

- protection and control of standards used to calibrate measurement systems to maintain the validity of their certified or assigned values

- the range of calibration for each measurement device or system and the minimum number of calibration runs (observations) needed to establish a calibration

- repeating of calibrations whenever any significant change occurs in a measurement system or when program data indicate a need for recalibration

All calibrations are made with the use of primary standards or primary reference materials (certified and issued by the National Institute of Standards and Technology, New Brunswick Laboratory, or equivalent organization) or with reference standards traceable to primary standards. The standards used for calibrations need not be representative of the unknowns to be measured by the system, unless they are to be regarded as a bias-free system that is calibrated during each time of use, in which case the calibrations standards must be representative.

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[2] The U.S. Nuclear Regulatory Commission (NRC) recommends the statistical methods described in NUREG/CR-4604, "Statistical Methods for Nuclear Material Management," issued December 1988, for satisfying the statistical requirements of 10 CFR 74.45, "Measurements and measurement control." Chapter 6 of this document contains further information.

The recalibration frequency for each measurement system should be compatible with its expected stability. Recalibrations for all measurement systems should be performed at frequencies compatible with widely established, or licensee-demonstrated, stability for each particular system. Furthermore, in accordance with 10 CFR 74.45(c)(6), calibrations must be repeated whenever there is a significant change in a measurement system or when program data indicate a need for recalibration.

Unlike control standards, standards used for calibrating measurement systems need not be representative of the process material or items to be measured by the calibrated device or system. If practical, the standard used during the calibration process should be subjected to all the steps involved in the measurement process that the process unknowns are subjected to (e.g., sample pretreatment), but this need not always be the case. The primary measurement device, not necessarily the entire measurement system, needs to be calibrated, especially when the primary measurement device is common to two or more measurement systems.

For example, the Davies & Gray titrimetric method (American Society for Testing and Materials (ASTM) Standard C1267-17) is often used to analyze samples for uranium concentration of two or more different material types (e.g., uranium hexafluoride, uranium dioxide, uranyl nitrate hexahydrate solutions). In this case, more than one measurement system is involved because different sampling and sample pretreatment methods and different control standards are used. The potassium dichromate titrant, however, is common to the systems; thus, the titrant is what is calibrated (or standardized) with a primary reference material such as certified potassium dichromate, certified urano-uranic oxide, or certified uranium metal.

In the case of nonconsumable standards used to calibrate measurement systems (e.g., weight standards), the frequency of recertification of assigned values should be specified. The recertification frequency should depend on how often the standards are handled, the standard's stability, and the adequacy of the controls used to maintain the integrity of the standards. The NRC usually considers biennial recertification of such standards to be acceptable.

The FNMC plan should contain a definitive statement that no SNM accountability value is based on a measurement that falls outside the range of calibration. The FNMC plan also should identify those measurement systems that are point calibrated. A point-calibrated measurement system is one in which the following are true:

- The entire measurement system is calibrated with a standard or set of standards that is representative of the process unknowns that the system measures. That is, the representative calibration standard(s) undergoes all the measurement steps, and in the same manner, that the unknowns undergo.

- One or more calibration standards are processed and measured along with each unknown or set of unknowns measured. That is, the system measures both the standard(s) and unknown(s) during the same general time interval, with the same individual measuring methods.

- The measurement values assigned to the process unknowns are derived from the measurement response observed for the standard(s) that was measured along with the unknown(s).

- The measurement response for each unknown should fall within plus or minus 10 percent of the response for a standard measured at the same time as the unknown, or, as in the case of a low concentration unknown, the difference between the unknown's response and the standard's response should be less than four times the standard deviation associated with the standard's response.

5.3.2 Control Standards

For those measurement systems that are not point calibrated, a defined method for the periodic measurement of control standards should be established and followed. Control standard measurements serve the dual purpose of (1) monitoring the stability of a previously determined calibration factor, and (2) estimating the average system bias over a period of time (e.g., an inventory period). Licensees or applicants need to specify the minimum total number of control standard measurements during the time period, as well as the typical frequency, for each measurement system.

Key measurement systems (as discussed in Chapter 4 and defined in the Glossary) for the current inventory period are any set of designated measurement systems (of the licensee's or applicant's choosing) that, based on the most recent previous period, account for at least 90 percent of the total measurement variance contribution to the standard error of the inventory difference (SEID)(See the SEID definition in 10 CFR 74.4). Included within the set of key measurement systems should be any system used to measure an SNM quantity (during an inventory period) greater than 25 percent of the active inventory, regardless of its contribution to SEID (Chapter 6 contains more information on SEID).

Generally speaking, for each key measurement system, a minimum of two control standard measurements should be made during each week that the system is in use. For those key systems that are used infrequently during a given material balance period, more than two control standard measurements per week of system use may be necessary to provide a measurement system performance that is controlled such that the SEID will not exceed 0.125 percent of the active inventory.

The minimum number of control standard measurements for any system used to measure an SNM quantity (during an inventory period) greater than 25 percent of the active inventory should be determined based on the system's characteristics, use, and frequency of control standard measurements. In any case, it should be greater than eight (i.e., the minimum number of control standard measurements may need to be set at a higher number than eight to ensure proper performance). The minimum number of control standard measurements is eight for nonkey measurement systems that measure from 10 to 25 percent of the active inventory, and the minimum number of control standard measurements can be reduced to four, respectively, for those nonkey systems used to measure less than 10 percent of the active inventory quantity.

Control standards must be representative of the process material or items being measured. To be representative, the standards need not always be identical to the process unknowns, but any constituent of the process material, or any factor associated with a process item, that produces a bias effect on the measurement should be present to the same degree in the control standards. For scales used to weigh very large items, the control standard weights should be artifact standards (e.g., both empty and full containers) of certified mass to avoid a bias effect caused by buoyancy or point loading.

For each measurement system that is not point calibrated, the control standards licensees or applicants should use for control standard measurements should be identified and described. Along with material composition and matrix factors, changes in (among other things) temperature, humidity, line voltage, and background radiation can also induce biases. Biases also can be operator or analyst induced. Therefore, the scheduling of control standard measurements should be based on the following considerations:

- Does the variation between analysts or operators need to be considered and monitored?

- Can environmental variables contribute to measurement bias?

- Is bias likely to vary with respect to the time of day?

- Is a particular bias likely to be long term, short term, or cyclic in nature?

- Is bias a function of the process measurement values over the range of calibration (i.e., the relative percent bias nonuniform over the range of calibration)?

- What controls or procedures are needed to ensure that sampling or aliquoting of the control standard is representative of the sampling or aliquoting of the process material?

- To estimate the bias for each measurement system, how much alike—in terms of chemical composition, uranium concentration, density, homogeneity, and impurity content—should the control standards be, relative to the process unknowns?

5.4 Statistical Control System

The FNMC plan should describe the statistical control system established and maintained to monitor the quality of each measurement device or system, in accordance with 10 CFR 74.45(c)(10). The statistical control system should include control charts and formal statistical procedures. The licensee or applicant should establish both 0.05 (warning) and 0.001 (out-of-control) limits to use for control standard measurements for those measurement systems used for nuclear material accountability, in accordance with 10 CFR 74.45(c)(10).

When a system generates a control measurement that falls beyond an out-of-control limit, the system should not be used for accounting purposes until it has been brought back into control (i.e., within the upper and lower warning limit).

Control limits should be recalculated at a predetermined frequency and modified, if required. The FNMC plan should clearly explain how control limits are established and the frequency for redetermining them.

5.4.1 Measurement Control Data Analysis

Licensees or applicants should plot measurement control data, such as control standard measurement results, and the differences between measurement values of replicate pairs for the generation of control charts. All control charts should be reviewed at least once every 2 weeks unless a measurement system was not used during that period. The review should assess the frequency of control data exceeding either the warning or the out-of-control limits and also evaluate any significant trends.

5.4.2 Response Actions

The licensee or applicant must ensure that, whenever a control datum exceeds a 0.05 control limit, or whenever a control datum exceeds a 0.001 control limit, each occurrence is promptly investigated and appropriate corrective actions are taken, in accordance with 10 CFR 74.45(c)(11). Either the analyst or the operator performing a control measurement or his or her supervisor should be responsible for promptly reporting any control measurement that exceeds a warning or out-of-control limit. Such reporting should be made to the measurement control program manager (or his or her designee), who should have the responsibility and authority to carry out or direct the necessary response and corrective actions.

Minimum response and minimum corrective action requirements should be clearly defined. In addition, the measurement control program manager (or his or her designee) should be responsible and have the authority for determining and executing additional response and corrective actions, as deemed appropriate.

The minimum response to a reported incident of a control measurement exceeding an out-of-control limit should consist of the following steps:

(1) Verify that the measurement system in question has been taken out of service with respect to accountability measurements.

(2) Document the occurrence of the event.

(3) Perform at least two additional control measurements.

(4) Perform additional control measurements, if results of item 3 do not show the system to be back in control, using a different control standard or different replicate sample (as appropriate), recalibrating the measurement system, or making any necessary system repairs.

(5) Review measurements performed on the system in question since the last within-control run to determine if there is a need to remeasure any items.

For those measurement systems that make a significant contribution to the SEID, the response to an out-of-control condition should also include the remeasurement of any samples (or items) the licensee measured before the out-of-control condition but after the last within-control measurement. The validity of the previous measurements may be established without a complete remeasurement of all the samples (or items) involved if remeasurement on a “last in, first out” basis is used. That is, the last sample (or item) measured before the out-of-control measurement should be the first to be remeasured, and the review should continue in reverse order until two consecutive remeasurements agree with their initial measurement at the 95-percent confidence level.

5.5 Sampling

Sampling materials is the process of selecting a subset or part of the entire population of material from a tank or container to represent a batch, lot, shipment, or inventory stratum in analyses or tests. The process of sampling and preparing samples for analyses may involve other steps, such as compositing, splitting (subdividing), drying, blending, grinding, and screening. An

understanding of the properties of the material and its degree of homogeneity is necessary before a good sampling procedure can be established. Random selection procedures should be used to obtain samples that are representative of the population being sampled.

5.5.1 Sampling Tests

The FNMC plan should describe how the licensee or applicant ensures that samples are representative by performing process sampling tests, as required by 10 CFR 74.45(c)(3). These sampling tests should use well-characterized materials to establish or verify the applicability of used procedures for sampling SNM and for maintaining sample integrity during transport and storage. The sampling tests or sample integrity tests, as appropriate, must be conducted whenever all of the following occurs:

- A new sampling procedure or technique is used, or new sampling equipment is installed.

- A sampling procedure, technique, or sampling equipment is modified to the extent that a systematic sampling error could be introduced.

- Sample containers, sample transport methods, or sample storage conditions are changed or modified to the extent that a systematic sampling error could be introduced.

5.5.2 Sampling Errors

Any of the many steps that may occur between selecting the sample items and making the final measurements can contribute to sampling error. The FNMC plan should also describe how potential sources of sampling error are identified, as required by 10 CFR 74.45(c)(3). Potential sources of error may include the following:

- heterogeneity of the material sampled
- changes in composition of samples during sample taking and preparation
- contamination or dilution of samples in sampling equipment
- improper design or malfunctioning of sampling and mixing equipment
- failure of operators to follow prescribed procedures

Sampling errors can be controlled by continual monitoring and by establishing accurate sampling procedures. The performance of operators should also be monitored to ensure that procedures are followed.

5.6 <u>Standard Error of Inventory Difference</u>

The measurement control program must ensure that, for each inventory period, SEID is less than 0.125 percent of the active inventory. All of the measurements and measurement controls generated during the current material balance period must be used to estimate SEID. Using appropriate statistical methods, all measurement system data generated must be evaluated to determine significant contributors to the measurement uncertainties associated with inventory differences as well as shipper-receiver differences. The FNMC plan should provide all relevant information on the determination of SEID. Chapter 6 of this document contains further information on the determination of measurement uncertainties and SEID.

5.7 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to the measurement control program. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for maintaining measurement quality and estimating measurement uncertainty values is acceptable and in accordance with 10 CFR 74.45(c) will be informed by the following acceptance criteria:

- The responsibility for planning, developing, coordinating, and administering the measurement control program is assigned to an individual with adequate authority and independence of action to obtain all the information to monitor and evaluate measurement quality.

- Any contractor that performs MC&A measurements on behalf of the licensee or applicant has an acceptable measurement control program determined by review and evaluation of the contractor's conformance to the agency's requirements for measurement control. The licensee or applicant should confirm that the contractor's measurement control program is adequate by conducting audit and assessment reviews of the contractor's program at intervals not to exceed 18 months.

- Potential sampling errors are identified, and representative samples ensured by performing sampling tests using well characterized materials to establish or verify the applicability of sampling procedures and for maintaining the sample integrity during transport and storage. The sampling tests are conducted whenever a new sampling technique, procedure, or equipment is used or installed, or an existing sampling technique, procedure, or equipment is changed.

- A measurement control program is established and maintained so that, for each inventory period, the total measurement standard error is less than 0.125 percent of the active inventory quantity, and any MC&A measurements performed under contract are controlled so that the licensee can satisfy this requirement.

- Current data are generated for each measurement system used during each material balance period and reflect the current process and measurement conditions and all errors that impact the inventory difference estimate.

- All measurements and measurement control data generated during the material balance period is used to estimate SEID, including estimates of bias, and variance components for calibration, sampling, and replicate measurements.

- Calibration and control standards are used on an ongoing basis for the calibration and control of all measurement systems used for SNM accountability.

- Routine control measurements are conducted to determine random error behavior, which includes evaluation of data generated from a replicate sampling program.

- Significant contributors to the measurement uncertainties associated with inventory and shipper–receiver differences are determined by evaluating all current measurement system data with appropriate statistical methods, including estimates of bias, and variance components for calibration, sampling, and replicate measurements.

- The quality of each measurement device or system is monitored by establishing and maintaining a statistical control system, including control charts and formal statistical procedures.

- Investigations are conducted and appropriate corrective action is taken whenever a control datum exceeds the 0.05 control limit. Whenever a control datum exceeds the 0.001 control limit, the measurement system is immediately taken out of service with respect to MC&A measurements until the deficiency has been corrected and the system brought back into statistical control.

6 STATISTICS

6.0 Regulatory Intent

Proper use of statistics is important for ensuring that licensees and applicants meet the regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) 74.41, "Nuclear material control and accounting for special nuclear material of moderate strategic significance"; 10 CFR 74.43, "Internal controls, inventory, and records"; and 10 CFR 74.45, "Measurements and measurement control." To achieve the performance objectives and system capabilities of 10 CFR 74.41 and related 10 CFR 74.43 and 10 CFR 74.45, each licensee or applicant should institute a statistical program that evaluates the MC&A data to ensure that (1) the data are analyzed in a rigorous manner and (2) statistical tests and inferences concerning the status of the nuclear material possessed are appropriately tested. An effective statistical program will ensure measurement systems perform within control limits, measurement uncertainties are calculated and propagated, the inventory difference (ID), active inventory (AI) and standard error of the inventory difference (SEID) are properly determined, and significant shipper–receiver differences (SRDs) are identified. For example, 10 CFR 74.43(c)(8)(i) requires licensees to calculate the ID and SEID for the material balance period terminated by each physical inventory. Proper use of statistics is important to correctly propagate the uncertainties from all measurements into an accurate SEID value.

