IAEA Nuclear Energy Series

No. NF-T-4.8

Basic Principles

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International Safeguards in the Design of Uranium Conversion Plants

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INTERNATIONAL SAFEGUARDS IN THE DESIGN OF URANIUM CONVERSION PLANTS

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA NUCLEAR ENERGY SERIES No. NF-T-4.8

INTERNATIONAL SAFEGUARDS IN THE DESIGN OF URANIUM CONVERSION PLANTS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2017

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email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
October 2017
STI/PUB/1766

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.
Title: International safeguards in the design of uranium conversion plants / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2017. | Series: IAEA nuclear energy series, ISSN 1995–7807 ; no. NF-T-4.8 | Includes bibliographical references.
Identifiers: IAEAL 17-01101 | ISBN 978–92–0–100517–5 (paperback : alk. paper)
Subjects: LCSH: Nuclear facilities — Design and construction. | Nuclear facilities — Security measures. | Nuclear nonproliferation.
Classification: UDC 621.039 | STI/PUB/1766

FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

This publication, part of the IAEA Nuclear Energy Series, is one in a series of facility specific 'safeguards by design' guidance publications that are currently in preparation. The topics of these publications will include international safeguards in the design of nuclear reactors, uranium conversion plants, facilities for long term spent fuel management, reprocessing plants and enrichment plants.

This series is introductory rather than comprehensive in nature and complements the general considerations addressed in the IAEA Nuclear Energy Series publication International Safeguards in Nuclear Facility Design and Construction (No. NP-T-2.8). These publications are intended principally for nuclear facility stakeholders including vendors, designers, operators, project managers and State (or regional) authorities responsible for safeguards implementation.

A great majority of States have concluded comprehensive safeguards agreements with the IAEA pursuant to the Treaty on the Non-Proliferation of Nuclear Weapons. The IAEA plays an independent verification role, ensuring that States adhere to their safeguards obligations as outlined in these agreements. The safeguards by design approach does not introduce new requirements. It simply advocates the consideration of IAEA safeguards throughout all the life cycle stages of a nuclear facility, from the initial conceptual design up to and including facility construction and into operations, including design modifications and decommissioning. Safeguards by design aims to (i) prevent safeguards requirements from unduly interfering with the smooth construction and operation of a facility; (ii) avoid costly and time consuming retrofits or redesigns of facilities to accommodate safeguards; (ii) minimize risks associated with licensing that may result from design changes; (iv) achieve efficiencies in safeguards implementation to the benefit of the operator, the State and the IAEA; and (v) ensure the implementation of effective safeguards.

The IAEA gratefully acknowledges the assistance received through the Member State Support Programmes to the Department of Safeguards from Argentina, Belgium, Brazil, Canada, China, Finland, France, Germany, Japan, the Republic of Korea, the United Kingdom, the United States of America and the European Commission in the preparation of this publication. The IAEA officers responsible for this publication were B. Boyer and J. Sprinkle of the Division of Concepts and Planning, and G. Dyck of the Division of Nuclear Fuel Cycle and Waste Technology.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The IAEA works to enhance the contribution of nuclear energy to peace and prosperity around the world while helping to ensure that nuclear material is not diverted to nuclear weapons or other nuclear explosive devices. IAEA safeguards, an important part of the global nuclear non-proliferation regime, provide for independent verification by the IAEA of States' compliance with their legal obligations under safeguards agreements. This publication is part of an IAEA guidance series developed to assist facility designers and operators in considering at an early stage the safeguards activities relevant to particular nuclear fuel cycle facility types.

This publication complements the general considerations addressed in International Safeguards in Nuclear Facility Design and Construction [1] and is written primarily for designers and operators of the specific facility type described within. It is written at an introductory level for an audience unfamiliar with IAEA safeguards and has no legal status. A State may incorporate elements of this guidance into its regulatory framework, as it deems appropriate. For specific guidance on IAEA safeguards implementation, the reader can refer to Ref. [2].

Safeguards should be considered early in the design process to minimize the risk of impacts on scope, schedule or budget [3], and to facilitate better integration with other design considerations such as those relating to operations, safety and security [4, 5]. In the IAEA publication Governmental, Legal and Regulatory Framework for Safety [6], Requirement 12 (Interfaces of safety with nuclear security and with the State system of accounting for, and control of, nuclear material) states that: "The government shall ensure that, within the governmental and legal framework, adequate infrastructural arrangements are established for interfaces of safety with arrangements for nuclear security and with the State system of accounting for and control of nuclear material."

Considerations of safety, security and safeguards are essential elements of the design, construction, commissioning, operation and decommissioning stages of nuclear facilities, as discussed in publications issued by the IAEA Department of Nuclear Safety and Security. The trend is for new facilities to be built with inherent safety and security features as well as accommodations for safeguards. The publication Safety of Nuclear Power Plants: Design [7] establishes in Requirement 8, pertaining to interfaces of safety with security and safeguards, which applies to any type of facility, that: "Safety measures, nuclear security measures and arrangements for the State system of accounting for, and control of, nuclear material for a nuclear power plant shall be designed and implemented in an integrated manner so that they do not compromise one another."

Safeguards by design (SBD) is a voluntary process to facilitate the improved implementation of existing safeguards requirements,[1] providing an opportunity for stakeholders to work together to reduce the potential of unforeseen impacts on nuclear facility operators during the construction, startup, operation and decommissioning of new facilities. SBD should not be confused with the effective design of a safeguards approach, but rather it enhances the design process through the early inclusion of safeguards considerations in the management of the facility design and construction project. As such, cooperation on safeguards implementation is improved when (1) the designer, vendor and operator understand the basics of safeguards and (2) the safeguards experts understand the basics of the facility design and operations.

The particular safeguards activities conducted by the IAEA vary from one facility to another. From a design perspective, there is value in understanding the full range of potential safeguards activities and their impact on the facility design before design choices are finalized. Early planning can incorporate flexibility into the facility's infrastructure to support safeguards, accommodating technology innovations over time that may benefit the operator during the facility's life cycle. The relative ease with which safeguards can be implemented in a facility is referred to as 'safeguardability'.

Involving the design–build–operation teams in the SBD process carries the potential benefits of:

— Increasing awareness of safeguards for all stakeholders;
— Reducing inefficiencies in the IAEA's safeguards activities;

[1] It should be noted that, in States with a comprehensive safeguards agreement in force, preliminary design information for new nuclear facilities and activities and for any modifications to existing facilities must be submitted to the IAEA as soon as the decision to construct or to authorize construction, or to authorize or to make the modification, has been taken.

— Improving the effectiveness of safeguards implementation;
— Facilitating the consideration of the joint use of equipment by the operator, the State (or regional) authority responsible for safeguards implementation and the IAEA;
— Reducing operator burden for safeguards;
— Reducing the need to retrofit for installation of safeguards equipment;
— Increasing flexibility for future safeguards equipment installation.

1.2. OBJECTIVE

This publication is part of a series that aims to inform nuclear facility designers, vendors, operators and State governments about IAEA safeguards and how associated requirements can be considered early in the design phase of a new nuclear facility. SBD dialogue during early design and construction facilitates the implementation of safeguards throughout all the life cycle stages of the facility. The potential to reduce costs, avoid costly retrofits and achieve efficiencies both for the operator and for the IAEA are important drivers for the early consideration of safeguards in a nuclear facility design project.

The State (or regional) authority responsible for safeguards implementation (SRA) is the entity in the State with primary responsibility for fulfilling the safeguards obligations of the State including formal communications with the IAEA [8]. The SRA may be part of a broader nuclear authority and thus have responsibilities in addition to safeguards, such as safety or security. The SRA plays a very important role in facilitating communications among all the key stakeholders.

1.3. SCOPE

This guidance is applicable for the design and construction of uranium conversion plants, such as the Springfields facility in the United Kingdom shown in Fig. 1.

