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

Prepared by
B. W. Moran, W. L. Belew, G. A. Hammond, L. M. Brenner

Oak Ridge K-25 Site

21st Century Industries, Inc.

Prepared for
U.S. Nuclear Regulatory Commission

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 2120 L Street, NW., Lower Level, Washington, DC 20555

2. The Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082

3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC bulletins, circulars, information notices, inspection and investigation notices; licensee event reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, international agreement reports, grant publications, and NRC booklets and brochures. Also available are regulatory guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG-series reports and technical reports prepared by other Federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions. *Federal Register* notices, Federal and State legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Administration, Distribution and Mail Services Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, for use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

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

Manuscript Completed: August 1991
Date Published: November 1991

Prepared by
B. W. Moran, W. L. Belew, Oak Ridge K-25 Site
G. A. Hammond, L. M. Brenner, 21st Century Industries, Inc.

Oak Ridge K-25 Site
Managed by Martin Marietta Energy Systems, Inc.

Oak Ridge K-25 Site
Oak Ridge, TN 37831

Subcontractor:
21st Century Industries, Inc.
P.O. Box 2636
Gaithersburg, MD 20886

Prepared for
Division of Safeguards and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN L1300
Under Contract No. DE-AC05-84OR21400

Abstract

A new section, 10 CFR 74.33, has been added to the material control and accounting (MC&A) requirements of 10 CFR Part 74. This new section pertains to U.S. Nuclear Regulatory Commission (NRC) -licensed uranium enrichment facilities that are authorized to produce and to possess more than one effective kilogram of special nuclear material (SNM) of low strategic significance.

The new section is patterned after 10 CFR 74.31, which pertains to NRC licensees (other than production or utilization facilities licensed pursuant to 10 CFR Part 50 or Part 70 and waste disposal facilities) that are authorized to possess and use more than one effective kilogram of unencapsulated SNM of low strategic significance. Because enrichment facilities have the potential capability of producing SNM of moderate strategic significance and also strategic SNM, certain performance objectives and MC&A system capabilities are required in 10 CFR 74.33 that are not contained in 10 CFR 74.31.

This document recommends to the NRC information that the licensee or applicant should provide in the fundamental nuclear material control (FNMC) plan. This document also describes methods that should be acceptable for compliance with the general performance objectives. While this document is intended to cover various uranium enrichment technologies, the primary focus at this time is gas centrifuge and gaseous diffusion.

Contents

Acronyms

DQ	Detection quantity
DT	Detection threshold
FKG	Formula kilogram
FNMC	Fundamental nuclear material control
HEU	High-enriched uranium
ICA	Item control area
ID	Inventory difference
LEU	Low-enriched uranium
MBA	Material balance area
MC&A	Material control and accounting
NDA	Nondestructive assay
NMMSS	Nuclear Materials Management and Safeguards System
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
U	Uranium
U-233	Uranium-233
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
U_3O_8	Urano-uranic oxide
UF_6	Uranium hexafluoride
wt %	Weight percent

Introduction

The U.S. Nuclear Regulatory Commission (NRC) has established nuclear material control and accounting (MC&A) requirements for uranium enrichment facilities in Section 74.33 of 10 CFR Part 74, "Material Control and Accounting for Special Nuclear Material." These requirements (1) apply to uranium enrichment facilities authorized to produce and to possess low-enriched uranium (LEU) of less than 10 wt % U-235 and (2) necessitate the development of objectives, criteria, and guidance for evaluating the acceptability of MC&A plans that applicants are required to submit. Uranium enrichment facilities, because of the nature of the operations and the types of materials that will be on-site, pose two unique problems that are addressed in the NRC's regulations. First, because the equipment used to enrich uranium to authorized enrichment levels also can be used to produce higher enrichment levels, the NRC cannot rule out the possibility that this may be done through deliberate misuse of the equipment. Second, the possibility exists that undeclared source material (SM) or LEU feed could be introduced into the process equipment for unauthorized production of enriched uranium. MC&A performance objectives are established in 10 CFR 74.33 to protect against, detect, and respond to such possibilities. In general, the objectives are consistent with MC&A requirements for other NRC-licensed facilities that are authorized to possess and use more than one effective kilogram of special nuclear material (SNM) of low strategic significance.

An applicant's fundamental nuclear material control (FNMC) plan must demonstrate how the basic capabilities specified in 10 CFR 74.33(c) will be achieved and maintained and how such capabilities will be used to achieve the performance objectives listed in 10 CFR 74.33(a). After accepting an FNMC plan and imposing it as a condition of license, the NRC will judge the adequacy of a licensee's MC&A performance by inspecting for compliance with commitments and practices described in the plan.

Because 10 CFR 74.33 is a performance-oriented regulation, the objectives are defined rather than the means for achieving them. Thus, applicants and licensees have many alternatives with regard to how their MC&A system and program are designed, managed, and operated. Hence, this document cannot begin to cover all possible methodologies that a licensee might use to achieve the desired objectives. Instead, this document provides examples of acceptable MC&A approaches commonly or typically used by uranium enrichment facilities using gas centrifuge or gaseous diffusion technology.

This document is intended for use by applicants, licensees, and NRC safeguards licensing reviewers. For the most part, recommended criteria are not to be regarded as rigid, fixed standards. That is, the lower effectiveness of one procedure relative to a particular aspect can be tolerated if there is a compensating feature, or combination of features, that provides an overall effective safeguards system. Although not likely, a licensee could fail to meet most of the criteria recommended in this document and still achieve the regulatory objectives. In the final analysis, an NRC reviewer must make a judgement as to whether the applicant or licensee can achieve with high probability, without going beyond its FNMC plan commitments, the objectives stated in 10 CFR 74.33(a). The recommendations provided herein pertain to both applicant submitted FNMC plans and any revisions made to existing approved plans.

The introduction of this document describes the basis of the nine general performance objectives of 10 CFR 74.33 and the MC&A system features and capabilities needed to meet the objectives. The chapters that follow incorporate and expand on (1) the general performance objectives and (2) the system features and capabilities. The chapters are arranged in a different sequence from the rule making and provide applicants or licensees an outline for the FNMC plan.

The body of an FNMC plan, corresponding to Chapters 1 through 12, shall be a condition of license, and compliance with the FNMC plan commitments and related procedures will be inspectable. Explanations and discussions appearing in the body of the plan should be detailed and precise, as opposed to general and vague, so that all parties concerned (i.e., NRC licensing reviewers, NRC inspectors, and licensee personnel responsible for plan execution) have a clear and nonconflicting understanding as to the *what*, *how*, and *when* aspects of any given plan commitment.

The annex (or appendix) of an FNMC plan should provide supplementary and general information about the facility and the MC&A system [e.g., copies of blank record forms, site map, process diagrams, an example standard error of the inventory difference (SEID) calculation, etc.]. The annex will not be incorporated as a condition of license and will not be the basis for inspection. Thus, procedures 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.

Performance Objectives and System Features and Capabilities

Performance Objectives

The general performance objectives that should be addressed by the FNMC plan are set forth in 10 CFR 74.33. The basis on which each of the six general performance objectives were formed is described in the following paragraphs of this section.

1. **Maintain Accurate, Current, and Reliable Information of and Periodically Confirm the Quantities and Location of Source Material and Special Nuclear Material in the Licensees Possession**

   The purpose of this objective is to confirm the absence of (or to detect the occurrence of) any significant loss or theft of SM or SNM. To maintain current information of the SM and SNM in their possession, licensees should have in place a program that provides timely information about how much material is in their possession and where that material resides. Accurate information means that item quantities for both the element uranium and the isotope U-235 are based on measured values or on reliable factors. Reliable information means that the quantity of material in an item and the location of all items is known (with the possible exception of items that have been created, transferred, or consumed within the past 8 hours) and that the location designations are 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 (with the possible exception of items that have been created, transferred, or consumed within the past 8 hours).

   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 introduced to the process and (2) to ensure that all SM and SNM quantities of record associated with receipts, shipments, discards, and ending inventory are based on measurements. Recommendations on the item control program is provided in Chapter 6 of this document, and recommendations on measurements and measurement control programs is provided in Chapters 2 and 3, respectively. Monitoring the material in process may involve the use of process or material control data. A detailed and accurate recordkeeping system for the generated data that provides knowledge of the material's location on a timely basis should be maintained to support this function.