The NRC sponsored the development of a comprehensive reference that specifically addresses the statistical treatment of MC&A data. The NRC recommends the statistical methods described in NUREG/CR--4604, "Statistical Methods for Nuclear Material Management," issued December 1988, as well as in TID-26298, "Statistical Methods in Nuclear Material Control," issued December 1973, and International Atomic Energy Agency (IAEA)/SG/SCT/5, "Statistical Concepts and Techniques for IAEA Safeguards," issued 1998, to satisfy the statistical requirements of 10 CFR 74.41, 10 CFR 74.43, and 10 CFR 74.45.

6.1 Determination of Measurement Uncertainties

Each measurement system used for quantitative determinations of a batch of nuclear material or an item has a degree of measurement uncertainty associated with its measured value. Measurement uncertainty is interchangeably called measurement error. Measurement uncertainties may originate from the following:

- bulk measurements for weight and volume quantities
- analytical techniques to determine the uranium element concentration, uranium-235 (U-235) isotope content, uranium-233 (U-233), and plutonium
- sampling techniques to determine the uranium element concentration, U-235 isotope content, U-233, and plutonium
- nondestructive assay (NDA) techniques to determine the U-235 isotope content
- measuring techniques to determine the enrichment process gas pressures (uranium enrichment facilities)

Because NDA measurement uncertainties do not rely on bulk or element values, NDA uncertainties are regarded as U-235 analytical variances. Pressure measurement uncertainties are regarded as bulk measurement determinations.

Measurement uncertainty is estimated by measuring standards and making replicate measurements. Measurement uncertainties have the potential to greatly affect the ID. Statistical evaluation becomes necessary to determine if the calculated ID represents actual missing nuclear material or only measurement variance. Repeating the measurement of a sample or an item produces measurement results that are distributed randomly about the mathematical mean of the set of values.

Measurement uncertainties are expressed in terms of variances and standard deviation. Variance is the expectation of the squared deviation of a random set of data from its mean value. Statistical variance gives a measure of how the set of data distributes itself about the mean or expected value. Unlike range that only looks at the extremes, the variance looks at all the data points and then determines their distribution. The variance of a set of measurements is defined as the square of the standard deviation of the distribution. It is mathematically the sum of the squares of the deviations of the randomly distributed values from the mean of the data set divided by the number of values around the mean. The variance of a sample is defined by the following formula:

$$var\,(x) = s^2 = \sum_{i=1}^{n} \left(x_i - x_{avg}\right)^2 / (n-1)$$

Where: s^2 = the sample variance

x_i = the i_{th} value from the sample

x_{avg} = the sample mean

n = the number of values in the sample

The variance is equal to the square of the standard deviation s. The standard deviation of the finite set of values is an estimate of the population standard deviation σ. Because the variance is computed using the square of the deviation from the mean, it is heavily influenced by larger deviations.

Measurement error values are typically expressed as relative standard deviations (RSDs). RSD, or the coefficient of variation, is used to determine if the standard deviation of a set of data is small or large when compared to the mean, so RSD can tell how precise the average of the results is. The higher the RSD, the more spread out the results are from the mean of the data. A lower RSD means that the measurement of data is more precise. RSD is expressed in percent and is obtained by multiplying the standard deviation by 100 and dividing this product by the average as follows:

$$RSD = \frac{s}{x_{avg}} \times 100$$

Where: RSD = relative standard deviation expressed as a percent

x_{avg} = mean value of the set of values

s = standard deviation of the mean of the set of values

6.1.1 Types of Measurement Uncertainty

Measurement errors may be classified as either random or systematic, depending on how the measurement is obtained. When attempting to estimate the error of a measurement, it is often important to determine whether the sources of error are systematic or random. For example, a measurement instrument could cause a random error in one situation and a systematic error in another. The total variance of a measurement consists of two types of uncertainty, the random error and the systematic error, or bias.

Random error is estimated by running replicate measurements. Random error is the variation encountered in all measurement activities, characterized by the random occurrence of both negative and positive deviations from the mean value. Random errors are due to some fluctuation or instability in the measuring instrument, the apparatus, or the analyst. To identify a random error, the measurement must be repeated a number of times. If the observed value changes apparently randomly with each repeated measurement, then there is probably a random error. Random error is also referred to as precision since more precise measurements have smaller random error. Precision is a measure of how well a result can be determined without reference to a true value. It is the degree of consistency and agreement among independent measurements of the same quantity and also the reliability or reproducibility of the result.

Systematic error is estimated by measuring standards. Systematic error is the constant unidirectional component of error that affects all members of a data set, characterized by how close the measurement is to the stated value of the standard. Systematic errors may be due to a calibration error or a technique associated with the analyst. If possible, a measurement of the same quantity, but by a different method, may reveal the existence of a systematic error. A systematic error may also be specific to the analyst. Having the measurement repeated by a variety of analysts would test this. Systematic error is also referred to as accuracy since more accurate measurements have smaller systematic error. Accuracy is the closeness of agreement between a measured value and a true value or accepted value. Measurement error is the amount of inaccuracy. The measurement uncertainty estimate should account for both the accuracy and precision of the measurement.

The random error and systematic error standard deviations for each measurement system are derived from measurement control program data. Licensees or applicants should document and maintain MC&A measurement control program records for all replicate measurements used in determining random variance and all measurements of standards used in determining systematic variance for each type of MC&A measurement.

6.1.2 Estimating Random Uncertainty for Measurement Systems

Replicate measurements are used to estimate the random component of the total variance for each measurement system. Random errors are statistical fluctuations in either direction of the measured data due to the precision limitations of the measurement device. Random errors can be reduced by averaging over a large number of observations.

For nonsampling measurement systems, such as weighing systems, replicate measurements are performed using control standards. For sampling systems, such as titration and mass spectrometry, replicate measurements are taken on actual samples to include any sources of

random variability that may be due to the inherent nature of the sample being measured. The random error associated with sampling is combined with the random error associated with analysis for a combined random error. The replicate sampling and analysis program for a measurement system should be designed to provide a minimum number of replicates or 100-percent replication, whichever is less, for each material category during each material balance period. The replications of sampling and sample measurements should be conducted as uniformly as practical throughout the material balance period.

Replicate measurement values that differ from the original average measured value by more than three standard deviations can be excluded from the calculations. In this way, the random variance can be controlled to within the historically established variability of the measurement process.

Licensees or applicants should provide detailed instructions for calculating the random variance for each type of measurement system in MC&A procedures and should provide a tabulated list summarizing the basis for determining the random variance for each type of measurement system used for physical inventories, including random variance for different weighing systems, destructive analysis measurement systems, and NDA systems. For example, the analyst calculates a pooled standard deviation of absolute difference data for paired measurements to include the analytical and the sampling random error components for the titration measurement system.

6.1.3 Estimating Systematic Uncertainty for Measurement Systems

Standard measurements are used to estimate the systematic component of the total variance for each measurement system. Systematic errors are reproducible inaccuracies that are consistently in the same direction. Consistent here refers to the direction of the error, not the magnitude. If a systematic error is identified when calibrating against a standard, applying a correction or correction factor to compensate for the effect can reduce the bias. Unlike random errors, systematic errors cannot be reduced by increasing the number of observations.

The systematic component of the total variance for each measurement system can be estimated as the difference between the mean of a set of control standard measurements and the assigned value for the control standard. If the assigned value of a control standard falls within the 95-percent confidence interval for the mean of a set of measurements of that control standard, then the systematic bias is not statistically significant at the 95-percent confidence level and bias correction is not necessary. When a measurement system is properly calibrated and in statistical control, systematic error is minimized and the dominant error that affects the measured value is random error.

Licensees or applicants should provide detailed instructions for calculating the systematic variance for each type of measurement system in MC&A procedures and should provide a tabulated list summarizing the basis for determining the systematic variance for each type of measurement system used for physical inventories, including for different weighing systems, destructive analysis measurement systems, and NDA systems. For example, special attention is given to the determination and control of bias for the uranium hexafluoride weighing systems because of the large mass of special nuclear material (SNM) measured by these weighing systems.

When the pooling of variances from prior material balance periods with the current period for a particular measurement method is desired, statistical tests at the 95-percent confidence level

should be used to confirm that these variances are not significantly different from current data. Statistical tests may include comparisons of means, variances, normality, or randomness, as appropriate for the particular situation.

Random and systematic error variance estimates for bulk measurements can be calculated using various formulas in TID 26298 (1973; Chapter 3) if mass standards data are used. If production data or SRD data are available, the approach of TID 26298 (1973; Chapter 8) or NUREG/CR 4604 (1988; Chapter 15) can be used. The use of SRD data is preferred, as they include the source of routine measurement error, whereas standards data may tend to underestimate the measurement errors. In uranium enrichment process equipment, variance components for the determination of gas pressures and temperatures are developed using engineering parameters, production data, and process knowledge, and the resulting data are combined using propagation techniques such as in TID 26298 (1973; Chapters 5 and 6) to calculate the error variance estimates. The sampling and analytical variance components can be calculated using the techniques in TID 26298 (1973; Chapter 3) or NUREG/CR 4604 (1988; Chapter 15). Data used in these techniques are obtained from the facility's measurement control program, combined with other programs such as replicate sample analytical comparisons, data exchange with other laboratories, and participation in a national uranium standards measurement program.

Statistical analyses should be summarized, updated, and reported on a periodic frequency to the MC&A organization and other organizations that implement measurements and measurement control functions.

6.2 Determination of Inventory Statistics

Three statistical analyses are performed to evaluate the physical inventory results. The requirement in 10 CFR 74.43(c)(8) stipulates calculating the ID and SEID. The requirement in 10 CFR 74.17(b) using NRC Form 327, "Special Nuclear Material (SNM) and Source Material (SM) Physical Inventory Summary Report," stipulates calculating the AI.

6.2.1 Calculating the Inventory Difference and Applying Bias Estimates to the Inventory Difference

As defined in 10 CFR 74.4, the ID is commonly expressed by the following mathematical equation:

$$ID = BI + A - R - EI$$

Where:
- BI = Beginning inventory (for the material period in question)
- A = Additions to inventory (receipts)
- R = Removals from inventory (shipments and measured discards)
- EI = Ending inventory

The expression BI + A - R represents the book inventory, while EI represents the physical inventory. The book inventory is obtained by calculating the algebraic total of the material quantities in the book records, which include the accounting records of the inventory of all materials in the facility at the beginning of the inventory period and all receipts, shipments, and discards during the period. Therefore, the ID is the difference between the material quantities in

the book inventory and the ending physical inventory, or in short, the expression "ID equals book minus physical." The ID is compared to its standard error to determine its significance. All of the terms in the ID equation must be based on measurements. In principle, the ID should be zero in the absence of any loss, theft, or diversion. In reality, an ID is almost never zero for processing facilities, and many contributors to nonzero IDs can be factored in, such as the following:

- measurement uncertainties from measurement systems
- incorrect measurements and improper measurement techniques
- recording errors or analyst errors
- unmeasured residual process holdup
- unmeasured losses

The ID can be either positive or negative. A positive ID implies a loss of material, while a negative ID implies a gain in material. Any ID that exceeds the regulatory limits can also be an indication that the measurements and measurement control program may not be functioning properly. Chapter 7 discusses response actions to the ID conditions.

Statistically significant biases should be identified, quantified, and corrected in each measured value or as a total in the facility ID equation. Most biases are too small to affect individual items, but the effect over many items may have a significant effect on the ID value. For those biases, an appropriate correction factor can be applied as an adjustment to the ID. The BI bias correction is due to biases that existed and were determined during prior periods. The R (shipments) and EI bias corrections can be a combination of prior and current period biases. The A and R (measured discards) bias corrections are due to biases that existed and were determined during the current period only. A significant bias of the ID should be reported on NRC Form 327. As an alternative, bias corrections on a line-item basis may be made to measurements reported on U.S. Department of Energy/NRC Form 741, "Nuclear Material Transaction Report," for the facility's material receipts and shipments. (Section 6.3 contains additional information on bias corrections.)

6.2.2 Estimating the Standard Error of the Inventory Difference

As defined in 10 CFR 74.4, SEID means the standard deviation of an ID that takes into account all measurement error contributions to the components of the ID. The SEID consolidates all uncertainties into a single value that is used to evaluate an internal control area (or material balance area (MBA)) or the total facility's material measurement system. SEID values are calculated for uranium, U-235, U-233, and plutonium. The ID is then evaluated by comparing it to the SEID to either explain the measurement error associated with the value of the ID or to determine if the ID represents SNM that has been lost or stolen.

For SNM of moderate strategic significance, licensees should not include nonmeasurement contributors to the ID in the SEID calculation. Including only measurement uncertainty, SEID (for either uranium, U-235, plutonium, or U-233, as applicable) can be expressed as follows:

$$SEID = \left[\sum_{i=1}^{k} (G_i)^2 \{(\sigma_i)_s^2 + (\sigma_i)_r^2/n\}\right]^{1/2}$$

Where:

k	= number of measurement systems
G_i	= total grams uranium (or U-235, U-233, or plutonium) measured during inventory period by measurement system i
$(\sigma_i)_s$	= systematic error standard deviation for measurement system i
$(\sigma_i)_r$	= random error standard deviation for measurement system i
n	= number of batches (items) measured by measurement system i

Relative random and systematic error variance are calculated for every measurement system used to measure components of the ID equation. The total combined relative measurement variance is then calculated. The total mass measured by each measurement system is squared and multiplied by the total combined measurement uncertainty variance for the measurement system, the variances are summed, and finally the standard deviation is calculated.

The total mass G_i, does not include common terms (see the definition of "active inventory" in 10 CFR 74.4 and the description of its calculation in Section 6.2.3 of this chapter). The uncertainty associated with a given ID value is expressed in terms of a certain confidence level. The fundamental nuclear material control (FNMC) plan and its MC&A procedures should provide all relevant information on the determination of ID, systematic error, random error, and SEID.

Licensees should also commit to having at least two individuals independently verify the accuracy of the ID and SEID calculations for each total plant material balance. If the SEID value is calculated by a computer, the verification by two or more persons involves a checking for correctness of the input data used by the computer to calculate SEID.

Measurement uncertainty is controlled so that SEID does not exceed 0.125 percent of AI as specified in 10 CFR 74.45(c)(4).

6.2.3 Calculating the Active Inventory

The active inventory (AI) is used to evaluate the significance of IDs and as an indicator of processing throughput or measurement activity, or both. AI is the sum of beginning inventory (BI), additions to inventory (A), removals from inventory (R), and ending inventory (EI), after all common terms (C) have been excluded. AI is defined by the following equation:

$$AI = BI + A + R + EI - C$$

Common terms are material values or items that appear more than once in the ID equation and in components with opposite signs (i.e., in both BI and EI, or both BI and R, or both A and R, or both A and EI) and come from the same measurement. Common terms are removed from the calculation because they do not contribute to the uncertainty associated with the current period ID. For example, if an item appears in both BI and EI at the same value, it cannot have contributed to the ID or SEID because these quantities cancel each other.