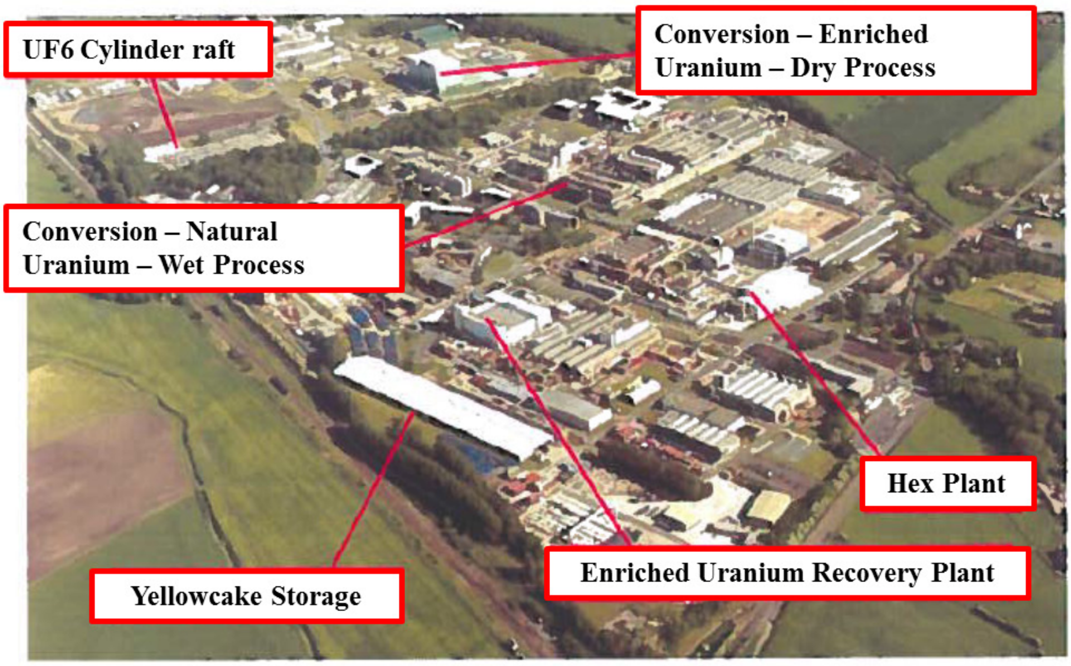

FIG. 1. Springfields uranium conversion plant with multiple paths.

1.4. STRUCTURE

Section 2 provides a general overview of IAEA safeguards implementation, followed by facility specific guidance in the subsequent section. This publication includes experience gained in past efforts to incorporate safeguards requirements in facility design, which can be useful in future efforts to build or operate nuclear facilities. Additional resources are suggested in the bibliography at the end of this publication. Reference material specific to the legal obligations undertaken pursuant to safeguards agreements can be found in Ref. [9]. It may also be useful to refer to the IAEA Safeguards Glossary [10], which can be accessed from Ref. [9].

Annex I provides explanations of specific safeguards terminology used in this publication. Annex II describes safeguards considerations at the various life cycle stages of a nuclear facility. Annex III describes the identification of safeguardability issues, and Annex IV provides information on the contents of a design information questionnaire.

2. OVERVIEW OF IAEA SAFEGUARDS

A basic understanding of IAEA safeguards objectives and activities can facilitate the consideration of international safeguards in nuclear facility design and construction. A brief overview of IAEA safeguards is provided below.

2.1. IAEA SAFEGUARDS IMPLEMENTATION

Pursuant to the IAEA's authority to apply safeguards stemming from Article III.A.5 of its Statute, the IAEA concludes agreements with States and with regional safeguards authorities for the application of safeguards. These agreements are of three types: (1) comprehensive safeguards agreements (CSAs), (2) item specific safeguards agreements and (3) voluntary offer agreements. A State with any one of these agreements may also conclude a protocol [11] additional to its safeguards agreement [8]. The large majority of safeguards agreements in force are CSAs and this publication focuses on those. A State with a CSA in force undertakes to place all nuclear material in all facilities and other locations in the State, on its territory, or under its control or jurisdiction anywhere, under IAEA safeguards. The IAEA undertakes to apply safeguards on such material in accordance with the agreement, which provides for measures to protect sensitive technology and proprietary or classified information.

Under a CSA, the following three generic safeguards objectives apply. At nuclear facilities, most safeguards activities focus on addressing the first two objectives:

- To detect any diversion of declared nuclear material at declared facilities or locations outside facilities (LOFs);
- To detect any undeclared production or processing of nuclear material at declared facilities or LOFs;
- To detect any undeclared nuclear material or activities in the State as a whole.

Nuclear material accounting and the associated verification activities in the field are at the core of safeguards implementation and are the primary basis for achieving the first objective above on the non-diversion of declared nuclear material. The verification of information about the features and characteristics of a facility, known as design information verification (DIV), contributes significantly to achieving the second objective.

2.2. OVERVIEW OF SAFEGUARDS MEASURES

In general, safeguards activities are designed to verify the State's declarations about nuclear material quantities, locations and movements, and to detect indications of undeclared nuclear material or activities. Examples of techniques and measures used by the IAEA include, inter alia:

— On-site inspections by IAEA inspectors [12] including short notice random and unannounced inspections[2];
— Nuclear material accountancy, such as the review of facility records and supporting documentation [13];
— Measurements of nuclear material (e.g. weight, gamma, neutron) [14, 15];
— Unique identifiers for nuclear material items;
— Surveillance (e.g. cameras), containment (e.g. seals) and monitoring (e.g. monitoring nuclear material flows using unattended radiation measurements, monitoring of facility operational data such as pressure, temperature or power levels);
— Collection and analysis of environmental and nuclear material samples;
— Verification of facility design for features relevant to safeguards.

Additional information on the above can be found in the most recent edition of Safeguards Techniques and Equipment [15].

2.3. VERIFICATION

IAEA verification activities at a facility fall into two broad categories — verification of design information and verification of nuclear material inventories and flows. Surveillance, containment and flow monitoring are measures used in support of these verification activities. Each is discussed below.

2.3.1. Design information verification

Provisional facility design information must be submitted by the State to the IAEA when a decision is taken to construct, or to authorize construction, of a nuclear facility. Design information may be examined by the IAEA even before construction begins. Design information is updated as the design becomes more detailed [1, 8] and throughout the life of the facility to reflect changes or modifications.

Design information is submitted using a form called a design information questionnaire (DIQ); an example DIQ form containing information relevant for a research reactor can be found in Ref. [16]. Annex IV lists a summary of the type of information provided to the IAEA for the facility type addressed in this publication.

The IAEA verifies design information through on-site physical examination of the facility during the construction and all subsequent phases of the facility's life cycle (see Fig. 2). During a typical early DIV at a nuclear facility under construction, IAEA inspectors may visit the site to inspect and photograph aspects of its construction. In later visits, they may walk through the facility with detailed building plans to confirm the as-built design and to look for design features not shown on the drawings that may indicate potential for undeclared production or processing of nuclear material.

The IAEA may also verify the design and capacity of any processing equipment and systems in the facility as well as its maximum capacity. Accommodation for this requirement may be considered in the design phase. In addition, the IAEA develops an 'essential equipment' list for the nuclear facility to use in determining whether a facility can be considered decommissioned for safeguards purposes. The designers of the facility can play a valuable role in helping the IAEA to identify the equipment that is essential for operating the nuclear facility.[3]

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[2] Short notice random and unannounced inspections optimize resource allocation while maintaining safeguards effectiveness.
[3] The IAEA *safeguards* essential equipment list is different from the *safety* essential equipment list.

2.3.2. Nuclear material accounting and verification

Under a CSA, State or regional authorities are required to report nuclear material inventories and inventory changes to the IAEA. Therefore, nuclear facilities establish nuclear material accounting systems in order to meet national and international requirements.

The IAEA verifies nuclear material inventories and flows as fundamental safeguards measures. For nuclear material accounting, one or more material balance areas (MBAs) will be established at a facility. By definition, an MBA is an area where (a) the quantity of nuclear material in each transfer into or out of the MBA can be determined and (b) the physical inventory of nuclear material can be determined. The nuclear material in an MBA is characterized as either direct use material (i.e. nuclear material that can be used for the manufacture of a nuclear explosive device without further transmutation or enrichment), indirect use material (i.e. all other nuclear material), or a combination of both. IAEA verification activities are typically more intensive for direct use material.

The IAEA also distinguishes between nuclear material in item and in bulk form. Facilities containing only nuclear material in item form are referred to as ‘item facilities’. In such facilities, the nuclear material is contained in discrete items (not designed to be opened) such as fuel rods or fuel assemblies in a typical power reactor. In ‘bulk handling’ facilities, such as fuel fabrication plants, the nuclear material is handled in loose form and can be repackaged with the possibility of combining or splitting the quantity of nuclear material in containers, and also of changing the chemical or physical form of the nuclear material. Different safeguards measures may be applied in the verification of nuclear material in item and in bulk forms. IAEA verification activities at bulk facilities are generally more intensive [13] and nuclear material samples are typically collected for analysis (see Fig. 3).

FIG. 2. IAEA design verification.

FIG. 3. Sample preparation in an IAEA laboratory.

One of the activities involved in verifying nuclear material is the evaluation of the consistency of facility records and supporting documentation with the reports submitted by the State [13]. The IAEA performs a physical inventory verification (PIV) after a facility operator has taken a physical inventory itself. The IAEA verifies the physical inventory of nuclear material in each MBA and compares its results with State reports and facility nuclear material accounting records. Key measurement points (KMPs) are established at locations where nuclear material inventory can be measured as well as at locations where nuclear material flows can be measured. Figure 4 illustrates item counting and the verification of item identification (tags) at a fresh fuel storage area in a power plant. The verification of nuclear material accountancy includes the assessment of the operator's measurement systems including the associated measurement uncertainties. Given resource limitations and the need to minimize disruption to facility operations, statistical sampling [17] is often used in nuclear material verification. Items are selected at random and verified by a number of measurement methods. These methods could include item counting, radiation and mass measurements, for example.

