ESTABLISHING A SYSTEM FOR CONTROL OF NUCLEAR MATERIAL FOR NUCLEAR SECURITY PURPOSES AT A FACILITY DURING STORAGE, USE AND MOVEMENT

DRAFT TECHNICAL GUIDANCE

INTERNATIONAL ATOMIC ENERGY AGENCY

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FOREWORD

By Yukiya Amano, Director General

The IAEA’s principal objective under its Statute is “to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world.” Our work involves both preventing the spread of nuclear weapons and ensuring that nuclear technology is made available for peaceful purposes in areas such as health and agriculture. It is essential that all nuclear and other radioactive materials, and the facilities in which they are held, are managed in a safe manner and properly protected against criminal or intentional unauthorized acts.

Nuclear security is the responsibility of each individual country, but international cooperation is vital to support States in establishing and maintaining effective nuclear security regimes. The central role of the IAEA in facilitating such cooperation, and providing assistance to States, is well recognized. The Agency’s role reflects its broad membership, its mandate, its unique expertise and its long experience of providing technical assistance and specialist, practical guidance to States.

Since 2006, the IAEA has issued Nuclear Security Series publications to help States to establish effective national nuclear security regimes. These publications complement international legal instruments on nuclear security, such as the Convention on the Physical Protection of Nuclear Material and its Amendment, the International Convention for the Suppression of Acts of Nuclear Terrorism, United Nations Security Council Resolutions 1373 and 1540, and the Code of Conduct on the Safety and Security of Radioactive Sources.

Guidance is developed with the active involvement of experts from IAEA Member States, which ensures that it reflects a consensus on good practices in nuclear security. The IAEA Nuclear Security Guidance Committee, established in March 2012 and made up of Member States’ representatives, reviews and approves draft publications in the Nuclear Security Series as they are developed.

The IAEA will continue to work with its Member States to ensure that the benefits of peaceful nuclear technology are made available to improve the health, well-being and prosperity of people world-wide.
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1. INTRODUCTION

1.1. BACKGROUND

The IAEA has developed guidance [1] for using a system of nuclear material accounting and control (NMAC) in support of nuclear security at the facility level. Such a system can improve deterrence and detection of unauthorized activities by an insider [2]. There is a need for more detailed guidance on how to use the individual elements of the NMAC system for nuclear security, including the control and movements of nuclear material. This publication addresses the aspects of nuclear material control during storage, use and movement in more detail than in other publications. For the purposes of this document nuclear material is defined in the Nuclear Security Fundamentals [3].

1.2. OBJECTIVE

The objective of this publication is to describe practical measures for controlling nuclear material for nuclear security purposes during all activities at a facility, including movements, and how to use a graded approach in applying such measures.

1.3. SCOPE

This publication focuses on the control of nuclear material during storage, use and movement through a facility’s NMAC system. Control of nuclear material comprises the administrative and technical measures applied to ensure that nuclear material is not misused or removed from its assigned location without approval and/or without proper accounting [1].

Accounting for nuclear material comprises the measures involved in tracking of nuclear material received, processed, produced, shipped, transferred, relocated, used or stored at a facility, for operations, for control, for facility accounting or for IAEA Safeguards [4]. This publication focuses on control of nuclear material rather than accounting. Other IAEA publications address accounting of nuclear material, e.g. Nuclear Material Accounting Handbook [4], which addresses accounting to meet the requirements for reporting nuclear material inventories and transactions to the IAEA. However, it should be noted that accounting and control are strongly linked: without control, nuclear material cannot be properly accounted for; without accounting, nuclear material cannot be properly controlled.

Physical protection aspects [5] of access to a facility, an area or a room of the facility are outside the scope of this publication, but control of access to locations where nuclear material is stored or processed...
is addressed. Although material control needs to continue during transport of nuclear material, this publication does not address specific control measures implemented during transport between facilities [6]. This publication describes the processes necessary for control of nuclear material during preparation for movements between facilities, within the facility between material balance areas, and within material balance areas.

This publication emphasizes the function of control of nuclear material but does not indicate which organization may be responsible for the function at a particular facility; States need to assign such responsibility in accordance with their national approach.

Response to and investigation of irregularities resulting from failure of a control measure are briefly discussed in this publication but not addressed in detail.

1.4. STRUCTURE

Following this Introduction, Section 2 describes the purpose of nuclear material control in a nuclear facility and during movements. Section 3 contains descriptions of measures to be taken for nuclear material control. Section 4 describes other facility systems that contribute to nuclear material control. Section 5 presents details for control of movements of nuclear material within a material balance area, from one material balance area to another, and from one facility to another facility. Section 6 describes guidance for managing nuclear material control including movements of the material. Section 7 contains a description of measures taken in response to irregularities associated with nuclear material, including investigation, corrective actions and reporting. Section 8 describes the process for evaluating nuclear material control at a nuclear facility.

2. PURPOSE OF CONTROL OF NUCLEAR MATERIAL

2.1. NUCLEAR MATERIAL CONTROL

The main purpose of nuclear material control measures is to maintain knowledge of the nuclear material, for the purpose of deterring and detecting any actions that could lead to its unauthorized removal or misuse. Such measures include activities related to handling, processing, or storing nuclear material; activities designed to control access to nuclear material, equipment for nuclear material processing, and nuclear material data; and activities related to controlling movements of nuclear material.
Measures that should be implemented in a facility for the control of nuclear material are discussed in detail in Section 3 below. These measures include material containment, material surveillance, monitoring packaged items containing nuclear material, monitoring nuclear material undergoing processing, and using tamper indicating devices (TIDs). The number and nature of measures necessary to provide adequate control is dependent on the threat identified by the State and the amount and security category (in terms of the type and the potential consequences of unauthorized removal or use) of nuclear material, located at the facility. Appropriate points or locations where nuclear material control measures are to be applied should be established taking into account nuclear material locations within the facility and movements. The results of evaluations of the NMAC and physical protection systems should also be considered.

Nuclear material control measures should be designed to provide continuous control and to prevent the loss of control of nuclear material because of a single-point failure of the NMAC system.

The operator of a facility should develop procedures for controlling the entry or removal of any objects or material, radioactive or non-radioactive, into or out of an area where nuclear material is held and/or used.

2.2 NUCLEAR MATERIAL MOVEMENTS

Nuclear material is more vulnerable during movements than when it is in its usual location in a facility. Control measures are therefore particularly important at each step of preparation, transport and receipt of nuclear material to ensure the material is not stolen or misused by an insider.

In this publication the terms “shipments” and “receipts” refer to movements and receipts of nuclear material from one facility to another facility. The term “transfers” refers to nuclear material movements within a facility between material balance areas. The term “relocations” refers to movements within a material balance area. The general term “movements” refers to all terms defined in this paragraph and used in this publication.

3. NUCLEAR MATERIAL CONTROL MEASURES

This section contains descriptions of the individual measures of a nuclear material control programme that are part of the NMAC system of a facility. The measures described here are:

— Control of access to nuclear material, equipment and data;

— Control of access to locations where nuclear material is stored or processed;
— Material containment;
— Tamper indicating devices (TIDs);
— Material surveillance;
— Programme for monitoring nuclear material items; and
— Programme for monitoring nuclear material during processing.

Each of these measures addresses a specific need in controlling nuclear material to detect anything that may or may not lead to unauthorized removal of nuclear material and to detect and deter misuse or unauthorized removal by an insider.

When designing material balance areas in a facility, it may be necessary to establish additional accounting and control areas within the material balance areas. This is because both accounting and control measures should be more stringent for material balance areas, locations, or processes within the material balance areas with higher quantities and/or more attractive materials.

Control of nuclear material should be implemented using a graded approach [5] based on the quantity and attractiveness of the material. For example, a high enriched uranium or plutonium item not undergoing processing should be kept in a vault or vault-like structure and have additional controls, such as the two person rule when the vault is opened or closed, during operations inside the vault and when the item is outside the vault. Low enriched uranium not undergoing processing may have less stringent controls applied for its protection. Even if it is not mentioned in each nuclear material control element that is discussed in this publication, each element should be implemented using a graded approach.

Operations involving nuclear material should be authorized and planned appropriately. Control of nuclear material should be coordinated among organizational units at the facility, including NMAC, physical protection, safeguards, operations and safety. There should be clear communication and sharing of information among personnel from the NMAC, physical protection, safeguards, safety, operations and management organizations regarding operations involving nuclear material. Personnel involved in activities with nuclear material should be trained and qualified in the necessary security measures.

A schedule of planned activities that involve nuclear material should be developed and maintained for all areas where nuclear material is stored or processed, including a list of all personnel who need access. A work plan should be written to provide a description of all planned activities and how they will be
executed, including all nuclear material movements, transfers, physical inventory taking, regulatory
inspections and IAEA Safeguards inspections. All activities and their results involving nuclear material in
a facility should be documented. It is recommended to have a logbook to record all events, times, names
of personnel involved, and a description of the work that was done and notes about any unusual events
that may have occurred.

Facility management should authorize activities involving nuclear material. There should be a formal
facility procedure documenting the instructions for authorization. If a licence or approval is required for
use of the equipment, those should be obtained in advance of the work.

3.1 CONTROL OF ACCESS

Control of access during routine, non-routine, and actual or simulated emergency situations is important
to effective nuclear security.

3.1.1 Control of access to nuclear material

The control of access to nuclear material and the locations where it is stored or processed is important to
the facility’s nuclear security programme and should be coordinated between the NMAC organization and
physical protection staff. Authorizations by the appropriate person should be required for personnel to
enter an area where nuclear material is located.

The facility operator should develop procedures for controlling access to its nuclear material during
routine, non-routine, and actual or simulated emergency situations. These procedures should include a
description of the requirements for the person(s) who will be responsible for the authorization for access.
Clear assignment of roles and responsibilities should be included in the procedures.

Training programmes should include testing to help ensure the knowledge of assigned personnel prior to
their involvement in activities with nuclear material. Procedures should also include instructions to ensure
the timely removal of authorization of personnel who may have been transferred to another work
organization or whose employment at the facility has been terminated.