6.3 Bias Corrections

Measurement bias is a unidirectional component of error that affects all members of a measurement data set. A bias can be estimated from the deviation of the mean of several measurements of a representative standard from the reference value or assigned value of such standard. From a statistical perspective, biases that are not statistically significant (at the 95-percent confidence level) should never be applied as adjustments (corrections) to the accounting records. To obtain the best estimate of the true ID value, such insignificant biases should be applied as a nonaccounting adjustment to the initially calculated ID (as obtained from the ID equation: ID = BI + A - R - EI). Such practice is not deemed necessary, however, for material balances pertaining to SNM of moderate strategic significance and is thus optional.

For biases that are statistically significant (at the 95-percent confidence level) and large enough to have an effect on the recorded values of individual items, it is common practice to adjust the accounting values for individual items if the bias effect (as grams uranium and grams U-235) on the item is more than the rounding error for that item, and if less than the rounding error, to apply the bias as a nonaccounting adjustment to the ID. If a bias is significant but too small to affect individual items, its effect across all measured items should be determined as an absolute quantity (i.e., grams of uranium or U-235). The net sum of all biases (as absolute quantities) not applied as corrections to individual items should then be applied as a bias correction to the ID. Under a well-designed and well-managed measurement control program, bias corrections to the accounting records should seldom, if ever, be necessary under the above mentioned approach. Although the effect on an individual item from a statistically significant bias should be negligible, the effect of that bias across hundreds or thousands of items (whose SNM values were derived from the biased measurement system) could have a very significant impact on the ID value.

Nevertheless, in view of the very large quantity of SNM of moderate strategic significance that is of safeguards significance, the NRC acceptance criteria do not normally call for applying bias corrections to either the accounting records or as an adjustment to ID unless the effect of a single significant bias or the net sum of all significant biases is unusually large.

All measurement systems should be calibrated, controlled, operated, and maintained in a manner to ensure that bias is minimized. Most measurement systems for uranium and U-235 in receipts and inventories are point calibrated and are regarded as bias free. Licensees or applicants should evaluate other key measurement systems for bias following the physical inventory taking as part of activities in closing the material balance period. Key measurement systems are those that account for at least 90 percent of the total measurement variance contribution to the SEID. As a minimum, to meet NRC acceptance criteria, a bias correction for a single key measurement system should be considered “significant” and thus applied either as corrections to the accounting records or as an adjustment to the ID if (1) such bias is statistically significant at the 95-percent confidence level, and (2) either or both of the following are also true:

- applying the correction would cause the ID to exceed three times SEID
- the bias is greater than 0.01 percent relative

Additionally, the net algebraic sum (expressed as grams SNM) of all statistically significant (95-percent confidence level) biases from key measurement systems not defined as bias free, that have not been applied as a correction or adjustment under either or both conditions above, is considered to be “significant” and is to be applied as a net adjustment to the ID if applying such correction would cause the ID to exceed three times the SEID.

As a good accounting practice, identified significant biases that can be quantified are corrected in each measured value or as a total in the facility ID equation.

6.4 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to maintaining an MC&A statistical program. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for the statistical program is acceptable and in accordance with 10 CFR 74.41 will be informed by the following acceptance criteria:

- A detailed discussion is provided of the procedures and methodologies for determining the measurement uncertainties, including estimation of random uncertainty and systematic uncertainty.

- A detailed discussion is provided of the procedures and methodologies for determining the inventory statistics, including calculation of the ID, estimation of the SEID, and calculation of the AI.

- A detailed discussion is provided on how biases are determined and how bias corrections are applied, including the following:

  - how often biases are estimated on all measurement systems, including key measurement systems

  - how the effect of the bias on the measured quantity of material in an item is determined

  - when and how bias corrections to items are made

  - how their effect on ID is determined

  - when and how bias corrections are applied to the ID

- A detailed discussion is provided of the procedures and methodologies for determining ID threshold values as required by 10 CFR 74.43 (c)(8)(iii). (Chapter 7 of this document contains additional information on ID limits and response actions.)

7 PHYSICAL INVENTORIES

7.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(c)(1)–(8) for inventory control and physical inventories is to require licensees and applicants to confirm the presence of special nuclear material (SNM) items within their recorded locations, to confirm that the accounting records are accurate and reliable, to detect any loss, theft, or diversion of a significant quantity of SNM, as defined by 10 CFR 74.41(a)(3), that could go undetected in the absence of physical inventories, and to provide for reconciling, adjusting, resolving, or reporting any occurrence of inventory difference (ID) that exceeds the inventory threshold specified in 10 CFR 74.43(c)(8). The regulation in 10 CFR 74.43(c)(7) requires licensees or applicants to conduct physical inventories of all possessed SNM for each plant at intervals not to exceed 9 calendar months. The principal method of confirming the presence of SNM is to establish and maintain inventory control (i.e., "item control" as discussed in Chapter 8) and to periodically perform a physical inventory and compare it to the book (record) inventory. If all SNM is included, the expected difference between the book inventory and the physical inventory is zero plus or minus the measurement uncertainty associated with both the physical and book inventories. In any actual case of a routine physical inventory, the size of the ID and its uncertainty depends on measurement errors, as well as on various nonmeasurement contributors, such as recording errors, unmeasured losses, or unmeasured residual holdup (the Glossary defines "residual holdup"). Licensees or applicants must maintain and follow inventory control and physical inventory procedures and instructions in 10 CFR 74.43(c)(1)–(8) to accurately reflect the status of the SNM they possess and ensure the quality of the physical inventories.

7.1 General Description

The licensee or applicant should provide the NRC with a general description of how physical inventories of the plant will be planned, conducted, assessed, and reported. The FNMC plan should contain a commitment to written instructions which assign physical inventory duties and responsibilities. These instructions should be reviewed with the involved individuals before the start of each physical inventory.

The licensee or applicant should generate a book inventory listing, derived from the MC&A record system, just before the actual start of each physical inventory. The listing shall include all SNM that the records indicate the licensee should possess at the inventory cutoff time.

The licensee must report the ID and related information associated with each physical inventory of all SNM, pursuant to 10 CFR 74.17(b), on an NRC Form 327, "Special Nuclear Material (SNM) and Source Material (SM) Physical Inventory Summary Report," as the result of a physical inventory. NUREG/BR-0096, "Instructions and Guidance for Completing Physical Inventory Summary Reports (NRC Form 327)," issued January 1992, contains more specific guidance for completing this form. Low-enriched uranium (LEU) (i.e., U.S. Department of Energy (DOE)/NRC material type code 20-E1 and 20-E2), high-enriched uranium (HEU) (code 20-E3 and 20-E4), uranium-233 (U-233) (code 70), plutonium (code 50), and plutonium-238 (code 83) possessed by the licensee are subject to the physical inventory requirements. The licensee should report each material type code ID and associated information on separate NRC Form 327 sheets, in accordance with the instructions in NUREG/BR-0096.

The licensee must report the material balance and physical inventory data with each physical inventory, under 10 CFR 74.13, “Material status reports,” on DOE/NRC Form 742, “Material Balance Report,” and DOE/NRC Form 742C, “Physical Inventory Listing.” NUREG/BR-0007, “Instructions for the Preparation and Distribution of Material Status Reports (DOE/NRC Forms 742 and 742C),” includes more specific guidance for completing these forms.

7.2 Organization, Procedures, and Schedules

The FNMC plan should explain the makeup and duties of the typical physical inventory organization. The individual having responsibility for the coordination of the physical inventory effort should be identified by position title.

The FNMC plan also should indicate how the preparation and modification of inventory procedures are controlled. In accordance with 10 CFR 74.43(c), the physical inventory procedures must assure the following:

- The quantity of SNM associated with each item on the ending inventory (EI) is a measured value.

- The validity of prior measurements associated with unencapsulated and unsealed items on EI is confirmed.

- Measurements for element and isotope content on all quantities of SNM not previously measured are performed.

- Each item on the EI is listed and identified to assure that all items are listed and no item is listed more than once.

- Cutoff procedures for transfers and processing are established so that all quantities are inventoried and none are inventoried more than once.

- Cutoff procedures for records and reports are established so that only transfers for the inventory and material balance interval are included in the records for the material balance in question.

- All book and inventory records, for total plant and individual internal control areas, are reconciled with and adjusted to the results of the physical inventory.

If tamper-safe seals are used for assuring the validity of prior measurements of containers or vaults containing SNM, procedures must be maintained and followed that include control of access to, and distribution of, unused seals and to records showing the date and time of seal application (Chapter 11 discusses tamper-safing).

The FNMC plan should contain a provision to ensure that physical inventories are conducted according to written instructions and specific inventory instructions are prepared and issued for each physical inventory. The written instructions must do the following:

- Assign inventory duties and responsibilities.

- Specify the extent to which each internal control area and process is to be shut down, cleaned out, or remain static.

- Identify the basis for accepting previously made measurements and their limits of error.

- Designate measurements to be made for physical inventory purposes and the procedures for making measurements.

The FNMC plan should describe the activities performed to prepare the facility for the physical inventory to ensure adequate preparation by the cutoff schedules and to minimize the occurrence of inventory listing errors.

7.3 Typical Inventory Composition

Licensees or applicants should specify the typical expected in-process inventory within the equipment for plutonium, uranium, uranium-235 (U-235), and U-233 at the time of the physical inventory. They should also present a typical composition of SNM as stored items at the time of a physical inventory. Plants may be (but are not required to be) divided into a number of material balance areas (MBAs) and item control areas (ICAs) to reflect the functional activities of internal control areas, as in the following examples:

- Processing—An MBA in which occurs (1) routine transfers of nuclear material from one container to another, (2) changes in chemical assay, or (3) changes in chemical or physical form. Various measurements are required to define material flows through the process and to perform physical inventories so that periodic material balances can be completed for the MBA. Because these measurements have associated uncertainties, a processing MBA will normally have a nonzero ID for each inventory. Of the total plant MBAs and ICAs, a relatively small number might be processing MBAs. Examples are the decontamination and recovery operations; analytical laboratory; and material rebatching, blending, and sampling operations. Physical inventories for the decontamination and recovery operations are the most complex and involve the most coordination and careful timing.

- Storage—ICAs in which all materials are within containers with measured values and are being stored for future processing or shipment. Some minor sampling of containers can occur in a storage ICA. Because nuclear materials in a storage ICA are primarily accounted for on an item basis, a true storage ICA typically will have a zero ID for each inventory period when all items are accounted for and their integrity and previously documented measured values are confirmed.

- Receiving and shipping—An ICA from which materials are shipped or into which materials are received from off site; normally serves as an interim storage area. This type of ICA will normally see more activity (i.e., changes in current inventory) than the typical storage ICA. At some facilities, sampling and rebatching of items may occur in this type of ICA.

7.4 Description of Typical Item Strata

The FNMC plan should describe the expected item population in terms of the following:

- type(s) of item (i.e., stratum)

- expected range of the number of items within each stratum
- average elemental and isotopic content of the items within each stratum
- expected rate of item generation and consumption for each stratum

7.5 Conducting Physical Inventories

Licensees or applicants should describe the methodology, including cutoff and inventory minimization procedures, and they should identify all measurements (including sampling) sufficient to meet the requirements of 10 CFR 74.43(c). The FNMC plan should contain sufficient information to show how licensees obtain the total in-process inventory for both elemental and isotopic content.

For uranium enrichment facilities, two types of physical inventories are performed so as to confirm that a loss or diversion of a significant quantity of SNM has not occurred: dynamic (i.e., in-process) materials, which is performed on a frequency not to exceed 3 calendar months, and static (containerized) materials, which is performed on a frequency not to exceed 9 calendar months. The dynamic inventory provides the amount of material estimated to be inside the enrichment processing equipment at a given time and can be conducted in conjunction with the static inventory. A static inventory is similar to a normal shutdown physical inventory. The total plant material balance is obtained by performing the static and dynamic inventories.

The means for measuring or estimating residual process material should be addressed in detail. The change or variation in such deposited holdup from one physical inventory to the next should also be discussed. This information is important to ensure that no SNM held under license will be omitted, and no quantity will be counted more than once.

The FNMC plan also should contain adequate commitments to ensure that each physical inventory will be organized and coordinated so that all involved persons are instructed in the use of uniform procedures for checking SNM quantities and recording observations. The means for conducting the inventory should ensure that any SNM held under license is properly inventoried. A detailed inventory notice should be prepared for each physical inventory. The notice should be issued to all involved parties and should contain instructions that define the timing and performance of various inventory steps and conditions under which the inventory is to be taken. The notice should identify specific sampling points throughout the process and instructions on data submission to the accountability organization. The instructions should highlight any required deviation from normal inventory procedures contained in the plant's operating procedures.

The FNMC plan should describe the procedures and methodologies associated with performing physical inventories in sufficient detail to demonstrate that valid physical inventories are conducted. Such description should include a general outline of the following:

- organization and separation of functions

- assignment of inventory teams and their training in the use of uniform practices

- obtainment, verification, and record of source data

- control of inventory forms

- assurance that item counts verify the presence of each item while preventing any item from being counted more than once

- implementation of cutoff and material handling procedures

Decontamination and recovery are complex operations involving the disassembly and decontamination of failed pieces of process equipment and recovery of uranium from various types of scrap materials. The basic inventory procedure should involve establishing a cutoff of movement of materials into the area and processing all materials to a measurable form, such as containers of solution or oxide. Except for a decontamination enclosure in which in-process solutions are mixed, sampled, and measured volumetrically, the inventory process should involve emptying and flushing process systems and piping, which then could be measured using NDA techniques to establish levels of residual holdup, if such holdup is significant.

The FNMC plan also should describe special item storage and handling or tamper-indicating methods, which are used to ensure that the previously measured and recorded SNM content values can be used for inventory purposes without remeasurements. In addition, the FNMC plan should describe how item identities are verified and how tampering with the contents of items will be detected or prevented.

