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Acceptable Standard Format and Content for the Material Control and Accounting Plan Required for Low-Enriched Uranium Enrichment Facilities

Final Draft Guidance

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ABSTRACT

This guidance document updates NUREG/CR-5734, K/ITP-415, "Recommendations to the NRC on Acceptable Standard Format and Content for the Fundamental Nuclear Material Control (FNMC) Plan Required for Low-Enriched Uranium Enrichment Facilities," issued 1991, and applies to uranium enrichment facilities licensed by the U.S. Nuclear Regulatory Commission (NRC) that are subject to Title 10 of the *Code of Federal Regulations* (10 CFR) 74.33, "Nuclear material control and accounting for uranium enrichment facilities authorized to produce special nuclear material of low strategic significance." In 1991, the NRC added 10 CFR 74.33 to the material control and accounting (MC&A) requirements of 10 CFR Part 74, "Material Control and Accounting of Special Nuclear Material." As revised, this regulation applies to NRC-licensed uranium enrichment facilities that are authorized to possess equipment capable of enriching uranium and to produce, possess, or use special nuclear material (SNM) of low strategic significance or more than 350 grams of contained uranium-235, uranium-233, or plutonium, or any combination thereof.

The 10 CFR 74.33 requirements are patterned after 10 CFR 74.31, "Nuclear material control and accounting for special nuclear material of low strategic significance," which applies to NRC licensees authorized to possess and use SNM of low strategic significance or unencapsulated SNM in a quantity greater than 350 grams of contained uranium-235, uranium-233, or plutonium, or any combination thereof.. Because enrichment facilities can produce SNM of moderate strategic significance and also strategic SNM, additional MC&A performance objectives and capabilities are required in 10 CFR 74.33 that are not required by 10 CFR 74.31.

This document provides a revised structure and information to facilitate compliance with 10 CFR 74.3, "General performance objectives," and 10 CFR 74.33 regarding the licensee or applicant preparation and implementation of MC&A plans and corresponding NRC review and inspection. Presented herein is the acceptable format and content for those MC&A plans, addressing (1) the performance objectives that must be met, (2) the MC&A program capabilities that must be achieved to meet those objectives, (3) the incorporation of checks and balances to detect falsification of data and reports that could conceal the theft, diversion, or misuse of SNM, and (4) basic commitments that should be made.

This document also provides guidance for implementing new requirements in 10 CFR 74.33 pertaining to tamper-safing procedures and designation of material balance areas and item control areas. All other modifications involve format and editorial changes designed to clarify and facilitate preparation or revision of the required MC&A plan.

CONTENTS

ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DQ	detection quantity
DT	detection threshold
DU	depleted uranium
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
RBIPI	running book in-process inventory
SEID	standard error of the inventory difference
SM	source material
SNM	special nuclear material
SRD	shipper-receiver difference
SWU	separative work unit
TID	tamper-indicating device
U	uranium
U-233	uranium-233
U-235	uranium-235
U-238	uranium-238
UO_2	uranium dioxide
U_3O_8	urano-uranic oxide
UF_6	uranium hexafluoride
wt %	weight percent

1. INTRODUCTION

The Atomic Energy Act of 1954, as amended, directed the U.S. Atomic Energy Commission (AEC) 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 all the licensing and related functions of the AEC to the U.S. Nuclear Regulatory Commission (NRC).

The principal requirements with respect to SNM licensing are in 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." Regulations in 10 CFR 70.22(b) specify that a full description of the applicant's program for the control and accounting of such SNM must be contained in a license application to show how compliance with the graded material control and accounting (MC&A) requirements of 10 CFR Part 74, Subparts C–E, will be accomplished. This document describes the standard format and content suggested by the NRC for use in preparing MC&A plans for uranium (U) enrichment facilities authorized to produce, possess, or use special nuclear material (SNM) of low strategic significance or SNM in a quantity greater than 350 grams of contained uranium-235, uranium-233, or plutonium, or any combination thereof, and are thus subject to the requirements in Subpart C of 10 CFR Part 74.

Facilities used to enrich uranium, because of the nature of the operations and the types of materials that will be on site, pose two unique problems addressed in the NRC's regulations. First, because the equipment used to enrich uranium to authorized enrichment levels can also be used to produce higher enrichment levels, the NRC considers the possibility that this may be done through deliberate misuse of the equipment. Second, it is possible that undeclared source material (SM) or low-enriched U (LEU) feed could be introduced into the process equipment for unauthorized production of enriched uranium. Additional MC&A performance objectives are established in 10 CFR 74.33(a) to protect against, detect, and respond to such possibilities. In general, the objectives are consistent with MC&A requirements for other NRC-licensed facilities authorized to possess and use more than 350 grams of SNM of low strategic significance.

Chapter 2 of this document describes the basis of the 10 general performance objectives of 10 CFR 74.3, "General performance objectives," and 10 CFR 74.33(a) and the MC&A program features and capabilities needed to meet the objectives. Chapters 3–13 address the program capabilities needed to maintain accurate, current, and reliable information on, and confirm the quantities and locations of, SM and SNM in the licensee's possession. Chapters 14 and 15 address the program capabilities needed to promptly investigate and resolve anomalies indicating a possible loss or unauthorized production of SNM and provide information to aid in the investigation and recovery of missing SM or SNM or in the investigation of unauthorized enrichment. Chapter 16 addresses recordkeeping requirements. These chapters are intended to provide an outline for an acceptable MC&A plan for low-enriched uranium enrichment facilities authorized to hold SM and SNM of low strategic significance.

The acceptance criteria are for the use of applicants (or licensees) and NRC licensing reviewers. An application or proposed revisions that meet these criteria should be acceptable to the NRC staff. However, comprehensive criteria are included as examples, and each applicant or licensee should develop an MC&A program and plan that take into account the unique features of its particular operation. Where additional guidance is available on particular topics, an appropriate reference is included in the acceptance criteria section. Recommendations in

this document provide guidance to applicants and licensees. This guidance may be used by licensees when making changes to their existing approved MC&A plans.

In preparing MC&A plans, applicants should keep in mind the capabilities specified in 10 CFR 74.33, "Nuclear material control and accounting for uranium enrichment facilities authorized to produce special nuclear material of low strategic significance," and the general performance objectives specified in 10 CFR 74.3 and 10 CFR 74.33(a). After accepting an MC&A plan and imposing it as a condition of license, the NRC will evaluate the adequacy of a licensee's MC&A performance by inspecting for performance with commitments and practices described in the plan.

Because 10 CFR 74.3 and 10 CFR 74.33 are performance-oriented regulations, they do not contain a detailed set of technical specifications. With this flexibility, applicants and licensees have many alternatives with regard to how their overall MC&A program is designed, managed, and operated, which would permit a risk-informed, performance-based approach that focuses and, in turn, concentrates licensee resources on MC&A activities most important to safeguards. Accordingly, this document does not attempt to cover all possible methodologies that a licensee might use to meet the MC&A requirements. Instead, it provides examples of acceptable MC&A approaches that may be chosen. It is intended for use by applicants, licensees, and the NRC safeguards licensing reviewers. Acceptance criteria are not to be regarded as rigid, fixed standards; that is, a lower effectiveness of one capability relative to a particular aspect can be tolerated 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 make a judgment as to whether the applicant's or licensee's MC&A plan provides adequate assurance that regulatory requirements will be met.

The contents of an MC&A plan are discussed in Chapters 3 through 16 below. The body of an approved MC&A plan will be made a condition of license in accordance with 10 CFR 70.32(c), and compliance with the MC&A plan's commitments and pertinent procedures will be inspectable. 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 MC&A plan have a clear and common understanding of what the plan requires.

The annex (or appendix) of an MC&A plan should provide supplementary and general information about the facility and the MC&A program (e.g., copies of blank record forms, site map, process diagrams, a sample standard error of the inventory difference (SEID) 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 applicant or licensee to satisfy regulatory intent 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. As a result, procedures detailed in the annex may be changed without NRC approval or notification, provided that plan commitments and capabilities are not degraded.

By using this standard format for preparing an MC&A plan, a licensee or applicant will minimize administrative problems associated with the submittal, review, and approval of the plan. Preparation of an MC&A 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. An 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 five general performance objectives for special nuclear material (SNM) that are to be addressed by the material control and accounting (MC&A) plan are set forth in 10 CFR 74.3, and the five parallel performance objectives for source material (SM) are stated in 10 CFR 74.33(a). The basis on which each of the 10 general performance objectives were established is described in the following paragraphs of this section.

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

2. **Maintain accurate, current, and reliable information on, and confirm the quantities and locations of SM in the licensee's possession.**

The purpose of these two performance objectives is to verify the presence of all SNM and SM 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 SM and SNM, licensees should have in place a program that provides timely, accurate, and reliable information about the quantity and location of SNM and SM in their possession. Accurate information means that item quantities for both the element uranium (U) and the isotope U-235 are based on measured values or on reliable information. Reliable information means that the quantity of SNM or SM in an item and the location of all items are known (except for items exempted from the item control requirements as specified in 10 CFR 74.33(c)(6)). The location designations should be specific enough to provide for the retrieval of the items in a prompt manner. Reliable information also means that the quantities and locations of all classes of material and items listed in the accounting records are, in fact, correct and verifiable.

The licensee or applicant should accurately account for all SNM and SM that is received and shipped. This should be accomplished by maintaining reliable records that are based on accurate measurements. When a shipment is received, the licensee should begin monitoring 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 that all SM and SNM quantities of record associated with receipts, shipments, discards, and ending inventory are based on measurements. Chapter 9 of this document contains recommendations on the item control system, and recommendations on measurements and measurement control programs are in Chapters 4 and 5, respectively. Monitoring the material in process may involve the use of process or material control data. To support this function, the licensee should maintain a detailed and accurate recordkeeping system for the generated data that provides knowledge of the material's location on a timely basis.

Once a year, at intervals not to exceed 370 calendar days, the licensee must conduct a total plant inventory in accordance with 10 CFR 74.33(c)(4) and be able to detect, with at least a 90 percent power of detection, an actual loss or theft of a detection quantity (DQ) that may have occurred since the last yearly inventory. A DQ is a site-specific quantity of U-235, the

magnitude of which is discussed in Chapter 6 of this document.

In accordance with 10 CFR 74.33(c)(4), the licensee must verify the presence of all SNM and SM it holds under license, and this verification must be accomplished by (1) a dynamic (i.e., nonshutdown) physical inventory of the U and U-235 contained within the enrichment processing equipment and (2) a static physical inventory of all other U material that is not within the enrichment process system.

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

- verifying the presence, on a 100 percent basis, of all uniquely identified SNM and SM items listed in the accounting records
- measuring (by direct measurement or, if direct measurement is not feasible, by indirect measurement) all bulk SM and SNM quantities on hand (i.e., all SM and SNM not in item form)
- measuring any items not previously measured
- verifying the integrity of all encapsulated items and items affixed with tamper-indicating seals
- measuring a sample of randomly selected unencapsulated and unsealed items, based on a statistical sampling plan, to verify the previously measured quantities of SNM or SM contained in the items

The dynamic physical inventory of uranium in the enrichment process system must be performed at intervals not to exceed 65 calendar days, in accordance with 10 CFR 74.33(c)(4)(i). This inventory provides a "snapshot" of the amount of material in process at a given time. The licensee is expected to strike a material balance around the processing equipment and any active feed, product, and tails containers (e.g., uranium hexafluoride (UF_6) cylinders in feed or withdrawal stations). This material balance could rely on indirect measurements and plant process parameters to estimate (1) the active material in the enrichment process, (2) the rate at which feed is being introduced to the process, (3) the rate at which product and tails are being removed from the process, and (4) the amount of process material deposited inside process equipment. The amount of material estimated to be inside the process equipment should be compared to the MC&A records to indicate whether a theft or unauthorized production may have occurred. The loss detection sensitivity associated with the bimonthly dynamic inventories should be sufficient to detect a DQ or greater loss or theft over a 12-month period with at least a 90 percent power of detection. Chapter 7 also provides recommendations on the conduct of these physical inventories.

3. Detect, respond to, and resolve an anomaly indicating a possible loss, theft, diversion, or misuse of SNM.

4. Detect, respond to, and resolve an anomaly indicating a possible loss, theft, diversion, or misuse of SM.

5. Permit rapid determination of whether an actual loss, theft, diversion, or misuse of SNM has occurred.

6. Permit rapid determination of whether an actual loss, theft, diversion, or misuse of SM has occurred.

The licensee or applicant should have a formalized program to detect, respond to, and resolve an anomaly indicating a possible loss of SM or SNM, including possible theft or diversion. Resolution of such indicators means that the licensee has made a determination that a theft or loss of SM or SNM has not occurred. A possible loss detected during a material balance closure must be investigated as required by 10 CFR 74.33(c)(6).

Resolution of an anomaly depends on the type of indicator. Various types of anomalies at uranium enrichment plants can indicate a number of possible underlying scenarios (e.g., from simple theft to isotopic substitution concealing diversion of product material). The investigation and resolution process should begin with a thorough review of the MC&A records to locate gross errors. These errors 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 calculational 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 accomplished, all of the information that contributed to the SM and 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 under 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 misuse of material, a licensee’s program should include monitoring process operations and personnel and process-related activities to detect the unauthorized production of enriched U. Timeliness is (1) an important aspect of protection and detection and (2) a function of the U-235 quantity and the enrichment level associated with the potential unauthorized production activity.

The licensee should have a program for monitoring the isotopic composition of process material at credible product withdrawal points to provide high assurance of timely detection of unauthorized production of uranium. During cascade startup operations, transient isotopic assays of between 10 and 20 weight percent (wt %) U-235 may occur. These transients normally are less than 4 hours in duration. The higher assay material produced during the transient should remain in and not be withdrawn from the cascade. The licensee should perform additional monitoring when the enrichment process system is expected to undergo an assay transient. The monitoring program can use process control data and samples that can be validated and verified, or it can use duplicate measuring systems, if necessary.

The enrichment technology installed may determine the extent of the monitoring program. For example, gaseous diffusion technology requires a limited program because of the difficulty in reconfiguring the equipment to produce higher enrichments in a short time; however, gas centrifuge technology will require a more extensive monitoring program because of the feasibility of reconfiguring the equipment to produce higher enrichments in a relatively short period. The program can use nondestructive assay (NDA) techniques with fixed or portable detectors or take samples to be analyzed for U-235 abundance.

The possibility of misusing the equipment or plant for unauthorized production differs for each enrichment technology. Following are some sample scenarios for each of the main

enrichment technology types.

Centrifuge: This technology is sensitive to misuse because of the large number of machines deployed and the possibility of isolating individual cascades. Cascades could be temporarily isolated (e.g., valved off) from the building process piping and, with temporary piping and with covert feeding of process material, used to produce higher-than-licensed enrichments or to produce greater-than-recorded quantities. Other operating parameters in the licensed production line could be surreptitiously altered to mask the scenario. Surreptitious feeding of SM or SNM should be considered among the possible misuse scenarios.

Gaseous Diffusion: This technology is more difficult to misuse than centrifuge; however, higher-than-licensed enrichments can be achieved by batching material repetitively through the same process equipment. Product from one pass could be refed and further enriched in a second or third pass through the cascade. However, establishing equilibrium status takes a relatively long time (i.e., weeks), and feeding the product from one pass would probably require use of autoclave equipment at the plant's designated feed points. More credible misuse scenarios for this technology are (1) altering process parameters to produce more than an authorized amount of product at licensed enrichment levels (but with reduced tails enrichment values) and (2) producing more than an authorized amount of product by feeding more than the reported quantity of normal U.

Laser Isotope Separation: The final design of a commercial plant has not been determined; therefore, misuse scenarios cannot be fully identified at this time. In general, however, expectations are that operating parameters may be changed to produce higher-than-licensed enrichments from natural U feed. Because of maintenance requirements, the process approximates a batch-processing system and, in this respect, is quite different from the centrifuge and gaseous diffusion processes, which are generally continuous. Unauthorized feed and the corresponding unreported product and tails are a credible possibility for misuse.

For all three technologies, the licensee should be able to detect the unauthorized introduction of any feed material and subsequent unauthorized production. Chapter 8 contains additional recommendations on the monitoring program.