Plans should be established for non-routine activities involving nuclear material. Such activities may be
unscheduled, but are often foreseeable. Operators should ensure that contingency plans are developed and
that these include mitigating measures to be put in place where normal access controls may be degraded
or lost. Facility operators should schedule and conduct exercises to prepare personnel to conduct non-
routine activities such as non-scheduled evacuations.
Additional controls may be needed during emergency conditions. Facility personnel should be trained and qualified on these measures to ensure their proper implementation during emergency events, for example, where emergency responders such as firefighters may require access to areas where nuclear materials are held. Written procedures for control measures to describe the steps to be taken in an emergency situation and responsible personnel should be identified.

It is important to limit the activities, access, and the number of personnel involved in the response to an emergency situation. If possible, only people who have been identified and trained in advance should participate in the response. Plans and procedures for responding to an emergency involving nuclear material should be integrated with the facility’s emergency preparedness programme. These plans should address the control of nuclear material during exercises or unplanned activities. For example, in the case of an unplanned evacuation procedures should be developed to describe the process to be used to monitor personnel who exited the area without normal monitoring. Compensatory measures, such as radiation monitoring of individuals, should be used to ensure no unauthorized removal of nuclear material occurred.

Facilities should have a programme for ensuring personnel trustworthiness [7] commensurate with the amount and attractiveness of the nuclear material at the facility. There should also be a system to authorize visitors and temporary workers to have access to the facility while being escorted. Typically information is needed in advance to prepare for the visit or planned work. Visitors or temporary workers should be required to present the appropriate documentation to prove their identity upon arrival at the facility.

Training for awareness of safety and security requirements and/or working conditions in the facility should be required prior to access to the facility. Escorts of visitors and temporary workers should be knowledgeable of the areas to be visited and of actions to take in case of an emergency. An effective authorization programme requires coordination among several organizations within the facility, e.g. NMAC, physical protection, safeguards, safety, and operations. Records should be kept to identify all visitors and temporary workers that are allowed access to the facility.

One example of controlling access to nuclear material is to implement procedures to ensure a single person cannot access the material. Controls should be implemented that would prevent one person from being able to open and access a secured storage area alone.
1 3.1.2. Control of access to equipment or objects used for nuclear material-related activities

Equipment, tools or objects used for all activities involving nuclear material handling, measuring, sealing, or processing could potentially be used for unauthorized removal or misuse of nuclear material and need to be controlled. Procedures should be written to describe the control measures required for authorizing the use of these objects or equipment in nuclear material-related activities. Authorization should be obtained from the appropriate NMAC or physical protection staff member before the objects or equipment are brought into the area where nuclear material is located. The NMAC and physical protection staffs should share information and communicate with each other regarding the presence and use of nuclear material and equipment or objects in nuclear material areas.

An example of control of equipment might be applying procedures that control the use of a crane that is needed in a processing area to move large equipment or containers of nuclear material. A TID or other control measures could be applied to the crane to prevent the unauthorized removal of nuclear material using the crane.

Devices including keys and combination locks, which provide access to nuclear material locations containing nuclear material or equipment for moving or processing nuclear material, should be controlled. If two keys or combinations are required, both keys and combinations should not be available to one individual. The two-person rule should be applied when issuing keys or combinations to access vault storage areas.

Other objects that should be controlled are devices or instruments that could be used for removing containment devices such as locks that are applied to a location where nuclear material is stored. Devices or instruments that could be used to remove sturdy TIDs from containers of nuclear material should be controlled if they are allowed in an area where nuclear material is located. Bolt cutters or hacksaws should not be allowed in a nuclear material processing area without controls to ensure they are used only for their intended maintenance purpose and not for unauthorized removal of nuclear material.

3.1.3. Control of access to data related to nuclear material

A major challenge facing nuclear security programmes is the security of data, especially electronic data. The security of information systems, nuclear material reports, maps of the facility, and access routes are sensitive topics and should be controlled. An evaluation should be performed on the information security needs of the nuclear facility. Procedures should be written to describe instructions to mitigate the identified risks, therefore, providing protection of the sensitive information (paper and digital).
Coordination among organizations within the facility, especially NMAC and physical protection, is critical to effective protection of the facility’s sensitive information.

There should be strict enforcement of the rules for authorization for access to sensitive information, especially to the electronic data systems. Personnel should have access to only such information contained in the systems as they need to know, and should be trained in how to use the systems. Controls and data verification should be established to ensure that a single individual cannot manipulate the data to accomplish, or delay detection of, the unauthorized removal of nuclear material. Procedures should be developed and implemented to control all activities involving the sensitive information systems, including reporting on such activities. These procedures should require that reports include the identity of the person making entries or corrections to the system, as well as a record of changes to show what the person did. All actions affecting the sensitive information systems should be documented and retained as required by the State’s competent authority.

Personnel who have access to the facility’s nuclear material should not be allowed access to the facility’s nuclear material accounting system without adequate controls. For example, when personnel in a processing area are packaging nuclear material for a shipment to another facility, they should not have the ability to input the data into the accounting system to show the nuclear material items being shipped without someone else having final control of the data entry. One way to control this is to have an accounting person from the NMAC organization assigned the responsibility of being present during the packaging process to review the data, confirm and validate that the nuclear material items shown as being packaged for shipment are actually the nuclear material items that are being shipped.

Special consideration should be given to information that may be more widely or publicly disseminated, for example in company newsletters or on an organization’s website, and adequate review and authorization processes should be put in place to ensure that sensitive information is not released. For example information about shipments and receipts might be especially sensitive and should be protected accordingly. Caution should be used when developing the procedures designed to protect this information at the level determined by the State. The facility operator should develop procedures that clearly address the sensitivity of the information to be protected. Electronic and physical access to a database with sensitive information should be protected based on the consequences of loss of control of the information in the database.
3.2 MATERIAL CONTAINMENT

Material containment refers to structural features of a facility, containers or equipment that are used to establish the physical integrity of an area or items. Containment may include the walls of a storage room or of a storage pool, transport flasks, or storage containers. A vault or vault-type room provides material containment. A can that holds uranium oxide is another form of containment. The types and levels of containment should be consistent with the quantity and attractiveness of the nuclear material. The purpose of material containment is to maintain the continuity of knowledge of the nuclear material by preventing undetected access to, or movement of, nuclear or other material or interference with these items.

The continuing integrity of the containment is usually assured by TIDs or surveillance measures (especially for containment penetrations such as doors, vessel lids, and water surfaces) and by periodic examination of the containment. A breach of containment may indicate the unauthorized removal of nuclear material. The removal of nuclear material from a secure storage location (for processing, shipping, or movement) should be controlled to prevent unauthorized removal. Secure temporary storage (e.g. cabinets, safes, cages with double locks and/or with TIDs installed) should be used to maintain the continuity of knowledge of material that is staged for processing.

Facility operators should employ a system of segregation and control in order to prevent substitution of less attractive material for more attractive material, including:

— Storing different categories of uranium (natural, depleted, low enriched and high enriched) in separate areas;

— Segregating waste from product material; and

— Controlling non-nuclear material that could be substituted for nuclear material.

Other controls, such as colour coded labels for containers holding different types of nuclear material, may also be considered.

Pathways for removal of nuclear material, for example, emergency exits, waste disposal points, ventilation ducts and other penetration points, should be identified and controlled. For example, installation of fine metal mesh in addition to grates on windows and ventilation ducts may prevent the unauthorized removal of nuclear material through these openings.
3.2.1 Design of containment measures

The design of containment measures depends on the type of facility to be protected, e.g. a facility that handles nuclear material items but does not process nuclear material has different requirements from a facility where bulk processing of nuclear material is done. Monitoring nuclear material during processing may be needed in a bulk facility but not needed in an item facility.

A design consideration for a facility with highly radioactive nuclear material might include, for example, the thickness of the walls, ceiling, and floor. Such features are principally intended to provide adequate radiation protection, but also provide robust containment for the materials held within. This type of facility typically requires use of specialized handling procedures, techniques and equipment in order to move materials into and out of the facility. These features present an obstacle to the removal of material and therefore contribute to nuclear material control.

Disposal of radioactive waste underground may rely, for example, on the quality and depth of the host rock in which the repository is located. These geologic characteristics, primarily chosen to ensure long term isolation of the waste from the environment, will also provide a physical barrier that assists in preventing the unauthorized removal of nuclear material.

The design process should involve physical protection personnel, as well as NMAC personnel, and should consider the needs of both physical protection and NMAC.

3.3 TAMPER INDICATING DEVICES

A tamper indicating device (TID) is a device with a unique identifier that is used to detect unauthorized removal of material by leaving evidence of access to the object to which it is applied. A TID by itself does not provide protection or resistance to removal of nuclear material from a container or location (i.e. it does not protect the physical integrity of the container or location) but is designed to indicate that access has occurred (thereby helping to protect the integrity of knowledge relating to the material). It should be noted that this publication does not address TIDs used by the IAEA for safeguards purposes.

3.3.1 Use of TIDs for nuclear material control

The objective of a TID is to provide control measures as part of the integrated nuclear security programme. The State’s competent authority may direct specifications, possibly including certification, for TIDs. TIDs are designed to secure the integrity of containers or objects containing nuclear material when they are in transit or when they are stored at the facility. During transport, TIDs provide assurance
of the integrity of material in transit, maintain the validity of the shipping container, and ensure for both
the shipper and receiver that the shipment integrity has not been violated.

The use of TIDs is a method to assess and demonstrate the integrity of measurements of item parameters
and nuclear material and thus eliminates or reduces the need for re-measurement for accounting purposes.
The use of TIDs to maintain the integrity of measurements reduces the effort of physical inventory taking
or nuclear material item control/item monitoring activities. TIDs allow the facility operator to maintain
current knowledge of the nuclear material items and allow the items to be stored in a manner such that
unauthorized removal of nuclear material can be detected. TIDs should be used in conjunction with an
effective material surveillance programme.