Items that are not encapsulated, affixed with tamper-indicating devices, or otherwise protected to ensure the validity of prior measurements need special attention. Licensees or applicants should present the basis for determining which items are to be measured at physical inventory time and the justification of any proposed alternatives to the measurement of any SNM included in the inventory. If statistical sampling is proposed as an alternative method to 100-percent verification, the FNMC plan should describe the sampling plan. Such description should include the following:

- the method of stratifying the types of items to be sampled (i.e., selected for remeasurement)

- the procedure for calculating the sample size (i.e., the number of items) for each stratum

- the parameter to be measured (e.g., gross weight or total U-235 content)

- the quality of the measurement methods used to verify original measurement values (for the parameter being measured)

- the procedure for reconciling discrepancies between original and remeasurement values and for scheduling additional tests and remeasurements

- the basis for discarding an original SNM value and replacing it with a remeasurement value

One acceptable means for establishing the number of items (to be randomly selected for remeasurement) from a given stratum to give the required 90-percent power of detecting a loss of a significant quantity is given by the following equation:

$$n = N\,[1 - (0.10)^{x/g}]$$

Where: n = number of items to be remeasured

N = total number of items in the stratum
x = maximum SNM content per item (kilograms)
g = SQ = significant quantity for statistical sampling plans, which is either one formula kilogram of strategic SNM or 10,000 grams of U-235 contained in uranium enriched to up to 20 percent

When using such a statistical sampling plan to confirm the validity of prior measurements, the remeasurement value obtained for each item (among the n items remeasured) must be compared to its original value. If the difference for a given item exceeds some predetermined limit (usually three times the standard deviation of the measurement, or three sigma (3σ)), that item is designated as a “defect.” To achieve the 90-percent power of detection capability for detecting an SQ, there must be at least a 90-percent probability that one or more “defects” will be encountered among the items remeasured across all involved strata if an actual loss of an SQ has occurred. If, across all strata, the licensee encounters one or more defects, a second set of n randomly selected items (or all remaining items if n is greater than 0.5 N) from each stratum should be remeasured. If one or more defects are encountered (across all item strata) while performing any second round of remeasurements, the licensee should remeasure all unsealed and unencapsulated items not yet remeasured. Any item, regardless of whether there are any defects, whose remeasured value differs from its original measurement by more than two sigma (2σ) should have its accounting value revised to reflect its remeasured quantity.

The FNMC plan also should identify a commitment that all items on EI that have not been previously measured are measured for inventory purposes. The plan should present the rationale for determining when the element and isotope factors for items, objects, or containers are measured directly for inventory and when they may be based on other measurements. For example, if the U-235 contained in liquid waste batches is derived by applying an average enrichment factor to the measured uranium element content, the rationale for such practice (as opposed to measuring each batch for both uranium and U-235 content) should be discussed, and the plan should describe the method for establishing the average enrichment factor.

If the content of items is established through prior measurements and those items are sealed with TIDs or access to them is controlled, the SNM quantity in those items may be based on those measured values. Otherwise, verification of SNM content can be achieved by reweighing either (1) all items within a given stratum or (2) randomly selected items from the stratum based on a statistical sampling plan. The NRC may not accept a statistical sampling plan if there is any significant change in the elemental concentration (or weight fraction) or in the isotopic distribution because of such factors as oxidation, change in moisture content, commingling with materials of different enrichments, or different compositions.

7.6 <u>Inventory Reconciliation, Inventory Difference Limits, and Response Actions</u>

The FNMC plan should describe the reconciliation activities performed upon completion of the physical inventory. (The Glossary defines “inventory reconciliation.”) In accordance with 10 CFR 74.43(c)(8), within 60 days after the start of inventory, the licensee or applicant must perform the following for the material balance period terminated by the physical inventory:

- Calculate the ID and its associated SEID for both element and isotope.

- Reconcile and adjust the book record of quantity of element and isotope content, as appropriate, to the results of the physical inventory.

- Investigate and report any occurrence of the following:

  – SEID exceeding 0.125 percent of the active inventory

  – ID exceeding both three times SEID and 200 grams of plutonium or U-233, or 300 grams of U-235 in HEU, or 9,000 grams of U-235 in LEU

The FNMC plan should describe how all book and inventory records, for total plant and individual internal control areas, are reconciled with and adjusted to the results of the physical inventory. As described in 10 CFR 74.4, "Definitions," ID is determined by subtracting the quantity of SNM tabulated from a physical inventory from the book inventory quantity. Book inventory quantity is equivalent to the beginning inventory (BI) plus additions to inventory (A) minus removals from inventory (R), while the physical inventory quantity is ending inventory (EI) for the material balance period. Mathematically, ID = (BI +A-R) -EI or ID = BI +A – R -EI. The ID value should reflect only current period activity, and an adjustment to the ID value may be made if necessary. (The Glossary defines "prior period adjustment.") The FNMC plan also should describe how the associated SEID is determined for the material balance period terminated by the physical inventory. (Chapter 6 of this document contains further information on SEID.) The FNMC plan should describe the steps taken to investigate and report any SEID that exceeds 0.125 percent of the active inventory.

Each licensee or applicant should have a well-defined system for evaluating total plant IDs and for taking actions when IDs exceed certain predetermined thresholds. As a minimum, there should be two response levels for evaluating IDs. The following would be an acceptable approach for two increasing levels of response actions with respect to material balances closed by physical inventories:

- warning-level ID:

  – plutonium, U-235, or U-233 ID ≥ 1.7(SEID) or
  – uranium ID ≥ 1.7 (SEID) and 10 kilograms uranium

- significant ID problem:

  – uranium, plutonium, U-235, or U-233 ID ≥ 3(SEID) and 300 grams of U-235 in HEU or

  – 200 grams of plutonium or U-233 or 9,000 grams of U-235 in LEU

All of the above limits are expressed in terms of absolute values of ID without regard for algebraic sign. The minimum response for a warning-level ID should be a documented licensee investigation conducted by the MC&A organization. Such an investigation should provide a conclusion for the probable cause of the ID in excess of the predetermined thresholds and give recommendations for avoiding recurrences. When a warning-level ID is positive, licensees or applicants should regard it as being equivalent to an indicator of a possible loss that requires investigation and resolution.

For a significant ID problem, a licensee or applicant should conduct an extensive investigation and report to the Director of the NRC's Office of Nuclear Material Safety and Safeguards. If a significant ID problem cannot be satisfactorily explained, a reinventory may be needed to resolve such an anomaly. The NRC considers a significant positive ID (loss) problem to be a serious

condition that calls for corrective action. The FNMC plan should fully describe in definitive statements the minimum response actions for each ID action level.

7.7 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to the physical inventories. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for conducting physical inventories is acceptable and in accordance with 10 CFR 74.43(c) will be informed by the following acceptance criteria:

- An MC&A system will be maintained that is capable of confirming, at intervals not to exceed 9 calendar months, the presence of all SNM expected to be present (at a given time) based on accurate, current, and reliable information.

- Physical inventories will be used as the basis for reconciling and adjusting the book inventory, which is done within 60 calendar days after the start of each physical inventory, unless otherwise required by facility attachments that satisfy 10 CFR Part 75, "Safeguards on nuclear material - implementation of the US/IAEA agreement."

- For each physical inventory, inventory procedures are clearly written and are reviewed and approved by the individual responsible for the conduct of the physical inventory.

- The individual responsible for the conduct of the physical inventory is either free from potential conflicts of interest or is overchecked sufficiently to prevent compromising the validity of the physical inventory.

- Each physical inventory listing will include all SNM possessed (on the inventory date), and all such listed SNM quantities shall be based on measurements.

- Within 60 calendar days after the start of each physical inventory, the ID will be determined. Any ID that exceeds both three times SEID and 300 grams of U-235 in HEU, or 200 grams of plutonium or U-233, or 9,000 grams of U-235 in LEU will be reported to the appropriate NRC office.

- Discrepancies in the identity, quantity, or location of items, objects, or containers of SNM that are detected during a physical inventory will be corrected.

- ID values will be corrected for (1) accounting adjustments resulting from prior period activity, and (2) significant biases that have not previously been taken into account. (Chapter 6 defines "significant bias.")

- Adjustments made to reconcile the book inventory to the physical inventory are in accordance with standard accounting practices and are traceable and auditable in the MC&A records.

- Whenever a finalized ID (after applying any appropriate bias corrections and prior period adjustments) exceeds both three times SEID and 300 grams of U-235 in HEU, or 200 grams of plutonium or U-233, or 9,000 grams of U-235 in LEU, and is not resolved within the 60-day reconciliation period, all SNM processing should be halted unless otherwise authorized by the NRC. (This applies to both positive and negative ID values.)

- The results of all physical inventories and of investigations and resolution actions following an ID that exceeds both three times SEID and 300 grams of U-235 in HEU, or 200 grams of plutonium or U-233, or 9,000 grams of U-235 in LEU, are recorded and auditable.

- The licensee or applicant may propose alternatives to remeasurement of unsealed SNM. The FNMC plan should describe the circumstances under which each proposed alternative may be used. The proposed alternatives should satisfy at least one of the following criteria:

  – SNM content is verified by statistical sampling and measurement of representative items, objects, or samples of the material. The total overall sampling plan shall support the capability for detecting any loss in excess of the pertinent SQ with 90-percent (or better) probability.

  – The previous measurement results are accepted because the items are stored in a controlled access enclosure that provides protection equivalent to tamper-safing.

  – Residual holdup in significant amounts that remains after cleanout or draindown may be estimated if the estimate is based on previously measured values and it is periodically verified or validated.

  – For material whose SNM content has been previously measured, and there is no likelihood of any significant change in the uranium concentration (or weight fraction) or in the uranium enrichment because of such factors as oxidation, change in moisture content, commingling with materials of different enrichment or different composition, the previously determined SNM content may be accepted without verification—provided the gross weight or net weight of all items within the population is confirmed by (1) a 100-percent reweighing of all such items, or (2) reweighing an adequate number of randomly selected items (based on a statistical sampling plan) to provide a 90-percent (or better) probability of detecting a loss equal to or greater than the current SQ.

- As an additional alternative to remeasurement (of unsealed SNM) at physical inventory time, a program of routine process monitoring will be acceptable when the combination of the process monitoring program and the inventory procedures will achieve the same level of loss detection capability as that provided by a physical inventory in which all unencapsulated items are either tamper-safed or remeasured.

- Any previously measured but unsealed (or unencapsulated) SNM that is on hand at the time of the physical inventory, and which is to be introduced into subsequent processing steps before inventory reconciliation, should be remeasured or have its prior measurement value confirmed (by an acceptable alternative) before the subsequent processing is initiated.

- The SQ for statistical sampling plans will be one formula kilogram of strategic SNM or 10,000 grams of U-235 contained in uranium enriched up to 20 percent.

- The FNMC plan should establish a threshold of three times SEID for evaluating an ID will result in a 90-percent (or better) probability of detecting a discrepancy equal to or greater than 0.4 percent of the active inventory for the inventory period in question. In general, a

licensee may assume the ID distribution approximates a normal distribution. The NRC describes acceptable methodology for calculating the measurement error contribution to the SEID by error propagation in NUREG/CR-4604, “Statistical Methods for Nuclear Material Management,” issued December 1988; TID-26298, “Statistical Methods in Nuclear Material Control,” issued 1973; and the International Atomic Energy Agency statistics handbook IAEA/SG/SCT/5*, “*Statistical Concepts and Techniques for IAEA Safeguards,” issued 1989. Special attention is given to inclusion of all measurable sources of error to avoid underestimating the SEID.

- In addition to the three times SEID ID limit required by 10 CFR 74.43(c)(8), an ID that exceeds the warning level limit should be investigated. The resources and level of effort a licensee or applicant should commit to the investigation of such an ID will be proportional to the magnitude and material type and enrichment of the ID. It will be sufficient to reassess the results of the physical inventory, the accounting records, and the measurement control program data; to confirm the relevant calculations and data analysis; and, when necessary, to carry out searches for unmeasured inventory, such as residual holdup and measurement discards. Investigations of any SEID and ID exceeding the regulatory limits are to be completed within 60 calendar days after initiating the inventory (except when additional time is granted by the NRC for extenuating circumstances).

8 ITEM CONTROL

8.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(b)(5) and (6) is to require licensees or applicants to establish, document, and maintain an item control program to protect against unauthorized and unrecorded removal of items, or of material from items, and to enable timely location of items. An item, as described in 10 CFR 74.4, "Definitions," means any discrete quantity or container of special nuclear material (SNM) or source material, not undergoing processing, having a unique identity, and also having an assigned element and isotope quantity. Examples of items are known quantities of SNM in well-defined and uniquely identified containments such as cans, drums, and canisters, or fixed units such as fuel assemblies. Uncontainerized solid SNM, such as uranium metal ingots or buttons, are also items if they are uniquely identified. To promptly locate a given item, licensees must record sufficient current information. Licensees or applicants are given some flexibility in controlling items by permitting certain exemptions as discussed further below.

8.1 Organization

The FNMC plan should identify the individual responsible for overseeing the item control program by position title. The plan should also identify the positions of those individuals who have significant item control program responsibilities.

8.2 General Description

The licensee or applicant should state that the overall MC&A system maintains a record of all SNM items, regardless of quantity or duration of existence. In addition, the item control program should provide current knowledge with respect to identity, element and isotope content, and stored location of SNM contained in all items that are not exempt from item control. The following items may be exempt from item control program coverage in accordance with 10 CFR 74.43(c)(6):

- items whose time of existence is less than 14 calendar days

- any licensee-identified items listed by material type, each containing less than 300 grams of uranium-235, or 200 grams of plutonium or uranium-233 but not to exceed a cumulative total of one formula kilogram of strategic SNM or 17 kilograms of uranium-235 contained in uranium enriched to 10.00 percent or more but less than 20.00 percent in the uranium-235 isotope

Each item that is not exempt from the item control program should be stored and handled in a manner that enables detection of, and provides protection against, unauthorized or unrecorded removals of SNM, in accordance with 10 CFR 74.43(b)(5). All items, whether or not they are subject to item control program coverage, should have a unique identity. For items subject to the item control program, the following are acceptable means for providing a unique identity:

- a unique alpha-numeric identification on a tamper-indicating device (TID) applied to a container of SNM

- a unique alpha-numeric identification permanently inscribed, embossed, or stamped on the container or item itself

- a uniquely prenumbered (or bar-coded) label applied to each item having good adhesive qualities such that its removal from an item would preclude reuse of the label

For items not subject to the item control program, the item identification system should possess attributes that provide protection as least equivalent to tamper-safing.

Location designations shown by the MC&A records need not be unique, but location designations should be specific enough so that any item may be located within 1 hour. Longer times may be acceptable, but the FNMC plan should further justify them. The MC&A record system should be controlled in such a manner that the record of an item's existence cannot be destroyed or falsified without a high probability of detection.

8.3 Item Identity Controls

Descriptions should be provided of the item records showing how items are identified for each material type and each type of container. If the unique number on a TID is the basis for providing unique item identity, the FNMC plan should do the following:

- Describe the type of TID used.

- Describe how the TIDs are obtained and what measures are used to ensure that duplicate (counterfeit) TIDs are not manufactured.

- Describe how the TIDs are stored, controlled, issued, and accounted for.

- Describe how TID usage and disposal records are maintained and controlled.

Licensees or applicants should provide similar information for other methods of unique item identity (e.g., labels). Chapter 11 of this document contains further information on TIDs.

8.4 Storage Controls

The FNMC plan should fully describe item storage areas and controls. In particular, controls that are used as the basis for ensuring the values of prior measurements, as opposed to remeasuring the item at inventory time, should be discussed in detail and the rationale for accepting prior measurements explained. Any controls used to ensure the validity of prior measurements should be equivalent to the protection provided by tamper-safing, which is defined by 10 CFR 74.4 as the use of devices on containers or vaults in a manner and at a time that ensures a clear indication of any violation of the integrity of previously made measurements of the SNM in the container or vault.