   Once a year, at intervals not to exceed 370 days, the licensee should conduct a total plant inventory 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 4 of this document.

   The licensee should verify the presence of all SNM and SM currently possessed by the enrichment facility, as stated in its accounting records. This verification should be accomplished by (1) a dynamic (i.e., nonshutdown) physical inventory of the uranium and U-235 contained within the enrichment processing equipment and (2) a static physical inventory of all other uranium material that is not within the enrichment process system. Recommendations pertaining to physical inventories are detailed in Chapter 5 of this document. In summary, a total plant inventory involves:

   (1) verifying the presence, on a 100 percent basis, of all uniquely identified SNM and SM items listed in the accounting records

   (2) 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)

   (3) measuring any items not previously measured

   (4) verifying the integrity of all encapsulated items and items affixed with tamper-indicating seals

   (5) 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 should be performed at intervals not to exceed 65 days. 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., 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 provide an indication as to 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 5 also provides recommendations on the conduct of these physical inventories.

2. **Protect Against and Detect Production of Uranium Enriched to 10 wt % or More in** U-235 and

3. **Protect Against and Detect Unauthorized Production of Uranium of Low Strategic Significance**

To achieve these two objectives, both of which are characterized as plant misuse (or unauthorized production of enriched uranium), a licensee's program should include monitoring process operations and monitoring personnel and process-related activities to provide detection of unauthorized production of enriched uranium. 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 enrichments. During cascade startup operations, transient isotopic assays of between 10 and 20 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. Independent monitoring should be performed 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 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 of time. The program can use nondestructive assay (NDA) techniques with fixed or portable detectors or the taking of samples to be analyzed for U-235 abundance.

The theoretical possibility of misusing the equipment or plant for unauthorized production differs for each enrichment technology. Following are some example 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 for 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 uranium.

Laser Isotope Separation — 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 uranium 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 program should be capable of detecting the introduction of any feed material not declared or entered into the facility MC&A system. Additional recommendations pertaining to the monitoring program are provided in Chapter 9.

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

4. Resolve Indications of Missing Uranium

The licensee or applicant should have a formalized program to resolve any indication that SM or SNM is missing. Resolution of such indicators means that the licensee has made a determination that a theft or loss of SM or SNM has not occurred. As stated in 10 CFR 74.33(c)(6), only indications that suggest a possible loss from items greater than 500 grams of U-235 need to be investigated; a possible loss detected during a material balance closure needs to be investigated as stated in 10 CFR 74.33(c)(4). Multiple loss indications from items within a material balance period must be resolved even though the loss from each event is less than 500 grams of U-235. This resolution need not occur until the total potential loss exceeds 500 grams of U-235.

Resolution of an indicator depends on the type of indicator. Anomalies at uranium enrichment plants can indicate a number of scenarios from simple theft to isotopic substitution concealing diversion of product material. The resolution process in some cases should begin with a thorough review of the MC&A records to locate blatant 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 NRC pursuant to 10 CFR 74.11.

5. Resolve Indications of Production of Uranium Enriched to 10 wt % or More in U-235 and

6. Resolve Indications of Unauthorized Production of Uranium of Low Strategic Significance

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 (1) production of excess quantities of uranium enriched to less than 10 wt % U-235 and (2) enrichment of uranium to 10 wt % or more in U-235 have not occurred. The resolution process should include the investigation of all information contributing to the indication of unauthorized production. The location of the indicators should be determined and the process area or storage area isolated to verify the indication. Instruments and measurement systems used for monitoring should be examined to determine if they are functioning properly; remeasurements should be conducted as necessary. A thorough examination of the processing equipment should be performed to ensure that unauthorized modifications have not been made. The presence of uranium 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. Additional information and recommendations pertaining to the identification, investigation, and resolution of indications of unauthorized production are provided in Chapter 10 of this document.

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 pursuant to 10 CFR 74.11.

7. **Provide Information to Aid in the Investigation of Missing Uranium** and

8. **Provide Information to Aid in the Investigation of the Production of Uranium Enriched to 10 Percent or More in the Isotope U-235** and

9. **Provide Information to Aid in the Investigation of Unauthorized Production of Uranium of Low Strategic Significance**

   If the NRC and/or other government agencies deem it necessary to conduct an investigation relating to actual (or highly suspected) events pertaining to missing uranium or unauthorized enrichment, the licensee is to provide, without specifically being asked, any information deemed 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 (without being asked to) all information that it recognizes as being relevant, as opposed to providing only information that the investigators are knowledgeable enough to request. Additional information and recommendations pertaining to providing information to aid in investigations are provided in Chapter 11 of this document.

System Features and Capabilities

To meet the nine general objectives, the MC&A system depends on features and capabilities as follows and as described in Chapters 1 through 12 of this document.

(1) A management structure that ensures: (a) clear overall responsibility for MC&A functions, (b) independence of MC&A management from production responsibilities, (c) separation of key MC&A responsibilities from each other, (d) use of approved written MC&A procedures, and (e) the periodic review of these procedures.

(2) A measurement program that ensures that all quantities of SM and SNM in the accounting records are based on measured values.

(3) A measurement control program that ensures that (a) measurement biases are estimated, minimized through implementation of measurement control programs, and eliminated (if statistically significant) from inventory difference values of record; (b) all MC&A measurement systems are controlled so that twice the standard error of the inventory difference, based on all measurement contributions, is less than the greater of 5,000 grams of U-235 or 0.25 percent of the active inventory for each total plant material balance; and (c) any measurements performed under contract are controlled so that the licensee can satisfy the requirements of 3(a) and 3(b).

(4) A physical inventory program that provides for (a) performing (unless otherwise required to satisfy 10 CFR Part 75) a dynamic (i.e., nonshutdown) physical inventory of in-process uranium and U-235 at least every 65 days and performing a static physical inventory of all other uranium and U-235 contained in enriched, normal, and depleted uranium located outside of the enrichment processing equipment at least every 370 calendar days (with static physical inventories being conducted in conjunction with a dynamic physical inventory of in-process uranium and U-235 so as to provide a total plant material balance at least every 370 calendar days); and (b) reconciling and adjusting the book inventory to the results of the static physical inventory and resolving, or reporting an inability to resolve, any inventory difference that is rejected by a statistical test (which has a 90 percent power of detecting a discrepancy of a quantity of U-235 established by NRC on a site-specific basis) within 60 days after the start of each static physical inventory.

(5) A detection program, independent of production, that provides high assurance of detecting (a) production of uranium enriched to 10 wt % or more in U-235 to the extent that SNM of moderate strategic significance could be produced within 370 calendar days, (b) production of uranium enriched to 20 wt % or more in U-235, and (c) unauthorized production of uranium of low strategic significance.

(6) An item control program that assures that (a) current information is maintained for items with respect to identity, uranium and U-235 content, and stored location; and (b) items are stored and

handled, or subsequently measured, in a manner so that the amount of U-235 involved in any unauthorized removal of items, or uranium from items, greater than 500 grams of U-235 will be detected. Exempted from 6(a) and 6(b) are licensee-identified items each containing less than 500 grams of U-235 up to a cumulative total of 50 kilograms of U-235 and items existing for less than 14 calendar days.

(7) A resolution program that assures that any shipper-receiver differences (SRDs) are resolved that are statistically significant and exceed 500 grams of U-235 on (a) an individual batch basis and (b) a total shipment basis for all SM and SNM.

(8) An assessment program that (a) independently assesses the effectiveness of the MC&A system at least every 24 months, (b) documents the results of the above assessment, (c) documents management's findings on whether the MC&A system is currently effective, and (d) documents any actions taken on recommendations from prior assessments.

The MC&A recordkeeping requirements of 10 CFR 74.33 are as follows:

(1) Each licensee shall establish records that will demonstrate that the performance objectives and the system features and capabilities have been met and will maintain these records in an auditable form, available for inspection, for at least 3 years, unless a longer retention time is required by 10 CFR Part 75.