Effective use of TIDs should include controls on the acquisition, procurement and destruction of TIDs;
information on their types and unique identification; and procedures for training on the use, application,
removal, destruction, storage, issuance and verification of TIDs. Devices that can be easily copied or
defeated (e.g. lead or wax seals) are not appropriate for use as TIDs for nuclear material.

3.3.2 Selection of TIDs

There are several types of commercially available TIDs, which have a broad range of characteristics and
capabilities. These include many different forms of physical devices, using a variety of means to indicate
tampering, e.g., cable locks, pressure-sensitive, steel padlock, type-E cup-wire, car/ball end (steel strap),
fibre optic, tamper-evident wire, and electronic radio frequency tags. The use of electronic TIDs allows
the continuous monitoring and near real-time alarm if the nuclear material item protected by the TID is
opened.

TIDs should be appropriate for the intended use, whether assuring the integrity of an item, a storage
cabinet or a whole room. TIDs can also be used to ensure that equipment is not used inappropriately. The
TIDs should be capable of withstanding the working environment, e.g., temperature, moisture, repeated
handling, radiation or chemicals without any degradation that could allow tampering or be mistaken for
evidence of tampering. The acceptability of TIDs should be based on engineering studies. These should
prove the appropriateness for the conditions of use through an evaluation of the attributes of the device in
relation to the time needed to defeat the tamper indicating features, e.g., evaluation of manufacturer’s data
and field tests. Each type of TID should be approved for use on a case-by-case basis by the facility and/or
the State competent authority.
3.3.3 Limitations of and precautions for TIDs

TIDs have weaknesses that can be exploited. A TID would fail to perform its function if it could be opened and reclosed without leaving any indications of tampering. The question is not whether unauthorized persons can defeat the TID, but whether they can do so given the time and resources available under the constraints imposed by the other security measures in place. For example, when a TID is used in a high security material access area, an adversary will be limited in what tools or chemicals they can bring into the area and may have only a few minutes to defeat the TID.

Substitutions

All TIDs are vulnerable to being destructively removed and replaced by new TIDs. Under this scenario, the potential exists for a TID to be removed and replaced with an identical TID.

TIDs should be uniquely identified in such a way that their identity cannot be duplicated. All users of TIDs should require assurance from the manufacturer of the TIDs that they are unique, that TIDs that could be confused with them will not be supplied to other users, and that the masters will be controlled.

All TIDs should bear a unique identification (e.g. a facility-specific logo and serial number), unless a facility operator determines that based on a graded approach the less attractive material may have a TID without unique identification. If an alphanumeric code sequence is used for unique identification, then the sequence should contain enough characters to allow it to remain unique for longer than the likely lifetime of the TID design. Serial codes (parts of an alphanumeric code indicating to whom or to which area the TIDs are assigned) should be short and as simple as possible to help TID custodians quickly recognize whether the serial codes are correct. One or two characters may be added to identify the material balance area so that each TID custodian can have a unique set of TIDs. The inclusion of more than two leading zeroes (e.g., 0000012345) should be avoided. If the numbering sequence is exhausted, facility operators should take steps to ensure that duplicate numbers are not used. To facilitate the recognition of serial codes and reduce manual recording errors, a bar coding system is recommended. The barcodes should preferably be printed directly on the TID.

Removal and reapplication

TIDs are vulnerable to being removed and reapplied. Clear installation instructions describing proper application and uses of TIDs should be readily available to relevant authorized personnel, but not to others. For example, there have been cases where TIDs consisting of braided metal wires were improperly applied, leaving a significant amount of extra wire in the looped portion of the TID enabling
the wire to be cut and replaced into the trap. Proper application of TIDs (e.g., pulling the excess wire all the way through the trap) is essential to prevent this type of failure.

Pressure sensitive TIDs are also subject to removal and reapplication, so it is important that facilities consider the surfaces to which pressure sensitive TIDs will be applied and the solvents which could be used to aid in removal of such TIDs. There are also cases where plastic TIDs were applied to surfaces where the TID had not been properly tested for leaving evidence of removal. Manufacturer recommendations should be followed on what TID should be used based on the application conditions.

Alterations

The design and use of TIDs should be such that it is not possible to alter recorded data on the TID, including the unique identifier, without the alteration being apparent. In the past, pressure sensitive TIDs often served as container labels on which the operator wrote information, such as the nuclear material item identification number or net weight. With modern computerized systems, the serial identification number, which is permanently printed on the TID, may be the only recorded information, and a computer system then uses that number to correlate the container with separately recorded nuclear material item identification and measurement data. If data needs to be manually recorded on TIDs, the facility operator should establish that this information cannot be erased or washed off without the alteration being readily apparent.

The use of a simple barcode and scanner may aid in identification. Barcodes can be applied to many types of TID, including pressure sensitive and cable-type TIDs. Facility operators should not rely solely on a TID serial number for container identification because removal or attempted removal of the TID may render the serial number unreadable, and resulting in loss of access to information about the contents of the container. Container numbers that are separately marked on containers will help facilities identify the container and its supposed contents even when the TID has been removed or destroyed. Pairing of codes (one on the TID and one on the container) may be used to ensure that TIDs remain attached to the proper container.

Facilities should control computerized or handwritten data associated with TIDs on containers to prevent or detect any attempt at unauthorized alteration of that data. A TID might be defeated and the NMAC records altered to reflect the quantity left in the container. If neither falsification were detected, the theft would be discovered only as part of the inventory difference at the time of the next physical inventory taking.
3.3.4 Features of a TID programme

A TID programme should include the following features:

— TIDs with unique serial identities, combined with unique information that identifies the facility using the TID;

— TIDs applied in a manner that makes undetected removal difficult;

— TIDs applied in a manner that ensures that the contents cannot be removed from the sealed container without compromising the integrity of the tamper indicating device or the container;

— Measures (such as continuous observation) to protect the contents during the time between measurement and application of the TID;

— The two person rule used when applying, verifying, removing and destroying TIDs;

— TIDs that are able to withstand exposure to the environment to prevent alteration that might be confused with tampering (thereby causing a false alarm);

— New, unused and removed (until destroyed) TIDs securely protected;

— The inventory of unused TIDs verified periodically;

— TIDs only applied and removed by individuals authorized for that purpose;

— Formal procedures providing instructions related to all parts of the TID programme;

— Personnel working with TIDs properly trained on all aspects of the programme;

— Records of TID application, verification, and removal (including the date of use, the identity of the people who applied the TID, the identity of the container to which the TID was applied, and the TID’s identification number);

— Measures to prevent alteration of records concerning containers protected by TIDs;

— Destruction of TIDs that have been removed to ensure they cannot be reapplied; and

— Procedures for auditing or inspecting the TID programme.
3.4 NUCLEAR MATERIAL SURVEILLANCE

Material surveillance systems may be used to detect unauthorized access to or movement of nuclear material. Access to nuclear material by an individual who is not authorized for the access is a concern to the nuclear security programme of a facility. Material surveillance as described in this publication refers to material surveillance measures implemented by the facility operator as part of its nuclear security programme. Surveillance performed for purposes of IAEA Safeguards is not addressed in this publication.

Depending on the quantities and attractiveness of nuclear material, a graded approach to implementing a material surveillance programme should ensure that:

— Only authorized and knowledgeable personnel who are capable of detecting incorrect or unauthorized actions are assigned responsibility for surveillance of nuclear material;

— Controls are sufficient to ensure that a lone individual cannot gain access to a secure area;

— All people in areas that contain nuclear material are under constant surveillance (e.g. the two person rule or equivalent surveillance) at all times the area is not locked and protected by an active alarm system;

— Unauthorized or unaccompanied authorized personnel cannot enter the storage/processing area undetected when the door is unlocked or open;

— In the case of higher quantities and more attractive nuclear material when the two person rule is utilized as a material surveillance method, the two authorized people are physically located where they have an unobstructed view of each other and/or the nuclear material and each person is capable of detecting unauthorized or incorrect procedures;

— Nuclear material in use, process, or storage is under material surveillance, alarm protection or protected by other approved equivalent protection;

— Control measures are established at waste disposal points. They should be monitored to ensure they are not used to remove nuclear material with the waste without authorization. Ventilation ducts, drains, or other penetrations of the facility structure should be monitored, e.g. by using non-destructive assay equipment to detect the unauthorized removal of nuclear material through any of these penetrations.
The NMAC organization may benefit from the monitoring done by other staff of the facility, such as environmental monitoring. Arrangements should be made for the personnel doing such monitoring to promptly notify the NMAC and/or physical protection personnel of any indication of unauthorized removals of nuclear material.

All movements of nuclear material should be authorized prior to the movement. Material surveillance measures can be designed and implemented to ensure nuclear material is not moved unless the appropriate personnel have authorized the movement. Local audible alarms are one measure that may be used to monitor nuclear material so that any unauthorized movement or access is made known to facility personnel who can provide the appropriate response. Facility personnel may be assigned to perform visual surveillance to ensure nuclear material is not accessed or moved without the appropriate authorization. More sophisticated equipment may be used to monitor nuclear material whose unauthorized removal would result in severe consequences to the facility and/or the State. An example of the more sophisticated equipment might be the monitoring of the flow of enriched uranium solution between tanks using a differential pressure manometer (dip tube technique).

Material surveillance can be used to detect unauthorized use of equipment used in nuclear material processing and storage. An insider who has authorized access to an area containing nuclear material may be able to adjust or damage equipment that is used to provide information related to nuclear material. For example, measurement equipment could be adjusted to show a measurement quantity greater than the actual measurement of the contents of the container. The false measurement could then be used to hide unauthorized removal of nuclear material. Tampering with the surveillance equipment could result in misleading or incorrect information regarding nuclear material, which could be used to mask the unauthorized removal of nuclear material.

Material surveillance can provide ongoing information about the status of equipment and nuclear materials. Such surveillance should ensure that materials are in authorized locations, that the location information is up to date, and that any unauthorized material flows and transfers are detected. The NMAC system should be able to produce, within a timeframe specified by the State, a list of nuclear material items and their related information to support response to an emergency situation should the need arise. Real-time surveillance can provide information to the appropriate personnel about unauthorized activities involving nuclear material or the equipment used with nuclear material.