The licensee should manage and maintain the MC&A program independent of the production or operations organization but should not exclude the use of process monitoring and production control data.

Licensees or applicants are responsible for developing and following a formalized program designed to resolve indications of unauthorized production. Resolution of such an indicator means that the licensee has made a specific determination that the following have not occurred: (1) production of excess quantities of U enriched to less than 10 wt % U-235 and (2) enrichment of U to 10 wt % or more in U-235. The resolution process should include the investigation of all information contributing to the indication of unauthorized production. The licensee should determine the location of the indicators and isolate the process area or storage area to verify the indication. It should examine the instruments and measurement systems used for monitoring to determine if they are functioning properly and conduct remeasurements as necessary. It should thoroughly examine the processing equipment to ensure that unauthorized modifications have not been made. The presence of U enriched to 10 wt % or more in U-235 should be verified through remeasuring the material in question, whether in item form or in process equipment. The material contained in the suspect

container or enrichment process equipment should be measured by NDA or mass spectrometric analysis to determine the U-235 isotopic abundance. Chapter 14 contains additional information and recommendations on identifying, investigating, and resolving indications of unauthorized production. If an investigation results in a licensee determination that unauthorized production has taken place, this finding must be reported to the NRC within 1 hour of such determination, under 10 CFR 74.11.

7. Provide information to aid in the investigation and recovery of missing SNM in the event of an actual loss, theft, diversion, or other misuse.

8. Provide information to aid in the investigation and recovery of missing SM in the event of an actual loss, theft, diversion, or other misuse.

9. Provide information to aid in the investigation of any unauthorized production of U, including unauthorized production of U enriched to 10 percent or more in uranium-235. (For centrifuge enrichment facilities, this requirement does not apply to each cascade during its startup process, not to exceed the first 24 hours.)

If the NRC or other government agencies find it necessary to conduct an investigation relating to actual (or highly suspected) events of missing U or unauthorized enrichment, the licensee is to provide any information it believes relevant to (1) the recovery of material involved in a loss, theft, or diversion and (2) the investigation of unauthorized enrichment activities; that is, the burden shall be on the licensee to provide all information that it recognizes as being relevant, rather than only providing information that the investigators are knowledgeable enough to request. Chapter 15 contains additional information and recommendations on providing information to aid in investigations.

10. Control access to MC&A information to preclude loss, theft, diversion, or misuse, of SNM.

The purpose of this performance objective in 10 CFR 74.3(e) is to implement the practices and procedures needed to provide effective MC&A with respect to deterrence and detection of loss, theft, diversion, or misuse, of SNM. Licensees should control access to MC&A information through access control, material containment, and material surveillance. Effective control systems should be multilayered, and redundant systems should be used to eliminate the consequence of a single-point failure.

The licensee should implement an effective quality assurance program that minimizes the possibility of potential failures for the MC&A program, and these control measures can contribute to deterrence of material loss, theft, diversion, or misuse by providing necessary checks and balances. Access control involving all movements of people and materials into and out of the material access areas should be carefully monitored and controlled. Adequate containment and surveillance measures should provide assurance that the integrity of nuclear material values is maintained.

The licensee should give primary attention to preventing errors or mistakes by MC&A personnel and violations of procedures, as well as compromising MC&A information and data. A system of balances and checks should be established to ensure data accuracy, and this system should detect any instances of unauthorized access to data. Mistakes caused by inadequate training, accidents, improper equipment operation or maintenance, or any other unintentional actions, can cause the MC&A program to lose its effectiveness.

Commitments and Acceptance Criteria on General Performance Objectives

In its MC&A plan, the applicant or licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria with respect to these 10 general performance objectives and corresponding program capabilities. The MC&A plan should state these commitments.

Chapters 3 through 5 and 7 through 16 of this document list the commitments and acceptance criteria.

The following chapters incorporate and expand on the performance objectives and on the MC&A program capabilities specified in 10 CFR 74.3 and 10 CFR 74.33. The chapters are arranged in a format and sequence to provide licensees and applicants an outline for their required MC&A plans.

3. MANAGEMENT STRUCTURE

3.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(1) is to require licensees to implement a management structure that permits effective functioning of the material control and accounting (MC&A) program and ensures that its performance will not be adversely affected by the plant management structure. Documentation, review and approval of critical MC&A procedures, and 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 provide overchecks that increase MC&A program reliability and make deceit and falsification 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

The corporate structure should be described in detail, and all corporate organization positions that have responsibilities related to MC&A at the licensee's site should be identified. A description of the corporate-level functions, responsibilities, and authorities for MC&A program oversight and assessments should be provided. At least one corporate official should have responsibilities for the control and accounting of all source material (SM) and special nuclear material (SNM) possessed by the licensee.

3.2 Plant or Site Organization

A description of the site's management structure emphasizing MC&A should be provided. 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 also should state how responsibilities are assigned for the following functions:

- overall MC&A program
- SM and SNM custodianship
- receiving and shipping of SM and SNM
- analytical laboratories
- bulk and nondestructive assay (NDA) measurements
- sampling operations
- measurement control program
- physical inventories
- monitoring program to deter and to detect unauthorized enrichment activities
- onsite nuclear material handling operations

A brief description should be provided for each site-level position, outside of the MC&A organization, that has responsibilities relating to MC&A activities (e.g., sampling, mass measurements, analytical measurements, and measurement control). For each position, the functions, responsibilities, and authorities should be clearly described.

3.3 MC&A Organization

An organizational chart and position-by-position description of the entire MC&A organization should be provided. An individual should be designated as the overall manager of the MC&A program. To ensure independence of action and objectivity of decision, the MC&A manager should either (1) report directly to the plant or site manager or (2) report to an individual who

reports directly to the plant or site manager and who has no production responsibilities.

3.3.1 Responsibilities and Authority

A description that clearly indicates the responsibilities and authority of each supervisor and manager should be provided 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 MC&A 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. A definitive statement should be made specifying that the MC&A manager will review and approve all written MC&A procedures, and any future revisions, both inside and outside of the MC&A organization, on MC&A-related activities. In addition to the MC&A manager function, the functions to be addressed should include, as a minimum, the following:

- nuclear material accounting
- measurement control program
- item control system
- statistical applications
- monitoring program to detect unauthorized enrichment activities

The discussion on statistics should identify those individuals responsible for such activities as calculation of the standard error of the inventory difference (SEID), determination of active inventory, evaluation of shipper-receiver differences (SRDs), and determination of control limits.

Whenever more than one key MC&A function is assigned to the same person, the MC&A 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

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

Examples of appropriate checks and balances are:

- Review measurement data and calculations by another individual.

- Maintain a duplicate copy of all source data and transfer forms under controls separate from the accounting function.

- Perform independent audits.

- Separate computer program maintenance from the program user function.

The management structure should assign responsibility for SNM and SM undergoing processing and in storage to a single individual or group. The duties of the individual(s) should include but are not limited to:

- Maintaining appropriate inventory control over SNM and SM in their assigned area

- Authorizing and recording all movements of SNM and SM into and out of their assigned area
- Maintaining appropriate local MC&A records or ensuring that other records, such as production records, contain necessary MC&A information
- Participating in physical inventories as required
- Assisting in internal or external alarm resolution activities as required
- Ensuring that, when SNM and SM is processed in bulk form, only authorized persons have hands-on access to the material
- Notifying proper authorities of irregularities in material and MC&A data handling.

For some individuals in management or supervisory positions, some modifications to procedures, such as restricted access without escort to some areas, may be necessary to provide sufficient assurance that the system cannot be compromised.

3.3.2 MC&A Procedures

Critical MC&A procedures to be described are those written procedures which, if not performed correctly, could result in a failure to achieve one or more of the performance objectives of 10 CFR 74.3 and 10 CFR 74.33(a) and the program capabilities of 10 CFR 74.33(c). All critical MC&A procedures should be identified in the body of the MC&A plan. A licensee's development of its critical MC&A procedures, and any changes later made to them, should involve technical review by cognizant licensee personnel, be approved by the line management directly affected, and also be approved by a level of management above the level responsible for executing the procedures. The MC&A plan should contain a definitive statement that the procedures will be followed. The set of critical MC&A procedures should, as a minimum, adequately address 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 system
- static and dynamic physical inventories
- investigation and resolution of shipper-receiver differences and loss indicators
- investigation and resolution of indicators of unauthorized enrichment to 10 wt % or more in U-235
- monitoring program to detect unauthorized production of U to enrichments less than 10 wt % in U-235
- determination of SEID, active inventory, and inventory difference

- providing of information to aid in investigations
- MC&A recordkeeping
- independent assessment of the effectiveness of the MC&A program
- tamper-safing
- designation of material balance areas (MBAs), item control areas (ICAs), and custodial responsibilities

3.4 Training and Qualification Requirements

This section of the MC&A plan should describe the training programs to be established and maintained to ensure qualified personnel and to provide for the continuing level of qualification with respect to personnel assigned responsibility for MC&A. Training procedures and qualification criteria should be discussed in definitive statements. Minimum qualification requirements should be stated for each key MC&A position.

3.5 MC&A 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 manner that explains how the 10 general performance objectives of 10 CFR 74.3 and 10 CFR 74.33(a) and the capabilities of 10 CFR 74.33(c) will be effectively achieved.

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

- overall MC&A program management (with no major non-MC&A-related responsibilities)
- measurements (noting that responsibility may be divided on the basis of type of measurements, e.g., analytical laboratory measurements, NDA measurements, bulk measurements, and sampling)
- measurement control and statistics
- accountability records
- item control
- physical inventories
- custodial responsibilities (e.g., SM and SNM storage and movement controls)
- monitoring program for detecting unauthorized enrichment activities
- investigation and resolution of indicators that suggest possible loss or possible unauthorized enrichment activities
- receiving and shipping of SM and SNM
- analytical laboratories

- MC&A recordkeeping system and controls

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

3.6 Material Control Boundaries

This section of the MC&A plan should describe how the licensee establishes various material control boundaries to minimize the occurrence of MC&A anomalies (e.g., inventory differences, missing items of SM or SNM, and potential theft or diversion of SM or SNM) and facilitate their resolution.

The MC&A plan should describe the establishment of MBAs and ICAs, because they are the basis for the control and accounting for all nuclear material in the facility. 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 into and out of an MBA or ICA must have quantitative measurements, as specified in the definitions of MBAs and ICAs in 10 CFR 74.4, "Definitions."

The MC&A plan should describe roles and responsibilities of nuclear material custodians for MBAs and ICAs. 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 MBA or ICA should not be able to make material transfers between MBAs or ICAs under their direct control. MBAs, ICAs, and custodians are discussed further in Chapter 13.

3.7 Commitments and Acceptance Criteria

In its MC&A plan, the applicant or licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to management structure. A finding that the licensee's MC&A plan for management structure is acceptable and in accordance with 10 CFR 74.33(c)(1) will be based on, but not limited to, 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. All critical MC&A procedures, and any revisions thereto, are reviewed and approved before their implementation.

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

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

- The descriptions (in the MC&A plan) 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 is also separate from organizations that generate source data, if practicable; 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 ensure independence of action and objectivity of decisions.
- No two key MC&A functions are assigned to the same person unless adequate checks and balances are provided. As a consequence of this criterion:
  - individuals who generate source data, such as performing measurements or 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, and
  - 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 MC&A procedures are made easily accessible to all affected individuals and are maintained to show, for each procedure, (1) revision number, (2) date issued, (3) name of person preparing the procedure, and (4) name of person approving 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 10 CFR 74.33(c)(2) measurement capability requirements is that licensees establish, maintain, and use a system of measurements to ensure that all quantities of source material (SM) and special nuclear material (SNM) (both element and fissile isotope) in their accounting records are based on reliable measurements. The measurement uncertainty associated with the values entered into the accounting records must be sufficiently small so as to ensure that the limit specified in 10 CFR 74.33(c)(3), for the total material control and accounting (MC&A) measurement uncertainty (associated with a physical inventory material balance), is not exceeded. Except for sealed sources and samples, all SM and SNM receipts are to be measured for the purpose of performing shipper-receiver evaluations. In the absence of any significant SRDs, a licensee may book either its measured values or the shipper's measured values. When recording shipper's values (for SNM receipts), the measurement uncertainty associated with the values should be known and used in the determination of the standard error of the inventory difference (SEID). It is also intended that a licensee's measurement program provide bias estimates to be used in correcting inventory difference values and shipper-receiver differences (SRDs) for significant measurement biases. Chapters 5 and 6 discuss the estimation of measurement bias.

4.1 Measurement Points

The MC&A plan should identify and describe each measurement that is used, either for accounting purposes or for a monitoring program, to detect an unauthorized activity. Measurements (1) establish the quantities in each custodial area, MBA, or ICA and in the facility as a whole, and (2) contribute to the desired capability to localize losses and generate and assess alarms. Typically, measurement points and sampling stations are selected to provide quantitative information about material flows and inventories that will permit detection and localization of any loss or diversion, or confirmation that no diversion has occurred. Essentially all nuclear material shipments and receipts to and from either diffusion or centrifuge enrichment plants involve uranium hexafluoride (UF_6) in metal cylinders. Various non-UF_6 materials are present at the plant as a result of process equipment maintenance, process vent gas trapping systems, routine equipment decontamination and cleaning activities, and laboratory operations. Typically, three functional types of material balance areas (MBAs) and item control areas (ICAs) are present: (1) processing, (2) storage, and (3) receiving and shipping. Typical processing MBAs include (1) the cascade or isotope separations facilities, (2) decontamination and recovery areas, (3) laboratory, and (4) feed and product sampling and transfer areas. The identification and definition of measurement points for processing MBAs are necessary because of the physical, chemical, or isotopic changes of the nuclear materials that occur in them. Storage and receiving and shipping areas are typically ICAs.

4.2 Measurement Systems

The MC&A plan should describe in detail each measurement system used for nuclear material accounting purposes. The principal elements and operations involved in the measurement system for MC&A at uranium enrichment plants include mass (or weight) or volume determination; sampling; chemical, nondestructive assay (NDA), and isotopic analyses; and process monitoring operations (for pressure, volume, temperature, and impurities) unique to the enrichment process operations. Each measurement system should also 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. For analytical laboratory

measurements, the following should also be identified: (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 element used for accountability.

The MC&A 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 used to ensure the ability 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 applicant or licensee should specify the 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 and sensitivity of the device(e.g., sensitivity is +/- Y grams), and the calibration frequency.

For each volume measurement system, the MC&A 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 MC&A plan should specify the following:

- type of material or chemical compound (e.g., UF_6, U alloy, urano-uranic oxide (U_3O_8), uranyl nitrate solution) being sampled or measured
- sampling technique(s)
- sample handling (i.e., preanalysis sample storage and treatment)
- analytical method used
- characteristics measured (e.g., grams of U per gram sample, U-235 isotopic composition)
- 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 MC&A 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
- SM or SNM material type
- attribute measured
- measurement configuration (including source to detector distance)
- calculational method
- expected measurement uncertainties

4.2.4 Other Measurement Systems

If applicable, the MC&A 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. For example, the plan should identify the measurement systems used for determining the enrichment process system inventory.

4.3 Measurement Uncertainties

The expected measurement uncertainties of the described measurement systems should be provided. Variance components for calibration, sampling, random, and systematic error for each measurement system should be stated. The units in which the errors are expressed should be clearly identified.

4.4 Measurement Procedures

The licensee or applicant should make a definitive statement that an approved measurement procedures (i.e., methods) manual, or set of approved manuals, will be established and maintained. The organizational units that are responsible for the preparation, revision, and approval of measurement procedures should be stated. A definitive statement also should be made that a periodic review of the procedures will be conducted.

The licensee or applicant should clearly state that a measurement procedure cannot be used for accountability purposes without documented approval. The overall MC&A manager and the manager of the organizational unit responsible for performing the measurement, as well as the measurement control program manager, should approve each procedure.

The MC&A plan should provide a definitive statement that all SM and SNM quantities in the material accounting records will be based on measured values and measurement systems will be maintained for the measurement of all SM and 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 may use 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 SRD (as defined by 10 CFR 74.33(c)(7)), or (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, the shipper's measurement uncertainty should be used in determining SEID.