Both administrative controls (e.g., custodian assignments and limiting authorized access to storage areas) and physical controls (e.g., locked or alarmed doors) should be identified.

8.5 Item Monitoring Methodology and Procedures

As part of the item control program, a licensee or applicant should maintain a system of item monitoring that achieves the following:

- verifies that items shown in the MC&A records are actually stored and identified in the manner indicated in the records

- verifies that generated items and changes in item locations are properly recorded in the MC&A record system in a timely manner

- detects, with high probability, any real loss of items or uranium from items

An acceptable approach for the item monitoring system would be to conduct the following activities at least every 2 weeks for strategic SNM and on a monthly basis for uranium-235 contained in uranium enriched up to 20 percent:

- For each item inventory stratum, compare the actual storage status to the recorded status of a sufficient sample of randomly selected items from the item control program records.

- For each item inventory stratum, check the accuracy of the MC&A records for a sufficient sample of randomly selected items from each storage area.

- Check the accuracy of a sufficient sample of randomly selected production records of created and consumed items.

The actual frequency of the above activities, and the size of the random sample, should be a function of the expected discrepancy rate based on prior observations. The FNMC plan should specify (1) minimum monitoring frequencies associated with each storage area, (2) discrepancy rates that trigger more frequent monitoring frequencies, and (3) commitments for resolving discrepancies.

8.6 Investigation and Resolution of Item Discrepancies

The licensee or applicant should describe the procedures and controls that will ensure that all incidents involving missing or compromised items or falsified item records will be investigated. A compromised item is (1) an item displaying evidence of tampering or (2) an unencapsulated and unsealed item assigned to a controlled, limited-access storage area that is found outside its documented location.

If any unencapsulated and unsealed item is located after having been determined to be missing, or if an item is found to be compromised, its contents should be reestablished by measurement (e.g., by nondestructive assay or by weighing, sampling, and analysis). Licensees or applicants should follow recommendations on the resolution of indicators (Chapter 12) of this document to resolve item discrepancies.

8.7 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to maintaining current knowledge of items and detecting

unauthorized removals. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for the item control program is acceptable and in accordance with 10 CFR 74.43(b)(5) and (6) will be informed by the following acceptance criteria:

- The item control program uses statistical sampling, as an alternative to 100-percent verification, at least every 2 weeks for strategic SNM and on a monthly basis for uranium-235 contained in uranium enriched up to 20 percent.

- The licensee's or applicant's item record system uniquely identifies items. The records include information on the chemical form, quantity of material (element and isotope), physical description, identification label or number, and location. The system provides reasonable assurance of detecting falsification or destruction of records of an item's existence.

- In its FNMC plan, a licensee or applicant may propose that certain groups of items that are produced, stored, processed, or otherwise handled together as a unit, such as a batch or sublot of material, may be uniquely identified and stored as a separate group under conditions such that group identity, composition, and quantity will be maintained constant.

- The record of the status of an item can be completed or updated in sufficient time to allow the licensee to meet the requirements for promptly locating an item.

- For items that will not be remeasured at inventory time, the item control procedures provide reasonable assurance that the SNM contents stated in the records are valid and that unauthorized removal of SNM from the item has not occurred. Remeasurement is not necessary if the SNM content of the item was measured previously and the licensee provides reasonable assurance that the SNM content has not subsequently changed.

- A current accounting is maintained of the total quantity of SNM contained in items that are exempted from item control. The accounts identify the quantities by material type category for both controlled and exempted items.

- For items not exempted from the item control program, the licensee or applicant maintains a record system to provide knowledge of the current status of such items. For items subject to this commitment, the item control and records system provides the capability to promptly locate and confirm the existence of any specific item or group of items upon demand. The item record system is secured in such a manner that the record of an item's existence cannot be destroyed or falsified by a single individual without a high probability of detection.

- For items not exempted from the item control program, each item is stored and handled in a manner that enables detection of or provides protection against unauthorized or unrecorded removals of 200 grams or more of plutonium or uranium-233 or 300 grams or more of uranium-235, as one or more whole items or as SNM removed from containers. Otherwise, knowledge of the SNM content is assured by TIDs or by maintaining the item as a sealed source (i.e., as encapsulated material).

- All incidents involving missing or compromised items or falsified item records are investigated. A compromised item is one for which there is evidence of tampering or that is found outside its assigned controlled access area.

- The contents of a compromised item or an unsealed, unencapsulated item located after it has been missing will be redetermined by measurements (i.e., by nondestructive assay or by weighing, sampling, and analysis).

9 SHIPPER–RECEIVER COMPARISONS

9.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(b)(7) is to require the licensee or applicant to conduct and document shipper–receiver comparisons for all special nuclear material (SNM) receipts on both an individual batch basis and total shipment basis and ensure that any shipper–receiver difference (SRD) that is statistically significant and exceeds twice the estimated standard deviation of the difference estimator and 200 grams of plutonium or uranium-233 (U-233) or 300 grams of uranium-235 (U-235) is investigated and resolved.

Shipper–receiver comparisons are important for confirming that either shippers' and receivers' values are acceptable for establishing the book accounting quantities associated with the received material or detecting unacceptable shippers' or receivers' values.

9.1 Receiving Procedures

The first action taken on receipt of SNM should be to verify the number of items, the item identities, and the integrity of individual items and of tamper-indicating devices (TIDs). All SNM shipments received from an external supplier are subject to shipper–receiver comparisons. Such comparisons involve measurement of received material by the receiver, or by the receiver's contractor (who is independent of the shipper), and comparing the receiver's total receipt measurement for element and isotope to that of the shipper's values.

Previously, in approving FNMC plans, the NRC staff has recognized situations in which the cost of conducting and documenting shipper–receiver comparisons outweighs the safeguards benefit of doing so, and it has accordingly granted relief in the form of exemptions, notwithstanding the applicable provisions in 10 CFR Part 74, "Material control and accounting of special nuclear material," that require shipper–receiver comparisons for all SNM receipts. Examples of situations in which such relief may be granted are as follows:

- shipments containing less than 300 grams of U-235 or 200 grams of plutonium or U-233

- individual items containing less than 15 grams of U-235, plutonium, or U-233

- encapsulated items whose encapsulation integrity has not been compromised and which are to be retained by the licensee as encapsulated items

- fuel assemblies and fuel rods previously shipped by the licensee that are being returned, provided that the original encapsulation has not been compromised

- uranium hexafluoride cylinders that are empty except for a heel quantity of uranium hexafluoride

- heterogeneous scrap that must be subject to dissolution before a meaningful accountability measurement can be obtained, noting that both shipper and receiver should agree to accept the "after dissolution plus residue" measurements for accounting purposes

Licensees seeking relief from the 10 CFR 74.43(b)(7) requirements, would need to submit specific exemption requests in accordance with 10 CFR 74.7, "Specific exemptions." If the law authorizes the granting of such exemption requests and doing so would not endanger life or property or the common defense and security and would otherwise be in the public interest, the NRC would consider such exemptions on a case-by-case basis.

For any SNM received, the licensee or applicant must provide all appropriate information on the U.S. Department of Energy (DOE)/NRC Form 741, "Nuclear Material Transaction Report," that accompanies the shipment, in accordance with 10 CFR 74.15, "Nuclear material transaction reports." (NUREG/BR-0006, "Instructions for Completing Nuclear Material Transfer Reports (DOE/NRC Forms 741 and 740M)," contains instructions and requirements for completing DOE/NRC Form 741.)

9.2 Determination of Receiver's Values

Licensees or applicants should measure SNM receipts for total quantity (mass), element concentration (such as for plutonium dioxide, uranium dioxide, or uranyl nitrate solutions), and fissile isotope abundance (U-235 or U-233).

The validity of the shipper's data should be substantiated with appropriate and timely receiver checks and measurements, including gross weight, adequate sampling techniques, NDA measurements (if appropriate), and destructive measurements (scrap excepted). (Chapter 4 contains further information on measurements.) Shipper's values may be accepted and booked without receiver element or isotope measurements for encapsulated items, such as fuel elements or rods, if the NDA measurement is not feasible.

9.3 Evaluation of Shipper–Receiver Differences

When the shipper's measurement uncertainty (or standard error) information is available, the following should define the estimated standard deviation of the difference estimator or combined standard error:

$$\text{combined standard error} = [(\sigma_S)^2 + (\sigma_R)^2]^{1/2}$$

Where: σ_S = shipper's measurement standard error
σ_R = receiver's measurement standard error

If the shipper's measurement uncertainty values are not available, the receiver can assume that the shipper's measurement uncertainty is equal to (but no greater than) its own uncertainty. In this situation (i.e., both shipper and receiver have the same measurement uncertainty), the following becomes the combined measurement standard error:

$$\text{combined standard error} = [2\,(\sigma_R)^2]^{1/2}$$

$$= 1.414\,\sigma_R$$

The difference between the shipper's value and the receiver's value (i.e., the SRD), in terms of the total shipment, must be regarded as significant whenever the SRD exceeds both 300 grams of U-235 or 200 grams of plutonium or U-233 and twice the combined standard error. Licensees also must regard as significant an SRD in excess of both 300 grams of U-235 or 200 grams of

plutonium or U-233 and twice the combined standard error with respect to an individual batch within the shipment.

9.4 Resolution of Significant Shipper–Receiver Differences

The FNMC plan should describe the steps involved with the investigation of a significant SRD and discuss how the difference is resolved. The plan also should present criteria for defining a resolved SRD. Generally, resolution of a significant SRD could involve a referee (or umpire) measurement of a retainer sample(s) but not of the material weight. The resolution process should specify whose weight value is used in the resolution process if shipper's and receiver's weights differ by more than one-half of the total combined standard error.

9.5 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to shipper–receiver comparisons. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for conducting SRD evaluations and resolving significant SRDs is acceptable and in accordance with 10 CFR 74.43(b)(7) will be informed by the following acceptance criteria:

- Each shipping container is inspected within 3 working days after receipt for loss or damage to the container or TIDs to determine whether SNM could have been removed. If the integrity of a container is questionable, the presence of all items that were packaged in the shipping container will be confirmed within 24 hours of discovering the questionable integrity. Only acceptable tamper-safing methods will be used as described in Section 11.1 of this document and as agreed to with the receiver.

- Measurements of the quantity of SNM received in each shipment are performed and the SRD is tested for statistical significance. The element and isotopic content of SNM shipped or received by the licensee are based on measurements obtained from measurement systems subject to the measurement control program. Occurrences of statistically significant SRDs in excess of 300 grams of U-235 or 200 grams of plutonium or U-233, and missing items are reported to the shipper promptly.

- Any SRD that exceeds both twice the estimated standard deviation of the difference estimator and 200 grams of plutonium or U-233 or 300 grams U-235 is considered statistically significant and is investigated and resolved within 90 days of material receipt or, if not resolved within that period, the unresolved difference is reported to the NRC.

- For SNM received, SRDs that are statistically significant and also greater than 300 grams of U-235 or 200 grams of plutonium or U-233 on a total shipment basis (or on a batch basis) are detected within 30 days of receipt, except for those materials granted an exemption by the NRC.

- SNM receipts for which the licensee has been granted an exemption from the shipper–receiver comparison requirements are clearly identified.

- Complete the receiver process for nuclear material within 60 calendar days of receipt, except in the cases of scrap that cannot be representatively sampled and irradiated material (Section 4.5).

- Measurement results for shipments and receipts are corrected for biases that are significant at the 0.05 level (i.e., for any bias that exceeds two times the standard error associated with a mean) and that impact individual items by more than their rounding error in terms of plutonium, U-233, U-235, or uranium content.

- Confirmatory measurements of scrap shipments are performed upon receipt to determine the amount of plutonium or uranium element and fissile isotope consistent with the accountability needs of the shipper. However, heterogeneous scrap that cannot be accurately measured in its received form need not be measured until after dissolution, within 18 months of receipt (Section 4.5).

- The investigation procedure for significant SRDs is sufficiently comprehensive to ensure that the difference will be resolved. Comprehensiveness is sufficient if the licensee or applicant shows the capability to verify records, resample, perform remeasurements, establish liaison with the shipper, provide samples to a referee laboratory, and perform the statistical analysis needed to evaluate the measurements.

- The documentation of shipments and receipts should be completed and transmitted within the time specified in NUREG/BR-0006.

10 ASSESSMENT AND REVIEW OF THE MATERIAL CONTROL AND ACCCOUNTING PROGRAM

10.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(b)(8) is to require independent assessments of the MC&A program. The licensee or applicant must periodically (at least every 18 months) assess the performance of the overall MC&A program, review its effectiveness, and document management's action on prior assessment recommendations and any identified deficiencies. The U.S. Nuclear Regulatory Commission expects that knowledgeable, technically competent individuals free from conflicts of interest will perform the review and that the deficiencies will be brought to the attention of plant management so that they will be corrected. The review must draw conclusions and make recommendations relative to overall program effectiveness and to the adequacy of the MC&A program—including that of any contractor that performs SNM measurements on the licensee's or applicant's behalf.

10.1 General Description

The capabilities, performance, and overall effectiveness of the licensee's or applicant's MC&A program should be independently reviewed and assessed at least every 18 months. The FNMC plan should describe the assessment and review program in terms of the following:

- maximum interval between assessments
- selection procedures for the assessment team
- number of team members to be selected
- qualification and expertise of team members
- independence of individual team members from the MC&A responsibilities and activities they are reviewing and assessing
- maximum elapsed time and minimum actual effort to be used for completion of the assessment and issuance of a final team report

The licensee or applicant should review and evaluate the entire MC&A program during each assessment. When the entire MC&A program is reviewed, intervals between assessments can be as long as 18 calendar months. However, if the licensee conducts assessments of only some subsystems of the MC&A program, other subsystems of the program should be assessed at intervals no longer than 9 calendar months. The schedule should ensure the entire program is reviewed over the course of 18 calendar months. Thus, the FNMC plan should specify the type of assessment (partial or total) and the maximum interval between assessments. "Interval" means the elapsed time between either the start or termination of successive assessments.

The responsibility and authority for the assessment program should be at least one level higher in the licensee's or applicant's organizational management structure than that of the MC&A manager. Such responsibility should include selecting the assessment team leader and initiating corrective actions. Individuals participating in the assessment may be selected from the facility

staff, but in that case no individual member should participate in the assessment of the parts of the MC&A system for which that person has direct responsibility. Hence, the MC&A manager may not participate in the assessment. Also, a given individual should not assess the parts of the system that are the responsibility of another team member if the other team member is assessing the given individual's area. The leader of the assessment team should have no responsibilities for managing any of the MC&A elements being assessed.

