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International Safeguards in the Design of Radioactive Waste Management Programmes

TECHNICAL REPORTS

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INTERNATIONAL SAFEGUARDS IN THE DESIGN OF RADIOACTIVE WASTE MANAGEMENT PROGRAMMES

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INTERNATIONAL SAFEGUARDS IN THE DESIGN OF RADIOACTIVE WASTE MANAGEMENT PROGRAMMES

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FOREWORD

The IAEA's statutory role is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". Among other functions, the IAEA is authorized to "foster the exchange of scientific and technical information on peaceful uses of atomic energy". One way this is achieved is through a range of technical publications including the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series comprises publications designed to further the use of nuclear technologies in support of sustainable development, to advance nuclear science and technology, catalyse innovation and build capacity to support the existing and expanded use of nuclear power and nuclear science applications. The publications include information covering all policy, technological and management aspects of the definition and implementation of activities involving the peaceful use of nuclear technology. While the guidance provided in IAEA Nuclear Energy Series publications does not constitute Member States' consensus, it has undergone internal peer review and been made available to Member States for comment prior to publication.

The IAEA safety standards establish fundamental principles, requirements and recommendations to ensure nuclear safety and serve as a global reference for protecting people and the environment from harmful effects of ionizing radiation.

When IAEA Nuclear Energy Series publications address safety, it is ensured that the IAEA safety standards are referred to as the current boundary conditions for the application of nuclear technology.

This publication, part of the IAEA Nuclear Energy Series, is one in a series of facility specific 'safeguards by design' guidance publications. The topics of these publications include international safeguards in the design of nuclear reactors, uranium conversion plants, fuel fabrication plants, facilities for long term spent fuel management, reprocessing plants, enrichment plants and radioactive waste management facilities. Spent fuel management and radioactive waste management are addressed separately in this group of publications within the IAEA Nuclear Energy Series.

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

Many 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. Safeguards by design does not introduce new requirements. Instead, it advocates the consideration of IAEA safeguards throughout stages in the life cycle 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 (1) prevent safeguards requirements from unduly interfering with the smooth construction and operation of a facility; (2) avoid costly and time consuming retrofits or redesigns of facilities to accommodate safeguards; (3) minimize risks associated with licensing that may result from design changes; (4) achieve efficiencies in safeguards implementation to the benefit of the operator, the State, and the IAEA; and (5) ensure the implementation of effective safeguards.

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EDITORIAL NOTE

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Guidance and recommendations provided here in relation to identified good practices represent experts' opinions but are not made on the basis of a consensus of all member states.

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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 with the early consideration of safeguards activities relevant to particular nuclear fuel cycle facility types.

This publication has been prepared for the application of safeguards in the design of radioactive waste management programmes, but the interaction of the waste process with the State's safeguards obligations is both varied and complex. For States implementing an open nuclear fuel cycle strategy (and planning to dispose radioactive waste and spent nuclear fuel in the same repository), this publication is fully applicable. For States implementing a closed nuclear fuel cycle strategy (active reprocessing of spent nuclear fuel and disposal of exclusively radioactive waste, keeping separate State records of nuclear material flows and radioactive waste flows), this publication is of an introductory nature and additional publications in this series will also be applicable. For States that are still leaving the choice of nuclear fuel cycle strategy open and implementing a dual approach, this publication will allow an assessment of the efforts necessary to ensure safeguards in the design of radioactive waste management programmes.

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. Several terms defined within the IAEA documents that make up the legal framework of IAEA safeguards are included in the glossary section of this publication. 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 the IAEA web page on safeguards and verification.

It is important that safeguards be considered early in the design process to minimize the risk of impacts on scope, schedule and budget [2] and to facilitate better integration with other design considerations such as those for operations, safety and security [3, 4]. In IAEA Safety Standards Series GSR Part 1, Governmental, Legal and Regulatory Framework for Safety [5], "**Requirement 12 (Interfaces of safety with nuclear security and with the State system of accounting for, and control of, nuclear material)**" imposes the following obligation:

> "**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 the IAEA Nuclear Security Series and IAEA Safety Standards Series (e.g. GSR Part 1 [5]). The trend is for new facilities to be built with inherent safety and security features as well as accommodations for safeguards. IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design [6], contains requirements pertaining to interfaces of safety with security and safeguards, which apply to any type of facility:

> "**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**", Requirement 8 [6].

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. Safeguards by design 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 a 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 the awareness of safeguards obligations for all stakeholders;
- Reducing inefficiencies in the IAEA's safeguards activities;
- Improving the effectiveness of safeguards implementation;
- Facilitating the consideration of joint use of equipment by the operator, the State (or regional) authority responsible for safeguards implementation (SRA) and the IAEA;
- Reducing operator burden and increasing efficiency for the application of 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 governments about IAEA safeguards and how associated requirements can be considered early in the design phase of a new nuclear facility. Safeguards by design dialogues 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. Guidance and recommendations provided here in relation to identified good practices represent experts' opinions but are not made on the basis of a consensus of all Member States.

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[1] Note 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 modify, has been taken.

FIG. 1. Aerial view of the low and medium activity waste disposal vaults and associated treatment facility at the Enresa El Cabril disposal site, Spain (photograph courtesy of Enresa).

1.3. SCOPE

This guidance is applicable to the design and construction of facilities for the management of radioactive wastes, such as the Enresa El Cabril disposal site in Spain shown in Fig. 1.[2] It is intended to support the consideration of safeguards in parallel with other considerations during the design and construction process. It is directed at the baseline case of waste processing plants for very low level wastes (VLLW), low level wastes (LLW) and intermediate level wastes (ILW), though some high level waste (HLW) processing will be discussed as well. Its scope encompasses the receipt of raw wastes in various chemical and physical forms and the on-site processing, packaging and potential short or long term storage of waste packages prior to transportation to a disposal facility, generally referred to as predisposal management. This guidance will not cover the siting, creation or licensing of disposal facilities but will refer to their existence as they may have significant impacts on radioactive waste management decisions.

1.4. STRUCTURE

Section 2 provides a general overview of IAEA safeguards implementation, followed by facility specific guidance in subsequent sections. The 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. The guidance provided herein represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States. 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 at the IAEA webpage on safeguards and verification. It may also be useful to refer to the IAEA Safeguards Glossary [7].

Section 3, entitled Safeguards Considerations for Radioactive Waste Management, discusses in detail proliferation concerns, misuse and diversion scenarios, general guidance and some examples of waste that may incur safeguards obligations.

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[2] For the purposes of this publication, both the term radioactive wastes/materials and the term nuclear wastes/materials will be used. Radioactive wastes/materials are defined by regulation or other legal instruments in each State. Nuclear wastes/materials are defined by isotope. Therefore, there are radioactive wastes/materials that are not nuclear wastes/materials; nuclear wastes/materials that are not radioactive wastes/materials; and wastes/materials that are both.

The general guidance section includes the following:

- Infrastructure to support safeguards;
- Design information, examination, and verification;
- Containment, tamper indicating seals, surveillance and monitoring;
- Transfer to retained waste;
- Termination of safeguards;
- Safeguards concepts for non-nuclear material handling facilities.

Examples of waste that may have safeguards obligations have been divided into five categories to allow more detailed discussion and illustration. The categories are described as:

- Source I — waste from normal operations;
- Source II — waste from decommissioning and operational replacements;
- Source III — waste from accidents and off-normal operations;
- Source IV — waste from past activities;
- Source V — waste from industrial sources, previously exempted materials and accidental gains.