IAEA measurements of nuclear material are designed to meet three goals — gross, partial and bias defect detection, as described below [10].

— 'Gross defect' refers to an item or batch that has been falsified to the maximum extent possible, so that all or most of the declared material is missing (e.g. substitution of an empty container for a full one).
— 'Partial defect' refers to an item or batch that has been falsified to such an extent that some fraction of the declared amount of material is actually present (e.g. removal of fuel pins from an assembly or some fraction of UF_6 from a cylinder).
— 'Bias defect' refers to an item or batch that has been slightly falsified so that only a small fraction of the declared material is missing (e.g. repeated removal of a very small amount of nuclear material from a flow stream).

Figure 5 shows verification measurements using handheld radiation instruments on fresh fuel in its shipping containers at a reactor, which is an example of a gross defect measurement.

Figure 6 shows measurements of irradiated fuel (irradiated direct use material) in a spent fuel storage pond. For an item facility such as a reactor, differences between the physical inventory and the accounting records are generally investigated by means other than statistical evaluation of measurement errors, e.g. by investigating the completeness and correctness of facility records. For a bulk facility, samples of nuclear material in bulk form may also be collected and analysed at IAEA laboratories.

Facility operators can support nuclear material accounting verification activities in several ways, including providing for access to nuclear material items and, once they have been verified, providing for the ability to segregate the verified items from those not yet measured. Inspectors might perform non-destructive assay (NDA) measurements with portable equipment or take samples of nuclear material from the process for destructive analysis (DA) measurements at IAEA laboratories. Ideally, the space provided for equipment storage, calibration standards and check sources, as well as the use of locations to perform measurements, should not interfere with routine plant operations.

FIG. 4. Item counting in a fresh fuel store.

FIG. 5. Verification of fresh fuel transport containers using a handheld HM-5 gamma monitor.

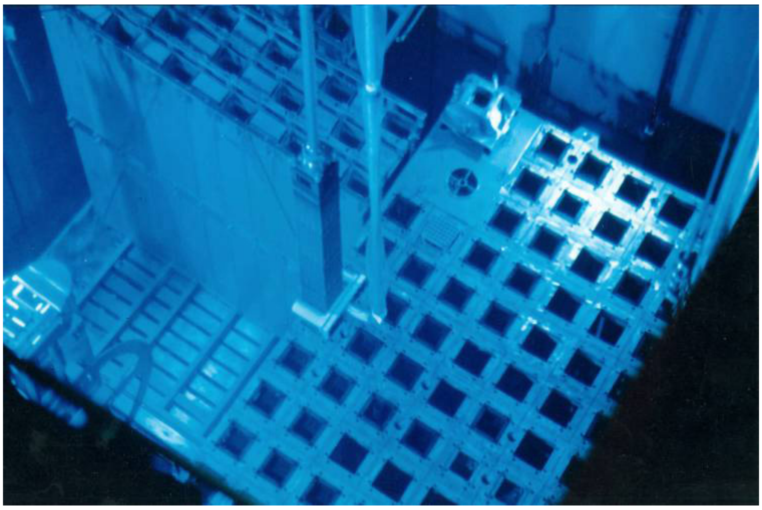

FIG. 6. Measurements of irradiated fuel in a cooling pond.

2.3.3. Surveillance, containment and monitoring

Surveillance, containment and nuclear material monitoring supplement the nuclear material accounting verification measures by providing additional means to detect undeclared access to, or movement of, nuclear material. Surveillance is the collection of optical or radiation information through human and instrument observation/monitoring. Containment refers to the structural components that make undetected access difficult. Seals are tamper indicating devices used to secure penetrations in containment thereby preventing undetected access.

During inspections, inspectors may examine optical records and data from the IAEA surveillance, containment and monitoring systems as part of verifying operator records and systems. The IAEA has several surveillance systems approved for use [15] that store optical and measurement data; include local battery backup; transmit state of health and image or other data off-site (typically to IAEA Headquarters); may be triggered by other sensors; and are sealed in tamper indicating enclosures. Figure 7 shows the interior of a tamper proof surveillance system and a typical installation.

Adequate and reliable illumination (at all hours of the day and night) is important for the effective functioning of most optical surveillance systems. Components of these systems also need to be accessible for maintenance and data retrieval. There are several ways facility operators can provide the basic support required for IAEA surveillance and monitoring systems, such as by:

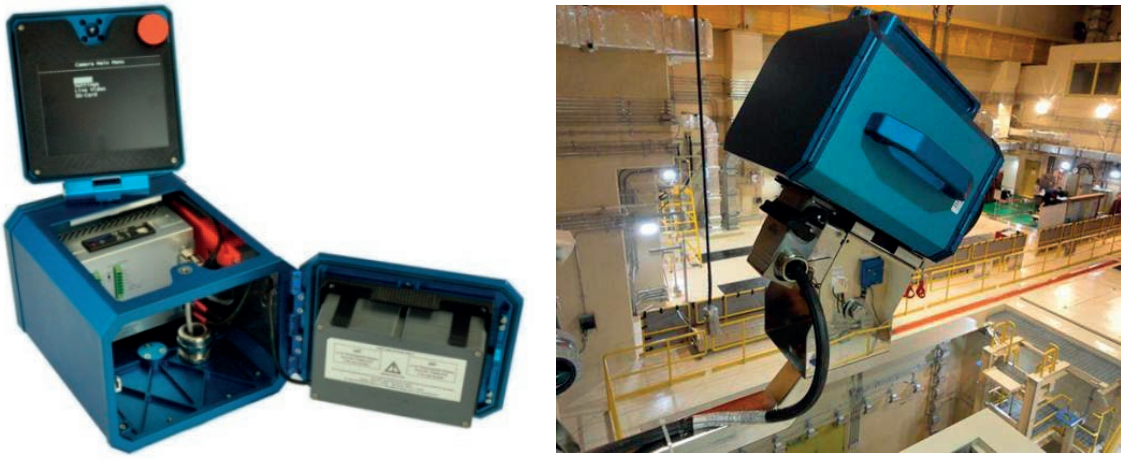

FIG. 7. A next generation IAEA surveillance system.

- — Supplying reliable power, secured access, dedicated working space and data transmission (wired or wireless) throughout the facility. Figure 8 shows a facility operator lowering an IAEA equipment rack with an overhead crane.
- — Locating data collection cabinets in easily accessible, clean areas with regulated temperature and humidity.
- — Foreseeing the impact of the operating environment on safeguards equipment (e.g. corrosion, heat).
- — Ensuring that optical surveillance systems are not blocked by equipment (e.g. cranes that move cylinders, heavy equipment or drums) and are protected from corrosion.
- — Considering a single dedicated space for electronic equipment[4] that can be access controlled by the IAEA. This space might include room for equipment, spare parts and a small office.
- — Providing sufficient access for attaching, replacing or servicing seals used by the IAEA.
- — Providing space for safeguards equipment in such a way that normal facility operation will not lead to inadvertent damage or interruption in service.
- — Labelling all installed relevant safeguards equipment (including cabling, power supplies and switches found in circuit breaker cabinets) clearly in English and the local language(s).
- — Consulting with the IAEA to facilitate the use of safeguards seals at measurement points and safeguards relevant features such as junction boxes where safeguards cables are terminated or connected.
- — Noting that seal attachment points should be part of the mechanical structure, appearing to be part of the original smooth design and not welded on after the fact, and must ensure that the attachment point cannot be removed without detection or without damaging or breaking the seal.

Maintaining the continuity of knowledge refers to the process of using surveillance, containment and monitoring to maintain the integrity of previously verified safeguards information by detecting any efforts to alter an item's properties that are relevant to safeguards. When continuity of knowledge is maintained successfully, it can reduce the amount of re-measurement activity in subsequent inspections. Figure 9 shows an inspector using seals to maintain the continuity of knowledge during a routine inspection.

The use of unattended monitoring systems, such as a gate monitor to detect movements of spent fuel to a cooling pond, allows inspectors to focus their efforts in the field on inventory verification, investigating possible undeclared activities and detecting irregularities in operations.

Furthermore, the remote transmission of safeguards data from unattended monitoring systems can notify the IAEA when equipment needs to be serviced, provide information to help plan inspections and reduce IAEA time on-site conducting inspections, thereby reducing the impact of inspections on facility operation in addition to making safeguards implementation more effective and more efficient.

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[4] Some safeguards equipment has dedicated electronics racks for signal processing, batteries, remote transmission and a data archive located remotely from the sensor in less hazardous space.