4.5 Commitments and Acceptance Criteria

In its MC&A plan, the applicant or licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to measurements. A finding that the licensee's MC&A plan for ensuring that all quantities of SM or SNM are based on reliable measurements is acceptable and is in accordance with 10 CFR 74.33(c)(2), will be based on, but not limited to, the following acceptance criteria:

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

- Measurement systems that are the key contributors to the total measurement standard error will be identified, and the list of such systems will be reviewed annually and updated as necessary so that these key measurement systems and their standard deviations will be monitored and controlled by the measurement control program.

- A basic description or summary of each key measurement system used to generate SM or SNM quantities 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, and one that can be characterized by its random and systematic error components.

- 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 SEID.

- The recalibration frequency for each measurement system is 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.

- All calibrations are made using primary standards or primary reference materials (certified and issued by the National Institute of Standards and Technology, the New Brunswick Laboratory, or an 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 it is to be regarded as a bias-free system that is calibrated during each time of use, in which case, the calibration standards must be representative.

- When determining an SM or 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 uranium dioxide (UO_2) powder or sintered UO_2 pellets, must be determined by direct mass measurement. However, the element and isotope concentrations for the batch need not be determined for each container but, instead, may be derived by sampling procedures, including:

  – Analysis of composite samples or measurements of representative items,

objects, or samples selected by statistical sampling.

– Use of concentration or enrichment factors, or both, 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 2.00 percent of the factor value, and diversions with material substitution are improbable. However, heterogeneous materials, such as ammonium diuranate, may not be assigned common factors unless the quantities are small, such as less than 500 grams of contained U-235 (per material type, per inventory period). The plan must justify any materials assigned common factors without batch-by-batch verification analyses.

5. MEASUREMENT CONTROL PROGRAM

5.0 Regulatory Intent

The intent of the measurement control requirements in 10 CFR 74.33(c)(3) is that measurement systems (as described in Chapter 4 of this document) used to establish source material (SM) or special nuclear material (SNM) accountability quantities be controlled such that, in terms of a 95 percent confidence level, twice the standard error associated with a material balance total material control and accounting (MC&A) measurement uncertainty (for U-235) is less than the greater of 5,000 grams U-235 or 0.25 percent of the U-235 active inventory. It is also intended that bias estimates be used for adjusting inventory difference results and correcting shipper-receiver measurements for significant measurement biases.

5.1 Organization and Management

The licensee should describe the organization and management of the measurement control program in sufficient detail to show how the measurement quality assurance function is assigned and how independence is maintained from the analytical laboratory and other units performing either sample taking or measurements. The measurement control program manager should be at a management level that is sufficiently high to ensure objectivity and independence of action. Thus, the measurement control program manager should 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 measurement control program should be properly managed to ensure adequate calibration frequencies, sufficient control of biases, and sufficient measurement precision to achieve the capability required by 10 CFR 74.33(c)(3).

5.1.1 Functional Relationships

The relationship and coordination among the measurement control program manager, the analytical laboratory, and other measurement performing groups should be clearly defined. Adequate assurance should be provided 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 and maintained in a manual that is kept current and readily available. This manual should contain all the currently applicable written procedures pertaining to measurement control and measurement quality assurance. Responsibility for the preparation, revision, and approval of manual procedures should be specified. 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., preparation or method of obtaining and traceability)
- control standard measurements

- replicate sampling and replicate measurements
- verification of process control instrumentation through comparison with other process instruments
- generation of control limits and control responses and collection of control data
- recordkeeping controls and requirements

5.1.3 Contractor Program Audits and Reviews

If an outside contractor or offsite laboratory provides measurement services, the review program used to monitor the offsite measurements must be described in accordance with 10 CFR 74.33(c)(3)(iii). Such reviews are to ensure that the contractor or offsite laboratory has an acceptable measurement control program to the extent that use of the contractor's measurements will not compromise the licensee's ability to meet any measurement or measurement control requirement contained in either 10 CFR 74.33(c) or in its MC&A plan. The licensee should conduct an initial review of the contractor's measurement control program before it uses 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 calendar days of completion of the review. The two managers should agree on corrective actions that should be taken, based on their evaluation of the report, and should transmit these findings to the contractor or offsite laboratory in writing. The licensee should verify that the contractors or offsite laboratories have instituted the corrective actions before using their measurements.

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

5.2 Calibrations

The MC&A plan should summarize the licensee's calibration program and confirm that the licensee has written procedures covering the following topics:

- calibration frequency for each measurement device or system
- identification of the reference standards used for calibration of 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

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 practicable, 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.

It is the primary measurement device, not necessarily the entire measurement system, that 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 is often used to analyze samples for U concentration of two or more different material types (e.g., UF_6, U_3O_8 , and uranyl nitrate 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 reference standard such as certified U_3O8 or certified U 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 be dependent 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. Biennial recertifications of such standards are usually acceptable.

The MC&A plan should contain a definitive statement that no SM or SNM accountability value will be based on a measurement that falls outside the range of calibration. The MC&A 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 are representative of the process unknowns that are measured by the system; that is, the representative calibration standard(s) undergoes all the measurement steps, and in the same manner, that the unknowns do.

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

- 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 must 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 Control Standards

For those measurement systems that are not point calibrated, the licensee should establish and follow a defined method for the periodic measurement of control standards. Control standard measurements serve the dual purpose of (1) monitoring the stability of a previously determined calibration factor and (2) estimating the system bias over a period of time (e.g., an inventory period). The minimum total number of control standard measurements during the time period, as well as the typical frequency, should be specified for each measurement system. Generally speaking, for each measurement system, a minimum of two control standard measurements should be made during each week that the system is in use. For those systems that are used less than 8 weeks during a given material balance period, more

than two control standard measurements per week of system use may be necessary to provide the following:

(1) a minimum of 12 control measurements for those systems used during the material balance period to measure material totaling less than 100 kilograms of U-235

(2) a minimum of 24 control measurements for those systems used to measure a total of 100 or more kilograms of U-235

Key measurement systems for the current inventory period are any set of designated measurement systems (of the licensee's choosing) which, based on the most recent previous period, account for at least 90 percent of the total measurement variance contribution to SEID. Within the set of key measurement systems should be included 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. The minimum number of control standard measurements for situations (1) and (2) above can be reduced to 8 and 16, respectively, for nonkey measurement systems that measure from 10 to 25 percent of the active inventory, and the minimum number of control standard measurements for situations (1) and (2) can be further reduced to 4 and 8, respectively, for those nonkey systems used to measure less than 10 percent of the active inventory quantity.

Control standards should 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, such as UF_6 cylinders, the control standard weights should be artifact cylinders (i.e., both empty and full) 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 to be used for control standard measurements should be identified or described, or both. Along with material composition and matrix factors, biases also can be induced by changes in (among other things) temperature, humidity, line voltage, and background radiation. Biases can also be induced by operators or analysts. 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 hence 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., is 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, U concentration, density, homogeneity, and impurity content—should the control standards be, relative to the process unknowns?

5.4 Replicate Sampling

For systems involving sampling, duplicate measurements performed on single samples (or single items) and measurements of replicate samples are necessary to estimate the combined analytical and sampling random error. For nonsampling measurement systems, such as NDA and weight measurement systems, the analytical variance component can be derived from (1) replicate measurements performed on the process items, (2) the replicate data generated from the measurement of control standards, (3) calibration data, or (4) engineering evaluations.

The licensee should ensure that replicate samples are independent of one another. 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 fewer 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 fewer than 8 batches)

(5) the greater of 8 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 MC&A 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 two analyses per sample are performed 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. Replicate or repeat measurements can be made on the same or similar production items. The scatter in the repeat measurements can be used to estimate the random error variance using a statistical technique known as the one-way analysis of variance. (The NRC recommends the statistical methods described in NUREG/CR-4604, "Statistical Methods for Nuclear Material Management" (1988), for satisfying the statistical requirements of 10 CFR 74.33; see also Chapter 6 of this document.) 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.

5.5 Control limits

Both 0.05 (warning) and 0.001 (out-of-control) limits are to be established and used for both control standard and replicate measurements for those measurement systems used for nuclear

material accountability. Out-of-control limits are also to be used for replicate measurements and measuring replicate samples. However, warning limits are optional for the replicate program. For point-calibrated systems, the assigned value of the standard(s) measured along with the unknown(s) is assumed to be valid. If the standard's true value could change because of factors such as evaporation, moisture pickup, or oxidation, the value of the standard should be checked periodically. Therefore, control limits for the verification measurements associated with such standards should be established. This is especially true for those point-calibrated systems that use a single standard, or aliquots from a single standard, over any extended period of time.

The warning and out-of-control limits are normally set by the licensee based on a tradeoff between (1) the cost of investigating and resolving incidents where limits are exceeded and (2) the cost of accepting measurements of poor quality. Warning limits set at the 0.05 level of significance and out-of-control limits set at the 0.001 level of significance are usually sufficient. 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 limits).

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

5.5.1 Measurement Control Data Analysis

Measurement control data, such as control standard measurement results and the differences between measurement values of replicate pairs, should be plotted manually on graphs or entered into a computer data base to generate 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 for any significant trends. For an established measurement system, a less frequent review period may be warranted.

5.5.2 Response Actions

Either the analyst or the operator performing a control measurement or the supervisor should be responsible for promptly reporting any control measurement that exceeds an 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 the necessary response and corrective action.

Minimum response and minimum corrective action requirements should be clearly defined. In addition, the measurement control 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:

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

(2) documenting the occurrence of the event

(3) performing at least two additional control measurements

(4) performing additional control measurements, if the 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), or recalibrating the measurement system, or making any necessary system repairs

(5) reviewing measurements performed on the system in question since the last in-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) that were measured before the out-of-control condition but after the last within-control measurement. The validity of the previous measurements can 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 continuing in reverse order until two consecutive remeasurements are found to be in agreement with their initial measurement at the 95 percent confidence level.

5.6 Commitments and Acceptance Criteria

In its MC&A plan, the applicant or licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to the measurement control program. A finding that the licensee's MC&A plan for maintaining measurement quality and estimating measurement uncertainty values is acceptable and in accordance with 10 CFR 74.33(c)(3) will be based on, but not limited to, the following acceptance criteria:

- The description of the measurement control program shows that the measurement systems that are the key contributors to the total measurement standard error will be routinely and adequately monitored for both bias and random error. The standard deviations of measurement systems are estimated from replicate data from measurements made in the same manner as made routinely on typical process samples and items. If standard deviations are based on replicated measurements of standards (for NDA or mass measurement systems), data is collected that demonstrate that the standard deviation estimates do not differ significantly from those based on replicated process item measurements. (NOTE: For analytical chemistry measurements, the combined analytical plus sampling random error must be derived from the measurement of replicate process samples, rather than based on multiple measurements of a standard.)

- All reasonable and probable sources of measurement error, such as the effects of sampling, instruments, environmental factors, and variability between operators or analysts are included in the estimates for standard deviations, either directly as experimental variables in an analysis of variance or by being included in the sample of measurement control data from which the standard deviations are determined.

- Bias tests are made by measurements of representative control standards with assigned values that are traceable to national measurement systems. As reasonably achievable, the control standards should closely resemble the unknowns to which the measurement is applied, and the measurement procedures and conditions of measurement must closely resemble those of typical measurements made on process unknowns.

- A record of bias estimates for each key measurement system (not defined as a bias-free, point-in-time calibrated system), as derived from control standard measurements, is maintained. The basis for determining the timeframe associated with each significant bias should be provided (so that the quantity of measured SM or SNM to which that bias applies can be determined). Bias corrections (expressed as both grams element and grams isotope) are derived for each significant bias (based on the quantity of measured SM or SNM to which the bias applies). The MC&A plan must confirm that each significant bias is either applied as a correction to items listed in the accounting records (if the correction for an individual item is greater than the rounding error for that item) or included in the net bias correction to inventory difference (on line 7 of NRC Form 327).

- Schedules and frequencies of replicate and control standard measurements are designed so that the estimates of standard deviations and measurement biases will be based on measurement control data collected under the same measurement circumstances and over the same time span as that of the SM or SNM accounting measurements to which the standard deviations and bias estimates will be applied. The standard deviation and bias of each key measurement system should be evaluated periodically. The frequency of such evaluations should typically be at least every 4 months. When determining the average bias and standard deviation of a particular measurement system for an inventory period, pooling of data from previous determinations may be used only if statistical tests show that the standard deviations and biases from prior determinations do not differ significantly from those of the current period, and further, provided the pooled data do not include any data generated more than 24 months before the current determination of such bias or standard deviation.

- The effort expended by the licensee in monitoring and controlling the bias and standard deviations of each measurement system is shown to be consistent with its impact on inventory difference and the total measurement standard error. The number of degrees of freedom for estimating the measurement standard deviation may be graded according to its contribution to the total measurement standard error.

- Warning limits for a change in bias (for those systems that are not point-in-time calibrated, bias free) will be set at the 0.05 level of significance (or tighter), unless adequate justification for less stringent limits is provided. Warning limits are optional, however, for monitoring replicate data (for standard deviations). If a control datum exceeds this limit, the individual responsible for the measurement control program will be notified (this normally should occur within 72 hours), a data review will be initiated to find the cause, and corrective action will be taken when appropriate. Such reviews and corrective actions are completed and documented within 2 weeks.

- Unless adequate justification for less stringent limits is provided, out-of-control limits for both standard deviation and bias are set at the 0.001 level of significance for all key measurement systems, except that no bias control limits are needed for bias-free, point-in-time calibrated systems. If a control datum exceeds this limit, the system in question shall not be used for MC&A purposes until corrective action and resolution is completed and the system is back in control within the upper and lower boundaries of the warning limit. Likewise, any measurement values generated between the last within-control datum and the out-of-control datum shall not be used for MC&A purposes until their validity has been confirmed. Such confirmation can be accomplished by remeasurement

of the involved items or samples on a "last in, first out" basis until two consecutive remeasurements are found to be in agreement with their initial measurement at the 95 percent confidence level. It should be noted that other criteria for initiating corrective action relative to potentially out-of-control measurement systems may be accepted where it can be demonstrated that the licensee's ability to meet the 0.25 percent of active inventory limit for total MC&A measurement uncertainty (as specified in 10 CFR 74.33(c)(3)) will not be jeopardized.

- The approach used for bounding the total measurement standard error for a typical material balance period meets the following criteria:
  - All reasonable and probable sources of measurement error affecting inventory difference are included.
  - Any assumed measurement standard deviations are shown to be reasonable. They may be shown to be reasonable by comparison either to records of the licensee's past performance data or to published measurement performance in similar applications.
- The calculation of the total measurement standard error is performed in accordance with a recognized error propagation method. Such methods have been published in NUREG/CR-4604 (1988); TID-26298, "Statistical Methods in Nuclear Material Control" (1973); and the International Atomic Energy Agency (IAEA) statistics handbook, "IAEA Safeguards Statistical Concepts and Techniques" (1998).
- The licensee will confirm that the accountability measurements provided by a contractor are controlled by a measurement control program and 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 24 months.
- The measurement systems have adequate calibration frequencies, sufficient control of biases, and sufficiently small standard deviations to achieve the requirements of 10 CFR 74.33(c)(3). Measurement control is used both in-house and by any contractor used to ensure that the quality of the measurements is maintained on a level consistent with the regulatory requirements.

6. STATISTICS

6.0 Regulatory Intent

Proper use of statistics is important to ensure that the regulatory requirements in 10 CFR 74.33 are met. An effective statistical program will ensure measurement systems perform within control limits, measurement uncertainties are calculated and propagated, the inventory difference (ID) and standard error of the inventory difference (SEID) are properly determined, and significant shipper-receiver differences (SRDs) are identified. For example, 10 CFR 74.33(c)(4) 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.

6.1 Determination of Measurement Uncertainties

To achieve the objectives and capabilities of 10 CFR 74.3 and 10 CFR 74.33, each licensee or applicant should institute a statistical program that evaluates the MC&A data to ensure that (1) the measurement data are analyzed in a rigorous manner and (2) hypotheses concerning the status of the nuclear material possessed are appropriately tested. The NRC sponsored the development of a comprehensive reference that specifically addresses the statistical treatment of measurement control and accounting data. The statistical methods described in this reference, NUREG/CR-4604 "Statistical Methods for Nuclear Material Management" (1988), as well as in TID-26298, "Statistical Methods in Nuclear Material Control" (1973), and the IAEA statistics handbook "IAEA Safeguards Statistical Concepts and Techniques" (1998), are recommended by the NRC for satisfying the statistical requirements of 10 CFR 74.33.