In addition, there are extensive examples of waste treatments, waste storage and common waste packages in use in the radioactive waste management industry, including drums and boxes.

Annex I provides explanations of specific safeguards terminology used in this publication. There are four subsequent annexes covering safeguards considerations in facility life cycle stages, identifying safeguardability issues, a draft design information questionnaire (DIQ) for radioactive waste management facilities and a collection of technical examples. They are as follows:

- Annex II: Safeguards Considerations in Facility Life Cycle Stages, which gives an overview of the actions for a designer or operator to include safeguards concepts from the conceptual design though to decommissioning of the facility.
- Annex III: Identifying Safeguardability Issues, which provides a list of questions that can be used by a State or operator to identify potential safeguards issues associated with a facility design.
- Annex IV: Information found in the Design Information Questionnaire for Radioactive Waste Management Facilities), which provides information that will be relevant for the start of the Design Information process tailored for waste management facilities.
- Annex V: Technical Examples for Termination of Safeguards provides nine synthesized case studies, based on real experiences, that are designed to exemplify the concepts presented in this publication.

1.5. USERS

A key audience for this publication is the SRA, 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 of the key stakeholders.

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 [9], it concludes agreements with States and with regional safeguards authorities for their application. These agreements are of three types: (1) comprehensive safeguards agreements (CSAs) [10] with or without a small quantities protocol added to them; (2) item-specific safeguards agreements [11]; and (3) voluntary offer agreements. A State with any one of these agreements may also conclude a protocol additional to its safeguards agreement [12]. The large majority of safeguards agreements in force are CSAs and this publication focuses on these agreements. 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. States that are part of a nuclear-weapon-free zone via treaty are also generally required under the terms of the treaty to conclude appropriate bilateral or multinational safeguards agreements with the IAEA [13–17].

Under a CSA, there are three generic safeguards 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; and
- To detect any undeclared nuclear material or activities in the State as a whole.

At nuclear facilities, most safeguards activities focus on addressing the first two objectives.

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, called design information verification (DIV), contributes significantly to achieving the second objective.

Note that throughout this publication, the word facility is used in multiple contexts. While this word is colloquially used to describe a location or place where a process occurs or work takes place, it also has a definition related to safeguards. Specifically, a facility for safeguards purposes is (a) a reactor, a critical facility, a conversion plant, a fabrication plant, a reprocessing plant, an isotope separation plant, or a separate storage installation; or (b) any location where nuclear material in amounts greater than one effective kilogram is customarily used. A LOF, by definition, is any installation or location, which is not a facility, where nuclear material is customarily used in amounts of one effective kilogram or less. For safeguards purposes, waste facilities may be considered a facility, a LOF or neither if nuclear material is not customarily used. Operators are encouraged to contact their regulatory authority for clarification of the status of their facilities in the State.

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. On-site safeguards verification activities by IAEA inspectors [9] include DIV, physical inventory verification (PIV), short notice random and unannounced inspection, interim inventory verification (IIV), and complementary access (CA) in States with an additional protocol (AP) in force [18]. Examples of techniques and measures used by the IAEA include, inter alia:

- Nuclear material accountancy, such as the review of facility records and supporting documentation [19];
- Measurements of nuclear material (e.g. weight, gamma or neutron fields) [20, 21];
- 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 IAEA Safeguards Techniques and Equipment [21].

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. Sections 2.3.1 to 2.3.3 describe these verification activities.

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 when construction begins on the facility and throughout the life of the facility to reflect changes or modifications. This process is reserved for facilities that are designed to handle safeguarded nuclear materials.[3]

Design information is submitted using the DIQ; DIQ templates can be requested from the SRA (for operators or designers) or from the IAEA (for the SRA). Annex V lists a summary of the type of information provided to the IAEA for the management of radioactive wastes addressed in this guide.

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, the IAEA may visit the site to inspect and document through photographs the aspects of its construction. In later visits, IAEA inspectors 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 the DIV requirements may be considered in the design phase. In addition, the IAEA develops an 'essential equipment' list for the nuclear facility

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[3] For LOFs, this process is called LOF information verification.

FIG. 2. IAEA design verification.

to use in determining whether a facility can be considered decommissioned for safeguards purposes.[4] The designers and operators of the facility can play a valuable role in helping the IAEA to identify the equipment that is essential for operating the nuclear facility.[5]

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. 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 [10]. 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 that requires enrichment or further processing) 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 may be referred to as item facilities. In such facilities, the nuclear material is contained in discrete items (not designed to be divided or opened), such as fuel rods or fuel assemblies in a typical power reactor. In bulk handling facilities, such as waste conditioning facilities, the nuclear material (or items contaminated with nuclear material) is handled in loose form and can be repackaged with the possibility of combining or splitting up the quantity of nuclear material in containers

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[4] "*Decommissioned facility* or *decommissioned location outside facilities* means an installation or location at which residual structures and equipment essential for its use have been removed or rendered inoperable so that it is not used to store and can no longer be used to handle, process or utilize nuclear material" [12]. 'Decommissioned for safeguards purposes' is a stage in the decommissioning process when all safeguards relevant materials, equipment, etc. have been removed and the facility MBAs and other accountancy instruments are dissolved. This stage is differentiated from decommissioned, which means the site has been remediated to the agreed upon end state and can be released from regulatory control or to a lower level of such control.

[5] The IAEA *safeguards* essential equipment list (EEL) is different from the *safety* essential equipment list. The EEL is facility specific and comprises the required equipment that allows the facility to operate as intended. The EEL must be rendered inoperable or removed for the facility to be decommissioned for safeguards purposes.

FIG. 3. Sample preparation at IAEA laboratory.

and 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 [19] and the collection of nuclear material samples for analysis is typically performed (see Fig. 3).

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 [19]. The IAEA performs a PIV after a facility operator has performed a physical inventory taking. 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 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. Verification of nuclear material accountancy includes assessment of the operator's measurement systems including the associated measurement uncertainties. Given resource limitations and the need to minimize the disruption to facility operations, statistical sampling [22] 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.

For verification purposes, a defect is a statistically significant difference between the declared amount of nuclear material and the amount of material as determined by the IAEA's verification measurement. Three levels of defects must be considered when verifying nuclear material [8].

- 'Gross defect' refers to an item or batch that has been completely 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 still 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 IAEA inspectors making 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.

FIG. 4. Item counting in fresh fuel store.

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

Figure 6 shows measurements of irradiated fuel (irradiated direct use material) in a spent fuel storage pool. 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 by 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 for equipment storage, calibration standards and check sources, as well as locations to perform measurements, should not interfere with routine plant operations.