(2) Records that must be maintained pursuant to 10 CFR Part 74 may be the original or a reproduced copy or a microform, if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by NRC regulations. The record also may be stored in electronic media with the capability for producing on demand legible, accurate, and complete records during the required retention period. Records such as letters, drawings, and specifications must include all pertinent information such as stamps, initials, and signatures.

(3) The licensee shall maintain adequate safeguards against tampering with and loss of records.

The following chapters of this document incorporate and expand on the performance objectives and on the system features and capabilities of 10 CFR 74.33. The chapters are arranged in a format and sequence to provide applicants and licensees an outline for the FNMC plan.

1 Organization

1.1 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 pertaining to the control and accounting of all SM and SNM possessed by the licensee.

1.2 Plant or Site Organization

A description of the site's management structure emphasizing MC&A should be provided. By means of comprehensive organization charts, the site management structure should be shown. As a minimum, the charts should indicate where the responsibility lies for the following functions:

(1) overall MC&A program or system

(2) SM and SNM custodianship

(3) receiving and shipping of SM and SNM

(4) analytical laboratories

(5) bulk and NDA measurements

(6) sampling operations

(7) measurement control program

(8) physical inventories

(9) monitoring program to deter and to detect unauthorized enrichment activities

(10) on-site 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.

1.3 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.

1.3.1 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 FNMC plan should explain how coordination is achieved and maintained between the MC&A organization and other plant organizational groups that perform MC&A-related activities. 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, pertaining to MC&A-related activities. In addition to the MC&A manager function, the functions to be addressed should include, as a minimum, the following:

(1) nuclear material accounting

(2) measurement control program

(3) item control program

(4) statistics

(5) monitoring program to detect unauthorized enrichment activities

The discussion pertaining to statistics should identify those individuals responsible for such activities as calculation of the SEID, determination of active inventory, evaluation of SRDs, and determination of control limits.

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

(1) performance of accounting or record control functions by individuals who also generate source data

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

1.3.2 MC&A Procedures

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 74.33(a) and the features and capabilities of 10 CFR 74.33(c). All MC&A procedures should be identified in the body of the FNMC plan. The FNMC plan also should contain a definitive statement that the procedures will be followed. This set of MC&A procedures should, as a minimum, adequately address the following topics, regardless of which facility organizational group is responsible for the particular topic:

(1) accountability record system

(2) sampling and measurements

(3) measurement control program

(4) item control program

(5) static and dynamic physical inventories

(6) investigation and resolution of loss indicators

(7) investigation and resolution of indicators of unauthorized enrichment to 10 wt % or more in U-235

(8) monitoring program to detect unauthorized production of uranium to enrichments less than 10 wt % U-235

(9) determination of SEID, active inventory, and inventory difference

(10) providing information to aid in investigations

(11) MC&A recordkeeping system

(12) independent assessment of the effectiveness of the MC&A program

1.4 Training and Qualification Requirements

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

1.5 MC&A System Description

The length of this section and its level of detail will be dependent 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 nine general performance objectives of 10 CFR 74.33(a) and the features and 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:

(1) overall MC&A program management (*Note: This individual should have no major nonMC&A-related responsibilities.*)

(2) measurements [*Note: Responsibility may be divided on the basis of type of measurements (e.g., analytical laboratory measurements, NDA measurements, bulk measurements, and sampling).*]

(3) measurement control and statistics

(4) accountability records

(5) item control

(6) physical inventories

(7) custodial responsibilities (e.g., SM and SNM storage and movement controls)

(8) monitoring program for detecting unauthorized enrichment activities

(9) investigation and resolution of indicators that suggest possible loss or possible unauthorized enrichment activities

(10) receiving and shipping of SM and SNM

(11) analytical laboratories

(12) MC&A recordkeeping system and controls

The information in this chapter 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 system.

2 Measurements

2.1 Measurement Points

The FNMC 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, material balance area (MBA), or item control area (ICA) and in the facility as a whole, and (2) contribute to the desired capability to localize losses and to generate and to assess alarms. Typically, measurement points and/or 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 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 MBAs and ICAs are present: (1) processing, (2) storage, and (3) receiving and shipping. 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 these MBAs. The storage and the receiving and shipping areas are typically ICAs. 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.

2.2 Measurement Systems

The FNMC plan should describe in detail each measurement system used for nuclear material accounting purposes. The principal elements and operations involved in the measurement systems for MC&A at uranium enrichment plants encompass mass (or weight) or volume determination; sampling; chemical, nondestructive, and isotopic analyses; and process monitoring operations (for pressure, volume, temperature, and impurities) unique to the enrichment process operations. Each measurement system also should be defined or identified by its unique set of the following parameters: (1) measurement device or equipment used, (2) standards used for calibration, and (3) standards used for control. Additionally, for analytical laboratory measurements, the following also should be identified: (1) sampling technique and equipment used, (2) sample aliquoting technique, and (3) sample pretreatment methodology. 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 are described in Chapter 3.

The FNMC plan should provide descriptions for 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.

2.2.1 Bulk Measurement Systems

For each mass (or weight) 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, range to be used, and sensitivity of the device. The description should include the capacity and the sensitivity of the scale (e.g., capacity not to exceed X kilograms, and sensitivity to be at least as good as Y grams).

For each volume measurement system, the FNMC plan should identify the vessel (e.g., tank, column, etc.), capacity of the vessel to which the measurement applies, the material being measured, the volume measuring device and instrumentation, the sensitivity of each device and system, and the range of operation and/or calibration.

2.2.2 Analytical Measurement Systems

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

(1) type of material or chemical compound (e.g., UF_6, uranium alloy, U_3O_8, uranyl nitrate solution)

(2) sampling technique

(3) sample handling (i.e., pre-analysis sample storage and treatment)

(4) analytical method used

(5) characteristics measured (e.g., grams of uranium per gram sample, U-235 isotopic composition)

(6) measurement interferences

(7) expected measurement uncertainty

2.2.3 NDA Measurement Systems

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

(1) the NDA equipment package (i.e., detector and electronics)

(2) the type of container measured

(3) SM or SNM material type

(4) attribute measured

(5) measurement configuration (including source to detector distance)

(6) calculational method

(7) expected measurement uncertainties

2.2.4 Other Measurement Systems

If applicable, the FNMC plan also should identify any other measurement systems used for accounting purposes that do not fall within the three categories covered by subsections 2.2.1, 2.2.2, and 2.2.3. For example, the measurement systems used for determining the enrichment process system inventory should be identified.

2.3 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.

2.4 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.

A clear statement should be made that a measurement procedure can not be used for accountability purposes without documented approval. Each procedure should be approved by the overall MC&A manager and by the manager of the organizational unit responsible for performing the measurement. Measurement procedures also should be approved by the measurement control program manager.

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

(1) additions to inventory (e.g., receipts)

(2) removals from inventory (e.g., shipments and measured discards)

(3) 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 shipper's value and the umpire value used to resolve the difference. However, when booking shipper's values, the shipper's measurement uncertainty should be used when determining SEID.

3 Measurement Control Program

3.1 Organization and Management

The organization and management of the measurement control program should be described in sufficient detail to show how the measurement quality assurance function is assigned and how independence from the analytical laboratory and other units performing either sample taking or measurements is maintained. The measurement control program manager should be at a 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).

3.1.1 Functional Relationships

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

3.1.2 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 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:

(1) calibration frequencies and methods

(2) standards used for calibration (i.e., description and storage controls)

(3) standards used for control (i.e., method of obtaining or preparation, and traceability)

(4) control standard measurements

(5) replicate sampling and replicate measurements

(6) verification of process control instrumentation through comparison with other process instruments

(7) control limits and control responses

(8) generation and collection of control data

(9) recordkeeping controls and requirements

3.1.3 Contractor Program Audits and Reviews

If measurement services are provided by an outside contractor or off-site laboratory, the review program used to monitor the off-site measurements should be described. Such reviews are to ensure that the contractor or off-site 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 FNMC plan. An initial review of the contractor's measurement control program should be conducted before licensee use of measurements performed by the contractor or off-site laboratory.