The MC&A plan should do the following:

- Provide a detailed discussion of the procedures and methodologies for estimating measurement variance components.
- Discuss how biases are determined and how bias corrections are applied, including:
  - how often biases are estimated
  - how the effect of the bias on the measured quantity of material in the item is determined
  - when and how bias corrections to items are made
  - how their effect on inventory difference is determined
  - when and how bias corrections are applied to the ID
- Describe the procedure and means for determining active inventory.
- Provide all relevant information on determining the SEID.
- Specify the DQ, which should not exceed 1.3 percent of the annual quantity of U-235 introduced into the enrichment process, except when 1.3 percent of additions to process is less than 25 kilograms of U-235, in which case the DQ need not be less than 25 kilograms of U-235.

- Specify the methodology for determining ID threshold values to be used to provide a 90 percent power of detecting the loss of a DQ, as required by 10 CFR 74.33(c)(4). (See Chapter 7 for additional information on ID limits and response actions.)

6.2 Determination of Standard Error of the Inventory Difference

As defined in 10 CFR 74.4, the term "standard error of the inventory difference" means the standard deviation of an inventory difference that takes into account all measurement error contributions to the components of the ID. For strategic SNM facilities, nonmeasurement contributors to the ID are not to be included in the SEID calculation. However, for facilities possessing only SNM of low strategic significance, the NRC allows licensees to take limited credit for nonmeasurement contributors. It is not really possible to quantify the nonmeasurement contribution to the uncertainty associated with an ID, but 10 CFR 74.33 licensees are permitted to assume that the total nonmeasurement contribution to SEID equals the total measurement error contribution. When including only measurement uncertainty, SEID (for either U or U-235, as applicable) can be expressed as follows:

$$SEID = [\sum_{i=1}^{k} (G_i)^2 \{(\sigma_i)_s^2 + (\sigma_i)_r^2/n\}]^{½}$$

where

k = number of measurement systems
G_i = total grams uranium (or U-235) 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

When taking the maximum allowable credit for nonmeasurement contribution (which assumes a 1:1 ratio of measurement to nonmeasurement contributions),

$$SEID = [2 \sum (G_i)^2 \{(\sigma_i)_s^2 + (\sigma_i)_r^2/n\}]^{½}$$

In theory, SEID provides the uncertainty, at the 67 percent confidence level, of the ID.

The MC&A plan should provide all relevant information on determining the SEID. There should also be a commitment that at least two individuals independently verify the correctness of the SEID calculation for each total plant material balance. If the SEID value is calculated using a computer program, the verification by two or more persons involves checking for the correctness of the input data used to calculate the SEID.

6.3 Bias Corrections

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 inventory difference 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), it is common practice to adjust the accounting values for individual items if the bias effect 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. 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 (with SM or SNM values 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 low 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.

As a minimum, to meet the 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 inventory difference, if (1) such bias is statistically significant at the 95 percent confidence level, and (2) either or both of the following are also true:

(A) Applying the correction would cause the ID to exceed its detection threshold (DT) value.

(B) The bias is greater than 0.0100 percent relative and also affects the ID value by more than 1,000 grams U-235.

Additionally, the net algebraic sum (expressed as grams U-235) 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 condition A and/or B, above, is considered to be significant and is to be applied as a net adjustment to the ID if either or both of the following are true:

(C) Applying such correction would cause the ID to exceed its DT value.

(D) The net correction affects the ID value by more than 5.00 percent of the licensee's DQ, or 10,000 grams U-235, whichever is larger.

7. PHYSICAL INVENTORIES

7.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(4) is to require licensees to perform both dynamic (i.e., nonshutdown) inventories of the enrichment process system and static inventories of the balance of the plant so as to confirm that a loss or diversion of a safeguards-significant quantity of low strategic special nuclear material (SNM) has not occurred. Licensees are required by 10 CFR 74.33(c)(4) to conduct dynamic inventories at least every 65 calendar days and a static inventory at least every 370 calendar days. The principal method of confirming the presence of source material (SM) and SNM is to perform a physical inventory and compare it to the book (record) inventory. If all SM and 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, the size of the estimated inventory difference (ID) depends on measurement errors, as well as various nonmeasurement contributors, such as recording errors, unmeasured losses, and unmeasured residual holdup, as discussed further in Section 7.6 (see Chapter 17, Glossary, for the definition of "residual holdup").

7.1 General Description

The applicant or licensee should provide a general description of how both dynamic (i.e., nonshutdown) inventories of the enrichment process system and static inventories of the balance of the plant will be planned, conducted, assessed, and reported. For enrichment facilities using laser isotopic separation technology, a total plant shutdown inventory may be required.

The material control and accounting (MC&A) plan should contain a definitive statement that physical inventory functions and responsibilities will be reviewed comprehensively with the involved individuals before the start of each dynamic and static inventory.

For static inventories, a book inventory listing, derived from the MC&A record system, should be generated just before the actual start of the inventory; such listing shall include all SM and SNM that the records indicate should be possessed by the licensee at the inventory cutoff time, except for material to be covered by the dynamic inventory that is to be conducted in conjunction with the static inventory.

For dynamic inventories, a book inventory quantity, to which the results of the dynamic physical inventory will be compared, is needed. One approach to estimate the in-process inventory is to use a "running book in-process inventory" (RBIPI) technique. The RBIPI is the quantity of U and U-235, calculated as follows:

$$RBIPI = BI + CI - CO$$

where

- BI = beginning in-process inventory (i.e., inventory at the start of the current inventory period) as determined from the previous dynamic inventory
- CI = cumulative measured input to the enrichment process for the current dynamic inventory period.
- CO = cumulative measured output from the enrichment process for the current

dynamic inventory period

Hence, the inventory difference associated with a dynamic physical inventory is derived from the following equation:

$$ID = RBIPI - EI = (BI + CI) - (CO + EI)$$

where

EI = ending in-process inventory as determined from the dynamic physical inventory.

For both static and dynamic physical inventories, the MC&A plan should contain sufficient information to show how the total in-process inventory for both U and U-235 is obtained. The means for measuring or estimating residual holdup should be addressed in detail, and the change or variation in such holdup from one inventory to the next should also be discussed. This information is important to ensure no SM or SNM held under license (except for waste materials assigned to holding accounts in accordance with the exceptions provided in 10 CFR 74.33(c)(6) and U.S. Department of Energy (DOE)/NRC Form 741 instructions) will be omitted, and no quantity will be counted more than once.

The MC&A plan should also 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 SM and SNM quantities and recording observations. The means for conducting the inventory should ensure that any SM or SNM held under license (except for waste materials as noted above) is properly inventoried.

The inventory difference and related information associated with each dynamic physical inventory are to be reported to the NRC, under 10 CFR 74.17(a), on NRC Form 327 as the results of a physical inventory associated with material code 89 (U in cascades). The inventory difference and related information associated with each static inventory are to be reported to the NRC on separate NRC Forms-327 for DOE/NRC material type codes 10, 20, and 81 (i.e., depleted, enriched, and normal U, respectively). In addition to these submittals, the results of the plant-wide material balance, for total U element and total U-235 isotope (across all four material type codes), associated with each annual physical inventory must be reported on a separate NRC Form 327.

7.2 Organization, Procedures, and Schedules

The MC&A plan should explain the makeup and duties of the typical physical inventory organization for both dynamic and static inventories. The individual having responsibility for the coordination of the physical inventory effort should be identified by position title. The MC&A plan also should indicate how the preparation and modification of inventory procedures are to be controlled.

The MC&A plan should contain a definitive statement that specific inventory instructions will be prepared and issued for each dynamic and static inventory.

7.3 Typical Inventory Composition

The typical expected in-process inventory within the enrichment equipment for both U and U-235 at the time of the dynamic physical inventory should be specified. Unlike other bulk nuclear material processing facilities, uranium enrichment facilities increase the strategic value of the U under complex dynamic operating conditions. For gas centrifuge and gaseous diffusion plants, the in-process inventory should be specified by accounting for UF_6 gas, solid UF_6, and

residual holdup solids deposited within equipment.

A typical composition, by material type codes, of a static physical inventory should also be presented. The total inventory of UF_6 cylinders should be accounted for by material type (i.e., tails, feed, and product). If cylinders or other containers of different sizes are used within any of the three UF_6 categories, they should be treated as different item strata.

Enrichment plants typically are divided into a number of MBAs and ICAs to reflect the functional activities as follows:

Processing—This is an MBA in which occur (1) routine transfers of nuclear material from one container to another, (2) changes in isotopic or chemical assay, or (3) changes in chemical or physical form. Various measurements are required to define flows of materials 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 inventory difference for each inventory. Of the total plant MBAs and ICAs, a relatively small number might be processing MBAs. Examples of operations are isotope separation (e.g., enrichment cascade facilities); decontamination and recovery; analytical laboratory; and material rebatching, blending, and sampling. Physical inventories for the enrichment process system and decontamination and recovery operations are the most complex and require the most coordination and careful timing.

Storage—These are ICAs in which all materials are sealed in 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 inventory difference for each inventory period, when all items are accounted for and their integrity and previously documented measured values are confirmed.

Receiving and shipping—This term refers to an ICA from which materials are shipped or into which materials are received from off site. This ICA type will normally serve as an interim storage area and will 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 ICA.

7.4 Description of Typical Item Strata

The MC&A plan should describe the expected item population in terms of the following:

- type of item (i.e., stratum)
- expected range of the number of items within each stratum
- the average U and U-235 content of the items within each stratum
- the expected rate of item generation and consumption for each stratum

7.5 Conducting Dynamic Physical Inventories

A description of the dynamic inventory methodology, including cutoff and inventory minimization procedures, should be presented, and all measurements (including sampling) sufficient to meet the requirements of 10 CFR 74.33(c)(4) should be identified.

Because of the size and complexity of a gaseous enrichment cascade system and the continuous dynamic operations, a detailed inventory notice should be prepared for each dynamic 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. Specific sampling points throughout the cascade and instructions on data submission to the accountability organization should be identified. The instructions should take into account the current cascade configuration (e.g., equipment offstream) and types of feed and withdrawal streams. The instructions should highlight any required deviation from normal inventory procedures contained in the plant's operating procedures. The basic procedures for the cascade in-process inventory should (1) maintain the cascade in a steady-state operating condition for at least 24 hours before inventory time, (2) record the necessary process measurement data and collect process samples over a period of about 6 hours before inventory time, and (3) establish a complete feed and withdrawal system switchover to preinventoried containers at inventory time so that the amount of material in the active containers at the feed and withdrawal stations can be measured.

Unless special circumstances require a change, the time for a routine inventory should be established (e.g., at 2400 hours) on the last day of the inventory period. For the gaseous enrichment processes, the dynamic gas-phase inventory requires recording gas pressure and temperature readings for equipment throughout the process system, quantities of UF_6 contained in desublimers (i.e., cold traps) and chemical traps, and other measurements (e.g., concentration of impurity gases). Typically, many data points are collected during these operations for calculating the in-process inventory for input into established computer models and calculation programs. These programs incorporate fixed-cascade parameters, such as equipment volumes, compressor circuit balances, and gas law relationships.

7.6 Conducting Static Physical Inventories

A description of the procedures and methodologies associated with performing static physical inventories should be provided in enough detail to demonstrate that valid inventories sufficient to meet the requirements of 10 CFR 74.33(c)(4) will be 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
- obtaining, verifying, and recording 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 for nonenrichment processes (e.g., scrap recovery)

Decontamination and recovery also is a complex operation involving the disassembly and decontamination of failed pieces of process equipment, cleaning of UF_6 cylinders, and recovery of U from various types of scrap materials. The basic inventory procedure should involve establishing a cutoff of movement of materials into the MBA and processing all materials to a measurable form, such as containers of solution or oxide. Except for the 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.

The MC&A plan should describe special item storage and handling or tamper-indicating methods, which are used to ensure that the previously measured and recorded SM or SNM content values can be used for inventory purposes without remeasurements. In addition, the MC&A 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 seals, or otherwise protected to ensure the validity of prior measurements, need special attention. 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 SM and SNM included in the inventory should be presented. If statistical sampling is proposed as an alternative method to 100 percent verification, the MC&A plan should describe the sampling plan. Such description should include the following:

- the method of segregating 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
- the quality of the measurement methods used to verify original measurement values
- the procedure for reconciling discrepancies between original and remeasurement values and for scheduling additional tests and remeasurements
- the basis for discarding an original SM or 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 detection of loss of a DQ 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 a stratum

x = maximum U-235 content per item (kilograms)

g = DQ = detection quantity (kilograms U-235)

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 3σ), that item is designated as a "defect." To achieve the 90 percent power of detection capability for detecting the loss of a DQ, there must be at least a 90 percent probability that one or more "defects" will be encountered among the items remeasured across all involved stata if the actual loss of a DQ has occurred. If, across all strata, one or more defects are encountered, a second set of n

randomly selected items (or all remaining items if n is equal to or greater than 0.5 N) from each stratum should be remeasured. If one or more defects are encountered (across all item stata) while performing any second round of remeasurements, all unsealed and unencapsulated items not yet remeasured are to be 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 MC&A plan should also contain a definitive statement that all items on ending inventory that have not been previously measured will be measured for inventory purposes.

The decision rationale for determining when the element and isotope factors for items, objects, or containers will be measured directly for inventory and when they may be based on other measurements should be presented in the MC&A plan. For example, if the U-235 contained in liquid waste batches is derived by applying an average enrichment factor to the measured U element content, the rationale for such practice (as opposed to measuring each batch for both U and U-235 content) should be discussed and the method for establishing the average enrichment factor should be described.

If the content of items is established through prior measurements and those items are sealed with tamper-indicating devices or access to them is controlled, the SM or SNM quantity in those items may be based on those measured values. Otherwise, verification of SM or 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. A statistical sampling plan will not be acceptable if there is any likelihood of any significant change in the U concentration (or weight fraction) or in the U isotopic distribution, because of such factors as oxidation, change in moisture content, commingling with materials of different enrichments, or different compositions.

7.7 Inventory Difference Limits and Response Actions

Each licensee should have a well-defined process for evaluating both dynamic and total plant IDs and taking action when IDs exceed certain predetermined thresholds. As a minimum, there should be three response levels for excessive IDs. The following would be an acceptable approach for three increasing levels of response actions with respect to static physical inventories:

Warning-level ID	U-235 ID ≥ 1.7 (SEID) + 500 grams or U ID ≥ 1.7 (SEID) + 10 kg U
Significant ID problem	U or U-235 ID ≥ 3 (SEID)
Major ID problem	U-235 ID ≥ DQ - 1.3 (SEID)

For dynamic physical inventories, the following three response levels for excessive IDs would be acceptable:

Warning-level ID	U or U-235 ID ≥ 2 (SEID)
Significant ID problem	U or U-235 ID ≥ 3 (SEID)
Major ID problem	U-235 ID ≥ DQ - 1.3 (SEID) - (cumulative enrichment process system U-235 ID for past 10 months)

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 excessive ID and give recommendations for avoiding recurrences. When a warning-level ID is positive, it should be regarded as being equivalent to an indicator of a possible loss that requires investigation and resolution (see Chapter 14).

For a significant ID problem, an extensive investigation by the licensee should be conducted. If a significant ID problem cannot be satisfactorily explained, a static or dynamic reinventory may be needed.

For any unresolved ID determination that remains a major ID problem (without regard to algebraic sign), the licensee should conduct a plantwide reinventory and investigation. The NRC considers a positive ID large enough to be a major ID problem as a very serious condition.

The MC&A plan should fully describe, in definitive statements, the minimum response actions for each ID action level.

7.8 Commitments and Acceptance Criteria

In its MC&A plan, the applicant or licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to the physical inventories. A finding that the licensee's MC&A plan for conducting physical inventories is acceptable and in accordance with 10 CFR 74.33(c)(4), will be based on, but not limited to, the following acceptance criteria:

- An MC&A program will be maintained that is capable of confirming, at intervals not to exceed 370 days, the presence of all SM and SNM expected to be present (at a given time) based on accurate, current, and reliable information. The means for conducting the inventory must insure that no SM or SNM currently on hand will be omitted and no quantity will be counted more than once.