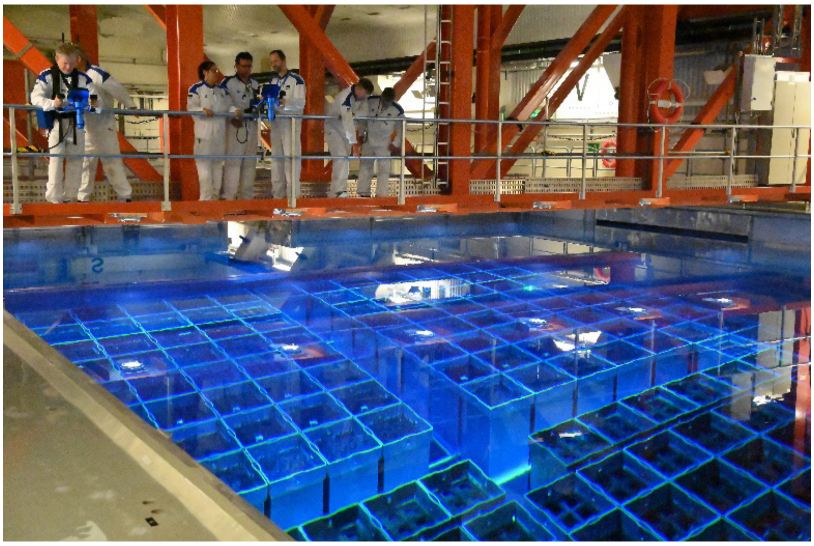

FIG. 6. A measurement of irradiated fuel in a cooling pond.

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 approved several surveillance systems for use [21] 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 tamperproof 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

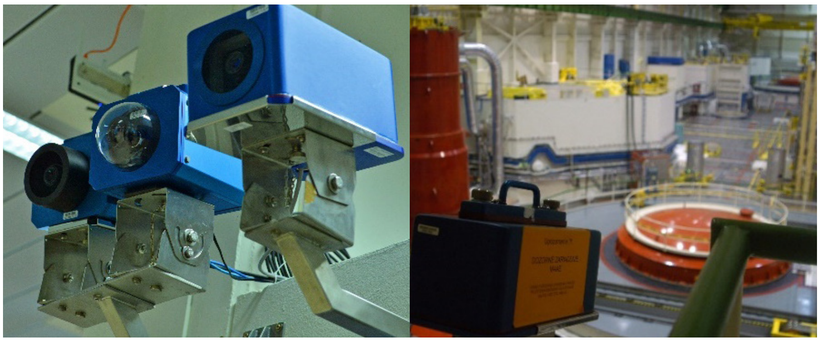

FIG. 7. Next generation IAEA surveillance system.

FIG. 8. Operator support to installation of IAEA equipment racks.

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:

- Supplying reliable power, secured access, dedicated working space and data transmission (wired or wireless) throughout the facility (Fig. 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 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 a local language;
- 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 should, as far as possible, ensure that the attachment point cannot be removed without detection or without damaging or breaking the seal.

Maintaining 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,

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

investigating possible undeclared activities and detecting irregularities in operations, which generally saves time for both operator and inspector.

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.

2.4. PHYSICAL INFRASTRUCTURE REQUIREMENTS FOR IAEA SAFEGUARDS ACTIVITIES

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

2.5. FACILITY DECOMMISSIONING

Implementation of IAEA safeguards continues after a facility is shut down and preparations for decommissioning begin. 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 both that nuclear material has been removed and that 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.[6]

While a facility may be decommissioned for safeguards purposes as described above, there exists the possibly that small amounts of material may be discovered as contamination or as hold-up within structures or equipment that will be designated as waste. States, or operators, should develop a plan in

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[6] See footnote 4 on page 7.

FIG. 10. Installation of a surveillance system.

conjunction with the IAEA or SRA for these materials during the decommissioning process to clearly define how these materials will be handled and, if needed, declared. It is possible that some objects or surfaces containing nuclear materials may be identified and will have to be declared as accidental gains through their normal State processes and transferred to an appropriate State facility or LOF for further treatment.

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 FOR RADIOACTIVE WASTE MANAGEMENT PROGRAMMES

3.1. PROLIFERATION CONCERNS

Recovery of uranium (U) or plutonium (Pu) may be carried out as a routine operation during the treatment of solid or liquid wastes containing the nuclear materials. Waste from stages of the nuclear fuel cycle, including fuel fabrication and fuel reprocessing operations — in particular, U–Pu mixed oxide fuel, including that used for fast breeder reactors, may contain plutonium, ^{233}U, highly enriched uranium (HEU), low enriched uranium (LEU), natural uranium (NU), depleted uranium (DU), thorium (Th), and other fissionable actinides such as neptunium (Np) and americium (Am). Although the absolute concentration and purity of nuclear material in waste could be quite low (owing to admixtures of fission products, other actinides or corrosion product), the quantities of nuclear material in waste could, nevertheless, be important (see Section 3.3.6). Therefore, the possibility of a State or organization seeking to clandestinely acquire nuclear material from waste cannot be excluded.

The concern stated above is valid for all wastes that contain nuclear material. However, the risk posed by the wastes will scale with the concentration of nuclear material contained therein and the physical characteristics of the waste. Consequently, the proliferation concerns related to wastes from spent fuel reprocessing and processes involving concentrated nuclear materials (e.g. fuel fabrication), which may have a significant nuclear material content, versus those from operational wastes, that typically have a lower nuclear material concentration, will be similar but of different magnitudes. This implies that these wastes will have safeguards measures applied to them generally proportional to their proliferation concern. Figure 11 shows the waste from certain facilities will have a higher significance and therefore a higher number of safeguards measures applied. This graded approach to safeguards is exemplified in the technical examples presented in Annex V.

Safeguards on nuclear material contained in certain waste forms or packages may be terminated if the IAEA determines that the nuclear material is practicably irrecoverable and meets criteria established for termination of the waste type and form (see Section 3.3.6). In States with an AP in force (based on INFCIRC/540) [12], Article 2.a.(viii)) requires the State to report changes in location and plans for further processing of ILW or HLW containing plutonium, HEU or ^{233}U on which safeguards have been terminated; it should be noted that processing does not include “repackaging of the waste or its conditioning not involving the separation of elements, for storage or disposal” [12]. This provision is to deal with the proliferation potential posed by recovery of fissile and fissionable isotopes from the waste. Special arrangements have also been made on a voluntarily basis for the IAEA to monitor the availability of separated neptunium and americium in States with a CSA in force.

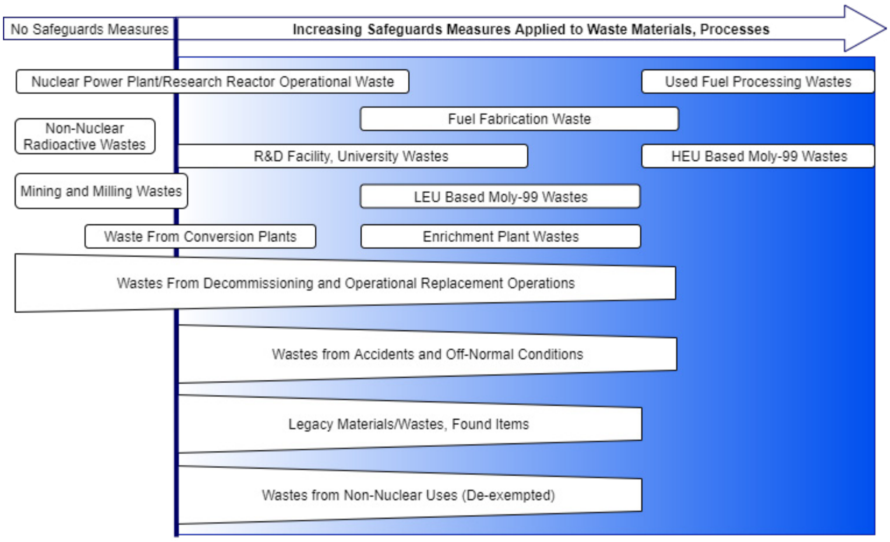

FIG. 11. The relationship between where radioactive wastes originate (described in the white shapes) and the potential intensity of safeguards measure applied to those wastes. Wastes that fall in a blue shaded region will likely have some level of safeguards measures applied, increasing in intensity from left to right, while those outside (to the left) are those wastes that either do not contain nuclear materials or those that are before the starting point of safeguards (i.e. pre-34(c) material [10]).