FIG. 8. A facility operator supporting the installation of IAEA equipment racks.

FIG. 9. Examples of seals that are used by the IAEA to maintain continuity of knowledge.

2.4. PHYSICAL INFRASTRUCTURE REQUIREMENTS FOR IAEA SAFEGUARDS ACTIVITIES

IAEA safeguards equipment requires physical space, reliable and well-regulated power supply, and infrastructure for data transmission. Even without detailed IAEA design criteria for safeguards equipment or systems (which may be only available later in the design life cycle), cabling and penetrations for IAEA equipment can be planned for in the facility design. Providing access to a stable and reliable source of power and secure data transmission capability (wired, fibre-optic or wireless) throughout a facility will eliminate the need for the most costly aspects of retrofitting for safeguards equipment systems (such as the installation of a surveillance camera, as shown in Fig. 10). Additionally, the possibility of incorporating facility equipment and the infrastructure needed to directly support IAEA verification activities into regular facility maintenance contracts could be considered. The ability to provide mounting fixtures for safeguards equipment that do not affect facility licensing or safety is desirable.

FIG. 10. Installation of a surveillance system.

2.5. FACILITY DECOMMISSIONING

Implementation of IAEA safeguards continues after a facility has been shut down and preparations for decommissioning have begun. During the initial design verification activities, the IAEA verifies the presence and characteristics of essential equipment. From the time essential equipment arrives at the facility until it is verified to have been removed or rendered inoperable, the facility is considered by the IAEA to be capable of its intended function. A facility is considered decommissioned for safeguards purposes when the IAEA has made a determination that nuclear material has been removed and the residual structures and equipment essential for its operation have been removed or rendered inoperable so that it can no longer be used to store, handle, process or utilize nuclear material [11].

2.6. FUTURE CONSIDERATIONS

Safeguards technologies continue to evolve, as does nuclear technology. The possibility to easily upgrade IAEA installed systems depends to some degree on the facility design. The electronics that support IAEA measurement hardware are changing, often in the direction of reduced physical size, modularity and increased capability. A facility design that accommodates modest changes in equipment size, shape and power requirements allows the use of newer alternatives as they become available on the market or as obsolescence removes older alternatives.

3. SAFEGUARDS CONSIDERATIONS RELATED TO URANIUM CONVERSION PLANT DESIGN

This section addresses safeguards considerations specific to the design of depleted, natural and low enriched uranium (DNLEU) conversion plants [18]. Nuclear facilities must address the need for nuclear material control and accounting as well as the conduct of inspections by relevant national and international authorities. It is helpful for facility designers to have a basic understanding of the safeguards measures and the objectives they are designed to meet at uranium conversion plants.

Two principal safeguards objectives at a uranium conversion plant are to detect the possible diversion of pure material for further processing or use elsewhere and to detect the processing of undeclared feed to produce undeclared product. These activities could potentially be concealed by:

— Understating the feed;
— Reporting a false material loss incident;

— Overstating a loss in a waste stream;
— Tampering with IAEA surveillance, monitoring or tamper indicating devices;
— Interfering with IAEA nuclear material verification activities (e.g. sampling or measurements);
— Replacing diverted nuclear material with nuclear material of lower strategic value;
— Association with process upset or off-normal activities.

Practical examples of design features to increase the safeguardability of a uranium conversion plant are discussed in the following subsections and include, inter alia:

— Easy to read, unique identifiers for nuclear material items;
— A minimum number of penetrations in the containment structures;
— Visible pipes, ductwork and processing equipment;
— Provisions for seals and other tamper indicating devices;
— The use of near real time accounting and process monitoring;
— Layout of the plant, including containment barriers to facilitate the segregation of material and to make mixing, substitution and inappropriate transfers more difficult;
— Accurate measurements of in-process material and measured discards;
— Controlled access to locations for receipts, storage and the measurement of nuclear material.

Once a uranium conversion plant has been built, it can be challenging to retrofit or modify it in order to accommodate measurement equipment. The need for subsequent adaption of the process equipment to accommodate sampling or measurement of the nuclear material should be avoided.[5] For example, the retrofitting of a large process vessel to allow direct measurement of its weight, the installation of flow monitoring equipment for chemically hazardous streams, and the replacement of rudimentary instrumentation with higher accuracy instrumentation can be difficult and expensive.

3.1. DESIGN INFORMATION VERIFICATION

The IAEA performs DIV before concrete for a new facility is poured, and will continue performing DIV throughout all the life cycle stages of the facility (see Annex II for more information about safeguards activities at each life cycle stage). During DIV at a uranium conversion plant, the IAEA may perform a variety of activities, such as:

— Requesting and reviewing additional safeguards relevant design and design related information;
— Comparing process and containment design with actual construction;
— Verifying the usability of essential equipment[6] and assessing its throughput or capacity;
— Verifying the quality of the operator’s measurement system, including the statistical evaluation of the measurement data;
— Assessing whether the site and general building design could support undeclared nuclear operations;
— Assessing possible indicators of undeclared nuclear activities or material, including analysis of environmental samples (selection of sample locations might require accurate as-is design drawings).

Uranium conversion plants include large numbers of process vessels with complex process pipework carrying not only uranium material but also process chemicals, water and gases. The IAEA needs to distinguish between pipework and vessels that contain nuclear material and those that do not. Moreover, the design and layout of the processing equipment should minimize the hold-up of material, and provide for measurements, keeping unverifiable material quantities low in the MBA. There should be the lowest possible number of entry and exit points for material into the process to minimize the number of pathways along which diversion of material or

[5] The design team can consider the value of engineering studies to ensure that samples will be representative of the material from which they are drawn, e.g. how long mixing should be performed or where the sample is best drawn from.

[6] The term ‘safeguards essential equipment list’ is defined in Annex I: Terminology.

introduction of undeclared feed could occur. It is ideal for safeguards if the operator's measurement system quickly and accurately determines the amount of uranium in the plant, even when the plant is running, and displays all uranium inventory information in a central location.

Design features to aid in the implementation of safeguards include providing:

— The IAEA with access to nuclear material sampling areas with adequate space for installing sampling equipment and checking IAEA seals;
— The IAEA with the capability to monitor sample withdrawal into sample containers, including provisions to uniquely identify and maintain control of each sample;
— For IAEA sample containers to be stored securely on-site under IAEA seals or locks until shipped to a laboratory for analysis;
— Sufficient spacing and shielding for NDA measurement systems, including any system for major uranium bearing process vessels to minimize the impact of background on measurement results.

3.2. NUCLEAR MATERIAL ACCOUNTING AND VERIFICATION

Verification of nuclear material accounting is a fundamental part of any safeguards approach. The nuclear material in a uranium conversion plant is processed in loose forms where the physical integrity of items is not maintained as received, i.e. it is a bulk facility where bulk processing is used. The feed material to a uranium conversion plant is uranium ore concentrate (UOC), which may not be subject to full safeguards procedures (uranium ore and ore residues are not subject to safeguards). In general, in a uranium conversion plant, purified oxides of uranium and purified solutions of uranium are subject to full safeguards procedures, while yellowcake and UOC often are not. In any case, full safeguards procedures are applied in a purification or conversion process no later than when the material first meets the composition and purity specified in paragraph 34(c)[7] of INFCIRC/153 (Corrected) [19, 20–22]. Often this is at the UNO_3 stage following solvent extraction purification. However, applying safeguards accounting procedures at that point in a uranium conversion plant may not be practical or economical. In such cases, safeguards measures begin at some point earlier (upstream) in the plant, e.g. at the input of UOC. The point at which nuclear material reaches a purity and composition suitable for fuel fabrication or isotopic enrichment will be determined by the IAEA and discussed with the SRA [23]. In general terms, the intensity of safeguards measures rises with the level of enrichment of uranium.

The material flow during a material balance period often exceeds the in-process inventory. The material flows include not only the feed into and the product out of the facility, but also the scrap, waste and in-process material suitable for recycle. Much of this material is processed in loose forms where the physical integrity of items is not maintained as received. The amount of nuclear material present at different stages of the process is estimated by weight and volume determination, combined with on-site measurements of concentration and isotopic composition, or sampling for DA at an IAEA laboratory. In some cases, stream averages are applied in lieu of measurements.

All measurement results have inherent uncertainties. As a result, the material unaccounted for (MUF), which is computed from the material balance components (i.e. the beginning inventory, increases, decreases and the ending inventory) is not zero and its magnitude depends on the uncertainties of the measurement systems (assuming no diversion occurred) [13, 15].

Nuclear material flow rates and concentrations fluctuate in a uranium conversion plant during operation. The large and variable throughput and the changing forms of the nuclear material are important considerations for safeguards as they increase the complexity of nuclear material accounting. In addition, the conversion process involves the accumulation of nuclear material in the process equipment, known as nuclear material hold-up, which is notoriously difficult to quantify and control.