All contractor or off-site laboratory assessment findings and recommendations should be documented and submitted to both the measurement control program manager and the overall MC&A manager within 30 days of completion of the review. The two managers should arrive at an agreement on corrective actions that should be taken, based on their evaluation of the report, and should transmit these findings to the contractor or off-site laboratory in writing. The licensee should not use measurements performed by such contractors or off-site laboratories until they have verified that the corrective actions have been instituted.

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

3.2 Calibrations

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

(1) calibration frequency for each measurement device or system

(2) identification of the reference standards used for calibration of each measurement device or system

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

(4) 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 practical, the standard used during the calibration process should be subjected to all the steps involved in the measurement process that the process unknowns are subjected to (e.g., sample pretreatment), but this need not always be the case. 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 uranium 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_3O_8 or certified uranium metal.

In the case of nonconsumable standards used to calibrate measurement systems (e.g., weight standards), the frequency of recertification of assigned values should be specified. The recertification frequency should 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. Biannual recertifications of such standards are usually acceptable.

The FNMC 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 FNMC plan also should identify those measurement systems that are point-calibrated. A point-calibrated measurement system is one in which the following are true:

(1) 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.

(2) 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).

(3) 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).

(4) The measurement response for each unknown must fall within plus or minus 10 wt % 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 that four times the standard deviation associated with the standard's response.

3.3 Control Standard Program

For those measurement systems that are not point-calibrated, a defined program for the periodic measurement of control standards should be established and followed. Control standard measurements serve the dual purpose of (1) monitoring the stability of a previously determined calibration factor, and (2) estimating the 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, needs to 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 eight weeks during a given material balance period, more than two control standard measurements per week of system use may be necessary to provide:

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

(2) A minimum of 16 control measurements for those systems used to measure a total of 100 or more kilograms of U-235

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 and/or described. 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 also can be operator or analyst induced. Therefore, the scheduling of control standard measurements should be based on the following considerations:

(1) Does the variation between analysts or operators need to be considered and hence monitored?

(2) Can environmental variables contribute to measurement bias?

(3) Is bias likely to vary with respect to the time of day?

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

(5) 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)?

(6) 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?

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

3.4 Replicate Program

Duplicate measurements performed on single samples (or single items) and/or 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 either from (1) replicate measurements performed on the process items, or (2) the replicate data generated from the measurement of control standards.

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 less than 15 batches)

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

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

For each measurement system involving sampling and analysis, the FNMC plan should indicate (1) how many samples are taken and measured for each accountability batch measurement, and (2) how many analyses are performed on each accountability sample. If two or more samples are used and 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 is used to estimate the random error variance using a statistical technique known as the one-way analysis of variance. (The statistical methods described in *Statistical Methods for Nuclear Material Management*, NUREG/CR-4604, are recommended by NRC for satisfying the statistical requirements of 10 CFR 74.33; see also Chapter 4 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.

3.5 Control Limits

Both warning and out-of-control limits should be established and used for both control standard and replicate measurements for those measurement systems used for nuclear material accountability. 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 limit).

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

3.5.1 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 for generation of control charts. All control charts should be reviewed at least once every two 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.

3.5.2 Response Actions

Either the analyst or the operator performing a control measurement or the supervisor should have the responsibility 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 for, 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 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

For those measurement systems that make a significant contribution to the SEID, the response to an out-of-control condition also should 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.

4 Statistics

4.1 Determination of Measurement Uncertainties

To achieve the objectives and capabilities of 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. 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, *Statistical Methods for Nuclear Material Management*," NUREG/CR-4604, are recommended by NRC for satisfying the statistical requirements of 10 CFR 74.33.

The FNMC plan should

(1) contain a detailed discussion of the procedures and methodologies for estimating measurement variance components

(2) discuss how biases are determined and how bias corrections are applied, including:

- (a) how often biases are estimated
- (b) how the bias' effect on the measured quantity of material in the item is determined
- (c) when and how bias corrections to items are made
- (d) how their effect on inventory difference is determined
- (e) when and how bias corrections are applied to the inventory difference (ID)

(3) describe the procedure and means for determining active inventory

(4) provide all relevant information regarding the determination of the SEID

(5) 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 that 25 kilograms of U-235, in which case the DQ need not be less than 25 kilograms of U-235

(6) specify the methodology for determining ID threshold values to be used to provide a 90 percent power of detecting a loss of a DQ, as required by 10 CFR 74.33 (c)(4). (See Chapter 5 for additional information on inventory difference limits and response actions.)

There should be a definitive statement in the FNMC plan for independent verification of the correctness of the SEID calculation for each total plant material balance. If the SEID value is calculated using a computer, the verification may involve two or more persons to check for correctness of the input data and to check the correctness of a sample calculation used to verify the computer program.

4.2 Determination of SEID

As defined in 10 CFR 74.4, the "standard error of 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 can be expressed as follows:

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

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),

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

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

Statistics

The FNMC plan must provide all relevant information regarding the determination of 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 by a computer, the verification by two or more persons involves a checking for correctness of the input data used by the computer to calculate SEID.

5 Physical Inventories

5.1 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 FNMC 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 uranium 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

The inventory difference and related information associated with each dynamic physical inventory are to be reported to the NRC, pursuant to 74.17(a), on an NRC Form 327 as the results of a physical inventory associated with material code 89 (uranium 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 uranium, respectively). In addition to these submittals, the results of the plant-wide material balance, for total uranium 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.

5.2 Organization, Procedures, and Schedules

The FNMC 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 FNMC plan also should indicate how the preparation and modification of inventory procedures are to be controlled.

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

5.3 Typical Inventory Composition

The typical expected in-process inventory within the enrichment equipment for both uranium 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 uranium 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 also should be presented. The total inventory of UF_6 cylinders should be accounted for by material type (i.e., tails, feed, and product). If different size cylinders or other containers 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 — 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 materials flows through the process and to perform physical inventories so that periodic material balances can be completed for the MBA. Because these measurements have associated uncertainties, a processing MBA will normally have a nonzero inventory difference for each inventory. Of the total plant MBAs and ICAs, a relatively small number might be processing MBAs. Examples are the isotope separation operations (e.g., enrichment cascade facilities); decontamination and recovery operations; analytical laboratory; and material rebatching, blending, and sampling operations. Physical inventories for the enrichment process system and decontamination and recovery operations are the most complex and involve the most coordination and careful timing.

Storage — 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 — 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.

5.4 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) should be identified. The FNMC plan should contain sufficient information to show how the total in-process inventory for both uranium and U-235 is obtained. The means for measuring or estimating residual process material (i.e., holdup) should be addressed in detail. The change or variation in such deposited holdup from one dynamic inventory to the next also should be discussed.

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 six hours before inventory time, and (3) establish a complete feed and withdrawal system switch over to pre-inventoried 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.

5.5 Conducting Static Physical Inventories

A description of the procedures and methodologies associated with performing static physical inventories should be provided in sufficient detail to demonstrate that valid inventories will be conducted. Such description should include a general outline of the following:

(1) organization and separation of functions

(2) assignment of inventory teams and their training in the use of uniform practices

(3) obtaining, verifying, and recording of source data

(4) control of inventory forms

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

(6) 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 uranium 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 of process systems and piping, which then could be measured using NDA techniques to establish levels of residual holdup.

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, also should be described. In addition, the FNMC plan also should provide a description of 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 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 FNMC plan should describe the sampling plan. Such description should include:

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

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

(3) the quality of the measurement methods used to verify original measurement values

(4) the procedure for reconciling discrepancies between original and remeasurement values, and for scheduling additional tests and remeasurements

(5) 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 detection quantity is given by the following equation:

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

where

n = number of items to be remeasured
N = total number of items in a stratum
x = maximum U-235 content per item (kilograms)
g = DQ = detection quantity (kilograms U-235)

The FNMC plan also should 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 FNMC plan. For example, if the U-235 contained in liquid waste batches is derived by applying an average enrichment factor to the measured uranium element content, the rationale for such practice (as opposed to measuring each batch for both uranium and U-235 content) should be discussed, and the method for establishing the average enrichment factor should be described.

If the content of items is established through prior measurements and those items are tamper-indicating 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 uranium concentration (or weight fraction) or in the uranium isotopic distribution because of such factors as oxidation, change in moisture content, commingling with materials of different enrichments, or different compositions.