Material surveillance should be considered for use in all areas that require or are designed for material containment. Material surveillance measures should be implemented to complement containment of
nuclear material and/or to work in combination with containment. However, material surveillance measures may be applied without containment measures. The use of surveillance methods in containment areas allows the evaluation of any indication of breach of containment. Surveillance measures should also be applied to equipment such as glove boxes or to areas where activities related to nuclear material are performed, such as the shipping or receiving of nuclear material. Both radioactive and non-radioactive waste streams should be monitored to ensure nuclear material is not removed through unauthorized activities.

Surveillance measures may include administrative and/or technical measures and should be implemented in combination with other measures, such as authorization and access control to provide defence in depth. The type of surveillance measures should be selected based on a graded approach that considers the quantity and overall attractiveness of the nuclear material. Surveillance equipment should be appropriate for the situation where the equipment will be used, e.g. motion detectors may not be effective in a busy processing area during operating hours.

3.4.1 Administrative measures

Administrative measures should be used to ensure that only authorized personnel are allowed to work with nuclear material and/or that nuclear material is under continuous observation during processing. The measure(s) chosen should be appropriate for the situation and the type and quantity of nuclear material to be protected.

Administrative measures can often be enhanced or enforced by implementing them in combination with technical measures. For example, when the two-person rule is applied to the entrance to a storage area, the doors could be locked with devices that require opening by two authorized people to ensure a single individual cannot enter the storage area alone.

The administrative controls should include a list of personnel authorized to open the storage or processing area. The area should be opened only by a combination of two of the people from the approved list of authorized personnel. The technical controls might be a biometric scanner or a fingerprint scanner to ensure that at least two people from the approved authorized list enter the area to ensure that a single individual cannot enter the area alone.

To be effective, personnel allowed to work with nuclear material under administrative measures, such as the two-person rule, should be authorized and trained to ensure they are capable of detecting and reporting unauthorized activities in a timely manner.
3.4.2 Technical measures

Technical measures for surveillance may include equipment to observe and control nuclear material and/or its associated equipment. Technical measures should be capable of providing real-time or near real-time alarms to indicate the failure of the surveillance or containment measures.

Examples of technical measures may include:

— Video surveillance,
— Weight sensors,
— Radiation monitors, and
— TIDs with radio transmitters.

Video surveillance

Equipment used for video surveillance may include different types of video camera and equipment for analysing and storing the video data. An example of basic video surveillance is a system where a direct video signal is displayed on a screen that is monitored by a guard or other personnel who are responsible for surveying the area or operations within the area.

To be capable of providing timely alarms, effective surveillance, including video surveillance, should have features such as:

— An independent power supply which provides the capability to keep the equipment operational in the case of an electrical outage;
— A system for recording and archiving so that data can be reviewed and analysed later if needed;
— A method for protection against data falsification;
— A means of using different approaches to analyse the video data and activate an alarm where necessary, such as
  o Using the sequence of normal operations as a basis for comparison to indicate where any movements or sequence of movements outside the normal sequence; or
Using the normal work hours as a basis for comparison to indicate when activities are being attempted outside normal work hours.

When considering the use of video surveillance, the location of cameras, the central video data server and monitoring stations should be evaluated. Access to cameras and data should be controlled to prevent unauthorized activities.

**Weight sensors**

Another possible surveillance measure is the use of weight sensors to monitor containers of nuclear material. For example a system of electronic weight sensors, connected through a network to server monitors, may be used to place individual containers of nuclear material on the sensors. If a sensor detects a large or rapid change in the weight of a container, an alarm should be activated. To avoid false alarms when using weight sensors, there should be an allowance for fluctuation of weights that may occur naturally, such as those resulting from the change in humidity or air pressure when a door is opened.

**Radiation portal monitors and other radiation monitoring equipment**

Radiation portal monitors could be used to monitor the movement of nuclear material. For example, radiation portal monitors used to screen personnel as they leave radiation areas could be considered a method of surveillance. Radiation portal monitors should be installed on locations or equipment such as entrances, gates, technological (processing) pipes or ventilation systems to ensure that all possible pathways for removal of nuclear material are monitored for unauthorized removal. Before installing radiation portal monitors, an evaluation of the area for installation should be carried out. For example, installing radiation portal monitors on doors in an area where the windows can be easily opened might not be worthwhile.

The radiation background in an area should be analysed to establish threshold values for the portal monitors. The sensitivity of the monitors should be controlled to adjust for the radiation background and to provide good sensitivity for security needs while maintaining a reasonable false alarm rate. The sensitivity threshold value should be protected as sensitive information to prevent an insider from using that information to determine the amount of material that could be removed undetected. The threshold level should be periodically verified to ensure the level has not been changed to allow unauthorized removal of nuclear material.

Alarms from radiation portal monitors can include audible alarms, visual alarms and radio alarms to alert appropriate personnel to the activation of the alarm. All alarms should be investigated. The appropriate
personnel, including those responsible for physical protection, safety and NMAC, should transfer alarms where appropriate, based on a graded approach, to the facility’s central alarm station for prompt investigation and resolution.

In addition to radiation portal monitors, the surveillance systems may include instruments such as handheld radiation monitors or contamination monitors. Alarms or unusually high readings from any radiation monitors may indicate that nuclear material has been removed without authorization.

**X ray equipment and metal detectors**

X ray and metal detection equipment may be deployed to ensure that no unauthorized equipment or other objects, such as a shielded container or tools not needed for the authorized tasks, is taken into a nuclear security area and that no nuclear material is removed from the area without proper procedures being followed. For example, the delivery of personal protective equipment should be closely monitored to ensure that unauthorized material or equipment is not introduced to the area at the same time. When the protective clothing or equipment needs to be removed from the area, it should also be monitored to ensure that no nuclear material has been hidden for unauthorized removal.

An alarm from a metal detector may be an indication of shielding being used to conceal the unauthorized removal of nuclear material and should be investigated.

X ray equipment may reveal unauthorized items concealed in material or equipment.

**TIDs with radio transmitters**

Some modern TIDs have the capability of exchanging radio signals with a computer server using wireless methods. In these cases an alarm can be activated by:

- The TID sending a signal to the server that the integrity of the TID has been violated, or
- The server activating an alarm if the TID does not respond to a request from the server for validation of the device’s integrity.

Monitoring nuclear material using these methods provides near real-time surveillance. Measures should be taken to protect the signals from falsification to conceal unauthorized removal of nuclear material.
Management of surveillance systems

No single surveillance measure should be considered sufficient to ensure timely detection on its own: a combination of measures is most effective. For example, the use of the two person rule, video surveillance, TIDs and radiation portal monitors at entrances and exits may all be used simultaneously to ensure no unauthorized removal of nuclear material occurs. These layers of containment and surveillance should be applied in a coordinated manner to provide defence in depth based on the quantity and attractiveness of the nuclear material being protected. Compensatory measures should be applied when repairs or maintenance take parts of the system out of service. For example if a door or access control equipment to the entrance of an area where nuclear material is stored is being repaired, a guard post may need to be set up temporarily to control entrances and exits to and from the area to protect the nuclear material.

No single individual should be able to control all surveillance systems or signals from surveillance systems. Automating the alarms and responses should be considered for ensuring efficiency and protection from possible insider threats.

3.4.3 Evaluation of surveillance systems

Periodic evaluation should be conducted of the area where surveillance systems are installed to ensure the design and application of the systems are effective in detecting unauthorized removal of nuclear material. All factors that may degrade performance of surveillance systems should be taken into account. For example, if the two-person rule is being used, the evaluation should ensure that both people are working close to each other and they are positioned so they can detect unauthorized activities. If cameras are used for surveillance, the lighting in the surveillance area and the field of view of the cameras should be adequate to allow clear viewing of area on the associated monitors. Measures should be put in place to ensure that materials and equipment that may be introduced to the area for operational reasons do not obstruct the field of view of the installed cameras. Compensatory measures should be identified and available in the case of failure of the primary surveillance system.

To confirm the effective operation of surveillance systems, procedures should be developed and implemented to describe the operation of each such system. These procedures should address how each system should function as well as how to identify irregularities\(^1\) that may be detected by the system. The

\(^1\)The term irregularity is used to indicate an unusual event or condition that could be an indication of unauthorized removal or misuse of nuclear material.
surveillance systems should be tested routinely to ensure effective performance. Any defects identified should be corrected and the system should be re-tested to ensure appropriate performance.

The effectiveness of surveillance systems depends on the people operating them. Qualified, alert personnel will notice inappropriate actions that may indicate unauthorized removal of nuclear material. Some surveillance systems may not provide adequate coverage of an area to be protected. An evaluation should be performed to ensure coverage is complete and effective before allowing dependence on the surveillance system for protection.

3.5 PROGRAMME FOR MONITORING NUCLEAR MATERIAL ITEMS

A programme for monitoring nuclear material items (referred to as item monitoring) should be implemented using an approach that takes into consideration the consequences of loss or misuse of the nuclear material. The State competent authority (or the facility, if not required by the State) should establish the rules for implementation of such a programme based on the type, quantity, form and attractiveness of the nuclear material.

Item monitoring using a statistical sampling plan should be conducted between physical inventory takings. The sampling method and population to be monitored should be defined. Item monitoring can be conducted without interrupting processing operations.

The objective of monitoring nuclear material items is to improve the quality and confidence of the NMAC system and to detect losses in a timely manner, including unauthorized removal of nuclear material. An item, as described in this publication, is a discrete container of nuclear material or a discrete piece of nuclear material—any nuclear material that is identified with a unique identity in the facility’s records system. Monitoring of nuclear material items is intended to address all nuclear material that is not subject to process monitoring. Individual nuclear material items that have been grouped into a larger container should be identified in the records system as a single nuclear material item. In such cases, the larger nuclear material item forms the basis for item monitoring.