Process hold-up occurs when a new facility begins to operate with nuclear material, as the new, clean surfaces become coated during their initial contact with various (potentially corrosive) nuclear material forms and as material collects in low points and other accumulation points in equipment, piping and ductwork. The design can minimize losses to nuclear material hold-up by reducing sharp corners, irregular surfaces and dead ends in the

[7] Paragraph 34(c) in INFCIRC/153/Corr. [19] provides that nuclear material of composition and purity suitable for fuel fabrication or for being isotopically enriched is subject to full safeguards procedures.

process equipment, sloping equipment toward drains or cleanout points, preparing the surface area to minimize coating and minimizing the amount of surface area exposed to nuclear material [23].

To accurately determine the material balance for the facility, it is necessary to clean as much nuclear material hold-up out of the process as feasible before taking the physical inventory. In the case of a conversion plant that handles uranium of different enrichments and therefore operates in campaigns, process hold-up is often cleaned out between campaigns. Minimizing the amount of nuclear material in difficult to measure locations reduces uncertainty in the total inventory. Where nuclear material hold-up cannot be reduced, techniques to quantitatively measure the hold-up are useful. A poorly executed cleanout prior to taking an inventory can result in error in the inventory determination. In some cases, a uranium conversion plant may not plan to shut down their process during inventory taking. This option then requires consideration of a design decision to include a comprehensive, accurate and near real time process measurement system.

The solid and gaseous residual uranium remaining in a transportation cylinder after extraction of UF_6 is a safeguards concern. The periodic recertification of cylinders may also result in revised tare weights. Safeguards considerations should be part of any container recertification process.

PIV is usually performed by the IAEA on a yearly basis immediately following a physical inventory taking performed by the facility operator. Material flows are verified during interim inspections as well as during a PIV. An evaluation based on error propagation and statistical methodologies indicates whether the MUF declared by the operator is due to legitimate measurement error. In addition, historical MUF trend analysis determines if the uncertainties are random or if a measurement bias may be causing a consistent trend. The same is true for the shipper/receiver difference whose validity is assessed on the basis of the shipper's and receiver's measurement uncertainties. A design to both minimize and accurately measure process losses (scrap, waste and hold-up) benefits safeguards, improves the operator's efficiencies and simplifies nuclear material verification activities.

The IAEA designates a typical uranium conversion plant as one MBA. A possible measurement structure for a low enriched uranium (LEU) conversion plant is depicted in Fig. 11. Some plants produce additional product forms better suited for long term storage that are not indicated in Fig. 11 and some receive uranium in various chemical forms as feed material.

A uranium conversion plant may have up to eight KMPs, as shown in Fig. 11:

(1) Feed entering the plant;
(2) Feed being fed to the dissolver;
(3) Uranyl nitrate solution before purification;
(4) Stripped organic solvent;
(5) Purified uranyl nitrate just after purification;
(6) The concentrated purified uranyl nitrate solution after evaporation;
(7) The first solid uranium after purification (after precipitation or thermal denitration);
(8) The final product(s).

In some cases, the IAEA does not identify KMPs internal to the conversion processing areas. It is recommended that designers clarify and document the determination of MBAs and KMPs with the safeguards authorities and the IAEA early in the design process.

Weighing is an important verification measure at uranium conversion plants. Inspectors can select a subset of containers or cylinders for independent weighing using either the operator's scales or IAEA equipment.[8] To verify the accuracy of the operator's scales, the inspectors may present weight standards for the operator to weigh. Such standards may be stored at the facility in a container with IAEA tamper indicating seals applied. After weighing cylinders or containers, the IAEA may apply seals in order to be able to verify that the contents have not changed. During subsequent inspection visits, the IAEA will focus its verification on containers without seals, or where seals have been compromised. To facilitate these activities, it should be ensured that:

— The stored containers or cylinders are accessible and discrete items are easily moved to scales for weighing.
— The containers or cylinders are designed such that IAEA seals can be applied and fixtures not simply welded on later.

[8] IAEA approved equipment includes alternatives to scales, e.g. load cells [13].

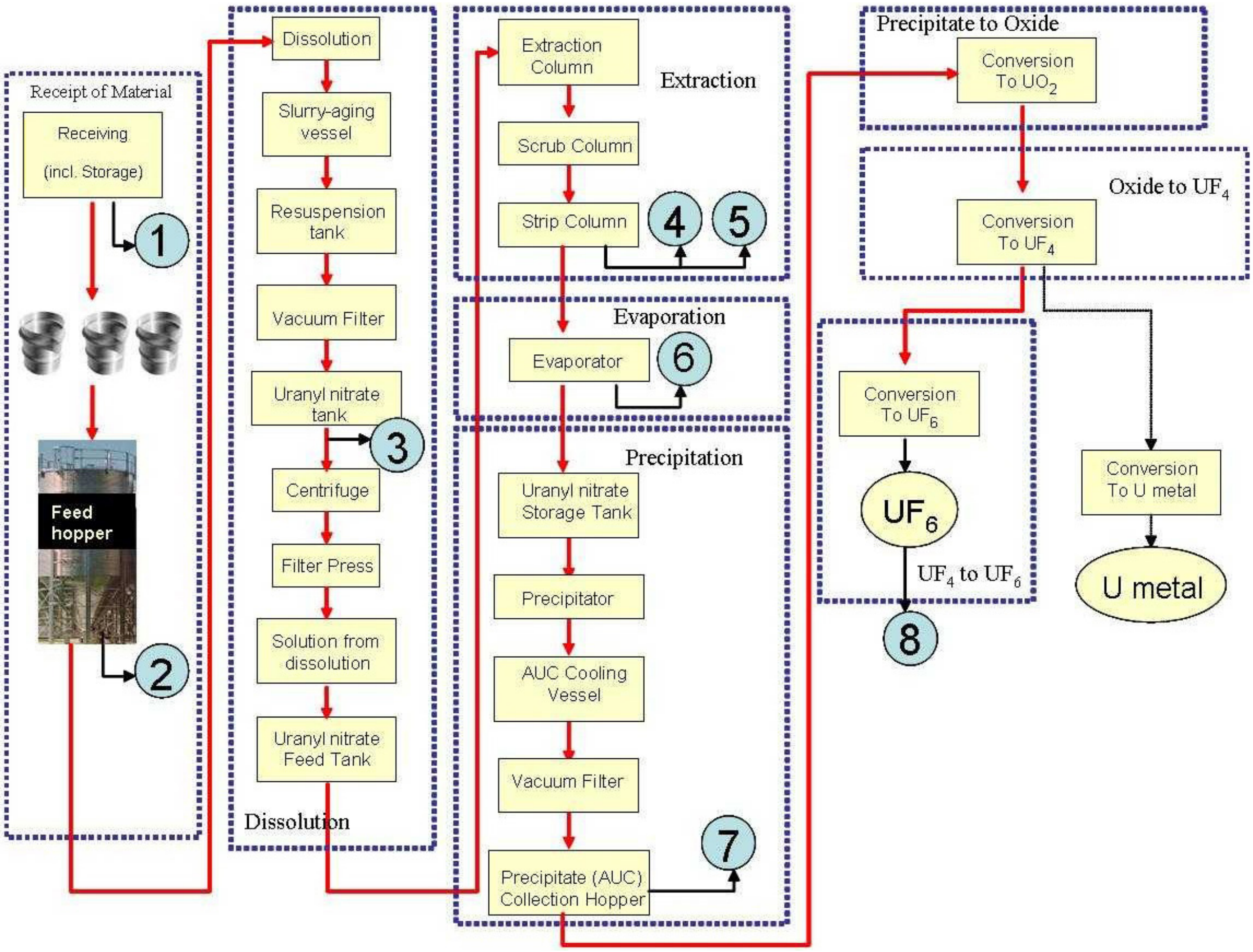

FIG. 11. Possible KMPs at a uranium conversion plant, shown as numbers in blue circles.

— Seals are accessible and protected from accidental damage.
— Certified scales with appropriate accuracies are available for weighing items.

Other nuclear material accounting related activities that may need to be facilitated at uranium conversion plants include:

— Verification of domestic and international transfers of nuclear material;
— Segregation of the feed material into batches, which may be required by treaty obligations;
— Drawing samples from the feed stream or product stream and shipping off-site for analysis at IAEA laboratories;
— Confirmation of the absence of borrowed nuclear material from other locations or facilities;
— Review of the operator's previous input into an inventory mailbox [24, 25];
— Use of a randomized inspection scheme;
— Follow-up activities to address any anomalies.