- Unless otherwise required by Facility Attachments that satisfy 10 CFR Part 75, "Safeguards on Nuclear Material—Implementation of US/IAEA Agreement," total plant static physical inventories will be performed at least every 370 calendar days and 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.

- Dynamic (nonshutdown) physical inventories of in-process (e.g., in the enrichment equipment) U and U-235 will be performed at least every 65 calendar days.

- For each physical inventory, inventory procedures are clearly written and are reviewed and approved by the individual responsible for conducting the physical inventory. The inventory procedures provide for confirming the presence of all items by direct observation and the presence, by direct measurement or an acceptable alternative, of all quantities of SM and SNM that are neither encapsulated nor tamper-safed.

- The individual responsible for conducting 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 SM and SNM possessed on the inventory date, except for waste materials assigned to holding accounts (in accordance with the exception provided in 10 CFR 74.33(c)(6) and DOE/NRC Form 741 instructions). All

such listed SM and SNM quantities are to be based on measurements for SM or SNM quantity.

- Within 60 calendar days after the start of each physical inventory, the inventory difference will be determined. Any inventory difference that is rejected by a statistical test that has a 90 percent power of detecting a discrepancy of a quantity of U-235 established by the NRC on a site-specific basis will be reported to the appropriate NRC safeguards organizational units.

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

- Inventory difference values will be corrected for (1) accounting adjustments resulting from prior period activity and (2) significant biases that have not been previously taken into account. (NOTE: See the definition of significant bias in Chapter 6.)

- 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 U-235 ID (after applying any appropriate bias corrections and prior period adjustments) is greater than the U-235 DT and is not resolved within the 60-calendar-day reconciliation period, all SM and SNM processing should be halted and a reinventory and investigation conducted. (NOTE: This applies to both positive and negative ID values.)

- The results of all physical inventories and of investigations and resolution actions following any excessive U-235 ID are recorded and auditable.

- The MC&A plan contains 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 SM and SNM quantities and recording observations.

- The licensee may propose alternatives to remeasurement. The MC&A plan should describe the circumstances under which each proposed alternative may be used. The proposed alternatives to remeasurement should satisfy at least one of the following criteria:

  - The SM or 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 current DQ 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 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 with SM or SNM content that has been previously measured, and there is no likelihood of any significant change in the U concentration (or weight

fraction) or in the U enrichment caused by such factors as oxidation, change in moisture content, commingling with materials of different enrichment or different composition, the previously determined U and U-235 content may be accepted without verification of SM or SNM content, provided the gross weight or net weight, or both, 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 DQ.

- As an additional alternative to remeasurement (of unsealed SM or 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) SM or 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 DQ (in kilograms U-235) for any given inventory period will be no greater than 1.3 percent of that period's throughput for facilities involved in chemical processing (such as UF_6 conversion, scrap recovery, oxidation or reduction processes), and no greater than 0.90 percent of throughput for facilities where material only undergoes physical changes (such as pressing UO_2 powder into pellets or loading pellets into fuel rods), unless the 0.90 or 1.3 percent of throughput (as appropriate) is less than 25 kilograms U-235, in which case the DQ need not be less than 25 kilograms. The U-235 throughput is defined as the greater of "additional to process" or "removals from process" during a 12-month inventory period.

- The information in the MC&A plan shows that the DT for an excessive ID will result in a 90 percent (or better) probability of detecting a discrepancy (i.e., an apparent gain or loss) equal to or larger than the U-235 DQ for the inventory period in question. In general, a licensee may assume the ID distribution approximates a normal distribution, and therefore:

$$DT = DQ - 1.3(SEID)$$

  Acceptable methodology for calculating the measurement error contribution to the SEID by error propagation is found in NUREG-4604 (1988), TID-26298 (1973), and the IAEA statistics handbook (1998). Special attention is given to inclusion of all applicable and measurable sources of error to avoid underestimating the SEID.

- In addition to the DT ID alarm limit (required by 10 CFR 74.33(c)(5)), there is at least one excessive ID warning level limit that, when exceeded, will require an investigative response action. The resources and level of effort to be committed to the investigation of an excessive ID will be proportional to the magnitude of the ID but 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 measured discards. Investigations are to be completed within 60 days after initiating the inventory (except when additional time is granted by the NRC for extenuating circumstances).

8. PROGRAM FOR PREVENTING AND DETECTING UNAUTHORIZED PRODUCTION OF ENRICHED URANIUM

8.0 Regulatory Intent

The intent of the 10 CFR 74.33(c)(5) detection program is to ensure that licensees establish an adequate detection program, independent of production, that provides assurance of detecting (1) the production of uranium (U) to 10 percent or more of U-235, to the extent that special nuclear material (SNM) of moderate strategic significance, as defined in 10 CFR 74.4, could be produced in any 370-calendar-day period, (2) the production of U enriched to 20 percent or more of U-235, and (3) the unauthorized production of uranium of low strategic significance.

8.1 Organization

The licensee should identify the individual responsible for executing the program for detecting unauthorized production of enriched U. This individual need not be part of the material control and accounting (MC&A) organization but should be independent of the production organization. Other personnel who are assigned responsibilities in this program should also be independent of production supervision. This program should be well coordinated with both MC&A and production management.

The overall organization, including the minimum staffing requirements and functions, should be in the MC&A plan. A definitive statement should be made that the program director will have the necessary authority to carry out all aspects of the program.

8.2 General Description of Program

The overall design of this 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. The analysis should be extensive and conducted by individuals having a thorough knowledge of the processing equipment and enrichment technology. All conceptual and credible scenarios for unauthorized production of U enriched to 10 wt % or more in U-235 by the employed enrichment technology should be identified. These scenarios should include cascade isolation, process system adjustments, batch recycle processing, cascade interconnections, and cascade reconfiguration (to increase the number of stages).

The program should be capable of satisfying the following detection criteria as part of each bimonthly inventory cycle:

- For any unauthorized production (from undeclared feed) of low-enriched U (LEU) within the cascade with an enrichment of less than 10 wt % U-235, detection should occur before the quantity of U-235 contained in such LEU amounts to 25 kilograms.

- For any unauthorized production of LEU within the cascade with an enrichment within the range of 10.00 to 19.99 wt % U-235, detection must occur before the quantity of U-235 contained in such LEU amounts to 10 kilograms.

- For any unauthorized production within the cascade of high-enriched U (HEU) (i.e., equal to or greater than 20 percent U-235), detection must occur before the quantity of U-235 contained in such HEU amounts to 1 kilogram.

The MC&A plan should address the following aspects of the program that are aimed at protecting against and detecting unauthorized production of U of low strategic significance:

- the type of surveillance, and its frequency, to be applied to the processing areas
- the type of surveillance, and its frequency, to be applied to the process control room and other areas where operation of processing equipment can be controlled or modified remotely
- the type of surveillance, and its frequency, to be applied to potential feed and withdrawal areas
- process monitoring activities (e.g., radiation monitoring and flow metering), other than process sampling, that could contribute to the detection of unauthorized production
- use of tamper-indicating devices (TIDs) on process valves and flanges
- personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms
- physical security controls, such as locked and alarmed doors and closed-circuit television monitors, that would detect unauthorized access to processing equipment or product material
- production control activities that could contribute to the detection of unauthorized production
- employee education and informant protection (e.g., whistle-blower protection rules) to increase the probability of detection and reporting of potential unauthorized activities by facility personnel
- notification of appropriate MC&A personnel by operations organizations of the operating status of the enrichment process system, especially when a cascade is isolated from the process stream

To address the unauthorized production of U enriched to 10 wt % or more U-235, the following types of measures should be considered:

- process design features that preclude production of higher enrichments from being conducted simultaneously with normal (i.e., authorized) production
- personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms
- physical security controls, such as locked and alarmed doors and closed-circuit television monitors, that would detect unauthorized access to processing equipment or product material
- process control systems that could detect unauthorized use of production equipment
- production control systems that could detect unauthorized production of U enriched to a level equal to or greater than 10 wt % U-235

- technical safeguards systems (e.g., optical surveillance, tamper-indicating seals, radiation monitors, flow meters, and visual inspection procedures) that could detect unauthorized production of enriched U

- nuclear material, minor isotope, and separative work unit (SWU) balances

In describing the portion of the program aimed at protecting against and detecting production of U enriched to a level equal to or greater than 10 wt % U-235, the MC&A plan should address the following, in addition to the previously stated aspects for detecting unauthorized production:

- location of the sampling ports, and frequency of sampling, to be used for monitoring product streams

- the means for verifying the validity of process control measurements and laboratory enrichment measurements (i.e., describing how the falsification of process measurements would be detected)

- the type of equipment or instrumentation (in addition to and independent from that used and controlled by production personnel) to be used for monitoring purposes

8.3 Data, Information, and Activities To Be Monitored

The licensee should identify the specific data, information, and activities to be monitored and should address the frequency of each specified monitoring activity and frequency of data evaluation.

The means for independently assessing the authorized process enrichment parameters should be shown. To accomplish this, the program should address verification of the following:

- weighing, sampling, and isotopic assay of material introduced at the feed station(s)

- weighing, sampling, and isotopic assay of material withdrawn at the product and tails withdrawal stations

- sampling and isotopic assay of in-process material at randomly selected points

- consistency of the quantity of U-235 determined to be in the product and tails with the quantity in feed

- determination of the nuclear material, minor isotope, and SWU balances

Licensees or applicants should consider monitoring process parameters such as UF_6 gas pressures, flow rates, enrichments, valve positions, cascade configuration and connections, and tracking of all potential UF_6 containers in the process area. Verification of measurements also can be obtained by independent observations of measurement processes and by using nondestructive assay (NDA) techniques to verify isotopic ratios and contents of containers.

The overall design of the program should include analyses of all processing and product streams to determine where U isotopic measurements should be made and at what frequency they should be performed to prevent clandestine enrichment activities; that is, for each credible scenario for clandestine enrichment, a monitoring program for the timely detection of any implementation of that scenario should be implemented. Because the activity of most interest is whether unauthorized HEU is being produced, NDA measurement techniques for enrichment

may be very practical. Either manual measurements using portable NDA instruments can be used or the instruments can be permanently affixed to the process equipment. In the former case, administrative controls should be used to prevent collusion of the measurement personnel with a potential clandestine perpetrator. In the latter case, frequent inspection and testing of the instruments should be performed to prevent tampering or disabling of the NDA measurement system.

The scenario analysis performed should address each product stream, regardless of material type or composition, and be conducted by individuals having a thorough knowledge of the processing equipment and enrichment technology. Credible means for producing U at enrichment levels equal to or greater than 10 wt % U-235 should be identified. These approaches should include process system adjustments, batch recycle processing, cascade interconnections, and cascade reconfiguration (e.g., to increase the number of stages).

The extensiveness and complexity of the monitoring program should be dependent on such factors as the following:

- the minimum time required to produce HEU containing 1 kilogram of U-235
- process design features that would prevent unauthorized enrichment from being conducted simultaneously with normal, authorized enrichment
- personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms
- physical security controls, such as locked and alarmed doors and closed-circuit television monitors, that would detect unauthorized access to enrichment equipment, feed or product material, or the enrichment production area
- process control systems that would detect unauthorized use of enrichment equipment

The MC&A plan should address such aspects as the following:

- type and frequency of U isotopic measurements
- type and frequency of NDA monitoring measurements
- required accuracy of the isotopic measurements
- administrative controls to be applied to all monitoring measurements

The MC&A plan should show the means for independently verifying the authorized process enrichment parameters given in this section, identify the specific data that will be collected and analyzed, and state the frequency of the measurements and of data evaluations.

The following are some examples of technical measures that could satisfy the licensee's responsibility for addressing unauthorized production and for providing auditability of the conclusion that unauthorized production has not occurred:

- Installation of supplemental materials verification techniques, such as NDA measurements, process and cylinder sampling, flow measurements, cylinder weighings, and item verification, will assist in detecting missing material or out-of-balance conditions.

- Tamper-safing and additional containment and surveillance techniques on instrumentation could provide evidence of both unreported cascade reconfiguration and suspect feed or withdrawal in the cascade hall.

- Potential containment and surveillance techniques include radiation measurement and surveillance instrumentation, personnel and vehicle portal monitors, package monitors, perimeter barrier sensor systems, optical surveillance instrumentation, automated key-control systems, and tamper-indicating seals.

- Installation of in-line enrichment monitors and gas flow meters at the product withdrawal points could address most unauthorized production scenarios.

- Installation of material surveillance systems, such as weight sensors, heat sensors, video surveillance cameras, radiofrequency tags, or motion detectors, will provide useful and necessary information for assessing alarms and localizing unauthorized material removal and quantity or the form of missing materials.

8.4 Reporting and Documentation Requirements

The applicant or licensee should make a definitive statement defining the basis for declaring that there has been (1) unauthorized production of U to greater than 10 percent enrichment and (2) unauthorized production of LEU.

Whenever systems indicate that unauthorized production of enriched U may have occurred or may be occurring, that determination becomes an "indicator" and subject to the investigation and resolution requirements of 10 CFR 74.33(c)(5).

If actual unauthorized production of enriched U is discovered, that discovery must be reported to the NRC within 1 hour as required by 10 CFR 74.11.

8.5 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to detecting unauthorized production of U to greater than 10 percent enrichment and unauthorized production of U of low strategic significance. A finding that the licensee's MC&A plan for the detection program is acceptable and in accordance with 10 CFR 74.33(c)(5), will be based on, but not limited to, the following acceptance criteria:

- The detection program provides high assurance of detecting and resolving production of U enriched to 10 percent or more in the U-235 isotope, to the extent that SNM of moderate strategic significance could be produced within any 370-calendar-day period; production of U enriched to 20 percent or more in the U-235 isotope; and unauthorized production of U of low strategic significance.

- The overall design of the detection program includes an analysis of all potentially credible means by which unauthorized production could occur. For each credible scenario, there exists a surveillance or an enrichment monitoring system for the timely detection of that scenario.

- The program will detect misuse of plant or equipment to deliberately produce U at an enrichment level greater than permitted by license, or the production of a quantity of enriched U greater than reported to the NRC (e.g., by undeclared feed or by unrecorded lowering of the tails assay). Specifically:
  - Detection of the unauthorized production (from undeclared feed) of LEU within the cascade, with an enrichment of less than 10 wt % U-235, should occur before the quantity of U-235 contained in such LEU amounts to 25 kilograms.
  - Detection of the unauthorized production of LEU within the cascade, with an enrichment in the range of 10.00 to 19.99 wt % U-235, must occur before the quantity of U-235 contained in such LEU amounts to 10 kilograms.
  - Detection of the unauthorized production within the cascade of HEU (i.e., equal to or greater than 20 percent U-235) must occur before the quantity of U-235 contained in such HEU amounts to 1 kilogram.
- The responsibilities and authorities for each position assigned a function having a significant impact on the program for detecting the unauthorized production of enriched U are clearly defined in a written position description that enumerates the responsibilities for that position.
- The qualifications and experience required for each position assigned functions associated with the program for detecting unauthorized production of enriched U will be sufficient to permit adequate performance of the duties required of that position.
- The descriptions in the MC&A plan of the duties and authorities show that those responsible for detecting the unauthorized production of enriched U will have sufficient authority to perform the function in the intended manner.
- The organization responsible for detecting the unauthorized production of enriched U is separate from the production organization and is also separate from organizations that generate source data, if practicable; otherwise, independence of the functions is attained by suitable controls and overchecks.
- Process and measurement data used for detecting unauthorized production of enriched U are independently verified.

9. ITEM CONTROL

9.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(6) is to require licensees to establish, document, and maintain an item control system to protect against unauthorized and unrecorded removal of items, or of material from items, and to enable timely location of items. An item, as defined in 10 CFR 74.4, means any discrete quantity or container of source material (SM) or special nuclear material (SNM), not undergoing processing, having an unique identity, and also having an assigned element and isotope quantity. Examples of items are known quantities of SM or SNM in well-defined and uniquely identified containment, such as cans, drums, and canisters, or fixed units such as fuel assemblies. Uncontainerized solid SNM, such as uranium (U) metal ingots or buttons, are also items if they are uniquely identified. To promptly locate a given item, sufficient current information must be recorded.