The frequency of item monitoring should take into consideration the attractiveness of the nuclear material and the level of surveillance and containment that is in place in the area where the nuclear material is located. Another factor to consider is the trending analysis of past item monitoring results: for example, a history of detecting a relatively large numbers of discrepancies may indicate the need for increased monitoring frequency. The monitoring frequency should be identified and documented in the appropriate facility documents.
Discrepancies that are identified during the item monitoring process should be investigated and resolved and the facility’s records should be corrected if needed. If a discrepancy results in an irregularity, it should be reported to the State’s competent authority as required.

An example of a method of item monitoring is shown below.

Monitoring of a stratum — a group of nuclear material items that have similar chemical and physical parameters — can be achieved by verifying a randomly selected sample of items from the stratum. The number of nuclear material items to be verified from the stratum (the sample size) should be specified, and documented in a written procedure, along with the rationale for choosing the sample size.

The following equation provides an example of a formula for calculating the sample size needed for item monitoring of a certain stratum:

\[ n = N (1 - \beta^{1/d}) = N (1 - \beta^{x/G}) \]

Where:

- \( n \) = number of nuclear material items to be randomly selected (sample size);
- \( N \) = total number of nuclear material items within the population to be tested (the stratum);
- \( \beta \) is such that \((1 - \beta) = \) the desired probability of obtaining at least one discrepancy among the sample of items chosen for verification (e.g., for a 99% probability, \( \beta \) would be 0.01);
- \( G \) = the quantity of material that the monitoring is intended to detect;
- \( d \) = the minimum number of individual discrepancies that could together make up the quantity to be detected;
- \( x \) = the maximum mass of nuclear material within a single item for the stratum being tested; and

A discrepancy is a missing nuclear material item or a container with some or all of its nuclear material contents missing.

The number \( d \) is a function of the amount of nuclear material per item. If the nuclear material content varies from item to item, the largest value should be used to calculate \( d \) to ensure that \( n \) is large enough to guarantee that the probability of detection is at least 99%. This results in a conservative value of \( n \). The \( 1/d \) exponent is equivalent to \( x/G \).
As an example, assume that a given nuclear material item stratum consists of 1000 items, each containing 100 g of $^{235}\text{U}$. If an insider were to remove 5000 g or more of $^{235}\text{U}$ from this item group, the minimum number of discrepancies would be 50 (100 g $^{235}\text{U}$ per item multiplied by 50 items = 5000 g $^{235}\text{U}$). Using the above formula, the sample size $n$ would be 88 items. Accordingly, there would be a 99% probability that at least one of the 50 or more discrepancies would be among the 88 selected items.

An irregularity should be declared if, during the initial test, two or more discrepancies are encountered. If only one discrepancy is encountered during an item monitoring test, a second test should be immediately performed, usually with a sample size of $2n$. If one or more discrepancies are encountered in the second test, an irregularity should be declared and an investigation should be initiated.

### 3.6 MONITORING NUCLEAR MATERIAL DURING PROCESSING

Nuclear material that is undergoing processing can be vulnerable to theft or misuse, since such material is not in a vault and not in the form of ‘an item’. It is important to maintain control of nuclear material even while it is being processed. Just as a container of nuclear material could be removed from the location where it is stored, nuclear material could be removed from equipment where it is being processed or from a processing line.

Establishing a programme for monitoring nuclear material undergoing processing begins with developing an understanding of the chemical, physical and technological processes at a facility. The State competent authority may establish the quantities that should be detected by monitoring techniques. The processes in a facility should be divided into processing units based on factors such as the amount of nuclear material and/or the chemical processes used, so that nuclear material input and output can be measured or estimated for each processing unit. Input–output differences (IODs) are the differences between the amount of nuclear material or product containing nuclear material that enters a processing line or unit and the amount of nuclear material that exits the line or unit. A processing unit could be a single tank, a few tanks or a whole technological line. Measurements from instruments used to control the process for operational purposes can be used to monitor nuclear material during processing, for example flow meters, pressure gauges, temperature gauges, volume measuring devices or manometers. In some cases additional measurements may be necessary to complete the determination of the IODs.

It is possible to use statistical evaluations for monitoring nuclear material in a processing area if the process, equipment, material and measurements are not being changed. The usual procedure for statistical evaluation is that the expected difference between the input and the output is evaluated for each
processing unit. The mean IOD for a stable process is usually based on previously established data. This value could be estimated as an absolute value (e.g., 300 g) or as a relative value (e.g., 2% of input).

Process monitoring should take into account how nuclear material is processed. It can be done, for example, by batch (if only one batch is in the processing line at once), for a technological cycle (sometimes referred to as production cycle or campaign) between cleanouts (when a few batches may be being processed at the same time within the processing line) or as a continuous process (where processing lines do not have cleanouts and may be working without stops).

For each processing unit, each calculated IOD should be compared to the expected IOD to determine whether the difference between the two (loss or gain) is statistically significant. Input to a processing unit may be relatively easy to determine, but output may include scrap or nuclear material that did not meet the requirements for the process, and all nuclear material, including scrap and waste, should be included in the estimate of output. Differences that exceed an established threshold (for example, a defined number of standard deviations) are considered to be significant. This comparison is more meaningful if the standard deviation of the calculated IODs is small. If large IODs are common (which might hide a loss) or if they vary widely (large standard deviations), it might be necessary to divide the process into more processing units.

Such statistical evaluations of IODs may be useful for industrial processing facilities in which a relatively small number of processes are used repeatedly. For a research facility, where there may be too much variation in processes to allow process monitoring, it may be more appropriate to establish other measures for control of the material.

It can be difficult to detect removal of nuclear material from a chemical or physical processing unit because processing losses, e.g. residual material in the process equipment, scrap or samples, are normal and expected. It is important that sufficient information about the processing unit is collected and analysed to understand the normal process variations that may occur.

An IOD should be calculated for every process. If processing is done by batch then the input–output analysis is usually done by the batch. If processing is done by technological cycle (a few or many batches between cleanouts) a balance should be calculated for the whole cycle (between cleanouts). If processing is continuous, a frequency for evaluations should be established and an evaluation should be done for a given time. The frequency depends on the quantity and attractiveness of the nuclear material being processed and the consequences of losing it. If the time between the beginning and the end of the evaluated process is too long, interim evaluations should be considered.
All statistically significant IODs should be investigated (and reported if required) to determine whether nuclear material could have been removed without authorization from the equipment where it was being processed. It may be necessary to shut down a process until the difference has been resolved. Cumulative trends should be evaluated as well as individual IODs.

If the process, equipment, material or measurements are changed (for example a change in technology is introduced or one of processing units is replaced) then control values such as expected IODs, their standard deviations and significance thresholds should be re-evaluated and adjusted, as needed.

An example of the statistical evaluation for monitoring nuclear material in a processing area:

Suppose a processing unit processes a mixture of plutonium oxide and uranium oxide powder. Batch sizes are approximately the same. The material put into the processing unit undergoes three operations: jet milling, sieving and lot blending. After blending, the material is removed from the processing unit. Residues are cleaned out by a routine cleaning procedure and are negligible. The process IOD is calculated between the amount of material put into the processing unit and the amount of material taken out of the processing unit.

Each evaluation test should have a defined action threshold that, if exceeded, initiates alarm resolution procedures for determining whether an unauthorized removal of nuclear material has occurred. Usually, such a threshold is set by a basic model as follows:

\[ A = Q - x_m - K\sigma_x \]

Where:

- \( A \) = action threshold;
- \( Q \) = goal quantity of material (or “significant” quantity);
- \( x \) = the quantity of interest, usually the IOD;
- \( x_m \) = mean value of \( x \);
- \( K \) = factor (number of standard deviations) chosen to reflect the desired probability of detection (for example 1.65 standard deviations to achieve a 95% detection probability);
- \( \sigma_x \) = standard deviation of the quantity of interest;
Suppose that for this unit test, the goal quantity of material is 5000, the quantity of interest is 2300, the mean IOD is 1539, and its standard deviation is 483.

\[ A = 5000 - 1539 - 1.65 \times (483) \]

\[ A = 2664 \text{ grams} \]

3.7 PHYSICAL INVENTORY TAKING

During physical inventory taking, procedures should be put in place that would prevent an insider from falsifying the accounting records to cover the unauthorized removal of nuclear material. Such a procedure should require that at least two knowledgeable, trained people do the physical inventory taking. These two people should independently verify the item identification numbers, the integrity and identification of the TIDs, the integrity of the containers, and the location of the nuclear material items prior to completion of the physical inventory taking. After completing the listing of the physical inventory, a statistical sample of the population of nuclear material items could be generated to allow verification of the identity, location, TIDs, and measurements of the nuclear material as it was listed during the physical inventory taking. The verification should be carried out by knowledgeable, trained people other than those who did the initial physical inventory taking.

4. INTERFACE WITH PHYSICAL PROTECTION SYSTEMS

Day-to-day activities that involve nuclear material require ongoing coordination between the parts of the operating organization responsible for NMAC and physical protection. One example of such an interface might be when nuclear material needs to be moved out of a locked and alarmed storage area for relocation to another area or for processing. Both organizations should be involved in the activity and its planning. Each day when nuclear material areas are initially accessed or when the areas need to be secured for the end of the work shift, both NMAC and physical protection personnel should be involved to ensure all protective measures are taken. Daily interface should improve the sharing of information between the personnel responsible for the two aspects of security.

Response to an investigation of irregularities should be coordinated with physical protection measures. For example if there is an indication (e.g. a broken TID on a vault door) that nuclear material may be missing, physical protection personnel should be notified and physical protection alarms should be reviewed. Similarly, if there is an indication that a nuclear material irregularity has occurred (e.g. a nuclear material item is declared to be missing), physical protection alarms should be reviewed. The
investigation of physical protection alarms in an area should take into account the facility’s nuclear material accounting and control systems. One or both systems may provide information that is beneficial to the overall investigation.

Facility procedures should specify when NMAC personnel should notify physical protection personnel and involve them in the investigation. Some situations call for immediate notification, while others may allow for initial investigation by NMAC personnel only before involving physical protection personnel.