Facility operators play a key role in supporting IAEA nuclear material accounting verification activities by, among others:

— Installing measurement systems for in-process material, which may be jointly used for safeguards and operational needs;

- — Collecting, packaging and assisting with the shipment of samples of nuclear material for IAEA analysis at an off-site location;
- — Providing access for the maintenance of IAEA safeguards equipment;
- — Minimizing the radiation and chemical hazard exposure of inspectors and equipment;
- — Providing access to nuclear material in storage and in process, e.g. during inventory verification;
- — Providing IAEA inspector training and briefings regarding facility access and routine operations;
- — Providing adequate illumination for personnel access and for surveillance equipment;
- — Ensuring surveillance equipment is not damaged by or blocked by operator equipment or activities;
- — Making a clear separation between IAEA and facility infrastructure and equipment (including electrical power and cabling);
- — Minimizing the impact on facility operation of inspector measurements by considering controlled space, access control, and access to facility infrastructure for verification measurements;
- — Labelling safeguards equipment and associated infrastructure in English.

3.3. CONTAINMENT, SURVEILLANCE AND MONITORING

Containment and surveillance (C/S) measures in a uranium conversion plant aim to verify information on movements of nuclear material or to preserve the integrity of previously verified material (maintain continuity of knowledge regarding the contents of an item, for example) as well as to preserve the integrity of IAEA equipment. Tamper indicating seals might be applied to verified feed, product or scrap material, or unused equipment. Also, surveillance measures may be applied at UO_3/UO_2 drum filling stations or at UF_6 cylinder filling stations.

Once a uranium conversion plant has been built, it may be expensive or problematic to retrofit or modify it in order to accommodate equipment for monitoring the process. Anticipating the possibility for process monitoring equipment will help to avoid expensive retrofits. Process monitoring can be discussed with the IAEA early in the design process.

3.4. DECOMMISSIONING

As mentioned earlier, safeguards continue well after a facility has been shut down and nuclear material has been removed. The IAEA makes a determination as to when the facility has been decommissioned for safeguards purposes, requiring, inter alia, that all safeguards essential equipment has been removed or rendered unusable. Some examples of safeguards essential equipment at uranium conversion plants [26] include:

- — Any production rate limiting equipment;[9]
- — Process equipment (e.g. dissolvers, fluidized beds, furnaces);
- — Chemical handling equipment;
- — Utility systems (e.g. steam, nitrogen, cooling water, hydrogen, compressed air, ammonia).

3.5. FUTURE CONSIDERATIONS

When nuclear material movements are performed in a nuclear facility without human access and access to the nuclear material storage locations is limited, process monitoring can reduce the need for on-site inspections [27]. However, the monitoring system must be reliable enough for the associated operating and maintenance costs to provide a benefit compared with the cost required for inspections. Improving the automated tools used to collect and review data from multiple sensors is important. This includes the infrastructure that connects sensors, electronics, computer systems and modes of transmission to off-site inspector review stations as well as the tools to support the review process tools.

[9] The IAEA can routinely verify that equipment that limits production has not been modified.

Designers can help to eliminate common mode failure paths and recommend suitable levels of redundancy and backup power to avoid loss of safeguards knowledge over the operating lifetime of the facility. As new facilities and upgrades to existing facilities incorporate more automation, the use of unattended and remote monitoring systems will play a critical safeguards role [28–30]. In IAEA process monitoring (e.g. operational transparency), the facility operator's process instrumentation can offer a complementary safeguards measure.

Uranium conversion plants are a vital part of the nuclear fuel cycle and continue to develop as industrial processes adapt to new requirements put forth by reactor operators. Correspondingly, IAEA safeguards will continue to evolve in order to address new verification challenges and new technology.

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Annex I

TERMINOLOGY

Like any technical field, IAEA safeguards has its own lexicon and applies specialized meanings to many words in common everyday usage. This annex offers simple definitions for common terminology used in this publication. More complete explanations as well as translations of these terms into eight languages can be found in the IAEA Safeguards Glossary[1].

NUCLEAR AND NON-NUCLEAR MATERIAL

hold-up. Nuclear material deposits remaining in and about process equipment, interconnecting piping, filters and adjacent work areas.

in-process inventory. Nuclear material in the bulk processing areas of the plant that is not considered to be in storage. Hold-up is sometimes included in the in-process inventory.

irradiated direct use material. Direct use material that contains a substantial amount of fission products (e.g. plutonium in spent fuel).

NUCLEAR MATERIAL ACCOUNTANCY

accountancy. The practice of nuclear material accounting as implemented by the operator and the State as well as the activities by the IAEA to independently verify the completeness and correctness of the information in the facility records and the reports provided by the State to the IAEA.

adjustment. An entry into an accounting record or a report showing a **shipper/receiver difference** or **material unaccounted for.**

attended monitoring. A mode of non-destructive assay or surveillance, containment, monitoring and tamper indicating measures, or a combination of these, that requires inspector presence for operation.

authentication. Measures providing assurance that genuine information has originated from a known source (sensor) and has not been altered, removed or replaced.

continuity of knowledge. Assurance that the safeguards relevant data (e.g. identity and integrity of the item, item contents or flow and inventory of nuclear material) remains valid.[2]

destructive assay. Measurement of the nuclear material content, or the elemental or isotopic concentration of an item, that produces significant physical or chemical changes in the item and generates waste.

electronic mailbox. A location where the facility operator can make inventory or inventory change declarations on a frequent basis. The mailbox may be a container on-site under IAEA control or an email address under IAEA control. See definition for **near real time accountancy**.

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[2] Usage illustrated in the Safeguards Glossary, but not defined.

inventory mailbox. A location where the facility operator can make inventory or inventory change declarations on a frequent basis. The mailbox may be a container on-site under IAEA control or an email address under IAEA control. See definition for **near real time accountancy**.

mailbox. An IAEA controlled location where an operator makes frequent declarations. (See **mailbox declaration**.)

mailbox declaration. A situation where the operator makes (typically) daily declarations of the nuclear material received, shipped or processed into an IAEA controlled location. (See **near real time accountancy**.)

material balance period. Term used to refer to the time between two consecutive physical inventory takings.

material unaccounted for. The difference between the book inventory in the facility records and the physical inventory.

near real time accountancy. A form of nuclear material accountancy for bulk handling material balance areas in which itemized inventory and inventory change data are maintained by the facility operator and made available to the IAEA on a near real time basis so that inventory verification can be carried out and material balances can be closed more frequently than, for example, at the time of an annual physical inventory taking by the facility operator.

non-destructive assay. Measurement of the nuclear material content, or the elemental or isotopic concentration of an item, without producing significant physical or chemical changes in the item.

nuclear material accountancy. The practice of nuclear material accounting by the facility operator and, in addition, the verification and evaluation of this accounting system by a safeguards authority and/or the IAEA.

physical inventory. The sum of all the measured or derived estimates of batch quantities of nuclear material on hand at a given time within a material balance area, obtained in accordance with specified procedures.

physical inventory verification. Also known as an inventory verification. An IAEA safeguards inspection activity involving a physical nuclear material inventory within an MBA carried out to verify the operator's book inventory of nuclear material present at a given time within that MBA.

remote monitoring. A technique whereby safeguards data from equipment installed in a facility and operating unattended are transmitted off-site via communications networks for review and evaluation.

safeguards approach. A set of nuclear material accountancy, containment, surveillance and other measures chosen by the IAEA for the implementation of safeguards in a given situation.

shipper/receiver difference. The difference between the shipping facility's measured value for an item and the receiving facility's measured value for the same item. The difference can be compared with the associated measurement errors.

state of health. Data that describe the operational state of an instrument or other hardware.

trigger. An electronic signal, usually from a sensor, to request that another sensor take a reading or perform a measurement.

unattended monitoring. Non-destructive assay or containment and surveillance measures, or a combination of these, that operate for extended periods without inspector intervention.

CONTAINMENT AND SURVEILLANCE

containment. Structural features of a nuclear facility or equipment which enable the IAEA to establish the physical integrity of an area or item by preventing undetected access to or movement of nuclear or other material, or interference with an item or with IAEA safeguards equipment or data.[3]

dual containment and surveillance system. Each credible diversion path is covered by at least two IAEA authorized devices which are functionally independent (e.g. a seal, monitor or surveillance camera) and not subject to a common tampering or failure mode.

mixed oxide. A mixture of the oxides of uranium and plutonium.

scrap. Rejected nuclear material removed from the product stream, containing nuclear material that is economic to recover and recycle.

seal. A tamper indicating device used to join movable segments of containment in such a manner that access to the contents without opening the seal or breaking the containment is difficult.

single containment and surveillance system. Each credible diversion path is covered by an IAEA authorized device, e.g. a seal, monitor or surveillance camera.

surveillance. The collection of information through inspector and/or instrumental observation aimed at the monitoring of the movement of nuclear material or the detection of interference with containment and tampering with IAEA safeguards devices, samples and/or data.

tampering. Interference in an unauthorized and undeclared manner to physically defeat a containment and surveillance device.

unirradiated direct use material. Direct use material that does not contain fission products.

waste. Rejected nuclear material in concentrations or forms that do not permit economic recovery and that is designated for disposal.