3.1.1. Reprocessing and fabrication wastes

The radioactive wastes that are generated from reprocessing have lower proliferation concerns than those posed by the product materials (the recovered nuclear materials) because of the large quantities of waste material that has to be processed to recover the contained nuclear material. For example, the PUREX process can normally recover uranium and plutonium from the input dissolver solution at an efficiency of >99% [23]. The unextracted plutonium and uranium remains with the fission products and other actinides into retained high level liquid waste (liquid HLW).

The recovery of plutonium from liquid HLW is not simple, although it is possible using newer separation techniques, such as the TRUEX process [24]. However, there have also been technical developments in recent years that led some States to consider long term waste management strategies for dealing with the liquid HLW that include partitioning of long-lived actinides to reduce the waste's radiotoxicity. In addition, commercial uses of some fission products and actinides could provide incentives for partitioning them. Such waste management strategies and isotope recovery programmes would increase the possibility that nuclear material could be acquired from the waste.

Similar to reprocessing wastes, enrichment, fuel fabrication and even medical isotope facilities can generate wastes with high concentrations of nuclear material. These may exist as residues on packing materials, dusts from manufacturing or sintering processes or cutting swarf. The nuclear materials typically exist as a separate phase within the waste stream (i.e. are not bonded to the raw waste) that could be recovered but typically is not due to economic or process specific reasons and is regarded as an acceptable process loss. The presence of these materials in waste streams could provide an incentive to recover the materials clandestinely.

3.1.2. Other sources of waste

While the most significant waste streams, in terms of nuclear material content and accessibility, are found in those facilities that deal with direct use materials (e.g. plutonium, HEU or ^{233}U) described above, significant amounts of nuclear materials can also be found in other waste streams generated throughout the nuclear fuel cycle. These waste streams, generated during normal operations or decommissioning activities, typically have much lower concentrations of nuclear material, making it attractive for States to pursue termination of the safeguards measures on them. These wastes may have significant safeguards obligations, typically due to their large volumes, and may pose verification challenges. Therefore, it is encouraged that appropriate management of these wastes within the State include safeguards concepts as early as possible. For example, the creation of national policies and strategies that identify termination of safeguards as a possible management route for wastes will ensure that safeguards are included in early discussions of the waste management process.

3.2. MISUSE AND DIVERSION SCENARIOS

The term 'misuse and diversion'[7] refers to the use of a safeguarded facility for the introduction, processing or production of undeclared material and/or the removal of declared nuclear material from a safeguarded facility. The facility designer and operator should review their facility to ensure that it can best accommodate any safeguards measures without any need for retrofitting and that it does not contain any features that may enable misuse and diversion. Safeguards objectives at a radioactive waste management facility include verifying that there is:

- No diversion of declared nuclear material;
- No misuse occurring through the processing of undeclared nuclear material;

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[7] Please see the included terminology in Annex I for more information on these terms.

- No overstatement of waste materials to cover diversion elsewhere;

There are several generic scenarios that should be considered related to misuse and diversion. The simplest concerns misuse. In such a case, unused production capacity in a facility is directed to process undeclared nuclear material feed. For example, if a facility is operating at 80% capacity, the remaining 20% could be used for processing an undeclared nuclear material feed. This undeclared material is, by its nature, never entered into the facility accounting system. In the case of diversion, there are multiple potential scenarios. Consider a facility that has a nuclear material extraction efficiency of 99.99%. This could be intentionally degraded to drive more nuclear material into the waste. At the same time, the accounting value for the waste could be understated. The excess nuclear material could be extracted from the waste at a later date. Conversely, the extraction efficiency could remain at its highest efficiency and the nuclear material accounting values for the waste could be overstated where that nuclear material is diverted from the waste at the original processing facility. In each case the accounting system appears to accurately represent the nuclear material in each item. These factors are especially important for wastes that may have the safeguards measures on them terminated as the IAEA will not be able to verify these materials in the future.

Misuse and diversion scenarios can be addressed by appropriate safeguards measures, e.g. design information examination (DIE), DIV, flow/inventory verification, containment and surveillance measures, and CA in States with an AP.

Safeguards measures and operator support may include:

- Remote monitoring of hot cells (if nuclear material is processed in hot cells);
- Calibration of liquid waste tank systems required for IAEA quantitative verification;
- A containment and surveillance system to maintain a continuity of knowledge of nuclear material that was verified or has not yet been verified;
- Implementation of NDA systems to verify nuclear material or to monitor movement of nuclear material;
- Support for inspector access to safeguards relevant operating information;
- Provision for the joint evaluation of facility sampling systems by the IAEA, State and operator (e.g. evaluating the possibility of evaporation, tamper vulnerability and access control).

3.3. GENERAL GUIDANCE

Safeguards measures vary from facility to facility depending on the safeguards concerns. In every case, the exact blend of measures required for the facility is based on how that facility is designed, how it will operate, what nuclear material is present and what agreements are in place that govern safeguards application. By involving the IAEA and the SRA at an early stage of facility design, or when a retrofit, upgrade or other changes are implemented, appropriate measures can be applied to the facility. As a general concept, the majority of waste facilities will have a comparatively small number of safeguards measures applied to them, at least when compared with most fuel cycle facilities. Typically, the more attractive the material contained in the waste the higher the safeguards burden; liquid HLW at reprocessing facilities or medical isotope processes using HEU are examples of attractive materials.

The guidance in this section can be applied to those waste management facilities that are designed to handle, process, containerize and/or store waste materials containing nuclear materials. This can be a new facility or a retrofit of an existing facility. Further guidance will be provided in Section 3.3.7 for processes and facilities that are non-safeguarded facilities (or not expected to handle nuclear materials) on how they can incorporate certain SBD concepts into their policies and procedures when dealing with items originating within the nuclear fuel cycle.

3.3.1. Infrastructure to support safeguards

The facility operator is responsible for providing access to buildings, structures and areas and the infrastructure necessary to support safeguards equipment. In cases where IAEA inspectors request that nuclear material needs to be moved or sampled, the facility operator is responsible for the provision of the necessary nuclear material handlers to support these activities. In many cases, the facility's safety regime requires that facility personnel perform equipment installation and any in situ maintenance. Accordingly, the IAEA is typically present when safeguards equipment is being installed or maintained. Figure 12 shows a waste crate assay system that is used to measure nuclear materials in waste packages; while it is used for safeguards purposes, this type of equipment is typically installed by the facility. SBD best practice is that provision be made for safeguards equipment handling and installation in the design and construction of the facility. Moreover, SBD recognizes that the techniques and methods applied for safeguards may change over the facility's operational lifetime and suggests that an infrastructure design be developed that can accommodate these changes.

When sensors are placed in high radiation or high traffic areas, the support electronics associated with those sensors can often be placed in low hazard, low traffic areas. A designer or operator can recommend optimum locations that avoid interference with operations. Shielding, lighting, cabling, backup power, maintenance and decontamination issues can be discussed. Segregated, well labelled utilities can reduce the chance of the operator inadvertently disabling safeguards equipment. Remote data transmission capability implies that the facility will provide connections (e.g. cabling or wireless) from the installed IAEA equipment sensors to the IAEA data collection and transmission equipment, and from the IAEA transmission equipment to the Internet.