5.6 Inventory Difference Limits and Response Actions

Each licensee should have a well-defined system for evaluating both dynamic and total plant IDs and taking actions 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 9).

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 plant-wide reinventory and investigation. **The NRC considers a positive ID large enough to be a major ID problem as a very serious condition.**

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

6 Item Control

6.1 Organization

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

6.2 General Description

The applicant or licensee should state that the overall MC&A system will maintain a record of all SM and SNM items, regardless of quantity or duration of existence. In addition, the item control program should provide current knowledge of the location, identity, and quantity of all SNM and SM contained in all items that are not exempt from item control. Items that can be exempt from item control program coverage are:

(1) items having an existence time of less than 14 calendar days

(2) any licensee-identified items listed by material type containing less than 500 grams of U-235 each but not to exceed a plant total of 50 kilograms of U-235

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

(1) a unique alpha-numeric identification on a tamper-indicating seal applied to a container of SM or SNM

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

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

6.3 Item Identity Controls

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

(1) describe the type of seal used

(2) describe how the seals are obtained and what measures are implemented to ensure that duplicate (counterfeit) seals are not manufactured

(3) describe how the seals are stored, controlled, issued, and accounted for

(4) describe how seal usage and disposal records are maintained and controlled

Similar information should be provided for other methods of unique item identity (e.g., labels).

6.4 Storage Controls

Item storage areas and controls should be fully described in the FNMC plan. In particular, controls that are used as the basis for ensuring the values of prior measurements, as opposed to remeasuring the item at inventory time, should be discussed in detail and the rationale for accepting prior measurements explained. Any controls used to ensure the validity of prior measurements should be equivalent to the protection provided by tamper-indicating seals.

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

6.5 Item Monitoring Methodology and Procedures

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

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

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

(3) can detect, with high probability, any real loss of items, or uranium from items amounting to 500 grams or more of U-235

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

(1) for each item inventory stratum, compare the actual storage status to the recorded status of a sufficient sample of randomly selected items from the item control program records

(2) 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

(3) check the accuracy of a sufficient sample of randomly selected production records of created and consumed items

The actual frequency of the above activities, and the size of the random sample, should be a function of the expected discrepancy rate based on prior observations. The FNMC plan should contain definitive commitments for resolving discrepancies.

6.6 Description of Typical Item Strata

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

(1) type of item (i.e., stratum)

(2) expected range of the number of items within each stratum

(3) the average uranium and U-235 content of the items within each stratum

(4) the expected rate of item generation and consumption for each stratum

6.7 Investigation and Resolution of Item Discrepancies

The applicant or licensee 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 NDA or by weighing, sampling, and analysis). Recommendations on resolution of indicators (Chapter 10 of this document) should be used to resolve item discrepancies.

7 Shipper-Receiver Comparisons

7.1 Receiving Procedures

The first action to be taken on receipt of SM and SNM should be the verification of the number of items, the item identities, and the integrity of the tamper-indicating seals. The applicant or licensee should specify what other checks and measurements are conducted and when they are conducted after receipt. The FNMC plan should state, for each material type, the maximum elapsed time (following actual receipt) for determining whether or not a significant SRD exists.

For any SNM received, and also for any received SM of foreign origin, the licensee must provide all appropriate information on the DOE/NRC Form 741 that accompanies the shipment. (NOTE: See NUREG/BR-0006 for instructions and requirements for completing DOE/NRC Form 741.)

7.2 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 uranium factor.

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

7.3 Evaluation of Shipper-Receiver Differences

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

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

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:

$$\text{combined standard error} = \left[2\,(\sigma_R)^2\right]^{1/2} = 1.414\,\sigma_R$$

The difference between the shipper's value and the receiver's value (i.e., the SRD), in terms of either (1) an individual container (for container batches) or a single batch or lot (when 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.

7.4 Resolution of Significant Shipper-Receiver Differences

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

8 Assessment and Review of the Material Control and Accounting Program

8.1 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 FNMC plan should describe the assessment and review program in terms of:

(1) maximum interval between assessments

(2) selection procedures for the assessment team

(3) number of team members to be selected

(4) qualification and expertise of team members

(5) independence of individual team members from the MC&A responsibilities and activities they will be reviewing and assessing

(6) 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 system, 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. "Interval" means the elapsed time between either the start of or 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 system 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 system that are the responsibility of another team member if the other team member is assessing the given individual's area. The leader of the assessment team should have no responsibilities for managing any of the MC&A elements being assessed.

The minimum number of individuals on any given assessment 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 system they review. The team should have authority to investigate all aspects of the MC&A system 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.

8.2 Report of Findings and Recommendations

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

(1) organizational effectiveness to manage and execute MC&A activities

(2) management responsiveness to indications of losses of uranium and possible unauthorized enrichment activities

(3) staff training and competency to carry out MC&A functions

(4) reliability and accuracy of accountability measurements made on SM and SNM

(5) effectiveness of the measurement control program in monitoring measurement systems and its sufficiency to meet the requirements for controlling and estimating both bias and SEID

(6) soundness of the material accounting records

(7) effectiveness of the item control program to track and to provide current knowledge of items

(8) capability to promptly locate items and effectiveness in doing so

(9) timeliness and effectiveness of SRD evaluations and resolution of excessive SRDs

(10) soundness and effectiveness of the inventory-taking procedures

(11) capability to confirm the presence of SM and SNM

(12) capability to detect and resolve indications of unauthorized enrichment activities, and the effectiveness of doing so

(13) capability to detect and resolve indications of missing uranium

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.

8.3 Management Review and Response to Report Findings and Recommendations

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

The FNMC plan should address resolution and follow-up 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.

9 Program for Precluding and Detecting Unauthorized Production of Enriched Uranium

9.1 Organization

The individual responsible for executing the program for detecting unauthorized production of enriched uranium should be identified. This individual need not be part of the MC&A organization, but should be independent of the production organization. Other personnel who are assigned responsibilities in this program also should 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 FNMC plan. A definitive statement should be made that the program director will have the necessary authority to carry out all aspects of the program.

9.2 General Description of Program

Alternative approaches are available to detect unauthorized production of enriched uranium. 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 uranium 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:

(1) For any unauthorized production (from undeclared feed) of LEU 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.

(2) For any unauthorized production of LEU 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.

(3) For any unauthorized production of high-enriched uranium (HEU, i.e., ≥20% U-235), detection must occur before the quantity of U-235 contained in such HEU amounts to 1 kilogram.

The FNMC plan should address the following aspects of the program that are aimed at protecting against and detecting unauthorized production of uranium of low strategic significance:

(1) the type of surveillance, and its frequency, to be applied to the processing areas

(2) 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

(3) the type of surveillance, and its frequency, to be applied to potential feed and withdrawal areas

(4) process monitoring activities (e.g., radiation monitoring and flow metering), other than process sampling, that could contribute to the detection of unauthorized production

(5) use of tamper-indicating seals on process valves and flanges

(6) personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms

(7) physical security controls such as locked and alarmed doors, closed-circuit television monitors, etc., that would detect unauthorized access to processing equipment or product material

(8) production control activities that could contribute to the detection of unauthorized production

(9) 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

(10) 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 uranium enriched to 10 wt % or more U-235, the following types of measures should be considered:

(1) process design features that preclude production of higher enrichments from being conducted simultaneously with normal (i.e., authorized) production

(2) personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms

(3) physical security controls such as locked and alarmed doors, closed-circuit television monitors, etc., that would detect unauthorized access to processing equipment or product material

(4) process control systems that could detect unauthorized use of production equipment

(5) production control systems that could detect unauthorized production of $\geq$ 10 wt % U-235

(6) 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 uranium

(7) 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 uranium enriched to or greater than 10 wt % U-235, the FNMC plan should address the following, in addition to the previously stated aspects for detecting unauthorized production:

(1) location of the sampling ports, and frequency of sampling, to be used for monitoring product streams

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

(3) 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

9.3 Data, Information, and Activities to be Monitored

The specific data, information, and activities to be monitored should be identified. The frequency of each specified monitoring activity and frequency of data evaluation should be addressed.