NUCLEAR INSTALLATIONS AND EQUIPMENT

item facilities. Nuclear facilities where all nuclear material is contained in identifiable items (e.g. fuel assemblies), the integrity of which remains unaltered during the time they are at the facility.

reprocessing plant. An installation for the chemical separation of nuclear material from fission products, using irradiated fuel as the feed material. Once purified, uranium and plutonium may be converted to oxides as the product material.

safeguards essential equipment list. A list of equipment, systems and structures essential for the declared operation of a facility. *Safeguards* essential equipment is often different from *safety* essential equipment.

[3] This definition differs from that generally used in safety.

Annex II

SAFEGUARDS CONSIDERATIONS IN FACILITY LIFE CYCLE STAGES

Safeguards implementation is relevant to each stage of a facility's life cycle. While safeguards implementation potentially has a small impact on project cost and schedule when considered early in the design process, failure to consider it can result in a much larger impact than necessary, both on construction and operation. Figure II–1 depicts the life cycle stages of a facility in a simplified form, and potential safeguards aspects at each stage are discussed below. The State (or regional) authority responsible for safeguards implementation (SRA) is the official contact with the IAEA and should always be included in the dialogue when the IAEA is involved. When the designer and the operator are from different States, each may deal with a different State authority. Once a location in a State is selected for the nuclear facility, the corresponding SRA will be the official contact with the IAEA.

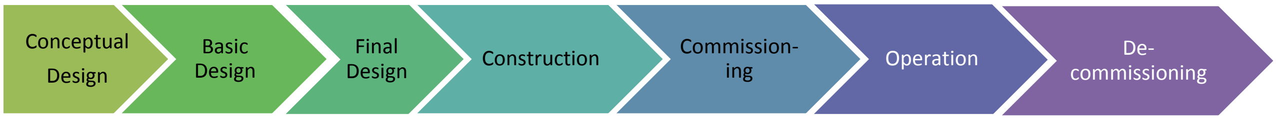

FIG. II–1. Facility life cycle stages.

II–1. CONCEPTUAL DESIGN

The conceptual design stage is the project planning period, the earliest design stage in which preliminary concepts for safeguards measures might be discussed. This stage may contain the following steps:

— A designer or operator assists the SRA to provide the IAEA with early design information.
— The IAEA examines the design information and may perform an evaluation of the operational process for features relevant to safeguards and identify possible safeguards measures for consideration.
— The IAEA prepares a preliminary safeguards approach and begins discussions with the SRA.
— The designer, operator, SRA and IAEA identify and mitigate potential safeguards risks in the conceptual design process.

II–2. BASIC DESIGN

In the basic design stage, the subsystem designs are under way and basic facility design details are available, including proposed safeguards equipment and locations. During this stage:

— The IAEA makes a preliminary definition of material balance areas and key measurement points and refines the safeguards approach.
— Discussions are held to consider how the design can be optimized to meet operational and safeguards goals, including physical infrastructure for safeguards instrumentation and equipment.
— Design information is updated and provided by the SRA to the IAEA and design information examination continues.

II–3. FINAL DESIGN

By the final design stage, the detailed facility design is complete; dimensions, equipment and planned operations are known, allowing for confirmation that the various systems will meet specified requirements. During this stage:

- The IAEA continues design information verification.
- Stakeholders review the detailed facility design.
- Stakeholders confirm that planned safeguards equipment will meet specified requirements under expected plant conditions.
- Design information is updated and provided by the State to the IAEA.

II–4. CONSTRUCTION

During the construction stage, the facility is constructed according to the specifications. Any necessary changes to the facility design or the planned safeguards equipment are assessed to ensure that they will not compromise safeguards performance. During this stage:

- The IAEA continues design information verification.
- SRA, IAEA and operator cooperate to install and test safeguards equipment.[1]

II–5. COMMISSIONING

During the commissioning stage, the final systems testing and licensing activities are under way. During this stage:

- The IAEA continues design information verification.
- The first nuclear material is introduced to the facility and may be used to calibrate safeguards equipment.
- The safeguards equipment and instruments are tested.
- The operator confirms the facility measurement and sampling equipment are adequate for reporting to the State.
- The operator tests facility systems.

II–6. OPERATION

The operation stage begins when the operator starts up the facility,[2] tests all systems and begins routine operation. During this stage:

- The IAEA continues design information verification and reviews the facility and associated systems.
- The IAEA performs inspections, e.g. verifies facility nuclear material accounting system, records and measurement systems.
- The IAEA confirms the operability and function of safeguards equipment, calibrates equipment, cooperates with SRA and the operator to troubleshoot any issues.

During routine operation, the IAEA performs safeguards activities as summarized in Section 2 of this publication. Operating and maintenance activities may include repair and replacement of equipment.

[1] During construction, safeguards equipment can be confirmed to be functional without nuclear material in the facility, whereas operational status includes all necessary aspects for routine operation (e.g. calibration, positioning and certification), including operation of the equipment with nuclear material present.

[2] The safeguards equipment should be certified for use before nuclear material is introduced into the facility.

II–7. DECOMMISSIONING

In the decommissioning stage, the operator takes the facility out of operation and begins cleanup and dismantlement. During this stage:

— The IAEA continues design information verification and inspections.
— The IAEA verifies the removal of nuclear material and removal or disabling of essential equipment.
— The IAEA may make a determination regarding the decommissioned status of the facility, for safeguards purposes.

Annex III

IDENTIFYING SAFEGUARDABILITY ISSUES

This annex gives an example of a facility safeguardability assessment approach.[1] It can be used as a structured approach to understanding and identifying potential safeguards issues. If an operator is building or modifying a standardized facility design for which a well understood safeguards approach exists, an analysis of safeguardability may not be needed. However, it may be possible to make existing safeguards tools and measures more efficient with slight modifications to the design, configuration or operating procedures.

A greater effort to assess facility safeguardability might be warranted for facilities that include novel design features or facilities that present particular safeguards challenges. Innovative designs that are different from those for which IAEA safeguards approaches have been established can present safeguards challenges that could be considered by the designer, who could help mitigate these issues or help accommodate innovative safeguards tools and measures to address them. In this case, the facility design team might benefit from the inclusion of safeguards expertise.

Safeguards issues can arise from design differences (as compared with existing facilities under IAEA safeguards) that:

- Use different isotopic, chemical or physical forms of the nuclear material;
- Create additional or alter existing diversion paths;
- Create different nuclear material categories for measurement;
- Alter nuclear material flows or pathways;
- Increase the difficulty of design information examination and verification;
- Impede the IAEA's capability to verify that diversion has not taken place;
- Create a new or alter an existing potential for the facility to be misused.

The screening questions in Table III–1 may be helpful in assessing safeguardability of a facility design, particularly as compared with a design of a similar facility which has an established safeguards approach.

[1] BARI, R.A., et al., Facility Safeguardability Assessment Report, Pacific Northwest National Laboratory Report, PNNL-20829, Pacific Northwest National Laboratory, Oak Ridge, TN (2011).

TABLE III-1. FACILITY SAFEGUARDABILITY ASSESSMENT

Facility safeguardability assessment screening questions	
1. Does this design differ from the comparison design/process in ways that have the potential to create additional diversion paths or alter existing diversion paths?	Yes/No
1.1. Does this design introduce nuclear material of a type, category or form that may have a different significant quantity or detection time objective than previous designs (e.g. mixed oxide rather than low enriched uranium, irradiated vs. unirradiated, or bulk vs. item)?	Yes/No
1.2. Does this design layout eliminate or modify physical barriers that would prevent the removal of nuclear material from process or material balance areas (e.g. circumvent a key measurement point)?	Yes/No
1.3. Does this design obscure process areas or material balance area boundaries making containment/surveillance or the installation of measurement and monitoring equipment more difficult?	Yes/No
1.4. Does this design introduce material that could be effectively substituted for safeguarded material to conceal diversion?	Yes/No
2. Does this design differ from the comparison design in a way that increases the difficulty of design information examination and verification by IAEA inspectors?	Yes/No
2.1. Does the design incorporate new or modified technology? If so, does the IAEA have experience with the new or modified technology?	Yes/No
2.2. Are there new design features with commercial or security sensitivities that would inhibit or preclude IAEA inspector access to equipment or information?	Yes/No
2.3. Do aspects of the design limit or preclude inspector access to, or the continuous availability of, essential equipment for verification or testing?	Yes/No
2.4. Are there aspects of the design that would preclude or limit IAEA maintenance of continuity of knowledge during the life of the facility?	Yes/No
3. Does this design or process differ from the comparison design or process in a way that makes it more difficult to verify that diversion has not taken place?	Yes/No
3.1. Does this design lessen the efficiency of physical inventory taking by the operator or the effectiveness of physical inventory verification by the IAEA?	Yes/No
3.2. Does this design impair the ability of the operator to produce timely and accurate interim inventory declarations or of the IAEA to perform timely and accurate interim inventory verification (IIV)?	Yes/No
3.3. Does this design impede timely and accurate inventory change measurements and declarations by the operator and verification by the IAEA?	Yes/No
3.4. Does this design impede the introduction of or reduce the usefulness of other strategic points within the material balance area?	Yes/No
4. Does this design differ from the comparison design in ways that create new, or alter existing, opportunities for facility misuse or make the detection of misuse more difficult?	Yes/No
4.1. Does this design differ from the comparison facility/process by including new equipment or process steps that could change the nuclear material being processed to a type, category or form with a lower significant quantity or detection time objectives?	Yes/No
4.2. If the comparison facility safeguards approach employs agreed upon short notice visits or inspections, measurements or process parameter confirmations, would this design preclude the use of, or reduce the effectiveness of, these measures?	Yes/No
4.3. Do the design and operating procedures reduce the transparency of plant operations (e.g. availability of operating records and reports or source data for inspector examination or limited inspector access to plant areas and equipment)?	Yes/No