Safeguards equipment requires regular maintenance and periodic replacement. Maintenance can sometimes be performed during normal facility operation if suitable arrangements are in place. Coordination with those responsible for the facility equipment installation and maintenance, including the sharing of resources between the operator and the IAEA, can be considered. Otherwise, maintenance can be performed by the IAEA only on equipment that has been checked for contamination and decontaminated if necessary after being in the nuclear facility.

Guidance based on lessons learned in the design and installation of infrastructure for safeguards equipment includes the following recommendations. Not all recommendations will apply to every facility.

It should be noted that the recommended aspects listed below are desirable but not always necessary. This list gives illustrative examples, and their application will depend on specific facility design information. The facility design will ideally:

- Provide penetrations through building structures for cabling that does not affect facility safety;
- Include safeguards equipment infrastructure requirements in design documents and in the design review process;
- Segregate the facility services (water, wastewater, electrical supply, compressed air, steam, helium, argon and waste removal) from the nuclear material locations to reduce the number of facility staff who require access to those locations and the potential diversion pathways;
- Position equipment to minimize impact on operations and to reduce the opportunities for damage to the equipment;
- Include space and mounting brackets for safeguards equipment in the facility design;
- Provide stable electrical power when critical to support safeguards measures (e.g. suitable for measurement equipment, when necessary; isolated from arc welders or other sources of noise);
- Provide backup emergency power to reduce the chances of a loss of safeguards data;
- Provide adequate lighting to perform inspection activities and for the surveillance, containment and monitoring equipment;
- Provide a suitably secure wireless or wired data transmission in line with site IT security;
- Facilitate access to safeguards equipment for maintenance or data retrieval;
- Consider safeguards equipment needs in the planning for installation, maintenance and refurbishment.

FIG. 12. A waste crate assay system for counting waste items and estimating nuclear material content (image courtesy of Mirion Technologies).

Designers can recommend options for environmental control when safeguards equipment requires it (e.g. space outside the processing area protected from extreme heat, humidity, radiation and contamination). Moreover, the designer can consider a single dedicated space for support equipment that can be access controlled by the IAEA (except for special operator access to respond to emergencies). This space may include temperature, humidity and dust control and clean, reliable electrical power. Furthermore, future needs for space in the design optimization can be considered, e.g. for future safeguards equipment or to accommodate temporary workspace for inspectors where lighting and noise can be held at acceptable levels.

3.3.2. Design information examination and verification

The IAEA may perform a DIE/DIV before the operator begins pouring concrete to build a new facility[8] and typically will continue to perform these activities through all life cycle stages of the facility. At any phase of the facility's design and operational life cycle, the nuclear material flow, the facility structures and measurement systems may be examined to gain assurance that they exist as declared, meet requirements and are without undeclared design changes.

During DIE/DIV at a radioactive waste management facility, the IAEA may perform a variety of activities. The following are some examples of these activities:

- Verifying the process or containment design by comparing design drawings with the current physical design being verified and assessing the containment structure, process capacity or declared function and capabilities;
- Performing a diversion path analysis to identify those diversion scenarios or safeguards concerns and design safeguards approaches to mitigate concerns;
- Preparing an essential equipment list for safeguards which may include specifications, descriptions and guidance on how to verify whether each piece of equipment is usable or not;
- Verifying the usability of essential equipment and assessing its throughput or capacity;
- Examining a subset of the essential equipment, including clearly identifying excess or redundant capacity in order to facilitate IAEA understanding of the waste facilities operating capacity;
- Comparing how the building design matches the description of operations;
- Checking the operations inside selected buildings for consistency with declared operations;

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[8] The design information process is only required for safeguarded facilities. See Section 2.1 or the IAEA Safeguards Glossary [8] for more information.

- Assessing whether the site and general building design could support undeclared nuclear operations;
- Assessing possible indicators of undeclared nuclear activities or material, including collection and analysis of environmental samples;
- Obtaining additional relevant safeguards and design related information, e.g. up to date, as-built drawings for IAEA use.

3.3.3. Nuclear material accounting and verification

The verification of nuclear material inventories and flows is referred to, collectively, as nuclear material accountancy and it is a fundamental part of safeguards activities at many facilities. In a radioactive waste management facility, materials are typically received as items and may be subsequently processed as items (e.g. compaction) or through bulk processes where multiple items are mixed and processed together (e.g. liquids, combustible materials). One point of safeguards interest is whether the facility is physically segregated into areas that handle nuclear material in bulk form or those where material is handled as discrete items. The designer or operator can consider barriers to prevent mixing of material forms in these areas. Verification in the bulk processing areas usually involves IAEA measurements (both NDA and DA), while counting of the items (sometimes with verification of item identifying markers) might be sufficient for nuclear material in item form. In most cases, statistical sampling may be used instead of 100% verification of nuclear material. Where continuity of knowledge can be maintained using containment and surveillance (C/S) measures, previously verified nuclear materials may not need to be re-verified.

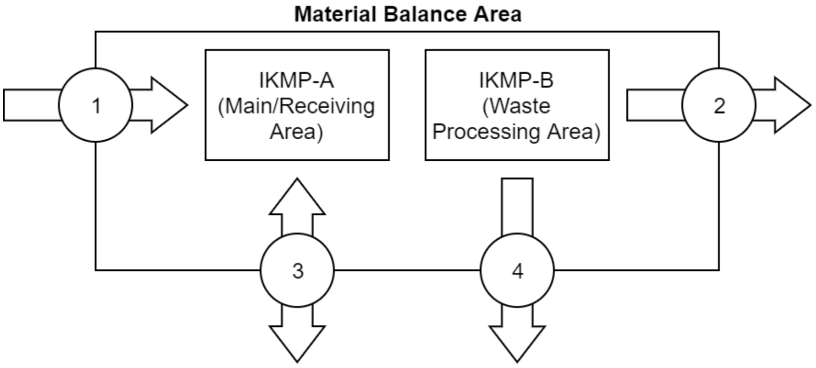
The amount of bulk nuclear material present at different stages of the process is normally determined by weighing and volume determination, combined with measurements of concentration and isotopic composition by NDA and/or DA. These values may have large uncertainties in waste facilities where nuclear material concentrations may be low, waste volumes may be large and waste homogeneity low.

Bulk processing of nuclear material involves an accumulation of material residues in the process equipment, which is known as nuclear material hold-up and can be considered part of the in-process inventory. Hold-up is notoriously difficult to control or quantify, though it can be minimized if it is considered and addressed during the design process. Lack of a process cleanout can be a source of error in the inventory determination; therefore, design features to minimize hold-up or to collect it in measurable form will benefit both operators and the safeguards authorities.

All measurement results have inherent uncertainties. As a result, the material unaccounted for, which is computed from the material balance components (i.e. beginning inventory, increases, decreases and ending inventory based on measured values), is usually not zero and its magnitude and variability depend on the uncertainties of the measurement systems. The amount of nuclear material that goes into hold-up may affect the magnitude and uncertainty of the amount of nuclear material. The designer and operator can consider safeguards nuclear material accounting verification requirements in the design optimization, such as:

- A compact layout of the process area and material transfers to reduce the amount of nuclear material, the number of pieces of equipment and the chance of nuclear material hold-up in the process;
- Planning nuclear material transfer routes so that C/S or flow monitoring systems can clearly distinguish between routine and non-routine nuclear material transfers, as well as between nuclear and non-nuclear items.