5. MOVEMENTS OF NUCLEAR MATERIAL

Nuclear material is particularly vulnerable during movements. Continuous surveillance is critical throughout the whole packing and shipping or transfer process. Nuclear material should be measured prior to shipment out of the facility or transfer between material balance areas. If nuclear material cannot be measured prior to movement, a technically defensible estimate should be applied and other controls should be implemented to ensure that unauthorized removal does not occur until a measurement can be done. Measures should be taken to ensure that unauthorized nuclear material is not added to the authorized movement. There should be controls in place, such as radiation monitoring, to ensure that containers labelled as “empty” are actually empty and do not contain nuclear material.

5.1 SHIPMENTS OF NUCLEAR MATERIAL

The facility operator should develop written procedures to ensure the control of nuclear material during shipment. These procedures should address each type of nuclear material item to be shipped.

Measures should be taken to ensure that the shipment is authorized and that the receiver is authorized to receive the nuclear material. Preliminary notification should be made to the State competent authority with information regarding the shipment, as required. The shipper should notify the receiver prior to the shipment of the intent to ship the nuclear material. The shipper should ensure that the shipment meets all requirements to transport the material.

Shipments of nuclear material should be made using only approved and certified containers in accordance with relevant international obligations and domestic legislation. Where shipments take place across national borders an export licence may also be required.

The parameters of the nuclear material items to be shipped should be measured before the shipment occurs. The nuclear material items should have a TID applied and the material should be kept under an
effective material surveillance programme during the movement process, including the preparation for
movement and transport. Prior to the nuclear material items leaving the facility, the identity and integrity
of the TIDs should be verified. In some situations other parameters, e.g. gross weight, should be verified
before the shipment. For example if the nuclear material to be shipped was packaged several months
before the shipment, the parameters of the nuclear material should be checked immediately prior to
shipment.

In preparation for the shipment, the shipper should ensure that the packaging and shipping documents
include unique identification of all nuclear material items to be shipped. There should be a list of all
nuclear material items being shipped, including physical and nuclear parameters (nuclear material type
and quantity, content and enrichment of each item (if required), and gross weight). The measurement
uncertainty should be included in the documentation, if required by the State. The shipping containers and
TIDs should be visually inspected for any signs of tampering. Once the nuclear material has been shipped
the shipper’s book inventory should be updated accordingly.

5.2 RECEIPTS OF NUCLEAR MATERIAL

Written procedures should be established to instruct facility personnel on the proper actions to take when
receiving nuclear material from another facility, including steps necessary for investigating and resolving
discrepancies that exceed the established control limits.

Checks should be performed by the receiving facility to confirm that the received material shipment is the
one that was planned and to ensure that any unauthorized removal is detected. The checks should be
performed by a minimum of two people and should be specific for the type and form of the nuclear
material in the shipment. Checks should include:

— Verification of the integrity of the shipping containers;

— Verification that the nuclear material item identities are the same as those given in the shipping
documents;

— Verification of the number of nuclear material items in the shipping container as stated in the
shipping documents;

— Verification of the identities of any TIDs and their integrity; and
— Verification measurements of nuclear material parameters, such as isotopic composition, which are required by facility procedures.

The State’s competent authority should specify the time within which all receipt activities should be completed and the criteria for shipper–receiver differences (SRDs). The information concerning the mass of nuclear material should be compared to the information contained in the shipping documentation. Nuclear material items should be entered in the facility records, including in the book inventory, following receipt verification. Information concerning the contents should be adjusted, if necessary, when the receiver’s measurements are completed. This may be addressed in the agreement between the shipper and receiver.

Nuclear material received from another facility should be isolated to prevent entry into a process prior to measurements being completed and accepted. Any significant discrepancies (differences between what the shipper recorded and the receiver found) discovered during the verification activities should be reported to the shipper and the State’s competent authority. Discrepancies should be investigated and resolved following the prescribed procedures. Nuclear material items under investigation should be isolated, secured and not processed or shipped until all discrepancies are resolved. A receipt of nuclear material cannot be completed until all discrepancies have been resolved.

SRDs should be evaluated as summarized in the following section of this publication.

5.3 SHIPPER–RECEIVER DIFFERENCE EVALUATION

Evaluation of differences between the quantities of nuclear material shipped and received [4] is important for ensuring that the quantity of nuclear material stated by the shipper is correct and that the receiver received the quantity of nuclear material stated by the shipper. Such evaluations require measurement of the nuclear material by the receiver and comparison of the receiver’s measurement to that of the shipper. The difference between the receiver’s and the shipper’s measurements is the shipper–receiver difference (SRD).

The shipper and receiver may have contractual agreements where the acceptable range for differences, based on a technically defensible evaluation, is documented. The acceptable differences should be based on State regulations or on State approval of the range determined by the shipper and receiver. Usually the contractual agreement between the shipper and receiver includes the requirements for controlling the nuclear material, the accounting information, and the criteria for acceptability of SRDs.
Complete evaluation usually includes receiver’s measurements of the weight of nuclear material items and measurement of samples (taken from the nuclear material items by the shipper or receiver) for elemental concentration and isotopic composition. Sometimes other measurements are more appropriate for evaluation; for example, cylinders of low enriched uranium UF$_6$ received at a fuel manufacturing facility can be measured by using non-destructive assay equipment to determine $^{235}$U isotopic concentration. In situations where measurement of the nuclear material mass is not immediately possible, gross weight should be measured.

Measurements should be made within the timeframe established by the State, and measurement results should be documented. Records should be updated, if appropriate, to reflect the receiver’s measured quantities.

A written procedure should be developed to provide guidance on the evaluation of SRDs. Any SRD that is statistically significant should be investigated and resolved, and the results of the investigation should be documented. The facility should establish criteria for the maximum acceptable SRD, in accordance with State requirements. The limits should be appropriate for the type and form of the nuclear material being measured.

SRD evaluation consists of comparing the difference between the shipper’s and receiver’s quantities to a critical value that is usually calculated using the shipper’s and receiver’s measurement variances. The following is an example of a basic model for calculating the total standard error of parameters that should be measured (gross weight, elemental concentration, and isotopic composition):

$$\text{total standard deviation} = \sqrt{(\sigma_s)^2 + (\sigma_R)^2}$$

where:

- $\sigma_s$ = shipper’s measurement standard error
- $\sigma_R$ = receiver’s measurement standard error

If the shipper’s measurement uncertainty values are not available, the receiver can use the receiver’s measurement uncertainty as the shipper’s measurement uncertainty, in which case the measurement standard error is $(2\sigma_R)^{1/2} = 1.414\sigma_R$. The receiver may also use the International Target Values [9] or set the value of the shipper's uncertainty to zero.

The following is an example of a shipper–receiver evaluation:
Suppose a fuel manufacturing facility receives a single cylinder filled with low enriched uranium (less than 5% enrichment). The shipping documents indicate that the gross weight of the UF₆ cylinder is 8101 kg. The measurement uncertainty for the scale used by the shipper is 0.05%. The fuel manufacturing facility weighs the cylinder and obtains a gross weight of 8080 kg. The measurement uncertainty for the scale used by the fuel manufacturing facility is 0.10%.

The State competent authority has established a requirement that the critical value for a SRD is twice the total standard deviation. If the limits are established at two standard deviations, the risk of concluding that there is a difference, when in reality there is no difference, is approximately 5%.

Using the example above, what is the amount of the SRD and is it significant?

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipper gross weight:</td>
<td>8101 kg</td>
<td>0.05%</td>
</tr>
<tr>
<td>Receiver gross weight:</td>
<td>8080 kg</td>
<td>0.10%</td>
</tr>
<tr>
<td>Shipper–receiver difference:</td>
<td>8101–8080 = 21 kg</td>
<td></td>
</tr>
<tr>
<td>Total measurement variance:</td>
<td>( (8101 \times 0.0005)^2 + (8080 \times 0.0010)^2 = 81.693 )</td>
<td></td>
</tr>
<tr>
<td>Total standard deviation:</td>
<td>9.038 kg</td>
<td></td>
</tr>
<tr>
<td>Critical value (2× total standard deviation):</td>
<td>± 18.076 kg</td>
<td></td>
</tr>
</tbody>
</table>

Because the SRD (21 kg) falls outside the acceptable limits (±18.076 kg), it is considered to be significant and requires further investigation.

When an SRD exceeds the acceptable limit, an investigation should be conducted. An excessive difference could be the result of faulty measurement by the shipper and/or the receiver or human error during preparation of the shipping documents. However, it could also mean that nuclear material has been removed (or added) without authorization. Procedures should be developed to specify the steps involved in investigating a significant SRD, including instructions on how such a difference should be resolved. Resolution of a significant SRD may need independent measurements by a third party.

Procedures for evaluating SRDs and for investigating and resolving significant differences [4] should conform to the requirements established by the State competent authority and, if applicable, to the State’s Safeguards Agreement with the IAEA.
In establishing the procedures, consideration should be given to such factors as the models used to estimate measurement uncertainty, the number and type of measurement systems used to produce the shipper’s and receiver’s and the precision of the scales used.

In addition to calculation and evaluation of SRDs for single nuclear material items, SRDs could be calculated and evaluated for batches or for entire shipments. Cumulative SRDs should also be calculated and trends should be analysed and evaluated because they can reveal systematic errors or protracted unauthorized removals of nuclear material.

Significant SRDs should be reported to the shipper and the State’s competent authority, as required by the State.

5.4 TRANSFERS AND RELOCATIONS WITHIN A FACILITY

Written procedures should be put in place to provide clear directions on transferring nuclear material between material balance areas to help deter and detect unauthorized removal or substitution of nuclear material during movement. These procedures should include instructions for investigating and resolving any differences identified during the checks.

5.4.1 Transfers between material balance areas within a facility

Before transfers are made between material balance areas, they should be authorized in accordance with the facility’s formal procedures. Personnel in the consigning material balance area should notify the accepting material balance area of the quantity and form of the materials to be transferred. The receiving material balance area should confirm that receipt would not violate any operational, regulatory or safety limits. The personnel consigning the material from one material balance area should not be the same as those accepting the nuclear material in the other.