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

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

(2) weighing, sampling, and isotopic assay of material withdrawn at the product and tails withdrawal stations

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

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

(5) determination of the SWU balance

For gaseous diffusion and gas centrifuge facilities, the licensee or applicant 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 NDA techniques to verify isotopic ratios and contents of containers. The purpose is to ensure that the facility has not been, and is not being, misused.

The overall design of the program should include analyses on all processing and product streams to determine where uranium isotopic measurements should be made and at what frequency they should be performed to preclude clandestine enrichment activities. That is, for each credible scenario for clandestine enrichment, a monitoring system 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 uranium 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:

(1) the minimum time required to produce HEU containing 1 kilogram of U-235

(2) process design features that would preclude unauthorized enrichment from being conducted simultaneously with normal, authorized enrichment

(3) personnel access controls that limit the number of individuals who could gain access to the enrichment processing equipment or its control mechanisms

(4) physical security controls such as locked and alarmed doors, closed-circuit television monitors, etc., that would detect unauthorized access to enrichment equipment, feed or product material, or the enrichment production area

(5) process control systems that would detect unauthorized use of enrichment equipment

The FNMC plan should address such aspects as:

(1) type and frequency of uranium isotopic measurements

(2) type and frequency of NDA monitoring measurements

(3) required accuracy of the isotopic measurements

(4) administrative controls to be applied to all monitoring measurements

The means for independently verifying the authorized process enrichment parameters given in this section should be shown. The specific data, which will be collected and analyzed, should be identified. The frequency of the measurements and of data evaluations should be stated.

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 are identified as follows for the three leading enrichment technologies:

Centrifuge — The 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. Instrumentation used for these techniques could be tamper-indicating, and additional containment and surveillance techniques 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 such as personnel and vehicle portal monitors, package monitors, perimeter barrier sensor systems, optical surveillance instrumentation, and tamper-indicating seals.

Gaseous Diffusion — The installation of in-line enrichment monitors and gas flow meters at the product withdrawal points could address most unauthorized production scenarios. Materials accounting techniques could be supplemented by containment and surveillance techniques such as radiation measurement and surveillance instrumentation for personnel, packages, and vehicles; perimeter barrier sensor systems; optical surveillance instrumentation; and tamper-indicating seals to assist in addressing theft scenarios.

Laser Isotope Separation — Examples will need to be developed upon completion of commercial designs.

9.4 Reporting and Documentation Requirements

The applicant or licensee should make a definitive statement defining the basis for declaring that (1) unauthorized production of enrichment has taken place, and (2) unauthorized production of uranium of low strategic significance has taken place. Whenever systems indicate that unauthorized production of uranium enrichment may have occurred or may be occurring, that determination becomes an "indicator" that should be subject to the investigation and resolution requirements of 10 CFR 74.33(c)(5). If actual unauthorized production of enriched uranium is discovered, that discovery must be reported to the NRC within 1 hour as required by 10 CFR 74.11.

10 Resolving Indications of Missing Uranium and of Unauthorized Production of Enriched Uranium

10.1 Methods and Procedures for Identifying Indicators

The FNMC plan should discuss the means by which the licensee will resolve indicators of (1) missing uranium involving 500 grams or more of U-235 or (2) unauthorized production. 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 uranium 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 uranium enriched to 10 wt % or more in U-235

The licensee's resolution program should address the possible indicators of missing uranium. The FNMC plan should enumerate all the 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 uranium:

(1) lack of agreement of dynamic or static inventories with the MC&A records

(2) determination through the item control program that a specific item is not in its authorized location and its actual location is not immediately known

(3) discovery that an item's integrity or its tamper-indicating seal was compromised

(4) information from the process control system indicating potential loss of material from the process system (e.g., improper valve settings)

(5) an allegation of theft or diversion

Examples of possible indicators of unauthorized production of uranium enriched to less than 10 wt % U-235 are:

(1) presence of unauthorized product, feed or tails cylinders

(2) SWU imbalances (e.g., reduced production capacity)

(3) presence of tails at enrichments lower than the design range

(4) presence of excess mass or amount of tails, or other ID

(5) discovery of records tampering

(6) discovery of unauthorized feed or withdrawal equipment or reset valve configurations to permit feeding and withdrawal

(7) unauthorized operational activities in the enrichment process facilities

(8) receipt of allegations

Examples of possible indicators of unauthorized production of uranium enriched to 10 wt % or greater in U-235 are:

(1) any of the preceding items

(2) any measurement from a stream monitoring program that indicates out-of-specification enrichment concentrations for any feed, product, or tails stream

(3) unauthorized reconfiguration, isolation, or interconnection of enrichment equipment, or changes in valve settings

(4) equipment used for monitoring enrichment levels in product streams not functioning properly or compromised

(5) an allegation that unauthorized production of uranium enriched to 10 wt % or more in U-235 has occurred or is under way

(6) radiation signatures or background radiation levels greater than normally expected

10.2 System and Procedures for Investigating and Resolving Indicators

At least one major MC&A procedure should address the system and procedures for investigating and resolving indicators because this topic pertains to three of the performance objectives of 10 CFR 74.33(a). Thus, the licensee should have well-defined procedures for investigating indicators of both (1) possible missing uranium (involving 500 grams or more of U-235), and (2) possible unauthorized production activities.

Likewise, there should be established criteria for defining what constitutes resolution of an investigated indicator.

Resolution of an indicator means that the licensee has made a determination that loss, theft, or unauthorized production of uranium 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 FNMC 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 time frame within which the loss or activity could have occurred, (5) the most probable cause(s), and (6) recommendations for precluding reoccurrence.

In the case of indicators that loss or theft of more than 500 grams of U-235 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) making a determination that the indication is or is not resolved. The resolution procedures should be prepared in such a manner that no individual that could have been responsible for the potential loss also would be responsible for its resolution. If an investigation of an indicator results in a conclusion that the indication is true, such conclusion must be reported to the NRC within 1 hour of its determination pursuant to 10 CFR 74.11. The FNMC plan should show the reasonable time allowed for resolution. In general, a time not exceeding 72 hours should be adequate.

In the case of indicators of unauthorized production of uranium 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 pursuant to 10 CFR 74.11. The FNMC plan should show the reasonable time allowed for resolution. In general, 72 hours should be adequate.

In the case of indicators of unauthorized productions of enrichments 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 uranium 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 uranium 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 enrichments of 10 wt % or more in U-235 is true, this condition is reportable pursuant to 10 CFR 74.11. The FNMC plan should show the reasonable time allowed for resolution. In general, 72 hours should be adequate.

If the investigation conducted to resolve the indication does not observe the production of uranium 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 uranium, a thorough investigation of the entire facility should be performed by individuals who are independent of the processing organization.

10.3 Response Actions for Unresolved Indicators

Response actions 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 also should be defined.

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

(1) whether the potential missing uranium is depleted, natural, or enriched

(2) the potential quantity of U-235 involved

(3) the material attractiveness (from the standpoint of its potential use in a nuclear explosive device) of the potential missing uranium 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 uranium enrichment generally have a higher level of safeguards concern than indicators of missing uranium. The degree of concern for unauthorized production indicators is related to such factors as:

(1) whether the indicator pertains to unauthorized production in the planning stage, currently in progress, or already accomplished

(2) whether the potentially produced material is low strategic SNM, moderately strategic SNM, or strategic SNM

(3) the potential quantity of unauthorized material already produced

10.4 Documentation Requirements

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

(1) investigation procedures

(2) resolution procedures

(3) reporting of indicator to MC&A management including date and time the indicator was reported, name of individual who discovered the indicator, and description of indication

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

(5) reports made to 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 NRC individual contacted

11 Informational Aid for Assisting in the Investigation and Recovery of Missing Uranium or Assisting in the Investigation of Unauthorized Enrichment

When an investigation relating to actual (or highly suspected) events pertaining to missing uranium or unauthorized enrichment is conducted by the NRC and/or other government agencies, the licensee is to have ready for and to provide to the investigators any information deemed relevant to (1) the recovery of material involved in a loss, theft, or diversion and (2) unauthorized production of uranium enrichment. The burden shall be on the licensee to provide (without being asked to) all information that it recognizes as being relevant, as opposed to only providing information that the investigators are knowledgeable enough to ask for. This information would include production records, accountability data, and routinely prepared reports. Kinds of information that may aid the investigation are:

(1) data or observations that led the operator to determine that a loss or theft of uranium or unauthorized production may have occurred

(2) data, observations, and assessments associated with attempts to resolve the indication of missing material or unauthorized production

Information indicating that a loss of uranium may have occurred are those provided by physical inventories, the item control program, and shipper-receiver comparisons (Chapters 5, 6, and 7, respectively). This information could include:

(1) material accountability data records and reports

(2) inventory records

(3) inventory difference and propagation of error calculations

(4) inventory reconciliation reports

(5) indications of unrecorded or unauthorized removals of SM or SNM from storage or process locations

(6) reports of apparent destruction or falsification of records of an items existence

(7) records of broken tamper-indicating devices or compromised item integrity

(8) indications of unauthorized entry into SM and SNM storage areas

(9) Reports from monthly item status inspections

(10) material receipt and log-in records

(11) results from shipper-receiver difference evaluations

(12) process monitoring and control records

Information indicating that unauthorized production may have occurred are those provided by the program for precluding and detecting unauthorized production (Chapter 9). This information could include:

(1) reports assessing potentially credible means for unauthorized enrichment

(2) indications of unauthorized activities in enrichment process areas

(3) indications of anomalous process configurations

(4) indications of anomalous process conditions

(5) indications of unauthorized entry into the enrichment process areas

(6) indications of anomalous enrichment levels (e.g., process sample or radiation measurement data)

(7) indications of anomalous feed, product, or tails quantities

(8) indications of unauthorized feed or withdrawal locations and/or containers

(9) anomalous production data (e.g., SWU imbalances)

Information associated with resolving indications of missing uranium and of unauthorized production are provided in Chapter 10. This information would include:

(1) the type of unauthorized activity detected

(2) the interval during which the loss or unauthorized production may have occurred

(3) the amount of material and form of the material involved in the loss

(4) estimates of the extent of unauthorized production

(5) results of measures to validate indicators

(6) results of extended measures to resolve indicators

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

(8) audit results of the SM and SNM accountability source data

(9) assessments of measurement data and measurement controls

(10) results from reviews of the material control and accounting program and status of corrective actions

(11) history of indicator investigation and resolution activities

(12) indicator investigation and resolution procedures and conclusions

(13) probable cause of the loss

(14) any abnormal events that may have contributed to or caused the loss

(15) 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 12.

12 Recordkeeping

12.1 Description of Records

The FNMC 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:

(1) documents that define changes in the MC&A management structure or changes in responsibilities relating to MC&A positions;

(2) procedures pertaining to any accountability or 10 CFR 74.33(c)(5) related measurement or sampling operation

(3) forms used to record or to report measurement data and measurement results, including source data

(4) forms and notebooks used to record calibration data associated with any accountability measurement system

(5) 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

(6) forms and official memos used to record or report measurement control program data, control limit calculations, and out-of-control investigations

(7) forms listings and instructions associated with a physical inventory, both dynamic and static

(8) forms and formal worksheets used in the calculation of SEID, ID, and active inventory values

(9) ledgers, journals, and computer printout sheets associated with the accountability system

(10) ledgers, journals, and computer printout sheets associated with the item control program, including seal usage and "attesting to" records

(11) DOE/NRC forms 741 and 742

(12) forms, memos, and reports associated with identification of, investigation of, and resolution of significant SRDs

(13) loss indication and alleged theft investigation reports

(14) investigation reports pertaining to indications of activities related to unauthorized production of enriched uranium

(15) investigation reports pertaining to excessive IDs

(16) official reports containing the findings and recommendations of MC&A system assessments and any letters or memos pertaining to response actions to assessment team recommendations

(17) forms used for recording data associated with the monitoring program

(18) monitoring program status or summary reports

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

(20) training, qualification, and requalification reports and records

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

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

The FNMC plan should describe the controls used to ensure that records are highly accurate and reliable. The record system also should provide a capability for easy traceability of all SM and SNM transactions from source data to final accounting records.

The following topics should be addressed:

(1) the auditing system or program to verify the correctness and completeness of records

(2) the overchecks for preventing or detecting missing or falsified data and records

(3) the plan for reconstructing lost or destroyed SM and SNM records

(4) the access controls used to ensure that only authorized persons can update and correct records

(5) the protection and redundance of the record system such that any 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 needed to achieve the performance objectives of 10 CFR 74.33(a)

Glossary

The following terms are defined in the context of (1) their usage in this document and/or (2) how they should be used if contained in the fundamental nuclear material control (FNMC) plans submitted pursuant to 10 CFR 74.33(b).

ACCOUNTABILITY — The determination of, and current record maintenance of, source material (SM) and special nuclear material (SNM) quantities associated with (1) receipts, (2) shipments, (3) measured discards, (4) transfers into or between material balance areas (MBAs) and/or item control areas (ICAs), and (5) total material on current inventory.

ACCOUNTANCY (ACCOUNTING) — The records (e.g., ledgers, journals, source documents, etc.) associated with accountability.

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 SM or 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, does not contribute to the uncertainty associated with the current period inventory difference). The active inventory is used as an indicator of processing throughput and/or processing activity.

ADDITIONS TO INVENTORY — Quantities of SM and SNM materials received by a "plant" and which, prior to such receipt, was not part of the plant's total possessed SM or SNM quantity.

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 UF_6 cylinder). Weighing error caused by buoyancy is eliminated by the use of artifact standards for scale calibrations.

ASSIGNED VALUE — A value for mass, volume, SM or SNM concentration, SM or SNM quantity, etc., assigned to a standard weight, standard material, etc., used for calibrating and/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 uranium enrichment level [i.e., weight percent (wt %) U-235] and the maximum quantity of U-235 (contained in enriched uranium) that can be possessed as specified by an issued NRC license.

BEGINNING INVENTORY — For each material type code, the total itemized quantity of SM or SNM possessed by a facility at the start of a material balance period (i.e., inventory period). The beginning inventory 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, etc.) that issues and/or certifies standards.

CHECK STANDARD (BENCH STANDARD, WORKING STANDARD) — A standard, not necessarily traceable to a primary standard, that is used routinely (e.g., daily or weekly) to check (or verify) the reliability of a measurement device, instrument, etc. (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.

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

DEPLETED URANIUM — Any uranium-bearing material whose combined U-233 plus U-235 isotopic content is less than 0.70 wt % (relative to total uranium elemental content).

DETECTION QUANTITY (DQ) — A site-specific U-235 quantity in SM or SNM for licensees whose processing activities are limited to SNM of low strategic significance. The DQ is normally a function of annual throughput, but for low-throughput low-enriched uranium (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:

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

EFFECTIVE KILOGRAM — An effective kilogram of SNM means (1) for plutonium and U-233, their weight in kilograms; (2) for uranium with an enrichment in the isotope U-235 of 1.00 wt % (i.e., 0.01 g U-235/g U) and above, its element weight in kilograms multiplied by the square of its enrichment expressed as a decimal weight fraction; and (3) for uranium with an enrichment in U-235 below 1.00 wt %, but above 0.71 wt %, its element weight in kilograms multiplied by 0.0001.

ENDING INVENTORY — For each material type code, the total itemized quantity of SM or SNM possessed by a facility at the end of a material balance period, as determined by a physical inventory. The ending inventory quantity for any given material balance period is (by definition) exactly equal to the beginning inventory quantity for the next period.

ENRICHED URANIUM — Any uranium-bearing material that does not qualify as natural uranium and whose combined U-233 plus U-235 isotopic content is 0.72 wt % or higher relative to total uranium elemental content.

FORMULA KILOGRAM (FKG)— The number of formula kilograms is computed by the following equation:

$$FKG = \frac{\text{(grams U-235 contained in high-enriched uranium)} + 2.5\ \text{(grams U-233 + plutonium)}}{1000\ \text{grams}}$$

FORMULA QUANTITY — Strategic SNM in any combination in a quantity of 5.00 FKGs or more.

HIGH-ENRICHED URANIUM (HEU) — Any uranium-bearing material whose U-235 isotopic content is 20.00 wt % or more relative to total uranium elemental content.