Radioactive waste management facilities may have only one MBA if they are designed to work with nuclear materials. A single MBA for the whole facility is normally used together with sufficient KMPs to account for flow and inventory of nuclear material. KMPs are generally located in nuclear material storage areas and at nuclear material transfer paths. Figure 13 shows one possible concept for the safeguards information flow in a radioactive waste management facility with one MBA. The IAEA may bring/place equipment in the facility or make use of operator equipment to support safeguards verification activities.



IKMP - Inventory Key Measurement Point

Flow Key Measurement Points
1. Receipt, De-Exemption, Accidental Gain
2. Shipment, Exemption, Accidental Loss
3. Transfer to/from Retained Waste
4. Measured Discards (termination of safeguards)

FIG. 13. Example of MBA/key measurement point structure for a radioactive waste management facility.

The PIV in a radioactive waste management facility is usually performed on a yearly basis, whereas material flow (increases and decreases in the material balance equation) is often verified during IIV. During IIV or PIV at a radioactive waste management facility, IAEA verification activities may include any of the following:

- Verification of nuclear material in bulk form by NDA equipment or sampling for DA;
- Measurement of nuclear material in item form using NDA equipment;
- Evaluation of the quality and functioning of the operator's measurement system;
- Review of facility records and supporting documentation;
- Verification of the quantity of in-process nuclear material, including verification of stock and process vessels and their contents;
- Verification of material in item form by item counting and container identification;
- Verification of domestic and international transfers of nuclear material;
- Evaluation of C/S measures applied to nuclear material;
- Verification of design information;
- Taking of environmental samples.

3.3.4. Containment, tamper indicating seals, surveillance and monitoring

The application of C/S measures in a radioactive waste management facility processing indirect use material (e.g. unirradiated DU, NU, LEU, Th) may be reduced in scope. Advances in monitoring and process control technology potentially may offer an opportunity for a more efficient use of C/S measures for direct use material (e.g. HEU, Pu, ^{233}U). The operator's (automated) process control and process monitoring information may offer the potential to provide improved assurance to both the IAEA and the State that the facility is operating as declared. Facilities that make extensive use of automated processing equipment for nuclear material or that process material with higher safeguards requirements can consider using continuous unattended monitoring. It is preferred that this data be remotely transmitted off-site to the IAEA to conserve resources for both the operator and the IAEA. Automatic transmission of selected operators' process data (via secure communication channels) might lead to a further reduction of personnel necessary at the facility and enhance safeguards implementation. Moreover, remote transmission can reduce process interruptions by minimizing safeguards activities on-site. Due to myriad technical and security implications, this should be agreed on between the State and the IAEA as early as possible.

C/S measures can be applied to conserve safeguards resources at either end of a shipment or receipt. In these cases, additional activities involving applying or cutting seals by the operator or the IAEA and the review of C/S data by the IAEA might be needed. Lessons learned and general guidance for States to consider in the application of containment, surveillance and monitoring lead to the following being advised:

- Consider use of unattended or remote monitoring, or both, of the receipt, storage, measurement, movement, and shipment of nuclear material;
- Minimize the number of penetrations in the containment and other structures through which movement of nuclear material is possible;
- Consider where surveillance in the facility might benefit both the facility operator and the IAEA;
- Consider sharing equipment, contingent on the various stakeholders' authentication and independence needs;
- Ensure that optical surveillance systems cannot be blocked by pieces of equipment (e.g. cranes moving large objects or scaffolding put in place for facility modification/maintenance);
- Facilitate the use of IAEA seals by including robust barriers and secure attachment fixtures at KMPs;
- Understand that IAEA sealing requires certain tamperproof design features, e.g. externally inaccessible hinges on doors and integrated fixtures for the seal wire or cable loop and ideally would include a design consideration to protect the seal from inadvertent damage resulting in the need for re-verification of sealed items.

3.3.5. Transfer to retained waste

Retained waste is defined as nuclear materials that are deemed to be unrecoverable for the time being but which are stored, without criteria for termination of safeguards being met (or where such criteria have not been agreed to for that facility) [10]. Retained waste can be thought of as temporary stored waste, as the wastes will eventually have to be transferred to another facility/MBA for further processing and conditioning, and then transferred to a disposal facility. Nuclear material in retained wastes may be generated from normal operations or a processing/operational accident. Nuclear material transfers to retained waste are subject to IAEA material accountancy reporting and flow verification or other safeguards measures as appropriate (e.g. CA, DIV). After nuclear material is transferred to retained waste, the facility's operator does not need to report nuclear material in retained waste in the physical inventory listing.

The State is encouraged to consult with the IAEA to obtain guidance for the safeguards measures to be applied to nuclear material before transferring items to retained waste. Such consultation will likely take into account the type of waste material, its quantity, chemical/physical form, the presence/absence of fission products, etc. The State or operator can use this information to set clear recommendations on when there is a benefit to transferring materials to the retained waste inventory that take into account national priorities and the State's waste management infrastructure (i.e. availability of processing and disposal sites).

At a radioactive waste management facility with retained waste, the quantity of retained waste is returned to the original MBA account or accounts (retransfer from retained waste), based on the same values reported previously in accounting reports as transfers to waste, before any or all of the following actions are taken:

- The waste is processed, repacked and conditioned;
- The waste is transferred to another MBA;
- Termination of safeguards (measured discards).

If a new nuclear material mass is determined for material in retained waste during the facility waste treatment activities, that change is accounted for in the MBA books. Therefore, the material is first returned from retained waste using the same basis as when transferred to waste and then the change in weight made after any subsequent processing and/or determination of new values.

Conditioned waste forms may be transferred to retained waste to reduce the safeguards burden on those wastes in the interim period after conditioning but prior to applying for termination of safeguards on those wastes. This is particularly true when a State decides to apply for termination in a batch mode and waits for a certain volume or mass of waste (per their regulations) to be conditioned prior to requesting termination. An interim storage facility may also place conditioned waste forms in their retained waste inventory after receipt at the facility for the same reasoning, as the wastes are subject to safeguards measures or will be sent to a safeguarded disposal site in the future.

3.3.6. Termination of safeguards

Safeguards may be terminated on nuclear material in accordance with safeguards agreements between a State and the IAEA. The safeguards agreements provide that safeguards measures may be terminated on nuclear material subject to safeguards upon determination by the IAEA that it has been consumed or has been diluted in such a way that it is no longer usable for any nuclear activity relevant from the point of view of safeguards, or has become practicably irrecoverable.[9] Safeguards may be terminated on nuclear material in wastes that are deemed practicably irrecoverable and not suitable for any further nuclear use. This is typically granted for three types of waste:

- Nuclear material that has been dispersed into the environment and is irretrievably lost.
- Conditioned waste that has been treated by specific actions (e.g. incorporated into or dispersed within a matrix), rendering the nuclear material contained in the waste practicably irrecoverable and thus not suitable for further nuclear use.
- Unconditioned waste with low concentrations of nuclear material which is practicably irrecoverable and thus not suitable for further nuclear use.