Prior to transfer, the consignor should confirm that the nuclear material being prepared for shipment is the material that is intended for transfer. Transfers between material balance areas should be recorded in the facility’s record system in a timely manner. The time for which the nuclear material is in transit should be minimized.

Upon acceptance of nuclear material items in the accepting material balance area, checks should be performed. Those checks should include, as appropriate:

— Verification of the integrity of the shipping containers;
— Verification of the nuclear material item identities with those given in the consignment documents;

— Verification of the number of nuclear material items in the consigning container as stated in the consignment documents;

— Verification of the identities of any TIDs and their integrity; and

— Verification measurements of nuclear material parameters, such as isotopic composition, which are required by facility procedures.

In processing facilities there may be transfers of nuclear material between material balance areas that are not in individual item form, e.g. a liquid stream that flows through a pipe from one material balance area to another. In this case controls should be established to ensure unauthorized removal does not occur during the transfer. Verification of the transfer may include the measurement of the volume, level, elemental concentration and isotopic content of material in bulk form.

Procedures should be developed for controlling analytical samples transferred to an analytical laboratory. The transfers should be made using the gross weights or net weights, if available, of the containers, including the samples. Upon completion of the analysis, the element and isotopic content should be updated in the facility’s records. (The same consideration should be given to relocations of analytical samples within a material balance area.)

Formal procedures, based on the guidance on SRDs in section 5.3 above, should be developed for investigating and resolving differences when transferring nuclear material between material balance areas.

5.4.2 Relocations within a material balance area

In some facilities a single material balance area may include nuclear material in more than one location (buildings or rooms). Relocations within a material balance area may therefore involve movements of nuclear material within a room, between rooms in a building or between buildings. Procedures for control measures should be appropriate for the type of relocation, e.g. the controls for relocation of nuclear material between buildings should be more stringent than the controls for relocations between rooms within a single building.

Relocations are usually less vulnerable than shipments or transfers, but proper attention should be paid to the preparation and conduct of the relocation, especially when it is between two buildings. A formal
procedure should be developed to instruct personnel on the appropriate actions to take for relocations of nuclear material within a material balance area.

During relocation, nuclear material should not be left uncontrolled. The containment of the nuclear material or continuous presence of authorized personnel (two-person rule) should be required. If the relocation will take place overnight or during more than one shift, the application of a TID should be considered. There should be clear agreement of the point in time at which custodial responsibility for the nuclear material changes.

When nuclear material is relocated within a material balance area, checks should be made. Those checks are normally limited to verification of the identity of the nuclear material items, the integrity of the items or their containers, the location, and TIDs, if applied. Re-measurement is normally not necessary, but might be considered if:

- TIDs will be applied to nuclear material that was previously not sealed;
- Scales or measurement equipment at the new location are more accurate than the previous location; or
- The nuclear material has not been measured for a long period of time.

Near real-time update to the records system should be made to reflect relocations of nuclear material within a material balance area. Any irregularities should be investigated and resolved in accordance with the facility’s formal procedures.

6. MANAGING NUCLEAR MATERIAL CONTROL, INCLUDING MOVEMENTS

Nuclear material control should be implemented in accordance with policies and requirements of the State competent authority and/or facility operator and taking account of IAEA guidance [1]. Elements of nuclear material control and movements of nuclear material, including movements of waste to be disposed, should be addressed in formally documented procedures.

The facility operator should ensure clear assignments of roles and responsibilities of personnel involved in control and movement activities. Personnel involved in activities involving nuclear material should be trained in the procedures for proper control of the nuclear material. Duties and responsibilities of nuclear
material custodians\textsuperscript{2} should be clearly defined and documented. Duties should be separated between personnel to prevent a single individual from accomplishing or hiding unauthorized removal of nuclear material. For example, personnel with access to nuclear material should not have the ability to make changes to records without adequate controls. Keys or combinations to secured areas where nuclear material is located should be controlled to ensure a single person cannot access the area alone. A nuclear material custodian should not have responsibility for more than one material balance area.

Separation of duties is an approach by which a process that involves nuclear material and related information is divided into steps that are performed by different persons acting independently. For example, one person weighs a container of nuclear material, and another person, acting independently from the first person, confirms the weight and enters the results of the measurement in the facility’s records. Separation of duties and multiple checks of data and operations serve as additional measures to deter and detect insider threats.

The nuclear material custodian plays a key role in the NMAC system and activities. The nuclear material custodian is responsible for the accounting and control of the nuclear material assigned to his/her area of responsibility. The nuclear material custodian should have the authority to stop work processes (or to direct the appropriate manager to stop work processes), at any time if a threat to the security of the nuclear material is detected.

Effective management of the nuclear material control measures should include configuration management to ensure that any change to any part of the measures, or any other relevant facility system, will not degrade the performance of the material control measures or overall nuclear security. Changes should be properly documented, assessed, approved, issued, implemented and incorporated in the facility documentation. The facility operator should control all changes and ensure reporting, where required, to the appropriate authority.

An example of the need for configuration management in controlling nuclear material is the monitoring of nuclear material undergoing processing. Any changes in the processing of nuclear material that can affect the nuclear material control and accounting should be coordinated with and approved by the NMAC manager.

\textsuperscript{2} The term “nuclear material custodian” refers to the individual (or individuals) assigned responsibility for overseeing the control and accounting of nuclear material in a designated area of a facility.
Another example of the need for configuration management is the installation of equipment that emits radiation in a research laboratory. If the new equipment is installed in the area near radiation portal monitors, the radiation could cause the portal monitors to alarm unnecessarily, creating what appears to be an irregularity. Careful consideration should be given when determining where to locate equipment that may interfere with other equipment that is designed to control nuclear material.

Maintenance of material control equipment should be coordinated and scheduled at the facility level to ensure that the designed defence in depth is not compromised. For example, periodic maintenance of portal monitoring equipment at the same time maintenance is being performed on video surveillance equipment in the area can create vulnerability in the material control measures.

Training and verification of knowledge of facility personnel involved in nuclear material activities should be kept current and verified before participation in scheduled activities. Personnel should be made aware of their role in nuclear security and the vulnerabilities that can be created when facility procedures are not properly followed. Other guidance is provided in Ref. [7].

7. RESPONSE TO IRREGULARITIES IN NUCLEAR MATERIAL CONTROL

Detection of irregularities can occur at any time and such detection should act as a trigger to initiate investigations into their cause. The facility operator should define what constitutes an irregularity. Procedures for response to irregularities should be developed and implemented. Facility management and the State’s competent authority should be notified of irregularities in accordance with facility procedures and the State’s reporting requirements.

Some irregularities may require involvement of physical protection personnel to implement compensatory measures to prevent unauthorized removal of nuclear material. This may involve keeping personnel within a material balance area, a building or the whole facility until the investigation is completed and the irregularity is resolved.

Each person working with nuclear material should understand their responsibility to act upon and report irregularities as part of a good nuclear security culture. Illustrative examples of possible irregularities are:

— A nuclear material item missing from its recorded location or a nuclear material item discovered that is not in the NMAC records;
— Evidence of unauthorized alteration of records (e.g. operations, nuclear material accounting, TID);

— Unexpected change in the quantity of nuclear material;

— Allegation of unauthorized removal (e.g. in an anonymous message);

— Nuclear material item found in the wrong location during item monitoring;

— Nuclear material of which there is no record found unexpectedly in processing equipment;

— Unauthorized movement of nuclear material from storage into the processing area;

— Damaged container discovered during receipt inspection;

— Damaged or broken TID discovered during item monitoring;

— Failure of a surveillance camera monitoring the input area to a process line;

— Damaged, incorrect or missing identification such as a damaged container label;

— Damage to or failure of a radiation portal monitor located at the entrance to or exit from a processing area;

— Violation of the two-person rule due to the access control system erroneously allowing entry of a single person;

— Discrepancy in the TID identification on a transfer;

— Significant difference between a measured and a recorded value of the nuclear material mass of an item,

— Statistically significant amount of material unaccounted for discovered during the determination of the material balance for a physical inventory taking;

— SRD that fails to meet the acceptability criteria established by the State competent authority;

— Contamination with fissile radionuclides (e.g. uranium or plutonium) found in an unexplained or unexpected location;
— Unauthorized access to nuclear material accounting data detected during the audit of the computer access log;

— Alarm of an active TID such as a radio frequency tag; and

— Violation of the two-person rule when one person leaves the area leaving the other member of the two-person team alone with nuclear material.

During an investigation the possibility should be considered that an irregularity was created intentionally to determine whether it will be detected in a timely manner or to disguise unauthorized removal. Some irregularities, like a nuclear material item not being in its expected location, require immediate investigation and response. A more serious irregularity would be if the nuclear material item could not be located in the material balance area, the facility or the transport unit. Other irregularities, such as finding a damaged TID on a container of nuclear material in a storage area may not appear to be a serious problem, but should be carefully evaluated, especially if there are other indications of possible tampering, e.g. a bolt cutter found in the area where the damaged TID was discovered. Investigations of all irregularities should be conducted as if unauthorized removal of nuclear material has occurred. Where possible, all nuclear material items associated with a possible irregularity should be isolated in separate storage areas until the issue is resolved.

7.1 INVESTIGATION

Irregularities should be investigated following formal procedures. Depending on the results of the investigation, notifications should be made to the appropriate facility managers and the State’s competent authority, as appropriate and/or required. A graded approach should be applied to irregularities, e.g. nuclear material that is more attractive to an adversary should be given greater consideration than less attractive material. Time limits should be established, to the extent possible, for investigating irregularities. The area or nuclear material item involved should be isolated to prevent any further changes to the item. Information needed to help with the investigation may include logbooks, records of TIDs, or any other records that may lead to resolution of the issue being investigated. The investigation should include determination of the cause of the irregularity.