The actual number of team members for any given assessment should depend on the knowledge and expertise of the team members relative to MC&A activities and to their experience in conducting assessments. Personnel assigned to the assessment team should have demonstrated an understanding of the regulatory objectives and requirements of the MC&A program and should have sufficient knowledge and experience to be able to judge the adequacy of the parts of the system they review. The team should have authority to investigate all aspects of the MC&A system and should have access to all necessary information.

To provide a meaningful and timely assessment, the review and evaluation process should not be protracted. The actual review and investigation activities should be completed in 30 calendar days, with an additional 15 calendar days allowed for completing and issuing a final team report.

10.2 Report of Findings and Recommendations

The areas to be reviewed should encompass the entire MC&A system, and the level of detail of the reviews should be sufficient to ensure the assessment team has made an adequate and reasoned judgment of the MC&A system effectiveness. The team report, as a minimum, should state findings pertaining to the following:

- organizational effectiveness to manage and execute MC&A activities
- management responsiveness to indications of possible losses of SNM
- staff training and competency to carry out MC&A functions
- reliability and accuracy of accountability measurements made on SNM
- effectiveness of the measurement control program in monitoring measurement systems and its sufficiency to meet the requirements for controlling and estimating both bias and the standard error of the inventory difference
- soundness of the material accounting records
- effectiveness of the item control program to track and provide current knowledge of items
- capability to promptly locate items and effectiveness in doing so
- timeliness and effectiveness of shipper–receiver difference (SRD) evaluations and resolution of excessive SRDs
- soundness and effectiveness of the inventory-taking procedures
- capability to confirm the presence of SNM

- capability to detect and resolve indications of missing SNM

On completion of each assessment, the evaluation team should document findings and recommendations for corrective action, if any. It should distribute the written report to the plant manager, the MC&A manager, and other managers affected by the assessment.

10.3 Management Review and Response to Report Findings and Recommendations

Management should review the assessment report and take the necessary actions to correct MC&A system deficiencies. The management review should be documented within 30 days following the submittal of the assessment team's report, and it should include a schedule for the correction of deficiencies. Corrective actions, if any, that pertain to daily or weekly activities should be initiated promptly after the submittal of the final assessment report.

The FNMC plan should address the resolution and followup actions associated with the concerns identified in the assessment report. The plan should specify the individuals responsible for resolving identified concerns and the timeliness of such resolution.

10.4 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to independent assessments of the MC&A program. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for such assessments is acceptable and in accordance with 10 CFR 74.43(b)(8) will be informed by the following acceptance criteria:

- The capabilities and performance of the MC&A program will be reviewed, and its effectiveness will be independently assessed, at least every 18 months. This means that the nominal elapsed time from the completion of one review or assessment to the completion of the next will not exceed 18 months.

- The periodic assessments will be comprehensive and sufficiently detailed to enable the assessment team to rate the MC&A system accordingly. The overall assessment objectives are to determine that the MC&A system, as designed and implemented, is continuing to meet the general performance objectives, and to identify weaknesses or deficiencies in the system design or performance that may need correcting.

- The areas to be reviewed encompass the entire MC&A program, and the level of detail of the reviews is sufficient to ensure that the assessment team has adequate information to make reasoned judgments of the MC&A system effectiveness, which includes the following:

  – organizational effectiveness and management responsiveness to indicators of possible SNM losses

  – staff training and competency to carry out MC&A functions

  – soundness of the material accounting records
  – capability to promptly locate items

- – timeliness and effectiveness of SRD evaluations and resolution of significant SRDs
- – soundness of physical inventory procedures and practices
- – effectiveness of the measurement control program to monitor key measurement systems, establish bias estimates and measurement uncertainties, and meet the requirements for controlling the total MC&A measurement uncertainty associated with inventory difference
- – capability to confirm the presence of SNM
- – capability to investigate and resolve anomalies and aid in any government-led investigation of missing SNM and to provide information that would aid in the recovery of missing SNM

- Generally accepted auditing principles are used to check each type of record in which a representative sample (of a sufficient number) of randomly selected records is examined.

- Reviews and assessments are performed either by qualified individuals from outside the facility or qualified individuals from inside the facility organization whose work assignments and positions within the organization will not impair their ability to make objective judgments of the MC&A program capabilities and performance. Personnel assigned to the assessment team should have an adequate understanding of the regulatory objectives and requirements of the MC&A system and have sufficient knowledge and experience to be able to judge the adequacy of the parts of the system they are asked to review. The team should have authority to investigate any aspect of the MC&A program and will have access to all relevant information.

- An individual participating in the assessment may not review any part of the MC&A system for which he or she has direct responsibility. Also, an individual “A” will not assess any part of the system that is the responsibility of person “B” if B is assessing an area under the responsibility of A.

- The entire MC&A program will be reviewed and evaluated during each single assessment (to be completed within an elapsed time that is short relative to the time between changes in the MC&A system and is demonstrated to be able to include any such changes made during the review or assessment). Conducting two or more assessments during an 18-month interval, in which only some subsystems of the MC&A program are covered in each assessment, is acceptable if other subsystems are covered at intervals of 9 months (or less). It is important to assess the MC&A program as a whole to evaluate how individual systems interact. Therefore, if more than one assessment is to be conducted, the review should include consideration of how well the other individual systems currently interact if conducted in separate assessments.

- The leader of the assessment team should not have responsibilities for performing or managing the functions being assessed. The assessment team leader should have no responsibility for managing or performing any of the MC&A functions.

- The responsibility and authority for the assessment program and for initiating corrective actions should be (1) at least one level higher in the organization than the MC&A manager, or (2) at a level equal to that of the onsite plant manager.

- If there are changes that have occurred in the MC&A program each overall review and assessment will include any such changes made during the time the review or assessment is being conducted.

- The completion date for any review and assessment is defined as the date when the team submits its final written report (of findings and recommendations) to plant management. The start date is the first day in which one or more team members actually inspect records or interview MC&A personnel, and the team will document such start date.

- The results of the assessment and recommendations for corrective action, if any, should be documented and reported to the plant manager and other managers affected by the assessment. Management should review the assessment report and take the necessary actions to correct MC&A program deficiencies. Such corrective actions (if any) that pertain to daily or weekly activities should be initiated within 30 calendar days following the submittal of the review and assessment final report.

- Management's response to recommendations from the review assessment, including any corrective actions ordered by management and the expected time frame for completing such actions, should be documented within 30 calendar days following the submittal of the team's report.

11 TAMPER-SAFING

11.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(c)(3) is to require licensees or applicants to maintain and follow tamper-safing procedures for special nuclear material containers and vaults, if tamper-safe seals are to be used for assuring the validity of prior measurements. The procedures should describe how the licensee or applicant controls access to, and distribution of, unused seals and to records showing the date and time of seal application. The intent of such procedures is to document the distribution, application, and destruction of tamper-safing devices (or tamper-indicating devices (TIDs)), as well as the routine inventory of unused TIDs. Licensees or applicants should retain records for at least 3 years (or longer if specifically required by regulations external to 10 CFR 74.41, "Nuclear material control and accounting for special nuclear material of moderate strategic significance"), thereby providing a means for assessing effectiveness of the tamper-safing procedures and inspecting for compliance with regulatory requirements.

11.1 Characteristics of Tamper-Safing Devices

The use of TIDs on containers or vaults is one such level of protection licensees or applicants use to secure the integrity of special nuclear material, either when it is in transit or stored on site. The one overriding objective of TIDs is to ensure that no tampering or entry has occurred while the TID is on the container. Therefore, for material control and accounting (MC&A) purposes, the degree of confidence in the selection of a TID sealing system will vary depending on its unique characteristics and intended use.

When selecting TIDs, licensees or applicants should consider the following:

- intended use: the determination that the TID is appropriate for tamper-safing the container and withstanding the working environment (i.e., temperature, moisture, repeated handling)

- application: the relative ease or difficulty of physically applying the TID

- substitution: the ability of a TID to be destructively removed and replaced by a new TID without detection

- removal and reapplication: the ability of a TID to be removed and reapplied without detection

- alteration of label data: the ability to alter recorded data on the TID without the alteration being apparent

- integrity verification: the degree of effort required to verify the TID is intact or indicates tampering

The licensee or applicant should confirm the manufacturer's claims that the removal of a TID is not possible without detection by testing potential TIDs to determine whether they can be removed from the containers on which they are to be used. The licensee or applicant should confirm the results by employing the manufacturer's documented procedures and the samples

used. The experiments should be documented, both with regard to what techniques the licensee or applicant used to attempt to defeat the TID and observations as to the degree of success in defeating the TID. In lieu of testing by the licensee or applicant, similar tests conducted by an independent third party may be considered acceptable.

11.2 Use of Tamper-Safing Devices

The FNMC plan may allow the use of TIDs to achieve the following:

- Ensure the long-term validity of measurement data. The application of a TID to an item containing measured quantities of nuclear materials may allow the licensee to maintain the validity of the original measurement value, thus eliminating or decreasing the frequency of the need to remeasure the items to verify their nuclear material content.

- Reduce the effort to conduct physical inventories or item control activities. The application of a TID to a container housing multiple items may allow the licensee or applicant to maintain the validity of the container's contents, thus minimizing the number of items required to be verified during a physical inventory or item control activity.

- Provide assurance of integrity of in transit material. The application of a TID to a shipping container may allow the licensee to maintain the validity of the shipping container's contents and provide assurance that the integrity of the shipment has not been violated. To achieve this goal, the shipper must apply the TID(s) to the shipping container, verify the integrity of the TID(s) shortly before departure of the shipment, and provide the appropriate information (i.e., shipping container serial numbers, TID(s) type(s), and serial number(s)) to the receiver. Upon receipt of the shipment, the receiver should verify the shipping container serial numbers, TID(s) type(s), serial number(s), and the TID(s) integrity. Any discrepancies should be considered an MC&A anomaly, and the facility's MC&A resolution program should address them.

11.3 Description of Tamper-Safing Records

The licensee or applicant should identify all records, forms, reports, and standard operating procedures associated with the use of TIDs. Such records should include, but are not limited to, the following:

- receipt of purchased TIDs

- issuance of TIDs

- identification of the person applying the TIDs

- identification of the person who verified the application of the TID

- identification of the container to which the TID was applied, including the TID serial identification (if applicable)

- removal and destruction of TIDs

- routine inventory of unused and unissued TIDs

- identification of roles and responsibilities, including:

  – designation of the TID control officer(s)
  – personnel approved to apply, verify, and destroy TIDs

- training of personnel in the application, verification, and destruction of TIDs

11.4 Commitments and Acceptance Criteria

The acceptability of a TID is based on an evaluation of the attributes of the device in relation to time to defeat the tamper-indicating features. TIDs that the U.S. Nuclear Regulatory Commission has already deemed acceptable include Type E, pressure-sensitive, tamper-evident wire seals, fiber optic seals, and steel padlocks (See guidance for TIDs in Regulatory Guide 5.80, "Pressure-Sensitive and Tamper-indicating Device Seals for Material Control and Accounting of Special Nuclear Material," December 2010.) Other TIDs may be equally acceptable. Licensees or applicants proposing to use TIDs not currently approved by the agency must provide the appropriate information, including references, to enable licensing reviewers to assess the adequacy of the proposed TID type.

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to the use of tamper-safing devices. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for tamper-safing is acceptable and in accordance with 10 CFR 74.43(c)(3) will be informed by the following acceptance criteria:

- Only TIDs that are controlled and accounted for are used to maintain the validity of previously established SNM quantities associated with items.

- Written procedures are maintained to ensure that individuals authorized to handle TIDs are properly trained.

- Preferably, a single individual, but no more than three individuals (none of whom have any responsibility for seal application or destruction), is (are) designated as the tamper-safing device control officer(s).

- TIDs are only applied and removed by individuals authorized for that purpose.

- Unused TIDs are controlled and inventoried. Unissued tamper-safing devices are stored in a locked container within a room that is locked when unoccupied or in an approved repository. Blocks of tamper-safing devices issued to designated individuals are stored in a locked container within a room that is locked when unoccupied or in an approved repository.

- When TIDs are not in storage, they are in the possession of authorized individuals (i.e., the tamper-safing device control officer or person responsible for applying the tamper-safing device). As a rule, the number of available seals issued to these individuals should be limited to a single day's use.

- The licensee or applicant has in its possession a commitment from the seal manufacturer that plates, dies, and production residuals are controlled and protected.

- Upon removal, TIDs are destroyed (i.e., crimped, flattened, or otherwise rendered unusable) and given proper disposal.

- Records of TID application, verification, removal, and destruction are documented, and control measures are implemented to prevent alteration of records concerning containers protected by TIDs.

12 RESOLVING INDICATIONS OF LOSS, THEFT, DIVERSION, OR MISUSE OF SPECIAL NUCLEAR MATERIAL

12.0 Regulatory Intent

The intent of the general performance objectives in Title 10 of the *Code of Federal Regulations* (10 CFR) 74.41(a)(2) and (3) is to ensure that licensees or applicants be able to rapidly determine whether an actual loss of a significant quantity of SNM has occurred and promptly investigate and resolve any anomalous conditions or situations that indicate a possible loss, theft, diversion, or misuse of SNM, whether arising from errors or deliberate actions.

12.1 Methods and Procedures for Identifying Indicators

The FNMC plan should discuss the means by which the licensee or applicant will resolve indicators of a possible loss, theft, diversion, or misuse of SNM. The licensee's or applicant's resolution program should address the possible indicators of missing SNM. The FNMC plan should enumerate all the potential indicators that can be postulated and develop resolution procedures for each. Any anomaly could potentially be an indicator of loss, theft, diversion, or misuse of SNM. An anomaly is an unusual observable condition (such as excessive discrepancies, missing items, broken tamper-indicating devices, or other possible indicators) that might result from theft, diversion, or other misuse of SNM. The terms "indicator" and "anomaly" may be used interchangeably to describe a condition that may require further investigation to determine whether an actual loss, theft, diversion, or misuse of SNM occurred.

The following are examples of possible indicators of missing SNM:

- lack of agreement between a physical inventory and its associated book inventory in which the inventory difference is positive and exceeds three times the standard error of inventory difference and more than 300 grams of uranium-235 (U-235) or 200 grams of plutonium or uranium-233 (U-233)

- determination through the item control program that one or more items are not in their designated locations and the actual locations are not immediately known

- discovery that an item's integrity or its tamper-indicating device was compromised

- information from the process control system indicating potential loss of material from the process system

- an allegation[3] of theft or diversion

12.2 System and Procedures for Investigating and Resolving Loss Indicators

One or more MC&A procedures should address the system and practices for investigating and resolving loss indicators. The licensee or applicant should have well-defined procedures both for

[3] Freedom of Employees in the Nuclear Industry To Raise Safety Concerns Without Fear of Retaliation (61 FR 24336; May 14, 1996) or NRC Allegation Manual (https://www.nrc.gov/docs/ML1700/ML17003A227.pdf)

promptly investigating and resolving indications of possible missing SNM and for rapidly determining whether an actual loss of a significant quantity of SNM has occurred, with significant quantity being either more than one formula kilogram of strategic SNM or 10,000 grams or more of uranium-235 contained in uranium enriched up to 20.00 percent. These procedures should include criteria for determining when to conclude an investigation of loss indicators.