9.1 Organization

The material control and accounting (MC&A) plan should identify, by position title, the individual responsible for overseeing the item control system. It should also identify the positions of those individuals who have significant item control system responsibilities.

9.2 General Description

The licensee or applicant should state that the overall MC&A program maintains a record of all SM and SNM items, regardless of quantity or duration of existence. In addition, the item control system should provide current knowledge of the location, identity, and quantity of all SM and SNM contained in items, and should enable the detection of unauthorized removals of individual items or 500 grams or more of uranium-235 from one or more items. The regulations allow certain types of items to be exempted from the item control requirements. As stated in 10 CFR 74.33(c)(6), the following items are exempted from its requirements:

- Solutions with a concentration of less than 5 grams per liter of plutonium or uranium-233 or uranium-235 or a combination thereof of less than 5 grams per liter
- Laboratory samples and reference standards maintained in the laboratory material management system and containing uranium enriched to less than 10 percent in the uranium-235 isotope
- Items existing less than 3 calendar days and containing less than 100 grams of uranium-235
- Items of waste destined for burial or incineration

All other items should be stored and handled in a manner that enables detection of, and provides protection against, unauthorized or unrecorded removals of SM and SNM. All items, whether or not they are subject to item control system coverage, should have a unique identity. For items subject to the item control system, 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 SM or 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 prevent its reuse

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 should be further justified in the MC&A plan. 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. Each nonexempt item should be stored and handled in a manner that enables detection of, and provides protection against, unauthorized or unrecorded removals of SM and SNM.

9.3 Item Identity Controls

The MC&A plan should describe 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 a unique item identity, the MC&A plan should do the following:

- Describe the type of TID used.

- Describe how the TIDs are obtained and what measures are implemented 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.

The plan should provide similar information for other methods of unique item identity (e.g., labels).

9.4 Storage Controls

The MC&A 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. If tamper-safe seals or TIDs are to be used, procedures should be established and maintained in accordance with 10 CFR 74.33(c)(9). Tamper-safing is discussed further in Chapter 12. Any other 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.

The MC&A plan should identify both administrative controls (e.g., custodian assignments and limiting authorized access to storage areas) and physical controls (e.g., locked and alarmed doors).

9.5 Item Monitoring Methodology and Procedures

As part of the item control system, a licensee should maintain a system of item monitoring to do the following:

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

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

    - Detect, with high probability, any real loss of items, or 500 grams or more of uranium-235 from one or more items.

The item monitoring system should conduct the following activities at least, on a monthly basis:

- 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 system 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 MC&A plan should specify minimum monitoring frequencies associated with each storage area, as well as discrepancy rates that trigger more frequent monitoring frequencies, and should contain definitive commitments for resolving discrepancies.

9.6 Investigation and Resolution of Item Discrepancies

The licensee or applicant should provide definitive statements of 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) one displaying evidence of tampering or (2) an unencapsulated and unsealed item assigned to a controlled, limited-access storage area that is found elsewhere.

If any unsealed or unencapsulated item is located after having been determined to be missing, or if an item is found to be compromised, the contents should be reestablished by measurement (e.g., by nondestructive assay (NDA) or by weighing, sampling, and analysis). The licensee should use the recommendations on resolution of indicators (Chapter 14 of this document) to resolve item discrepancies.

9.7 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to maintaining current knowledge of items and detecting unauthorized removals. A finding that the licensee's MC&A plan for the item control system is acceptable and in accordance with 10 CFR 74.33(c)(6) will be based on, but not limited to, the following acceptance criteria:

- The licensee'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 MC&A plan, a licensee 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 SM or SNM contents stated in the records are valid and that unauthorized removal of SM or SNM from the item has not occurred.

  Remeasurement is not necessary, if the SM or SNM content of the item was measured previously and reasonable assurance is provided that the SM or SNM content has not subsequently changed.

- Items that are excepted from the 10 CFR 74.33(c)(6) item control requirements fall into one of the following categories:

  - Solutions with a concentration of less than 5 grams per liter of plutonium or uranium-233 or uranium-235 or a combination thereof of less than 5 grams per liter

  - Laboratory samples and reference standards maintained in the laboratory material management system and containing uranium enriched to less than 10 percent in the uranium-235 isotope

  - Items existing less than 3 calendar days and containing less than 100 grams of uranium-235

  - Items of waste destined for burial or incineration

- A current accounting is maintained of the total quantity of SM or 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 that are subject to the 10 CFR 74.33(c)(6) item control requirements, a record system is maintained to provide knowledge of the current status of such items with respect to their identity, U and U-235 content, and stored location. For items subject to this commitment, the item control and records system can 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 very high probability of detection.

- Each item that is subject to the 10 CFR 74.33(c)(6) item control requirements will be stored and handled in a manner that enables detection of, or provides protection against, unauthorized or unrecorded removals of SM or SNM consistent with the criteria in that paragraph. Knowledge of the SM or SNM content is otherwise ensured by tamper-safing or 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 NDA or by weighing, sampling, and analysis).

10. SHIPPER-RECEIVER COMPARISONS

10.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(7) is to require the licensee to conduct and document shipper-receiver comparisons for all source material (SM) and special nuclear material (SNM) receipts, on both an individual batch basis and total shipment basis, and to ensure that any shipper-receiver difference (SRD) that is statistically significant and exceeds twice the estimated standard deviation of the difference estimator and 500 grams of U-235 is investigated and resolved.

10.1 Receiving Procedures

The first action to be taken on receipt of SM or SNM should be the verification of the number of items, the item identities, and the integrity of individual items and of tamper-indicating devices (TIDs). All SM and SNM shipments received from an external supplier are to be subject to shipper-receiver comparisons. Such comparisons involve measuring 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.

Previously, in approving MC&A plans, the U.S. Nuclear Regulatory Commission (NRC) staff has recognized situations where the cost of conducting and documenting shipper-receiver comparisons outweighs the safety benefit of doing so and has accordingly granted relief in the form of exemptions, notwithstanding the 10 CFR 74.33(c)(7) provision that the requirement applies to "all SM and SNM receipts." The following are examples of situations in which such relief has been granted:

- shipments containing less than 500 grams of U-235;
- individual items containing less than 50 grams U-235;
- encapsulated items, the encapsulation integrity of which 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;
- UF_6 cylinders that are empty except for a heel quantity of UF_6; and
- 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.

Should licensees in the future seek similar relief from the 10 CFR 74.33(c)(7) requirements, specific exemption requests will need to be submitted in accordance with 10 CFR 74.7, "Specific Exemptions." The NRC will determine, on a case-by-case basis, whether granting such exemption requests is authorized by law and will not endanger life or property or the common defense and security, and whether such requests are otherwise in the public interest.

For any SM or SNM received, the licensee must provide all appropriate information on DOE/NRC Form 741 that accompanies the shipment, in accordance with 10 CFR 74.15, "Nuclear Material Transaction Reports." (NOTE: See NUREG/BR-0006, "Instructions for

Completing Nuclear Material Transaction Reports (DOE/NRC Forms 741 and 740M)," for instructions and requirements for completing DOE/NRC Form 741.)

10.2 Determination of Receiver's Values

For normal and depleted UF_6, the licensee may establish receiver's values by (1) measuring the U-235 isotopic concentration (either by NDA or by sampling and analysis), (2) weighing each cylinder, and (3) using a nominal percent U factor.

SNM receipts and any SM receipts not in the form of UF_6 should be measured for total quantity, U concentration, and U-235 enrichment.

10.3 Evaluation of Shipper-Receiver Differences

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

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

$$= 1.414\,\sigma_R$$

Under 10 CFR 74.33(c)(7), the difference between the shipper's value and the receiver's value (i.e., the SRD), in terms of either (1) an individual container (for container batches) or a single batch or lot (when there is more than one container per batch), as appropriate, or (2) the total shipment, must be regarded as significant whenever the SRD exceeds both 500 grams of U-235 and twice the combined standard error. If subject to 10 CFR Part 75 (international safeguards), an SRD in excess of both 500 grams U-235 and twice the combined standard error with respect to a single batch within the shipment must also be regarded as significant.

10.4 Resolution of Significant Shipper-Receiver Differences

The MC&A plan should describe the steps involved with the investigation of a significant SRD and discuss how such a difference is resolved. It should also present the criteria for defining a resolved SRD. Generally, the resolution of a significant SRD involves 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 the shipper's and receiver's weights differ by more than one-half of the total combined standard error.

10.5 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to shipper-receiver comparisons. A finding that the licensee's MC&A plan for conducting SRD comparisons and resolving significant SRDs is acceptable and in accordance with 10 CFR 74.33(c)(7), will be based on, but not limited to, 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 if SM or 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 is confirmed within 24 hours of discovering the questionable integrity. Only acceptable tamper-safing methods will be used as described in Chapter 12 of this document and as agreed to with the receiver.

- Confirmatory measurements of scrap shipments are performed by the receiver to determine the amount of element and isotope within a time period consistent with the accountability needs of the shipper.

- The test for the significance of an SRD is based on statistical tests.

- The investigation procedure for significant SRDs is sufficiently comprehensive to ensure that the difference will be resolved. Comprehensiveness is sufficient if the licensee 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. Investigation and resolution should be completed within 90 days of material receipt.

- Measurements of the quantity of SM or SNM received in each shipment will be performed and the SRD will be tested for statistical significance. The element and isotope content of SM or SNM shipped or received by the licensee is based on measurement systems subject to measurement control. Occurrences of significant SRDs in excess of 500 grams U-235 and missing items will be reported to the shipper promptly.

- Measurement results for shipments and receipts will be 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 affect individual items by more than their rounding error in terms of either U-235 or U content, or both.

- For SNM received, SRDs that are statistically significant and also greater than 500 grams U-235, on a total shipment basis (and also on a batch basis, when subject to 10 CFR Part 75), will be detected within 30 calendar days of receipt.

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

11. ASSESSMENT AND REVIEW OF THE MATERIAL CONTROL AND ACCOUNTING PROGRAM

11.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(8) is to require independent assessments of the material control and accounting (MC&A) program. Licensee management must periodically (at least every 24 months) review and assess the performance of the MC&A program, evaluate its effectiveness, and document management's actions on prior assessment recommendations and any identified deficiencies. It is intended that the review be performed by knowledgeable, technically competent individuals free from conflicts of interest and that the deficiencies be brought to the attention of plant management so that they will be corrected. It should be emphasized that this review process is intended to be much more than a routine audit for compliance with existing procedures and commitments. Conclusions and recommendations relative to overall program effectiveness and to the adequacy of the MC&A program—including that of any contractor who performs source material (SM) and special nuclear material (SNM) measurements on the licensee's behalf—must be made.

11.1 General Description

The capabilities, performance, and overall effectiveness of the licensee's MC&A program should be independently reviewed and assessed at least every 24 months. The MC&A 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 will be 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 entire MC&A program generally should be reviewed and evaluated during each assessment. When this occurs, intervals between assessments can be as much as 24 calendar months. However, if individual assessments only cover part of the MC&A program, individual subsystems should be assessed at intervals no greater than 12 calendar months. Thus, the type of assessment (partial or total) and the maximum interval between assessments should be specified in the MC&A plan. "Interval" means the elapsed time between either the start or the termination of successive assessments.

The responsibility and authority for the assessment program should lie at least one level higher in the licensee's organizational structure than that of the MC&A manager. Such responsibility should include selecting the assessment team leader and initiating corrective actions. Team members may be selected from the facility staff or from outside, but an individual member should not participate in the assessment of the parts of the MC&A program for which that person has direct responsibility. Hence, the MC&A manager may not be a team member. Also,

a given individual should not assess the parts of the program 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 responsibility for managing any of the MC&A elements being assessed.

The minimum number of individuals on any given assessment team should be dependent on the knowledge and expertise of the team relative to MC&A activities and their experience in conducting assessments. Personnel assigned to the assessment team should have a demonstrated understanding of the objectives and the 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 program they review. The team should have authority to investigate all aspects of the MC&A program and should be given 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.

11.2 Report of Findings and Recommendations

The areas to be reviewed should encompass the entire MC&A program, and the level of detail of the reviews should be sufficient to ensure that the assessment team has adequate information to make reasoned judgments of the MC&A program effectiveness. The team report, as a minimum, should state findings on the following:

- organizational effectiveness to manage and execute MC&A activities
- management responsiveness to indications of losses of U and possible unauthorized enrichment activities
- staff training and competency to carry out MC&A functions
- reliability and accuracy of accountability measurements made on SM and 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 (SEID)
- soundness of the material accounting records
- effectiveness of the item control system 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) comparisons and resolution of excessive SRDs
- soundness and effectiveness of the inventory-taking procedures
- capability to confirm the presence of SM and SNM
- capability to detect and resolve indications of unauthorized enrichment activities and the effectiveness of doing so
- capability to detect and resolve indications of missing U

On completion of each assessment, the findings and recommendations for corrective action, if any, should be documented. The written report should be distributed to the plant manager, the MC&A manager, and other managers affected by the assessment.

11.3 Management Review and Response to Report Findings and Recommendations

Management should review the assessment report and take the necessary actions to correct MC&A program 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 MC&A plan should address resolution and followup actions associated with concerns identified in the assessment report. The individuals responsible for resolving identified concerns, and the timeliness of such resolution, should be specified.

11.4 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to independent assessments of the MC&A program. A finding that the licensee's MC&A plan for such assessments is acceptable and in accordance with 10 CFR 74.33(c)(8) will be based on, but not limited to, 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 24 months; that is, the nominal elapsed time from the completion of one review or assessment to the completion of the next will not exceed 24 calendar months.

- The periodic assessments will be comprehensive and sufficiently detailed to enable the assessment team to rate the MC&A program effectiveness, capability, and performance by comparison with the expected and required performance. The overall assessment objectives are to determine that the MC&A program, as designed and implemented, is continuing to meet the overall safeguards goals, and to identify weaknesses or deficiencies in the program 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 program effectiveness, which includes the following:

  - organizational effectiveness and management responsiveness to indicators of possible SM or 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 comparisons 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 ID
  - capability to confirm the presence of SM and SNM
  - capability to resolve indications of missing SM or SNM, as well as aid in any government-led investigation of missing SM or SNM, and provide information that would aid in the recovery of missing SM or 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 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 will have an adequate understanding of the regulatory objectives and requirements of the MC&A program and will have sufficient knowledge and experience to be able to judge the adequacy of the parts of the program they are asked to review. The team will have authority to investigate any aspect of the MC&A program and will have access to all relevant information.
- An individual team member will not participate in the assessment of any part of the MC&A program for which he or she has direct responsibility. Also, an individual "A" will not assess any part of the program that is the responsibility of person "B" if person "B" is assessing an area under the responsibility of individual "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 program, and to demonstrate the ability to include any such changes made during the review or assessment). Conducting two or more assessments during a 24-month interval, in which only part of the MC&A program is covered in each, is not deemed acceptable; that is, reviewing a single component of the MC&A program at 24-month intervals is not very meaningful unless knowledge is obtained of how well the other components currently interact. Piecemeal review and evaluation is permissible, however, if each subsystem is covered at 12-month (or fewer) intervals.
- The leader of the assessment team will have no responsibility for performing or managing the functions being assessed. The assessment team leader will 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 will lie (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.
- Each overall review and assessment will be conducted and completed in a timeframe that is short (e.g., a week), with respect to the time for changes that have occurred in the MC&A program, and will include any such changes made during the time the review and 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 such start date will be documented.

- The results of the assessment and recommendations for corrective action, if any, will be documented and reported to the plant manager and other managers affected by the assessment. Management will review the assessment report and take the necessary actions to correct MC&A program deficiencies. Such corrective actions (if any) that apply to daily or weekly activities will be initiated within 40 calendar days following the submittal of the final report of the review and assessment.

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

12. TAMPER-SAFING

12.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(9) is to require licensees to maintain and follow procedures for tamper-safing (as defined in 10 CFR 74.4) which include control of access to, and distribution of, unused seals and records. The intent of such procedures is to document the distribution, application, and destruction of tamper-indicating devices (TIDs), as well as the routine inventory of unused TIDs. Licensees are required to retain records for at least 3 years (or longer if specifically required by regulations external to 10 CFR 74.33), thereby providing a means of assessing the performance of the tamper-safing program and inspecting for compliance with regulatory requirements.