Because each irregularity in a nuclear facility will be slightly different from other irregularities, personnel who are experienced in nuclear material accounting and control should be involved in the investigation. Each investigation should be specific to the particular irregularity and should be handled on a case-by-case basis. Formal procedures may be developed for the routine steps to be taken in an investigation, but
NMAC personnel should determine the case-specific steps. The first question that should always be asked is whether there are any indications of the unauthorized removal of nuclear material. If there are any, physical protection personnel should be notified to implement appropriate measures. If there are no apparent indications of unauthorized removal of nuclear material, the investigators should still keep in mind the possibility of unauthorized removal.

The following examples describe possible investigative actions:

**Item monitoring**

An irregularity identified through nuclear material control measures might be the discovery during item monitoring (or at any other time) that a nuclear material item is not in its recorded location. In such a case, the nuclear material item should be located using appropriate actions and personnel. The first step should be to search the area adjacent to the location where the nuclear material item should be. The next step should be to review the operations and accounting records to see if any movements of the nuclear material item were made and not accurately recorded. It might be that an entry was made to the records maintained for operational purposes indicating the movement of this item, but that the movement was never recorded in the NMAC accounting system.

If the nuclear material item cannot be located with these actions, physical protection personnel should be notified to implement measures to control exits from the facility to ensure that if an insider has removed the nuclear material item, it is not taken from the facility. Simultaneously, the NMAC personnel should begin an emergency physical inventory taking, initially in the material balance area or location where the irregularity was discovered. If the nuclear material item is not located in the affected area during this limited emergency physical inventory taking, the search area should be widened, up to a full emergency physical inventory taking if necessary.

**Tamper indicating devices**

An irregularity identified by nuclear material control could be the discovery of a TID that is broken, missing or shows other signs of having been tampered with. The first steps to resolving this discrepancy should be to review the records maintained for operational purposes, the accounting records, and the records of the TID programme. As part of the investigation, the nuclear material in the container should be measured to ensure that the contents of the container have not changed. If the cause of the irregularity is not identified and/or the measurement indicates the loss of nuclear material, personnel involved in the activities that led to the
identification of the irregularity should be interviewed. If the interviews do not reveal the cause of
the irregularity, an emergency physical inventory taking should be conducted. Physical protection
personnel should be notified to implement appropriate control measures to prevent the removal of
any nuclear material from the facility.

Material unaccounted for

An irregularity may be an inventory difference (material unaccounted for) that exceeds the
acceptable limits. The quantities of nuclear material should be verified to ensure the accounting
entries are correct and that they do not include mistakes such as transposition errors or
duplications. The uncertainties associated with the measurements should be reviewed to
determine that their contributions to the limit calculations are correct. If the irregularity is not
resolved through these actions, an emergency physical inventory taking should be performed. If
the physical inventory taking in the affected material balance area does not resolve the
irregularity, the search and/or physical inventory taking should be expanded to other material
balance areas in the facility. NMAC personnel should always be alert to the possibility of
unauthorized removal of nuclear material when an amount of material unaccounted for exceeds
the acceptable limits and should take appropriate action to contact physical protection for the
organizations to work together to resolve the irregularity.

Monitoring of material undergoing processing

An irregularity identified by nuclear material control may be the discovery of an IOD that
exceeds the acceptable limits. Actions to investigate a situation where the IOD exceeds the
acceptance criteria should begin with a review of the accounting records. Personnel who are
familiar with nuclear material and accounting should review the data. The quantities of nuclear
material should be verified to ensure the quantities recorded as inputs and outputs are correct,
that they do not include mistakes such as transposition errors or duplications, and that data
calculations are correct. The data from the processing units should be reviewed to determine
whether off-setting gains or losses might explain the alarm.

If examining the data does not reveal any error, measurements should be made. If the material
moved was in the form of gas, pressure readings should be confirmed. If the material that was
moved is a solution, the data from process control instrumentation should be confirmed. If the
material is in an individual nuclear material item such as a can of oxide, measurements should be
made to verify that the recorded weights are correct.
If verifying the data from an accounting standpoint and remeasuring the material does not result in resolution of the irregularity, the next steps should include conducting interviews of personnel involved in the movement of the material. Questions should be asked about implementation of the two-person rule to determine whether procedures were correctly followed. Personnel involved in the movement should be asked whether they noticed anything unusual during the movement of the material. A process malfunction might lead to a difference in the amount of nuclear material that is thought to have been transferred. Personnel from the NMAC organization and personnel from the operating organization should work together to resolve the irregularity.

If necessary, operations in the processing unit with the excessive IOD should be discontinued until the difference is resolved. If the irregularity is not resolved by the preliminary actions, more extensive actions may be necessary, e.g., an emergency physical inventory taking. The physical protection personnel should be informed of the situation to allow them to take appropriate actions.

**Shipper–receiver difference**

If the receipt of nuclear material into a facility shows a statistically significant SRD when the receiving facility does its checks, an investigation should be conducted. The first question that should be asked is if there were any indications of possible unauthorized removal of nuclear material during the shipping and receiving process. Personnel at the receiving facility should be questioned to identify any unusual activities or discoveries that might indicate tampering with the nuclear material. The shipping facility and transport authority should be contacted to ask whether there were any events that could have caused a lapse in control, which could have allowed unauthorized removal of nuclear material during the shipping and transport process.

A review of the accounting records of the individual nuclear material items in the shipment should be made. This review should include verifying the accuracy of the data input for each of the items. The calculations for the limits of error should be reviewed to identify any possible erroneous data. If the irregularity is not resolved with the review of the records, the nuclear material items should be remeasured to ensure the quantities recorded in the accounting system are correct.
In all cases, investigations should continue until the irregularity is resolved or all possible avenues of discovery have been exhausted. The State’s competent authority should establish time limits allowed for investigations and reporting of irregularities.

7.2 CORRECTIVE ACTIONS

Irregularities should be investigated in a systematic and thorough manner to ensure that all contributory factors and their causes are identified, for example, by use of a root cause analysis. All contributory factors and causes so identified should be addressed and mitigated by developing and implementing a corrective action plan. If the facility has a corrective action programme, the response to the irregularity should include entering and tracking it in the corrective action system.

All investigations should be documented and should include details regarding the corrective actions. Complete records should be maintained and reviewed for trends that indicate the need for further investigations. Time limits should be established, to the extent possible, for correcting irregularities.

Actions taken to correct an irregularity depend on the type and severity of irregularity. For example, if a nuclear material item thought to be missing is found because it was moved to another location without appropriate changes to the accounting records, records should be corrected to reflect the actual situation and an investigation should be made to determine the cause of the incorrect records. Where a missing nuclear material item is not easily found further steps will be required to locate the item, such as searching other material balance areas. Physical protection measures, such as restricting exits from the facility are necessary if the nuclear material item is not located within the prescribed period of time.

Facility procedures should identify the level of management that is responsible for final correction of the investigation and, where appropriate, the required notification to the State competent authority.

A follow-up evaluation should be conducted to ensure that actions taken to correct the irregularity are effective. Irregularities should be monitored to identify trends that could be indicative of insider attempts at unauthorized removal of nuclear material from the facility.

7.3 REPORTING

Procedures for reporting irregularities should be developed before they are needed. Time limits should be established for reporting irregularities by the State competent authority.
All irregularities should be reported to facility management and to the State competent authority, if required. Discovery of an irregularity, investigation of the irregularity, and measures taken to correct the irregularity should be documented. The State competent authority should establish requirements for the content of the report, such as a description of the irregularity, the time and date, steps taken to investigate the irregularity, corrective actions, and actions taken to prevent recurrence.

### 8. EVALUATION OF NUCLEAR MATERIAL CONTROL

Nuclear material control should be periodically evaluated to determine whether all necessary measures are in place and functioning as required by the State competent authority.

A facility’s nuclear material control measures should be evaluated on a periodic or as-needed basis by trained and qualified NMAC personnel of the facility or by equally qualified independent personnel. Independent personnel may be from another part of the facility or may be external to the facility, such as invited experts from an organization that specializes in NMAC. Inspectors from the State’s competent authority may also perform evaluations. The individuals performing the evaluations should not have any conflicts of interest, such as having direct responsibility for the activities being evaluated.

Procedures should be developed for evaluating the function of nuclear material control on a routine and as-needed basis.

One method of evaluating nuclear material control measures is performance testing. Performance testing can be described as testing to determine whether or not the measure is implemented as designed, adequate for the proposed natural, industrial and threat environments, and in compliance with established performance requirements.

All performance tests should be planned in advance and approved by the NMAC manager and other appropriate managers, e.g. the manager of physical protection and the manager of operations. The plan should include a description of the test, a list of personnel who should be involved, identification of the area where the test will be performed, expected results and actions to be taken in the event of the discovery of an irregularity.

The element of nuclear material control should be tested as part of the evaluation of the NMAC system to ensure the system can detect unauthorized access to nuclear material or other actions that could lead to unauthorized removal of nuclear material. Nuclear material control measures may be evaluated by the introduction of simulated irregularities (for example a sign indicating a TID on a container of nuclear
material is broken) to check that the measures are capable of detecting the irregularity when they are implemented as described in the facility’s procedures.

Evaluations should be made to determine the status of compliance with the procedures. For example, an assessor may choose to evaluate the procedure for movements of nuclear material between material balance areas. One method of evaluating the implementation of the procedure is to interview personnel in the material balance areas who are responsible for movements to determine their understanding of the procedure. Another method is to observe movements of nuclear material as they are taking place. This method may be considered a performance test especially if the assessor introduces a simulated irregularity, such as telling the personnel involved in the movement to pretend there was a container with a TID that had been broken. The assessor could then ask what they would do if this really happened. The assessor could compare the responses of the personnel with the procedure to determine the level of compliance.

The results of all evaluations should be documented and reported as required. Deficiencies identified during evaluations should be recorded in the facility’s corrective action system, if one exists. Corrective actions should be sufficient to prevent the recurrence of the deficiency, as described above. Individual deficiencies should be evaluated to determine whether unauthorized removal of nuclear material may have occurred or may have been attempted. Analyses of all deficiencies (cumulative) should be conducted to identify any possible trends that might indicate the attempt to remove nuclear material in an unauthorized manner.
REFERENCES