INVENTORY DIFFERENCE (ID) — The arithmetic difference between a book inventory and the corresponding physical inventory, calculated by subtracting ending inventory (EI) plus removals from inventory (R) from beginning inventory (BI) plus additions to inventory (A). Mathematically, this can be expressed as:

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

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 and/or prior period adjustment associated with the ID value.

ITEM — Any discrete quantity or container of SM or SNM, not undergoing processing, having a unique identity and also having assigned uranium and U-235 quantities.

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

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

LOW-ENRICHED URANIUM (LEU) — Any uranium-bearing material whose U-235 isotopic content is greater than 0.72 wt % but less than 20.00 wt % relative to total uranium elemental content.

MATERIAL BALANCE — A comparison on a measured basis of beginning inventory plus additions to inventory to ending inventory plus removals from inventory for a given control area (or combination of control areas) over a specified period of time.

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

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

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

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

*For DOE/NRC Form 742, material code 20 has 4 subcodes to denote enrichment range: E1, E2, E3, and E4. For NRC Form 327, material code 20 has 2 subcodes: LEU and HEU.

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

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

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

MEASUREMENT — The process of determining a (1) uranium elemental concentration, (2) specific uranium isotopic content, (3) U-235 enrichment (i.e., isotopic abundance), (4) bulk material mass or item mass, or (5) bulk material volume. Measurement values are derived through a calibration process that establishes the relationship between instrument (i.e., device) response and the parameter being determined.

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

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

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

PHYSICAL INVENTORY — A determination by physical means (visual and measurement) of the quantity of SM or SNM on hand for a given material type code at a specified point in time. The primary purpose for a physical inventory is to confirm the absence of (or to detect) a loss, theft, or diversion of SM or SNM. For the conclusion drawn from a physical inventory to be meaningful, not only does the physical presence of all material (or at least the vast majority of the material) need to be confirmed, but the quantities of material in the inventory also need to be remeasured, or other assurance provided, to verify that prior measurements are still valid. Physical inventories are to be conducted on a "plant" as well as on a "material type code" basis.

PLANT — For SM and SNM control and accounting purposes, a plant is defined as a set of processes or operations (on the same site, but not necessarily all in the same building) coordinated into a single manufacturing, research and development, or testing effort. Most licensees have only one plant in this context. Independent on-site manufacturing efforts, such as a scrap recovery operation serving both on-site and off-site customers, should be treated as separate plants.

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, etc.), 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, uranium concentration, uranium isotopic distribution, etc.) whose value is certified (within a specified uncertainty) by a nationally or internationally recognized bureau, laboratory, etc., that issues and/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 (SRD) on material received during a prior inventory period, correction of a recording error, etc. 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, etc.) 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.

RANDOM ERROR — The variation encountered in all measurement work, characterized by the random occurrence of both positive and negative deviations from a mean value.

RECEIPT — A quantity of SM or SNM in a shipment received by a facility from another facility.

REFERENCE STANDARD — A material, device, or instrument whose assigned value is traceable to a national standard (i.e., primary standard) or nationally accepted measurement system.

REMOVALS FROM INVENTORY — All measured quantities of SM and SNM falling within the categories of (1) shipments, (2) measured discards released to the environment, (3) measured discards transported off-site, and (4) measured discards stored on-site and formally transferred in the accounting records to a holding account via a DOE/NRC Form 741 transaction.

RESOLUTION OF AN INDICATOR — A definitive determination (with auditable evidence) by the licensee that an indicated possible theft or unauthorized production of uranium 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 (SRD) — 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.

SOURCE MATERIAL (SM) — (1) Natural uranium or thorium, or depleted uranium, or any combination thereof, in any physical or chemical form, or (2) ores that contain 0.05 wt % or more of (a) uranium, (b) thorium, or (c) any combination thereof. Source material does not include SNM.

SPECIAL NUCLEAR MATERIAL (SNM) — (1) Plutonium, U-233, uranium enriched in U-235, and any other material that the NRC, pursuant to the provisions of Section 51 of the Atomic Energy Act of 1954 (as amended), determines to be SNM; or (2) any material artificially enriched in any of the foregoing. There are three levels of strategic significance applied to SNM, depending on the type and quantity, defined as follows:

SNM OF HIGH STRATEGIC SIGNIFICANCE — Same as FORMULA QUANTITY (see definition).

SNM OF MODERATE STRATEGIC SIGNIFICANCE — (1) Less than a formula quantity, but more than 1,000 grams of U-235 contained in HEU, or more than 500 grams of U-233 or plutonium, or more than a combined quantity of 1,000 formula grams when formula grams are computed by the following equation:

formula grams = (grams U-235 in HEU) + 2 (grams U-233 + grams Pu)

or (2) 10,000 grams or more of U-235 contained in LEU enriched to 10.00 wt % or more, but less than 20.00 wt %, U-235.

SNM OF LOW STRATEGIC SIGNIFICANCE — (1) Less than an amount of SNM of moderate strategic significance, but more than 15 grams of (a) U-235 contained in HEU, (b) U-233, (c) plutonium, or (d) any combination thereof; (2) less than 10,000 grams but more than 1,000 grams of U-235 contained in LEU enriched to 10.00 wt % or more (but less than 20.00 wt %) U-235; or (3) 10,000 grams or more of U-235 contained in LEU enriched above natural but less than 10.00 wt % U-235.

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

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

$$\text{std. dev.} = \left[\frac{\sum_{i=1}^{n} (\bar{x}_i - x)^2}{n - 1} \right]^{1/2}$$

where

n = number of measurements performed

x_i = the value obtained for the i th measurement for i = 1, 2, 3 ....n

$\bar{x}$ = the average value for all n measurements

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

STANDARD ERROR OF THE INVENTORY DIFFERENCE (SEID) — (1) For licensees subject to 10 CFR 74.31 or 74.33, SEID is equal to the square root of the sum of both measurement and non-measurement variances associated with the ID. (2) For licensees subject to 10 CFR 74.59, SEID is equal to the square root of only the measurement variance associated with the ID.

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

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

TRACEABILITY — The ability to relate individual measurement results to national standards (i.e., primary standards) or nationally accepted measurement systems through an unbroken chain of comparisons.

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

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-5734
K/ITP-415

2. TITLE AND SUBTITLE

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

3. DATE REPORT PUBLISHED

MONTH	YEAR
November	1991

4. FIN OR GRANT NUMBER

L1300

5. AUTHOR(S)

B.W. Moran, W.L. Belew, Oak Ridge K-25 Site
G.A. Hammond, L.M. Brenner, 21st Century Industries, Inc.

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION — NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Oak Ridge K-25 Site
Oak Ridge, TN 37831

Subcontractor: 21st Century Industries, Inc.
P. O. Box 2636
Gaithersburg, MD 20886

9. SPONSORING ORGANIZATION — NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Safeguards and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

A new section, 10 CFR 74.33, has been added to the material control and accounting (MC&A) requirements of 10 CFR Part 74. This new section pertains to U.S. Nuclear Regulatory Commission (NRC)-licensed uranium enrichment facilities that are authorized to produce and to possess more than one effective kilogram of special nuclear material (SNM) of low strategic significance.

The new section is patterned after 10 CFR 74.31, which pertains to NRC licensees (other than production or utilization facilities licensed pursuant to 10 CFR Part 50 and waste disposal facilities) that are authorized to possess and use more than one effective kilogram of unencapsulated SNM of low strategic significance. Because enrichment facilities have the potential capability of producing SNM of moderate strategic significance, and also strategic SNM, certain performance objectives and MC&A system capabilities are required in 10 CFR 74.33 in addition to those contained in 10 CFR 74.31.

This document recommends to the NRC information that the licensee or applicant should provide in the fundamental nuclear material control (FNMC) plan. This document also describes methods that should be acceptable for compliance with the general performance objectives. While this document is intended to cover various uranium enrichment technologies, the primary focus at this time is gas centrifuge and gaseous diffusion.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

Enrichment
Safeguards
Source Material
Special Nuclear Material
Material Control
Material Accountability
Fundamental Nuclear Material Control
Low-Enriched Uranium

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page) Unclassified

(This Report) Unclassified

15. NUMBER OF PAGES

16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC

PERMIT No. G-67