Before conditioning waste for the purpose of termination, the State should consult with the IAEA to ensure that the proposed conditioning will meet termination criteria. The values used to meet the termination criteria are usually negotiable on a case-by-case basis and thus the SRA and the IAEA should be contacted as appropriate to begin discussions, ideally during the waste planning stage and prior to generation of any waste materials. In order to terminate safeguards on nuclear material in waste, the IAEA must determine that the nuclear material is ‘practicably irrecoverable’, which is the IAEA’s determination that the waste form characteristics and the concentration of nuclear material in the waste are such that the nuclear material is in a state or condition where it would be more economical to produce similar material from scratch than to recover the material itself. Nuclear materials for which safeguards have been terminated are no longer subject to safeguards inventory verification. If the wastes contain direct use materials (Pu, HEU, ^{233}U), and are contained in HLW or ILW (i.e. not VLLW or LLW), the materials may be subject to a CA inspection if there is an AP in force in the State.

Per current IAEA practice, termination of safeguards on *conditioned* waste forms containing nuclear material generally require that conditions (a) to (d) below are met. These are typically specified in the facility attachment [25][10] of the waste facility or another mutually agreed upon procedure or document.

(a) The State has notified the IAEA of the storage location of the waste in question at the time of termination.

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[9] While not discussed in detail, safeguards can be terminated on nuclear materials used for non-nuclear uses, such as in alloys or ceramics, provided that the State and the IAEA agree that such material is practicably irrecoverable.

[10] A facility attachment is a part of the subsidiary agreements and specifies details about how IAEA activities are carried out within a facility or LOF. Procedures for the creation of waste forms and their declaration as measured discards may be contained in the facility attachment [25].

(b) The State has agreed to report to the IAEA without delay any subsequent transfer of the waste in question to another location.
(c) The State has agreed to inform the IAEA in advance of planned chemical or physical processing for recovery of any contained material.
(d) The State has agreed to re-apply safeguards to nuclear material in waste on which safeguards have been terminated before starting any type of processing as described in (c) above.

For unconditioned waste forms there are typically restrictions on the amount of nuclear material that can be terminated. This limit is defined as a percentage of the total inventory or throughput of the facility and/or a defined percentage of a significant quantity per material type across the whole State.

3.3.6.1. Safeguards termination process

The process for the termination of safeguards on nuclear materials can be thought of in two phases — planning and implementation. During the planning phase, the State will identify those materials on which they plan to request the termination of safeguards measures. At this point, the State is encouraged, through their national regulator or SRA, to contact the IAEA for consultation and specific information on the termination process. The detailed information regarding conditioning of waste containing nuclear materials, which is relevant to safeguards, are described in the DIQ responses (see Annex V).

This process, in general, is as follows:

- A treatment, conditioning (if required) and packaging plan is agreed upon by the State and the IAEA;
- Appropriate nuclear material accountancy reporting and safeguards measures are identified for the waste packages *and* for the processing facility (if not already safeguarded);
- Specification of the anticipated throughput/inventory for the waste produced (nuclear material concentration, waste throughput, chemical/physical compositions);
- Agreement on the appropriate mass values to be used to determine the waste nuclear material concentration.

Specifically, in the planning phase, the State will likely have to answer the following questions related to the materials' final form and properties to assist the termination application to succeed:

- What will be the final waste form? E.g. concrete, glass, compacted, etc.
- What concentration and quantities of nuclear material(s) can be found in the waste?
- How homogeneous is the nuclear material within the waste form?
- What chemical form is the nuclear material prior to treatment? And within the waste form?
- How will the facility's nuclear material accountancy (e.g. nuclear material measurement/estimation, batch identification, source data) be applied?

Once the safeguards termination process has been discussed and reviewed by the IAEA (to ensure there are no issues prior to committing resources), the project will typically proceed to the implementation phase. In this phase, it is encouraged that regular communication with the IAEA is maintained to ensure all relevant information is captured and transmitted as this will be used to bolster the application of safeguards measures and inform the IAEA's determination of the termination of safeguards on the nuclear material. When the State's termination request is approved by the IAEA, a notification will be sent to the State to proceed with any additional waste management activities.

During the implementation phase, the operator can process and condition the waste materials and produce waste forms. The amount of nuclear material present at different stages of the conditioning process is generally determined by declaration information, though supplemental measurements of concentration and isotopic composition by NDA and/or DA may be performed and combined with weight and volume information from the waste management system for concentration calculations. Once the waste has been conditioned, meets the agreed-upon termination requirements, and documentation to that effect has been provided, the safeguards on the final waste forms can be reported to be terminated, subject to IAEA verification. This may be done for a batch of waste forms or for a single waste form, depending on the throughput of the facility and the need to move the final waste forms to an interim or final location. In cases where seals were applied to the waste form, for example where vitrified HLW cannisters are used, the IAEA will typically make arrangements to collect or remove the seals in line with existing procedures.

3.3.6.2. Safeguards termination considerations

There are several considerations that have to be weighed when a State would like to pursue termination of safeguards on waste materials beyond the non-proliferation aspects. The dilute nature of the waste coupled with the chemistry of the waste form (e.g. concrete, glass, metal, etc. if present) is what provides a barrier to recovery and allows safeguards to be removed from the materials. Practically, this means that while a significant time and effort could be spent to extract the nuclear material, the effort to do this without raising suspicions or alarms is very high (it may also be very expensive). The end result is that there would be more likely pathways for acquiring nuclear material rather than recovering the terminated material for non-peaceful reuse.

- Volume: When considering engineered waste forms, the terminated wastes may have a higher volume than safeguarded waste forms. This will in turn increase the volume required in the final waste location. The State will have to understand the disposal burdens required for terminating wastes and placing them in, for example, a near surface disposal facility, as the inclusion of the terminated wastes may significantly impact the loading of that facility. In addition, some States have a legal requirement to minimize waste volume through waste management which may make it difficult to meet the agreed safeguards termination criteria. Early communication is key to identifying these potential issues.
- Cost: If the technical capacity to make, test and certify the final waste forms is not already present in the State, or if it needs to be acquired from a third-party State, there may be significant startup costs. This is also true if a new facility needs to be built or retrofitted.
- Conditioning: The technical capacity to create the waste form and test it, beyond costs, may take several years to put in place. This may also require the development of human capital to administer the tests and keep the capacity operational and certified. If the waste to be terminated is not a recurring waste (i.e. a waste that will be generated once or twice or in a limited volume) this capacity building may be considered too costly for too little benefit.
- Payment for services: Wastes could be treated by a third-party State and repatriated for termination, storage and disposal. This is generally applicable for small volumes or wastes from a singular event (i.e. non-recurring).
- Disposal options: An appropriate disposal site should ideally be identified for waste prior to conditioning to ensure compliance with waste acceptance criteria (WAC). If a State is also pursuing a HLW disposal site that will be under safeguards, it may be less costly to concentrate and dispose waste streams as safeguarded wastes along with the HLW.

The size and complexity of the State’s fuel cycle will have a large impact on the State’s decision to pursue termination. For States with a small inventory, it may make more sense to terminate a small volume of waste, even if the costs are high to condition and dispose or if the conditioning requires the use of a third State contractor, as it will likely be less expensive than long term safeguarded storage[11] or the creation of a safeguarded repository (e.g. a geological repository). However, for States that are pursuing a safeguarded ILW or HLW repository, consolidating waste materials and disposing them in these repositories, under safeguards and with smaller volumes, may be a viable option. Each State, in

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[11] Long term storage is only considered a temporary solution that is used prior to emplacement in a disposal facility.

consultation with the IAEA where appropriate, is encouraged to carry out a detailed analysis to determine whether termination is the proper path forward for their waste streams.