12.1 Characteristics of Tamper-Safing Devices

Tamper-safing devices on containers or vaults are used to secure the integrity of special nuclear material (SNM) or source material (SM) either when it is in transit or stored on site. The objective of TIDs is to ensure that no tampering or entry has occurred while the TID is on the container. Therefore, for 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 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 new seals 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 that the TID is intact or indicates tampering

The licensee should confirm manufacturer claims that the removal of a TID is not possible without detection by testing potential TIDs to see if they can be removed from the containers on which they are to be used. The licensee should confirm the results by using the manufacturer's documented procedures and the samples used. The experiments should be documented, both with regard to what techniques were 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, similar tests conducted by an independent third party may be considered acceptable.

12.2 Use of Tamper-Safing Devices

The MC&A plan may allow the use of TIDs to do the following:

- They could 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 measured value, thus eliminating or decreasing the need to remeasure the items to verify the nuclear material content.

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

- They could 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 should 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), and serial number(s), and the integrity of the TID(s). Any discrepancies should be considered an MC&A anomaly and be addressed by the facility's MC&A resolution program.

12.3 Description of Tamper-Safing Records

The tamper-safing system should identify all records, forms, reports, and standard operating procedures used throughout the system. 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 verifies the application of the TID
- identification of the container to which the TID(s) was(were) applied, including the TID(s) 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

12.4 Commitments and Acceptance Criteria

The acceptability of a TID is based on an evaluation of the attributes of the device in relation to the time needed to defeat the tamper-indicating features. TIDs already deemed acceptable by the NRC include Type E, pressure-sensitive, tamper-evident wire seals; fiber optic seals; and steel padlocks. Other TIDs may be equally acceptable. Licensees proposing to use TIDs not currently approved by the NRC must provide the appropriate information, including references, to enable licensing reviewers to assess the adequacy of the proposed TID type.

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to the use of TIDs. A finding that the licensee's MC&A plan for tamper-safing is acceptable and in accordance with 10 CFR 74.33(c)(9) will be based on, but not limited to, the following acceptance criteria:

- Only TIDs that are controlled and accounted for are used to maintain the validity of previously established SM or 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 TID control officer(s).
- TIDs are only applied and removed by individuals authorized for that purpose.
- Unused TIDs are controlled and inventoried. Unissued TIDs are stored in a locked container within a room that is locked when unoccupied or in an approved repository. Blocks of TIDs 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 TID control officer or person responsible for applying the TID). As a rule, the number of available seals issued to these individuals should be limited to a single day's use.
- The licensee 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 properly disposed of.
- 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.

13. DESIGNATION OF MATERIAL BALANCE AREAS, ITEM CONTROL AREAS, AND CUSTODIANS

13.0 Regulatory Intent

The intent of 10 CFR 74.33(c)(10) is to ensure that licensees establish various material control boundaries to minimize the occurrence of, and facilitate resolution of, material control and accounting (MC&A) anomalies, such as excessive IDs, missing items or nuclear material, and potential theft or diversion of nuclear materials. The intent is also to ensure that there is a designated individual who is responsible for having knowledge of the placement and movement of source material (SM) or special nuclear material (SNM) within a specified area and transfers into and out of the area. Such an individual should be vested with the authority to obtain the information necessary to accomplish his or her task and to ensure that activities are carried out in accordance with approved policies and procedures.

Regulations in 10 CFR 74.33(c)(10) require licensees to designate one or more material balance areas (MBAs) or a combination of MBA(s) and one or more item control areas (ICAs), , and assign custodial responsibilities in a manner that ensures that such responsibility can be effectively executed for all SM or SNM possessed under license. This regulatory provision provides flexibility for licensees to determine the appropriate MBA or ICA structures and design these areas as needed, thus enhances the licensee's capability to deter or detect unauthorized movement or removal of SM or SNM at the licensee's facility.

13.1 Material Control Boundaries

For accounting and control purposes, a facility may be divided into a number of MBAs or ICAs in order to simplify the administrative controls and localization of material or item losses. The main purpose of an MBA or ICA is to know how much material or items should be in that area and to verify and monitor the material or items in that area. If the facility is small enough, or the number of material or item movements is small, one MBA or ICA may be sufficient. When there is a need to establish more than one MBA or ICA, the subdivision should be done according to the following practices:

- Each MBA or ICA should be defined by a physical or administrative boundary
- Any location in the facility should belong to one and only one MBA or ICA
- Custodial responsibility within one MBA or ICA should be clearly assigned (i.e., to a single individual)
- MBA or ICA subdivision should be implemented taking into account the material movements carried out in the areas and the administrative responsibilities involved.

The MC&A plan should describe how the licensee establishes various material control boundaries to minimize the occurrence of MC&A anomalies and facilitate their resolution. Examples of such anomalies are excessive inventory differences, missing items of SM or SNM, and potential theft or diversion of SM or SNM. Regardless of the number and size of MBAs and ICAs used for control and accounting purposes, the structure should be clearly described and properly documented, including boundaries for each area and categories of material in each area. A type of MBA or ICA is exemplified by a storage area or a receiving and shipping area where items are received, stored, and released. Another type of MBA or ICA is one in which

items or material batches are received and modified by a process (e.g., mixing, blending, or physical and chemical transformations).

Because MBAs and ICAs are important foundations for controlling and accounting for all SM or SNM in a facility, the MC&A plan should describe the process for how their locations are chosen. An MBA or ICA should correlate to physical or administrative boundaries and monitored locations. An MBA or ICA should be designed to limit losses to a specific area (i.e., the MBA should not be so large that the licensee cannot localize inventory or process differences to a manageable level). In addition, an MBA or ICA should be designed such that the quantity of material or items in each movement into or out of each area can be determined, and the quantification of the physical inventory of material or items in each area can be determined, when necessary. For increased capability, smaller areas make control of material easier and reduce the size of the area to which an unauthorized removal or loss can be attributed. Each item or material batch at the facility should be assigned to an MBA or ICA and not to more than one MBA or ICA. Materials transferred into and out of an MBA or ICA must be subject to quantitative measurements, as specified in the definitions of MBAs and ICAs in 10 CFR 74.4, "Definitions."

13.2 Custodians

The MC&A plan should describe the roles and responsibilities of the custodians for MBAs and ICAs. Each custodian should have direct interaction with the MC&A organization, and such individuals should be located within the physical operations area. When material is moved from one MBA or ICA to another, custody of the material and responsibility for its movement should be transferred from one custodian to another. Custodians who are responsible for more than one MBA or ICA should not have the authority to make material transfers between MBAs or ICAs that are both under their direct control.

13.3 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet the acceptance criteria applicable to the designation of MBAs, ICAs, and custodians. A finding that the licensee's MC&A plan for designating MBAs, ICAs, and custodians is acceptable and in accordance with 10 CFR 74.33(c)(10) will be based on, but not limited to, the following acceptance criteria:

- MBAs and ICAs should have defined physical and administratively controlled areas that allow for the physical and administrative control of nuclear materials such that the quantity of nuclear materials being moved into or out of the MBA is a measurement-based assigned value for element and isotope contents.
- MBAs and ICAs are established in such a way as to minimize the occurrence of MC&A anomalies and facilitate their resolution.
- MBA and ICA structures are properly documented and clearly described, including physical boundaries and categories of material in the individual MBA or ICA.
- Clear directions should be provided on transferring material between MBAs or ICAs to help deter and detect unauthorized removal or substitution of material during movement. Material transfers should be recorded in a timely manner.
- Control measures should be appropriate for material relocations within an MBA or ICA and updates to the records system should be made to reflect material relocations.

- Custodial responsibilities are assigned for each designated MBA and ICA.
- Custodians responsible for more than one MBA or ICA are not authorized to transfer material between MBAs and ICAs under their control.

14. RESOLVING INDICATIONS OF MISSING URANIUM AND OF UNAUTHORIZED PRODUCTION OF ENRICHED URANIUM

14.0 Regulatory Intent

The intent of the general performance objectives in 10 CFR 74.3(b) and (c) and in 10 CFR 74.33(a)(2) and (3) is that licensees be able to promptly investigate and resolve indications of a possible loss, theft, diversion, or misuse of source material (SM) or special nuclear material (SNM), whether arising from errors or deliberate actions. Additionally, uranium enrichment facilities are to have a system in place for detecting, investigating, and resolving indications of unauthorized production of enriched uranium.

14.1 Methods and Procedures for Identifying Indicators

The material control and accounting (MC&A) plan should discuss the means by which the licensee will resolve indicators of the unauthorized production of enriched U, or indicators of missing material. The MC&A plan should enumerate potential indicators that can be postulated and develop resolution procedures for each. An anomaly could potentially be an indicator of loss, theft, diversion, or misuse of SM or SNM. An anomaly is an unusual observable condition (such as excessive discrepancies, missing items, broken tamper-indicating devices (TIDs), or other possible indicators) that might result from theft, diversion, or other misuse of SM or SNM. The terms “indicator” and “anomaly” may be used interchangeably to describe a condition that may require further investigation to determine if an actual loss, theft, diversion, or misuse of SM or SNM occurred. The three generic types of indicators are as follows:

(1) indications that SM or SNM is missing

(2) indications that the enrichment equipment has been or is being used to produce undeclared U enriched to less than 10 wt % for unauthorized use or distribution

(3) indications that the enrichment equipment has been or is being used to produce U enriched to 10 wt % or more in U-235

The licensee’s resolution program should address the possible indicators of missing U. The MC&A plan should enumerate potential indicators that can be postulated for indicator types (1) through (3) above and develop resolution procedures for each.

The following are examples of possible indicators of missing U:

- lack of agreement of dynamic or static inventories with the MC&A records
- determination through the item control system that a specific item is not in its authorized location and its actual location is not immediately known
- discovery that an item’s integrity or its TID was compromised
- information from the process control system indicating potential loss of material from the process system (e.g., improper valve settings)
- an allegation of theft or diversion

The following are examples of possible indicators of unauthorized production of U enriched to less than 10 wt % U-235:

- presence of unauthorized product, feed, or tails cylinders
- SWU imbalances (e.g., reduced production capacity)
- presence of tails at enrichments lower than the design range
- presence of excess mass or amount of tails, or other ID
- discovery of records tampering
- discovery of unauthorized feed or withdrawal equipment or reset valve configurations to permit feeding and withdrawal
- unauthorized operational activities in the enrichment process facilities
- receipt of allegations

The following are examples of possible indicators of unauthorized production of U enriched to 10 wt % or greater in U-235:

- any of the preceding items
- any measurement from a stream monitoring program that indicates out-of-specification enrichment concentrations for any feed, product, or tails stream
- unauthorized reconfiguration, isolation, or interconnection of enrichment equipment or changes in valve settings
- equipment used for monitoring enrichment levels in product streams not functioning properly or compromised
- an allegation that unauthorized production of U enriched to 10 wt % or more in U-235 has occurred or is underway
- radiation signatures or background radiation levels greater than normally expected

14.2 System and Procedures for Investigating and Resolving Indicators

One or more MC&A procedures should address the system and practices for investigating and resolving indicators. Thus, the licensee should have well-defined procedures for investigating indicators of both (1) possible missing U and (2) possible unauthorized production activities. These procedures should include criteria for determining when an investigation of loss or unauthorized production indicators can be concluded.

Resolving a loss or unauthorized production indicator means that the licensee has made a determination that loss, theft, or unauthorized production of U has not occurred and is not occurring. For each type of indicator, the licensee should develop detailed resolution procedures and should describe or outline them in the MC&A plan.

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

For indications that 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 or SM involved, and (5) determining that the indication is or is not resolved. The resolution procedures should be prepared in such a manner that no individual who could have been responsible for the potential loss would also 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. The MC&A plan should specify the time allowed for resolution. In general, a time not exceeding 72 hours should be adequate.

For indications of unauthorized production of U enriched to less than 10 wt % U-235, the licensee should verify that the indicator is true, determine its cause, and conclude if unauthorized production has occurred or is occurring. 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. The MC&A plan should specify the time allowed for resolution. In general, a time not exceeding 72 hours should be adequate.

For indications of unauthorized production of enrichment of 10 wt % or greater in U-235, the resolution process should include investigation of all the information that contributed to the indication of such unauthorized production. On receipt of an indication that U enriched to 10 wt % or more has been discovered, the licensee should immediately isolate the process area or storage area from which the indication came to verify the indication. The instruments and measurement systems used for monitoring should be examined to determine if they are functioning properly. A thorough examination of the processing equipment should be performed to ensure that unauthorized modifications were not made. The presence of U enriched to 10 wt % or more in U-235 should be verified through remeasuring the material in question, whether in item form or in process equipment. If this investigation determines that an indication of unauthorized production of enrichment of 10 wt % or more in U-235 is true, this condition is reportable under 10 CFR 74.11. The MC&A plan should specify the time allowed for resolution. In general, a time not exceeding 72 hours should be adequate.

If the investigation conducted to resolve the indication does not observe the production of U enriched to 10 wt % or more in U-235, further measures are needed before the licensee may conclude that the indicator is fully resolved. To protect against the relocation and concealment of the enriched U, a thorough investigation of the entire facility should be performed by individuals who are independent of the processing organization.

14.3 Response Actions for Unresolved Indicators

Actions in response to unresolved indicators should be clearly defined and should be on a graded scale appropriate to the level of potential safeguards significance. The responsibility and authority for initiating and executing response actions should also be defined.

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

- whether the potential missing U is depleted, natural, or enriched
- the potential quantity of U-235 involved
- the material attractiveness (from the standpoint of its potential use in a nuclear explosive device) of the potential missing U relative to its composition or form (i.e., U metal, U_3O_8,

uranyl nitrate solution, UF_6, scrap, or waste)

At LEU enrichment facilities, indicators of unauthorized production of U enrichment generally have a higher level of safeguards concern than indicators of missing U. The degree of concern for unauthorized production indicators is related to such factors as the following:

- whether the indicator applies to unauthorized production in the planning stage, currently in progress, or already accomplished
- whether the potentially produced material is low strategic SNM, moderately strategic SNM, or strategic SNM
- the potential quantity of unauthorized material already produced

14.4 Documentation Requirements

The MC&A plan should identify all documentation requirements associated with the licensee's program for reporting, investigating, and resolving missing U indicators and of unauthorized production indicators. The plan should also define the review and approval requirements and document custodial responsibility. As a minimum, documentation of the following should be included:

- investigation procedures
- resolution procedures
- reporting of 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 indication
- 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

14.5 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to regulatory requirements and meet acceptance criteria applicable to investigating and resolving anomalies indicating possible missing SM or SNM or unauthorized production of enriched U. A finding that the licensee's MC&A plan for resolving indications of loss, theft, diversion, or misuse of SM or SNM is acceptable and in accordance with 10 CFR 74.33(a)(2) and (3) and with 10 CFR 74.3(b) and (c), will be based on, but not limited to, the following acceptable criteria:

- Adequate commitments are provided to ensure a high probability that an indicator of missing SM or SNM or misuse of SM or SNM will be (1) recognized as an indicator, (2) investigated, and (3) resolved.
- A prompt investigation will be conducted by the licensee for indications of possible loss, theft, diversion, or misuse of SM or SNM.

- A cause or probable cause that is based on objective evidence will be assigned to each indication of possible loss that is investigated by the licensee.
- 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 SM or 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 SM or SNM exceeding the current DQ should be declared as completed but unresolved without first conducting a shutdown, cleanout inventory in which all unsealed SM or SNM is remeasured for element and isotope.
- The results of all investigations of alleged thefts, as well as any indications of a loss of SM or SNM that remains unresolved after 30 calendar days, will be reported by the licensee to the appropriate NRC MC&A licensing authority.

15. INFORMATIONAL AID FOR ASSISTING IN THE INVESTIGATION AND RECOVERY OF MISSING URANIUM OR ASSISTING IN THE INVESTIGATION OF UNAUTHORIZED ENRICHMENT

15.0 Regulatory Intent

The intent of the 10 CFR 74.3(d) and 10 CFR 74.33(a)(4) and (5) general performance objectives is for licensees to have ready and provide to investigators any information deemed relevant to the recovery of SM or SNM involved in a loss or theft or to investigating the unauthorized production of such material. The burden is on the licensee to provide (without being asked) all information that it recognizes as being relevant, as opposed to only providing information that the investigators are knowledgeable enough to request. This objective applies to investigations and recovery operations relating to actual (or highly suspected) events applying to missing SM or SNM, which would be conducted by the NRC or other government agencies, such as the Federal Bureau of Investigations.