Annex IV

EXAMPLES OF DESIGN INFORMATION QUESTIONNAIRE INFORMATION FOR URANIUM CONVERSION PLANTS

The following information is written at an introductory level for an audience unfamiliar with IAEA design information questionnaires. It has no legal status. Official templates are available from the IAEA.

A conversion facility design information questionnaire includes at least the following:

- — Facility name, location, address, owner, operator, status, purpose.
- — Officers responsible for the facility.
- — Facility status — planned, under construction, in operation, decommissioned.
- — Facility and site layout.
- — Facility description, including general flow diagrams, storage areas, and feed, product and waste points.
- — Process description, indicating type of conversion, including the modification of chemical and physical forms.
- — Design capacity (principal products per year).
- — Anticipated annual throughput (including growth projections as applicable).
- — Important items of equipment using, producing or processing nuclear material.
- — Nuclear material description and flow (for feed, intermediate product and product):
    - Accountability units to be used;
    - Chemical and physical forms including drawings with dimensions;
    - Throughput, U enrichment ranges, Pu contents (if applicable);
    - Batch size and flow rates;
    - Storage and plant inventory;
    - Frequency of shipments;
    - Frequency of receipts.
- — Feed material.
- — Product material.
- — Scrap material:
    - Sources;
    - Chemical and physical form;
    - Estimated U enrichment ranges and Pu content ranges;
    - Estimated quantities per year, storage periods;
    - Generation rates;
    - Storage inventory and maximum capacity;
    - Method and frequency of recycle.
- — Waste material:
    - Sources;
    - Chemical and physical form;
    - Estimated U enrichment ranges and Pu content ranges;
    - Estimated quantities per year, storage periods;
    - Generation rates;
    - Storage inventory and maximum capacity;
    - Method and frequency of disposal.
- — Waste treatment system.
- — Other nuclear material in the facility, including location.
- — Flowsheets.
- — Types, forms, enrichment range, Pu content (range), flow rates (ranges) of nuclear material in each nuclear material handling and storage area.
- — Recycle processes (including diagrams).
- — In-process, feed and storage inventory.
- — Nuclear material inventories and flows in other areas.

— Container information, including packing and storage description.
— Methods and means of transfer of nuclear material.
— Transportation routes followed by nuclear material (including drawings).
— Shielding for storage and transfer.
— Maintenance, decontamination and cleanout plans:
  - Methods to ensure vessels are empty;
  - Tools and accessories used for cleanout.
— Plant startup and shutdown procedures.
— Basic physical protection measures.
— Specific health and safety rules for inspector compliance.
— Nuclear material accounting and control:
  - System description;
  - Ledger format, operational records and accounts;
  - Form (electronic, paper, other);
  - Procedures for making adjustments;
  - Procedures for making measurements;
  - Procedures for measurement control;
  - Receipts;
  - Procedure for shipper and receiver differences;
  - Shipments (products, waste, measured discards);
  - PIV including procedures, frequency, measurement method details, cleanout;
  - Retained waste;
  - Unmeasured losses.
— Features related to C/S measures.
— Description of measurement points, items being measured, possibility to use for PIV, sampling procedures, measurement instruments, precision and accuracy of measurement, calibration details, measurement control details.
— Overall limits of error (shipper/receiver differences, book inventory, physical inventory, MUF).
— Optional information the operator considers relevant to safeguards.

ABBREVIATIONS

C/S	containment and surveillance
CSA	comprehensive safeguards agreement
DIQ	design information questionnaire
DIV	design information verification
DNLEU	depleted, natural or low enriched uranium
KMP	key measurement point
LEU	low enriched uranium
LOF	location outside facilities
MBA	material balance area
MUF	material unaccounted for
PIV	physical inventory verification
SBD	safeguards by design
SRA	State or regional authority responsible for safeguards implementation
UOC	uranium ore concentrate

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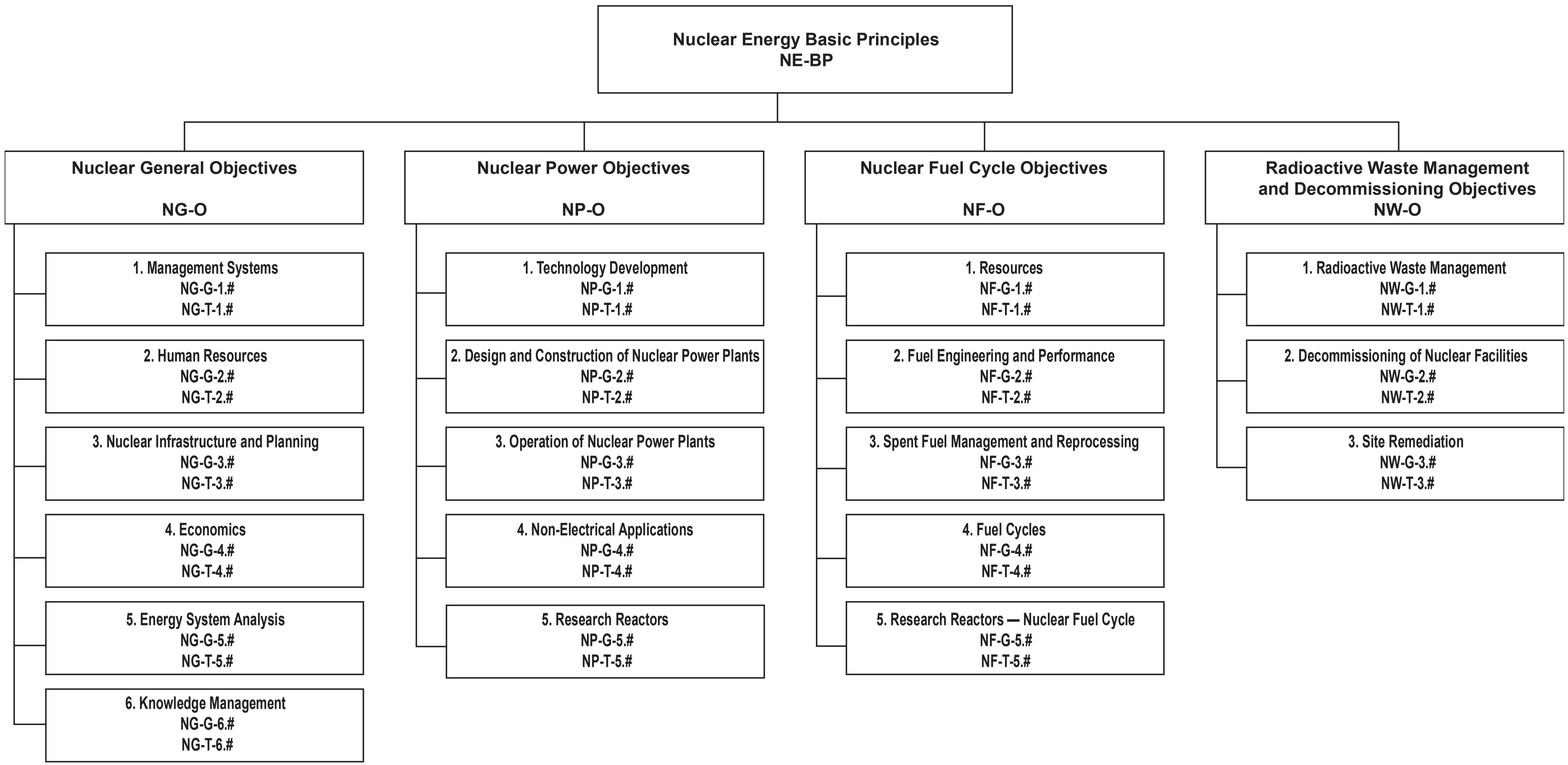

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ISBN 978–92–0–100517–5
ISSN 1995–7807