Additionally, uranium enrichment facilities should have a system in place for detecting, investigating, and resolving an indication of unauthorized production of enriched uranium. Licensees or applicants are responsible for developing and following a formalized program designed to resolve indications of unauthorized production. Examples of possible indicators of unauthorized production of uranium could be the presence of unauthorized product, feed or tails cylinders, separative work unit imbalances, or discovery of unauthorized reconfiguration, interconnection or isolation of enrichment equipment. Various types of anomalies at uranium enrichment facilities can indicate a number of possible underlying scenarios (e.g., from simple theft to isotopic substitution concealing diversion of product material). Resolution of an indicator of possible unauthorized production means that the licensee or applicant has made a specific determination that the following have not occurred: (1) production of excess quantities of uranium enriched to 10 percent in U-235 and (2) enrichment of uranium to 20 percent or more in U-235. The resolution process should include the investigation of all information contributing to the indication of unauthorized production.

Resolving a loss indicator means that the licensee or applicant has made a determination that loss, including possible diversion or theft, has not occurred and is not occurring. For each type of indicator, the licensee or applicant should develop detailed resolution procedures and should describe or outline them in the FNMC plan.

Any investigation of an indication of a loss or theft should provide, whenever possible, (1) an estimate of the quantity of SNM involved, (2) the material type or physical form of the material, (3) the type of unauthorized activity or event detected, (4) the time frame within which the loss or activity could have occurred, (5) the most probable cause(s), and (6) recommendations for preventing reoccurrence.

For indications that a loss or theft may have occurred, the resolution process should include (1) thoroughly checking the accountability records and source information, (2) locating the source of the problem, (3) isolating the exact reason for the problem within the area or processing unit, (4) determining the amounts of SNM involved, and (5) making a determination that the indication is or is not resolved. The licensee or applicant should prepare the resolution procedures in such a manner that no individual who could have been responsible for the potential loss also would be responsible for its resolution. If an investigation of an indicator results in a conclusion that the indication is true, such conclusion must be reported to the NRC within 1 hour of its determination under 10 CFR 74.11, “Reports of loss or theft or attempted theft or unauthorized production of special nuclear material.” The FNMC plan should specify the time allowed for resolution. In general, a time not exceeding 72 hours should be adequate.

12.3 <u>Response Actions for Unresolved Indicators</u>

Response actions to unresolved indicators should be clearly defined and should be on a graded scale appropriate to the level of potential safeguards significance. Licensees or applicants also should define the responsibility and authority for initiating and executing such escalating levels of response actions.

For indicators of missing SNM, the level of safeguards concern is related to such factors as the following:

- the potential quantity of SNM involved

- the material attractiveness of the potential missing uranium or plutonium (in terms of fabricating a nuclear explosive device) relative to its type, enrichment, composition, or form (e.g., uranium metal, urano-uranic oxide, uranyl nitrate solution, uranium hexafluoride, scrap, or waste)

12.4 Documentation Requirements

The FNMC plan should identify all documentation requirements associated with the licensee's or applicant's program for the reporting, investigation, and resolution of missing SNM indicators. Review and approval requirements and document custodial responsibility also should be defined. As a minimum, the plan should include documentation of the following:

- investigation procedures

- resolution procedures

- reporting of the indicator to MC&A management, including date and time the indicator was reported, name of the individual who discovered the indicator, and a description of the indicator

- investigation findings and conclusion, including resolution status, date issued, name and signature of the principal investigator, and approval signature of the MC&A manager

- reports made to the NRC for unresolved indicators and for indicators determined to be real, including date and time the report was made, method of communication, and name of the NRC individual contacted

Section 13.3 of this document provides additional types of information that may be necessary.

12.5 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to investigating and resolving anomalies indicating possible missing SNM. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for resolving indications of loss, theft, diversion, or misuse of SNM is acceptable and in accordance with 10 CFR 74.41(a)(2) and (3) will be informed by the following acceptance criteria:

- The licensee or applicant will conduct a prompt investigation for all indications of possible loss, theft, diversion, or misuse of SNM.

- The licensee or applicant will assign a cause or probable cause that is based on objective evidence to each indication of possible loss that it investigates.

- Investigation and resolution procedures will provide for adequate overchecks to ensure that no individual who could have been responsible for a possible loss or theft of SNM would be the sole or primary individual responsible for resolving the indicator.

- No investigation relative to an indication of a loss or theft of SNM exceeding the current significant quantity shall be declared as completed but unresolved without first conducting a shutdown, cleanout inventory in which all unsealed SNM is remeasured for element and isotope contents.

- The licensee or applicant will report to the appropriate NRC MC&A licensing authority the results of all investigations of alleged thefts and any indications of a loss of SNM that remain unresolved after 30 calendar days.

13 INFORMATIONAL AID FOR ASSISTING IN THE INVESTIGATION AND RECOVERY OF MISSING SPECIAL NUCLEAR MATERIAL

13.0 Regulatory Intent

Title 10 of the *Code of Federal Regulations* (10 CFR) 74.41(a)(4) states that the licensee or applicant must be able to provide, in a timely manner, information to aid in the investigation and recovery of missing SNM in the event of an actual loss. The intent of the general performance objective in 10 CFR 74.41(a)(4) is for licensees or applicants to have ready and provide to investigators any information deemed relevant to the recovery of SNM involved in a loss, theft, diversion, or misuse. The licensee or applicant must provide complete and accurate information relevant to the investigation, as opposed to only providing information that the investigators are knowledgeable enough to request. This objective pertains to investigations and recovery operations, relating to actual (or highly suspected) events pertaining to missing SNM, which would be conducted by the U.S. Nuclear Regulatory Commission and other local, state, or federal government agencies.

13.1 Types of Information

The following kinds of information may aid the investigation and recovery effort:

- data or observations that led the licensee to determine that a loss or theft of uranium or plutonium may have occurred
- data, observations, and assessments associated with attempts to resolve the indication of missing material
- the time period during which the material may have left the facility
- the path and means by which the material may have left the facility

13.2 Information Indicating Possible Losses of Special Nuclear Material

Information indicating that a loss of uranium or plutonium may have occurred can come from process or production yield data, physical inventory results, item control, and shipper–receiver comparisons. This information could include the following:

- material accountability data records and reports
- inventory records
- inventory difference and propagation of error calculations
- inventory reconciliation reports
- indications of unrecorded or unauthorized removals of SNM from storage or process locations

- indications that the enrichment equipment has been or is being used to produce undeclared uranium enriched to 20 percent or more for unauthorized use

13.3 Information on Resolving Indications of Missing Special Nuclear Material

Chapter 12 provides information associated with determining an actual loss of SNM and resolving indications of missing SNM. This information, and information that may be of aid in the recovery of missing material, would include the following:

- the type of unauthorized activity detected

- the interval during which the loss may have occurred

- the amount of material and form of the material involved in the loss

- results of measures to validate indicators

- results of extended measures to resolve indicators

- results from special inventories (or reinventories) and tests performed

- audit results of the SNM accountability source data

- assessments of measurement data and measurement controls

- results from reviews of the material control and accounting program and status of corrective actions

- history of indicator investigation and resolution activities

- anomaly investigation and resolution procedures and conclusions

- probable cause of the loss

- any abnormal events that may have contributed to or caused the loss

- the names of individuals who could have been responsible for the loss

Much of the backup information necessary to assist in an investigation would be records maintained in the facility records system described in Chapter 14.

13.4 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to providing information to assist in the investigations and recovery of missing uranium. The NRC staff's regulatory finding that the licensee's or applicant's plan for providing informational aid is acceptable and in accordance with 10 CFR 74.41(a)(4) will be informed by the following acceptance criteria:

- Procedures are in place for the efficient and timely gathering of relevant information to be provided to government investigators to aid them in the investigation and recovery activities associated with missing SNM.

- Information will promptly be provided to appropriate government authorities to aid in investigations of indications or allegations of missing material and in the recovery of SNM in the event of a loss that could include theft or diversion.

14 RECORDKEEPING

14.0 Regulatory Intent

The intent of Title 10 of the *Code of Federal Regulations* (10 CFR) 74.43(d) is to require licensees or applicants to establish and maintain records that demonstrate that the general performance objectives of 10 CFR 74.41(a)(1) through (4) and the requirements of 10 CFR 74.43, "Internal controls, inventory, and records," and 10 CFR 74.45, "Measurements and measurement control," have been met. Records should include those documenting the following information:

- receipt, shipment, disposal, and current inventory of the special nuclear material (SNM) held under license

- quantities of SNM added to and removed from a process

- shipper–receiver evaluations associated with SNM receipts

In accordance with 10 CFR 74.43(d)(4), each record pertaining to the receipt and disposal of SNM should be retained until the NRC terminates the license. Further, in accordance with 10 CFR 74.19(b), MC&A procedures (as documented in licensee records) must be retained until the Commission terminates the license that authorizes possession of the material and any superseded portion of the procedures retained for 3 years after the portion is superseded. Records provide a means for assessing the performance of the MC&A system and inspecting for compliance with regulatory requirements.

In accordance with 10 CFR 74.43(d)(5), records that demonstrate compliance with the performance objectives of 74.41(a)(1) through (4), the system capabilities of 74.43(b) and (c) must be retained for a minimum of 3 years (or longer if specifically required by 10 CFR Part 75, "Safeguards on nuclear material—implementation of US/IAEA Agreement").

In accordance with 10 CFR 74.41(c), the MC&A program must incorporate checks and balances that are sufficient to detect falsification of data and reports that could conceal diversion of SNM by a single individual, including an employee in any position, or collusion between two individuals, one or both of whom have authorized access to SNM.

14.1 Description of Records

The FNMC plan should identify all records, forms, reports, and standard operating procedures that show compliance with the requirements of 10 CFR Part 74, "Material control and accounting of special nuclear material." Such records should include, but are not limited to, the following:

- documents that define changes in the MC&A management structure or changes in responsibilities relating to MC&A positions

- procedures pertaining to any accountability-related measurement or sampling operation

- forms used to record or to report measurement data and measurement results, including source data

- forms and notebooks used to record calibration data associated with any accountability measurement system

- forms and notebooks used to record quantities, volumes, and other data associated with the preparation of standards, both calibration and control, used in connection with accountability measurement systems

- forms and official memoranda used to record or report measurement control program data, control limit calculations, and out-of-control investigations

- forms listing and providing instructions associated with physical inventories, including both dynamic (nonshutdown) and static (shutdown) inventories

- forms and formal worksheets used in the calculation of standard error of the inventory difference (SEID), inventory difference (ID), and active inventory values

- ledgers, journals, and computer printout sheets associated with the accountability system

- ledgers, journals, and computer printout sheets associated with the item control program, including tamper-indicating device usage and “attesting to” records

- U.S. Department of Energy/NRC Form 740M, “Concise Note”; Form 741, “Nuclear Material Transaction Report”; Form 742, “Material Balance Report”; and Form 742C, “Physical Inventory Listing”; and NRC Form 327, “Special Nuclear Material (SNM) and Source Material (SM) Physical Inventory Summary Report”

- forms, memoranda, and reports associated with identification of, investigation of, and resolution of significant shipper–receiver differences

- loss indication and alleged theft investigation reports

- investigation reports related to excessive IDs

- investigation reports pertaining to indications of activities related to unauthorized production of enriched uranium

- official reports containing the findings and recommendations of MC&A system assessments and any letters or memoranda on response actions to assessment team recommendations

- forms used for recording data associated with the item monitoring program

- monitoring program status or summary reports

- records of training sessions, including date given, topics covered, name of instructor(s), and names and signatures of those attending

- training, qualification, and requalification reports and records

Licensees or applicants should list in the FNMC plan annex or appendix examples of MC&A forms to be retained. The retained records and reports should contain sufficient detail to enable NRC inspectors to determine that the licensee has implemented the program and system capabilities of 10 CFR 74.43 and 10 CFR 74.45 and has met the general performance objectives of 10 CFR 74.41(a)(1) through (4).

14.2 Program and Controls for Ensuring an Accurate and Reliable Record System

The FNMC plan should describe the controls used to ensure that records are accurate and reliable.

The record system also should provide a capability for easy traceability of all SNM transactions from source data to final accounting records.

The following topics should be addressed:

- the auditing system or program to verify the correctness and completeness of records

- the overchecks and balances for preventing or detecting missing or falsified data and records

- the plan for reconstructing lost or destroyed SNM records

- the access controls used to ensure that only authorized persons can update and correct records

- the record system to have sufficient redundancy to enable reconstruction of lost or missing records so that knowledge of the SNM inventory is always available.

14.3 Commitments and Acceptance Criteria

In its FNMC plan, the licensee or applicant should identify all commitments that relate to the acceptance criteria applicable to recordkeeping. The NRC staff's regulatory finding that the licensee's or applicant's FNMC plan for recordkeeping is acceptable and in accordance with the performance objectives of 10 CFR 74.43(d) and system capabilities of 10 CRR 74.41(c) will be informed by the following acceptance criteria:

- Licensees should retain such records for at least 3 years, unless a longer retention time is specified by 10 CFR 74.15(b), 10 CFR Part 75, or a specific license condition. The records referred to in 10 CFR 75.22, "Accounting records," and 10 CFR 75.23, "Operating records," and generated during any period in which the facility is under International Atomic Energy Agency safeguards will be retained for at least 5 years. Licensees or applicants will retain and maintain current versions of the following records for at least 3 years:

  – management structure, MC&A job descriptions, and MC&A policies and procedures

  – accounting source data records (accounting source data normally consist of shipping and receiving forms, physical inventory forms, and the forms used for

initially recording measurement and measurement control data, noting that after an item is destroyed, the item location record needs to be retained for an additional 14 calendar days but then may be destroyed)

  - records of shipments and receipts and investigations of significant shipper–receiver differences, plus the information used to resolve them

  - measurement data for receipts, shipments, discards, and inventory

  - calibration of measurement systems, measurement control data, bias estimates, and the statistical analyses of the measurement control data

  - data used to demonstrate that the measurement system performance achieves the SEID limits required by 10 CFR 74.45(c)(4)

  - physical inventory listings and inventory work sheets

  - calculations of detection thresholds for excessive IDs of a safeguards-significant event (i.e., any ID that exceeds three times SEID and specified minimal quantities)

  - calculations of the standard error of the ID and information used to reconcile an excessive ID

  - reports of investigations and resolution of indications of loss of SNM

  - the results of independent assessments and management action taken to correct any deficiencies identified

- MC&A procedures (as documented in licensee records) will be retained until the Commission terminates the license in accordance with 10 CFR 74.19(b).

- All SNM transactions, from source data to final accounting records, will be readily traceable.

- The source data should be retained in its original form, if it is possible, until the physical inventory and any subsequent ID investigations have been completed. After this time, any readable facsimile is acceptable for the remainder of the required retention period. All other records may be retained as hard copy, microfiche, permanent computer-readable forms, or other permanently readable forms.