The 10 CFR 74.3(d) performance objective states that the licensee 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, theft, diversion, or misuse. The 10 CFR 74.33(a)(4) and (5) general performance objectives impose similar requirements for SM and for the unauthorized production of enriched U, respectively.

15.1 Types of Information

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

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

15.2 Information Indicating Possible Losses of Special Nuclear Material

Information indicating that a loss of U may have occurred is provided by physical inventories, the item control system, and shipper-receiver comparisons (Chapters 7, 9, and 10, respectively). 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 SM or SNM from storage or process locations

- reports of apparent destruction or falsification of records of an item's existence
- records of broken TIDs or compromised item integrity
- indications of unauthorized entry into SM and SNM storage areas
- reports from monthly item monitoring activities
- material receipt and log-in records
- results from SRD comparisons
- process monitoring and control records

Information indicating that unauthorized production may have occurred is provided by the program for preventing and detecting unauthorized production (Chapter 8). This information could include the following:

- reports assessing potentially credible means for unauthorized enrichment
- indications of unauthorized activities in enrichment process areas
- indications of anomalous process configurations
- indications of anomalous process conditions
- indications of unauthorized entry into the enrichment process areas
- indications of anomalous enrichment levels (e.g., process sample or radiation measurement data)
- indications of anomalous feed, product, or tails quantities
- indications of unauthorized feed or withdrawal locations or containers
- anomalous production data (e.g., SWU imbalances)

Information associated with resolving indications of missing U and of unauthorized production is discussed in Chapter 14. This information would include the following:

- the type of unauthorized activity detected
- the interval during which the loss or unauthorized production may have occurred
- the amount of material and form of the material involved in the loss
- estimates of the extent of unauthorized production
- 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 SM and SNM accountability source data
- assessments of measurement data and measurement controls
- results from reviews of the MC&A program and status of corrective actions
- history of indicator investigation and resolution activities
- indicator 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 the people 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 16.

15.3 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to regulatory requirements and meet acceptance criteria applicable to providing information to assist in the investigations and recovery of missing U or unauthorized production. A finding that the licensee's MC&A plan for providing informational aid is acceptable and in accordance with 10 CFR 74.3(d) and 10 CFR 74.33(a)(4) and (5) will be based on, but not limited to, the following acceptance criteria:

- Procedures are in place for the efficient and timely gathering of relevant information to be provided to government investigators, so as to aid them in the investigation and recovery activities associated with missing SM or SNM or unauthorized enrichment activities.
- Information will be provided to appropriate government authorities to aid in their investigation of indications or allegations of missing material and in the recovery of SM or SNM in the event of a loss that could include theft or diversion.

16. RECORDKEEPING

16.0 Regulatory Intent

The intent of 10 CFR 74.33(d) is to require the licensee to establish and maintain records that demonstrate that the general performance objectives of 10 CFR 74.3 and the 10 CFR 74.33(a)–(c) requirements have been met. Records should include those documenting the following:

- receipt, shipment, disposal, and current inventory of SM or SNM held under license,
- quantities of SM or SNM added to and removed from process, and
- shipper-receiver evaluations associated with SM or SNM receipts.

Records must be retained for at least 3 years (or longer if specifically required by regulations external to 10 CFR 74.33), thereby providing a means for assessing the performance of the MC&A program and inspecting for compliance with regulatory requirements. However, 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.

16.1 Description of Records

The MC&A plan should identify all records, forms, reports, and standard operating procedures that must be retained for a minimum of 3 years, as required by 10 CFR 74.33(d). 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 for 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 listings and instructions associated with a physical inventory, both dynamic and static
- forms and formal worksheets used in the calculation of SEID, 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 seal usage and “attesting to” records

- DOE/NRC Forms 741 and 742 and NRC Form 327
- forms, memoranda, and reports associated with identifying, investigating, and resolving significant SRDs
- loss indication and alleged theft investigation reports
- investigation reports on indications of activities related to unauthorized production of enriched U
- investigation reports on excessive IDs
- official reports containing the findings and recommendations of MC&A program assessments and any letters or memoranda on response actions to assessment team recommendations
- forms used for recording data associated with the 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

Examples of the more important MC&A forms should be provided in the MC&A plan annex or appendix. The retained records and reports should contain sufficient detail to enable NRC inspectors to determine that the licensee has met the requirements of 10 CFR 74.33(c) and the general performance objectives of 10 CFR 74.3 and 10 CFR 74.33(a).

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

The MC&A plan should describe the controls used to ensure that records are highly accurate and reliable. The record system also should provide for easy traceability of all SM and 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 for preventing or detecting missing or falsified data and records
- the plan for reconstructing lost or destroyed SM and SNM records
- the access controls used to ensure that only authorized persons can update and correct records
- the protection and redundancy of the record system, such that any act of record alteration or destruction will not eliminate the ability to achieve the performance objectives of 10 CFR 74.3 and 10 CFR 74.33(a).

16.3 Commitments and Acceptance Criteria

In its MC&A plan, the licensee should provide definitive commitments that adhere to the regulatory requirements and meet acceptance criteria applicable to recordkeeping. A finding that the licensee's MC&A plan for the recordkeeping system is acceptable and in accordance with 10 CFR 74.33(d) will be based on, but not limited to, the following acceptance criteria:

- Access to MC&A information will be controlled to provide deterrence and detection of loss, theft, diversion, or misuse, of SNM.

- A record retention system is maintained for those records necessary to show that the MC&A system requirements of 10 CFR 74.33(d) have been met. Such records are retained for at least 3 years, unless a longer retention time is specified by 10 CFR 74.15(b), by 10 CFR Part 75, or by 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 that the facility is under IAEA safeguards will be retained for at least 5 years. Records of the following will be maintained current and will be retained for at least 3 years:

  - management structure, MC&A job descriptions, and MC&A policies and procedures;

  - accounting source data records (data that normally consist of shipping and receiving forms, physical inventory forms, and the forms used for initially recording measurement and measurement control data);

  - records of shipments and receipts and investigations of significant SRDs, 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 74.33(c);

  - physical inventory listings and inventory work sheets;

  - calculations of detection thresholds for excessive IDs of safeguards significance (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 SM or SNM, or unauthorized production, and

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

- Sufficient protection and redundancy of the record system is provided so that an act of record alteration or destruction will not eliminate the ability to provide a complete and correct set of SM and SNM control and accounting information that could be used to

confirm the presence of SM and SNM, resolve indications of missing material or unauthorized production, or aid in the investigation and recovery of missing material.

- All SM and SNM transactions from source data to final accounting records will be readily traceable.
- The source data will be retained in its original form 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 will be retrievable and sufficiently complete and detailed to permit auditing all parts of the MC&A system and will be traceable back to original source data.
- The records of the data that are the basis of the calculated SEID will permit traceability to the sources of the variances because of 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 SM or 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 related to their use. In general, the record retention system should be able 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. Physical inventory listings are to be 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 9.7.
- 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.

17. GLOSSARY

The following terms are defined in the context of (1) their usage in this document or (2) how they should be used if contained in the material control and accounting (MC&A) plans submitted in accordance with 10 CFR 74.33, "Nuclear material control and accounting for uranium enrichment facilities authorized to produce special nuclear material of low strategic significance."

ACTIVE INVENTORY—The sum of beginning inventory (BI), additions to inventory (A), removals from inventory (R), and ending inventory (EI), after all common terms have been totally excluded. A common term is any source material (SM) or special nuclear material (SNM) material value (or item) that appears in both BI and EI, or both BI and R, or both A and R, or both A and EI, with both values derived from the same measurement (and thus, it does not contribute to the uncertainty associated with the current period inventory difference). The active inventory is used as an indicator of processing throughput or measurement activity, or both.

ADDITIONS TO INVENTORY (A)—Quantities of depleted uranium (U), SM, and SNM, by given material type code, added to a "plant" inventory and which, before such addition, were not part of the plant's total possessed depleted U, SM, or SNM quantity for the material type code in question. For an enrichment facility conducting a bimonthly dynamic inventory, additions to inventory are typically "feeds" to the cascade or enrichment equipment.

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 (e.g., a U hexafluoride ($UF_{6)}$ cylinder). Weighing error caused by buoyancy is eliminated by the use of artifact standards for scale calibrations.

ASSIGNED VALUE—A value for such entities as mass, volume, SM or SNM concentration, SM or SNM quantity, assigned to, for example, 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, nevertheless, it is the best estimate of the standard's true value.

AUDITABILITY—The availability of evidence to U.S. Nuclear Regulatory Commission (NRC) inspectors demonstrating the validity of a licensee's conclusion that unauthorized production has not taken place.

AUTHORIZED LEVELS—The maximum U enrichment level (i.e., weight percent (wt %) U-235] and the maximum quantity of U-235 (contained in enriched U) that can be possessed as specified by an issued NRC license.

BEGINNING INVENTORY—The total itemized quantity of depleted U, SM, or SNM of a given material type code possessed by a "plant" at the start of a material balance period (inventory period). The BI quantity for any given material balance period is (by definition) exactly equal to the ending inventory quantity for the immediately previous period.

BIAS (MEASUREMENT BIAS)—A constant, unidirectional component of error that affects all members of a measurement data set. Thus, 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.

CALIBRATION—The process of determining the numerical relationship between the observed output of a measurement system and the actual value of the characteristic being measured, as based on primary or reference standards.

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, for example, a measurement device or instrument (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. That is:

$$\text{combined S.E.} = [(\sigma_1)^2 + (\sigma_2)^2]^{1/2}$$

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 or reference standard.

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

DETECTION QUANTITY (DQ)—A site-specific U-235 quantity for licensees subject to 10 CFR 74.31, “Nuclear material control and accounting for special nuclear material of low strategic significance,” or 10 CFR 74.33. The DQ is normally a function of annual throughput, but for low-throughput low-enriched U (LEU) facilities, the DQ need not be less than 25 kilograms of U-235. The DQ also can be described as a goal quantity, the loss or theft of which must be detected with a 90 percent (or better) probability at the time of a physical inventory.

DETECTION THRESHOLD (DT)—An inventory difference (ID) limit that will be exceeded (with 90 percent or higher probability) by an ID resulting from the taking of a physical inventory whenever there has been an actual loss of a detection quantity. The DT is a function of both the DQ and the standard error of the inventory difference (SEID), as shown by the following equation:

$$DT = DQ - 1.3\,(SEID)$$

ENDING INVENTORY (EI)—The total itemized quantity of depleted U, SM, or 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 U-bearing material that does not qualify as natural or normal U, and that has a combined U-233 plus U-235 isotopic content of 0.725 wt % or higher, relative to the total U 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 ID for the material balance period in question, (2) the uncertainty (i.e., SEID) 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.

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

MATERIAL TYPE CODES—Number codes for identifying basic material types with respect to SM, SNM, and byproduct materials. These codes are used by the Nuclear Materials Management and Safeguards System for tracking U.S.-owned and U.S.-possessed materials worldwide. For depleted U, SM, and SNM, eight material type codes have been assigned as follows:

CODE	MATERIAL TYPE	CODE	MATERIAL TYPE
10	Depleted U	81	Normal U
20	Enriched U (*)	83	Plutonium-238(***)
50	Plutonium	88	Thorium
70	U-233 (**)	89	U in Cascades

* For U.S. Department of Energy (DOE)/NRC Form 742, material code 20 has four subcodes to denote enrichment range: E1, E2, E3, and E4. For NRC Form 327, material code 20 has two subcodes: LEU and HEU.

** U materials should be regarded as material code 70 if the U-233 isotopic abundance is greater than (1) 10.00 wt % relative to total U 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 U 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 (MD)—A measured quantity of gaseous, liquid, or solid waste that is no longer possessed by a facility, or which has been transferred (accounting-wise) to a waste-holding-account using a DOE/NRC Form 741 transaction.

MEASUREMENT CONTROL PROGRAM—A managed program for monitoring and controlling both accuracy and precision of depleted U, SM, and SNM accountability measurements.

NATURAL URANIUM—Any U-bearing material with a U isotopic distribution that has not been altered from its naturally occurring state. Natural U is nominally 99.283 wt % U-238, 0.711 wt % U-235, and 0.006 wt % U-234.

NORMAL URANIUM—Any U-bearing material having a U 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. (NOTE: All natural U having a U-235 isotopic abundance in the range of 0.700 wt % to 0.724 wt % is normal U, but not all normal U is natural U.)

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) that was measured 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 (such as mass, U concentration, U isotopic distribution) the value of which is certified (within a specified uncertainty) by, for example, a nationally or internationally recognized bureau or laboratory 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, for example, material received during a prior inventory period or correction of 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 SM or SNM or indicate unauthorized enrichment activities.

RESIDUAL HOLDUP—Any SM or SNM that remains within the processing equipment (including ventilation filters and ductwork) after system draindown or cleanout, or both. 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 SEID.

RESOLUTION OF AN INDICATOR—A definitive determination (with auditable evidence) by the licensee that an indicated possible theft or unauthorized production of U has not occurred and is not occurring.

RUNNING BOOK IN-PROCESS INVENTORY (RBIPI)—The dynamic inventory of a process system calculated by subtracting the cumulative measured outputs from the process system (CO) from the beginning inventory (BI) plus the cumulative measured inputs to the process system (CI). Mathematically, this can be expressed as:

$$RBIPI = BI + CI - CO$$

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

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 a measure (or indication) of the precision relating to a set of measurements (or set of data) applying to the same item or sample of material. Standard deviation is calculated as follows:

$$\text{standard deviation} = S = \{ [\sum_{i=1}^{n} (x_i - \overline{x})^2] / (n-1) \}^{½}$$

where
n = number of measurements performed
x_i = the value obtained for the i^{th} measurement for i = 1, 2, 3, ..., n
$\overline{x}$ = 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 the concentration of which, with respect to a nuclide or isotope, 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.

UNAUTHORIZED PRODUCTION—Defined as (1) the misuse of plant or equipment to deliberately produce U at an enrichment level greater than permitted by license or (2) the production of a quantity of enriched U greater than reported to the NRC (e.g., by undeclared feed or by unrecorded lowering of the tails assay).

VERIFICATION MEASUREMENT—Defined as either (1) a nondestructive assay (NDA) measurement of an item conducted to verify that a previous NDA 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).

18. REFERENCES

International Atomic Energy Agency (IAEA), *IAEA Safeguards Statistical Concepts and Techniques*, 5th revised edition, 1998, Vienna, Austria.
NUREG/BR-0006, "Instructions for Completing Nuclear Material Transfer Reports" (U.S. Department of Energy (DOE)/NRC Forms 741, 741A, and 740M), Revision 8, U.S. Nuclear Regulatory Commission, May 2018.

NUREG/BR-0007, "Instructions for the Preparation and Distribution of Material Status Reports" (DOE/NRC Forms 742 and 742C), Revision 7, U.S. Nuclear Regulatory Commission, May 2018.

NUREG/BR-0096, "Instructions and Guidance for Completing Physical Inventory Summary Reports" (NRC Form 327), U.S. Nuclear Regulatory Commission, October 1992.

NUREG/CR-0602, "Active Nondestructive Assay of Nuclear Materials," U.S. Nuclear Regulatory Commission, January 1981.

NUREG/CR-2078, "Handbook of Nuclear Safeguards Measurement Methods," U.S. Nuclear Regulatory Commission, September 1983.

NUREG/CR-4604, "Statistical Methods for Nuclear Material Management," U.S. Nuclear Regulatory Commission (NRC), December 1988.

NUREG/CR-5550, "Passive Nondestructive Assay of Nuclear Materials," U.S. Nuclear Regulatory Commission, March 1991.

TID-26298, "Statistical Methods in Nuclear Material Control," U.S. Atomic Energy Commission, 1973.

U.S. Code of Federal Regulations, Title 10, "Energy," Part 74, "Material Control and Accounting of Special Nuclear Material."