- The records of the data that are the basis of the calculated SEID will permit traceability to the sources of the variances caused by calibrations, bias adjustments, and random effects in the measurements. These records may be summaries of calibrations, bias tests, and variance monitoring data or control charts.

- The record system will have sufficient redundancy to enable reconstruction of lost or missing records so that knowledge of the SNM inventory is always available. The primary records, as contrasted with duplicate or backup records, will be provided security against computer failure, fire or water damage, vandalism, and access by unauthorized persons.

- All retained MC&A records are to be readily accessible to meet time restraints relative to their use. In general, the record retention system is to possess the capability to retrieve records used for measurement control or accountability within 24 hours if the record was generated within the past 12 months, and within 7 calendar days if generated more than 12 months ago. Licensees must make physical inventory available within 24 hours for the latest two physical inventories. Item control records are to be retrievable in time to satisfy the criteria in Section 8.7.

- Overchecks or other controls, including access controls for updating and correcting records, are provided so as to prevent or detect errors in the records that would affect inventory difference and item location.

- Checks and balances are incorporated that are sufficient to detect falsification of data and reports that could conceal diversion of SNM, as required by 10 CFR 74.41(c).

15 GLOSSARY

This section defines selected terms in the context of (1) their usage in this document or (2) how they should be used if contained in the fundamental nuclear material control plans submitted under Title 10 of the *Code of Federal Regulations* (10 CFR) 74.41, "Nuclear material control and accounting for special nuclear material of moderate strategic significance."

ADDITIONS TO INVENTORY—Quantities of special nuclear material (SNM), of a given material type code, added to a "plant" inventory and that, before such addition, were not part of the plant's total possessed quantity for the material type code in question.

ANOMALY—An unusual observable condition (such as excessive discrepancies, missing items, broken tamper-indicating devices, or other possible indicators) that might result from theft, diversion, or other misuse of SNM.

ARTIFACT STANDARD—A container or item, of certified mass, having a size, shape, and mass that is representative of a particular type of process-related item or container. Weighing error caused by buoyancy is eliminated by the use of artifact standards for scale calibrations.

ASSIGNED VALUE—A value such as for mass, volume, SNM concentration, or SNM quantity, assigned, for example, to a standard weight or standard material, used for calibrating or controlling a measurement device or system. An assigned value may not necessarily be a certified value, but if it is not, it should be traceable to a certified standard. In any event, assigned value is the best estimate of the standard's true value.

CERTIFIED STANDARD—A standard weight, material, device, or instrument having an assigned value that is guaranteed to be within specified limits by a nationally or internationally recognized organization (e.g., bureau, laboratory) that issues or certifies standards.

CHECK STANDARD (BENCH STANDARD, WORKING STANDARD)—A standard, not necessarily traceable to a primary standard, that is used routinely (e.g., daily or weekly) to check (or verify) the reliability of a measurement device, instrument, or other device (including those of accountability measurement systems). Such standards are not, however, used for the actual calibration or control of accountability measurement systems.

COMBINED STANDARD ERROR—An error band derived from the respective standard error values associated with each of two measurements (usually independent of each other) performed on a given material quantity. For both measurement values (of the pair) to be regarded as being in agreement, they must not differ from each other by more than the calculated combined standard error, which is normally calculated by taking the square root of the sum of squared individual standard errors:

$$\text{Combined Standard Error} = [(\sigma_1)^2 + (\sigma_2)^2]^{1/2}$$

CONFIRMATORY MEASUREMENT—A measurement that confirms (within measurement uncertainty at the 95-percent confidence level) a previously established parameter, such as net weight or enrichment, associated with an SNM item (or SNM quantity), but that does not thoroughly verify the previously established element or isotope quantity assigned to such item. Confirmatory measurements are sometimes used as the basis for concluding that previous measurement values for plutonium, uranium, and uranium-235 (U-235) or uranium-233 (U-233) (or element and isotope) quantities are still valid.

CONTROL STANDARD—A standard that (1) is representative of the process material being measured, and (2) is itself measured periodically to monitor for and to estimate any bias associated with the measurements of the process material in question. A control standard must be traceable to a primary standard or to a primary reference material.

CRITICAL MATERIAL CONTROL AND ACCOUNTING PROCEDURES—Those written procedures that, if not performed correctly, could result in a failure to achieve one or more of the four general performance objectives of 10 CFR 74.41(a) and the program and plan capabilities of 10 CFR 74.41(c).

CUSTODIAN—A designated individual who is responsible for (1) the control and movement of all SNM within a specified control area, and (2) maintaining records relative to all SNM that is transferred into or out of the area and that is currently located within the control area. Control areas are usually designated as material balance areas (MBAs) or item control areas (ICAs). From the standpoint of good safeguards practice, a single individual should not be a custodian of more than one control area.

DEPLETED URANIUM—Any uranium-bearing material whose uranium isotopic distribution can be characterized as being (1) less than 0.700 weight percent (wt %) in combined U-233 plus U-235, and (2) at least 99.200 wt % uranium-238 (U-238).

ENDING INVENTORY (EI)—The total-itemized quantity of SNM of a given material type code possessed by a "plant" at the end of a material balance period, as determined by a physical inventory. The EI quantity for any given material balance period is (by definition) exactly equal to the beginning inventory quantity for the next period.

ENRICHED URANIUM—Any uranium-bearing material that does not qualify as natural or normal uranium and whose combined U-233 plus U-235 isotopic content is 0.725 percent or higher by weight, relative to the total uranium element content.

INVENTORY RECONCILIATION—The adjustment of the book record quantity of both element and fissile isotopes to reflect the results of a physical inventory. In the broad sense, inventory reconciliation also includes the activities of calculating (1) the inventory difference (ID) for the material balance period in question, (2) the uncertainty (i.e., standard error of the ID) value associated with the ID, (3) the active inventory for the period, and (4) any bias adjustment or prior period adjustment associated with the ID value.

ITEM CONTROL AREA (ICA)—An identifiable physical area for the storage and control of SNM items. Control of items moving into or out of an ICA is by item identity and SNM quantity as determined from previous measurement.

ITEM CONTROL PROGRAM—A system that tracks (i.e., records) the creation, identity, location, and disposition of all SNM items of certain predetermined item categories. In addition, item control programs usually provide a periodic verification of the existence and location for static items.

KEY MEASUREMENT SYSTEM—A set of measurement systems that are the key contributors to the total measurement standard error. These measurement systems can be characterized by systematic and random error components on a relative percentage basis.

MATERIAL BALANCE AREA (MBA)—An identifiable physical area for the physical and administrative control of nuclear material such that the quantity of nuclear material being moved into or out of the MBA is represented by a measured value (for both element and isotope).

MATERIAL BALANCE PERIOD—The time span to which a material balance or physical inventory relates.

MATERIAL TYPE CODES—Number codes for identifying basic material types with respect to source material, SNM, and byproduct material. These codes are used by the Nuclear Materials Management and Safeguards System (NMMSS) for tracking U.S.-owned and U.S.-possessed materials worldwide. Detailed instructions on reporting to NMMSS are given in NUREG/BR-0006 and NUREG/BR-0007. For SNM, the following seven material type codes have been assigned:

CODE	MATERIAL TYPE
10	Depleted Uranium
20	Enriched Uranium (*)
50	Plutonium
70	Uranium-233(**)
83	Plutonium-238(***)
88	Thorium
89	Uranium in Cascades

*For DOE/NRC Form 742, “Material Balance Report,” material code 20 has four subcodes to denote enrichment range: El, E2, E3, and E4. For NRC Form 327, “Special Nuclear Material (SNM) and Source Material (SM) Physical Inventory Summary Report,” material code 20 has two subcodes: LEU and HEU (low- and high-enriched uranium).

**Uranium materials should be regarded as material code 70 if the U-233 isotopic abundance is greater than (1) 10.00 wt % relative to total uranium elemental content or (2) both (a) the U-233 isotopic abundance is greater than the U-235 isotopic abundance and (b) the U-233 isotopic abundance exceeds 5.00 wt % relative to total elemental uranium content; otherwise, report as material code 10, 20, or 81 as appropriate.

***Plutonium materials should be regarded as material code 83 if the plutonium-238 isotopic abundance is greater than 10.00 wt % relative to total plutonium elemental content; otherwise, report as material code 50.

MEASURED DISCARD—A batch or quantity of waste with an SNM content determined by measurement that (1) has been shipped to a disposal site, released to the environment, or stored on site and (2) has been taken off the accounting ledgers as part of the current inventory of possessed SNM.

MEASUREMENT CONTROL PROGRAM—A managed program for monitoring and controlling both the accuracy and precision of SNM accountability measurements.

NATURAL URANIUM—Any uranium-bearing material with a uranium isotopic distribution that has not been altered from its naturally occurring state. Natural uranium is nominally 99.283 wt % U-238, 0.711 wt % U-235, and 0.006 wt % U-234. However, the terms “natural uranium” and “normal uranium” are practically used interchangeably for nuclear materials management and safeguards system purposes in the use of material type code 81 for source material other than thorium.

NORMAL URANIUM—Any uranium-bearing material having a uranium isotopic distribution that can be characterized as being (1) 0.700 wt % to 0.724 wt % in combined U-233 plus U-235 and (2) at least 99.200 wt % in U-238. (All natural uranium having a U-235 isotopic abundance in the range of 0.700 wt % to 0.724 wt % is normal uranium, but not all normal uranium is natural uranium (see NATURAL URANIUM).)

POINT-CALIBRATED MEASUREMENT SYSTEM—A measurement system in which the measurement value assigned to an unknown measured by the system is derived from the response obtained from the measurement of a representative calibration standard(s), along with (i.e., at the same time as) the unknown. The standard(s) must undergo all the measurement steps (e.g., aliquoting, sample pretreatment), and in the same manner, as the unknown. Point-calibrated measurement systems can be regarded as bias free, provided that adequate controls are in place to ensure the validity of the standard's assigned value.

PRIMARY STANDARD—Any device or material having a characteristic or parameter (e.g., mass, uranium concentration, uranium isotopic distribution) whose value is certified (within a specified uncertainty) by a nationally or internationally recognized bureau, laboratory, or other entity that issues or certifies standards.

PRIOR PERIOD ADJUSTMENT—Any correction (i.e., adjustment) to an ID value because of a correction applied to a component of beginning inventory after the inventory period started. Such corrections may be because of resolution of a shipper–receiver difference on material received, for example, during a prior inventory period or to correct a recording error. Because these types of corrections have nothing to do with current period losses or errors, and because the official beginning inventory value is not adjusted, an adjustment to the ID value (derived from the ID equation) is necessary to obtain an ID that reflects only current period activity.

PROCESS MONITORING—A system of monitoring production data (e.g., flow rates, yields, densities) and of production control or quality control measurements (as opposed to accountability measurements) that could provide early (i.e., timely) detection of an anomaly that may indicate a significant loss or theft of SNM or indicate unauthorized enrichment activities.

RESIDUAL HOLDUP—Any source material, or SNM, that remains within processing equipment (including ventilation filters and ductwork) after system draindown or cleanout. If, at the time of physical inventory, the total quantity of residual holdup is significant, such holdup must be measured (or estimated on the basis of partial measurements and engineering calculations) and included in the physical inventory listing. The uncertainty associated with a total measured or estimated residual holdup quantity must be included in the calculation of the standard error of the ID.

RESOLUTION OF AN INDICATOR—A definitive determination (with auditable evidence) by the licensee that an indicated possible theft or loss of uranium or plutonium was a false indicator.

SHIPPER–RECEIVER DIFFERENCE—The difference between what a sending facility (i.e., shipper) claims was contained in a shipment (of SNM) and what the receiving facility claims was received, where both the shipper's and receiver's values are based on measurement.

SIGNIFICANT QUANTITY OF SNM OF MODERATE STRATEGIC SIGNIFICANCE—More than 1 formula kilogram of strategic SNM, or 10,000 grams or more of U-235 contained in uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope. (For statistical

sampling plans, however, significant quantity is conservatively set to 1 formula kilogram for strategic SNM and 10,000 grams of U-235 for Category II amounts of low-enriched uranium.)

STANDARD—See definitions for CERTIFIED STANDARD, CHECK STANDARD, CONTROL STANDARD, PRIMARY STANDARD, and STANDARD REFERENCE MATERIAL.

STANDARD DEVIATION—The random error (at the 67-percent confidence level) associated with a single value of a data set, which, in turn, is also a measure (or indication) of the precision relating to a set of measurements (or set of data) concerning the same item or sample of material. Standard deviation is calculated as follows:

$$\text{standard deviation} = s = \left\{ \left[\sum_{i=1}^{n} (x_i - \bar{x})^2\right] / (n-1) \right\}^{1/2}$$

Where:
- n = number of measurements performed
- x_i = the value obtained for the i th measurement for i = 1, 2, 3.......n
- $\bar{x}$ = the average value for all n measurements

STANDARD ERROR—The random error (at the 67-percent confidence level) associated with the average, or mean, value of a data set derived from repetitive determinations on the same item or sample. Mathematically, standard error is the standard deviation divided by the square root of the number of individual measurements used to derive the mean value.

STANDARD REFERENCE MATERIAL—A material or substance that qualifies as a primary standard and whose concentration with respect to a nuclide or isotope, a chemical element, or chemical compound is certified within a specified uncertainty.

SYSTEMATIC ERROR—A unidirectional error that affects all members of a data set. The terms “bias” and “systematic error” are often interchanged. However, any determined bias (i.e., a bias estimated from control standard measurements) has an uncertainty value associated with it. Thus, after correcting for any estimated bias, the uncertainty of that bias can be regarded as a systematic error. If an estimated bias is not applied as a correction, the combination of the bias plus its uncertainty should be regarded as the systematic error.

VERIFICATION MEASUREMENT—(1) A nondestructive assay measurement of an item conducted to verify that a previous nondestructive assay measurement value for isotope content of that item is still valid. (2) The reweighing and resampling of an item, batch, lot, or sublot and performing chemical assays of the resample for element and isotope concentrations so as to verify a previously measured value for element and isotope content of the item (batch, lot, or sublot). Verification is achieved if the original and verification measurement values (for element and isotope quantities) agree within the range of measurement uncertainty (at the 95-percent confidence level).

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11. ABSTRACT (200 words or less)

The U.S. Nuclear Regulatory Commission (NRC) regulations govern the material control and accounting (MC&A) program for licensees authorized to possess and use special nuclear material of moderate strategic significance. This class of material is sometimes referred to as a Category II quantity of material. The MC&A regulations are in Subpart D, “Special Nuclear Material of Moderate Strategic Significance,” in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 74, “Material control and accounting of special nuclear material.” These MC&A regulations apply to licensees or applicants who are authorized to hold special nuclear material of moderate strategic significance. This document provides a structure and information as one means of facilitating compliance with 10 CFR Part 74, Subpart D, about the licensee or applicant preparation and implementation of fundamental nuclear material control plans and corresponding NRC review and inspection.

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