3.3.6.3. Conditioning for safeguards termination

Part of the process for the termination of safeguards includes determining or ensuring that nuclear materials in waste forms are deemed practicably irrecoverable. This may be interpreted to mean the nuclear material is technically recoverable but at such a cost and time that it would be unlikely that the materials could be recovered without being noticed and that more likely acquisition paths exist to gather the same materials. That being said, the termination process generally requires both a dilution or dispersal of the nuclear material within the waste form and some level of incorporation into a matrix; in other words, the final concentration of nuclear material that can be terminated depends on the amount of material and how it is incorporated into the final matrix.

In the scenarios presented below, only those characteristics and needs related to the termination of safeguards on the nuclear materials contained in the waste forms are discussed. In all cases, the wastes will still need to meet the transport, storage and/or disposal WAC applicable to that waste. While a waste may be eligible to have the safeguards on the nuclear material terminated, this does not automatically mean the waste is suitable for disposal and, conversely, waste that meets WAC criteria cannot be automatically considered to meet the requirements to have safeguards measures terminated. The titles of these sections (a)–(f) match the categories of waste used by the IAEA when discussing terminations of safeguards.

The physical form and radiation characteristics of the final waste form are broken down into a number of categories shown below. For conditioned wastes, there is a caveat regarding the radiological characteristics of the waste form: if the final waste form would require a hot cell to recover the nuclear material, indicated by a dangerous intrinsic radiation field typically due to the inclusion of fission products, the concentration of nuclear material upon which safeguards can be terminated in the waste form is increased.

(a) Unconditioned wastes

Unconditioned wastes are those wastes that have not been physically or chemically bound into a waste form. There are a few variations within the unconditioned waste category. The first subcategory is raw waste. At this stage, the wastes have had no pre-treatment or conditioning applied to them. They may include waste streams such as nuclear waste material in contaminated equipment and structures. This waste can either be packaged directly (see Section (b) on overpacked waste below) or sent for further treatment and conditioning. While uncommon, raw wastes can be sent for direct disposal with no further conditioning if they meet the acceptance criteria of the disposal facility. This is most common for those wastes that would be considered below regulatory control, or ‘exempt’ wastes. These wastes could be freely released to any waste processing stream (i.e. municipal or site waste) after an appropriate clearance process. Accordingly, if agreement is reached that the termination criteria have been met, then these wastes will also have any safeguards measures applied to them terminated. These materials have the lowest nuclear material concentration for termination as there is no engineered waste form present which forms a barrier to recovery and therefore this is waste type is strictly governed by concentration. As such, limits on the total amount of nuclear material in unconditioned wastes that can have their safeguards measures terminated will be set between the State and IAEA.

A second variant of unconditioned wastes is wastes generated from decontamination or leaching process to remove residual radioactive materials, usually using a process specifically designed to recover the nuclear materials in the raw waste. For example, this process can be applied to solid materials that have adhered, or fixed, surface contamination (e.g. residual nuclear material on metallic surfaces, material adhered to a concrete floor). After subjecting the waste to repeated cycles of decontamination, for example leaching with concentrated acids such as nitric or hydrofluoric acids or strong bases with or without a mechanical decontamination step, any material that remains would be significantly harder to recover (as dissolution is the typical recovery method). However, no additional physical conditioning is applied to the waste items in this category. These wastes could then be released to any waste processing stream (i.e. municipal or site waste) on completion of the required clearance processes. As these materials have undergone some extensive leaching, they have a higher allowable residual concentration of nuclear material compared with unleached wastes with respect to concentration calculations for termination of safeguards on nuclear material. This is due to the fact that the nuclear materials would be harder to recover as they have already resisted attempts to recover them. Note that this process will generally create a secondary waste stream with the bulk of the radioactivity that would need to be handled separately and disposed (see Section 3.4.6.5).

Finally, unconditioned wastes may be placed in containers that provide a protective boundary between the waste and the storage/disposal facility environment, to possibly provide some measure of structural integrity. This may be achieved by the use of a drum or box to contain the waste. When packaged in this manner, the wastes are no longer considered unconditioned but are then considered overpacked, compacted or treated (see below).

(b) Overpacked, compacted or treated in any manner presenting a moderate additional recovery effort

Overpacked waste is any waste materials that have been placed in a container for disposal as shown in Fig. 14. These materials commonly contain bulk operational waste (personal protective equipment, construction and maintenance materials, lightly contaminated metal parts, laboratory materials) that have a low level of radioactive contamination. Such waste may be compacted prior to emplacement or further storage where the primary container the waste is stored in (e.g. a 200-L steel drum) is placed in a hydraulic press and compressed to reduce the void space and overall volume of the package. Treatments include actions carried out to remove the radionuclides from the waste materials (similar to leaching above but with the materials emplaced in a radioactive waste site rather than freely released), to compact, as above, or to change the composition of the wastes such as by incineration. Larger items of scrap (such as the overpacked waste shown in Fig. 15), building waste (e.g. concrete, pipes, etc.) or machinery (e.g.) may be directly overpacked by placing in a primary container and immobilized with cement, grout or other stabilizing materials (see Section 3.4.8.3 for an additional example of this overpacking method using concrete caissons).

FIG. 14. A set of cutaway drums showing various types of solid LLW (image courtesy of the Australian Nuclear Science and Technology Organisation).

FIG. 15. Large format metallic and construction materials embedded in grout (image courtesy of Nuclear Decommissioning Authority, United Kingdom).

(c) Macroencapsulated within polymeric, cementitious or bituminous matrices

Macroencapsulated waste is waste material (e.g. ashes, slags, shredded metal, ion exchange resins) that is physically incorporated within a stabilizing matrix with limited chemical bonding; Fig. 16 shows an example of a supercompacted waste form that has been grouted into a secondary container. In this situation, there are larger waste particle sizes (of the order of millimetres up to tens of centimetres) of waste that are only in contact with the bulk matrix at a particle’s surface. In this case, a physical separation might be possible after extensive breakup of the waste matrix but without dissolving the matrix. An example of this would be cladding metal pieces (containing some amount of fuel particles and fission products) encapsulated in a cement matrix; after crushing the bulk material, the metallic phase could be recovered by sieving, as the cladding’s density would be approximately twice that of the cement. This would also apply to items encapsulated in epoxy or bitumen. Similarly, supercompacted pucks are typically categorized as macroencapsulated waste forms. Metallic wastes that have been heated or compressed, such that they are macroencapsulated waste forms, may also be overpacked for disposal, storage, handling or shipment. There may be chemical considerations that need to be examined in accordance with the WAC.

(d) Microencapsulated within polymeric, metallic or cementitious matrices

Microencapsulated wastes are close to a fully integrated waste form as the small grain sizes (on the order of microns) are well dispersed within the matrix, and a complete dissolution of the matrix will be required to recover the nuclear material. An example of this waste type is finely divided uranium oxide dust or dissolved nuclear material (e.g. a plutonium nitrate solution) in a well mixed cement or geopolymer (see Fig. 17); a second example would be contaminated metal scraps that have been melted into a solid monolithic matrix or compressed to a high fraction of theoretical density (see Fig. 18). In such cases, not only will the waste form need to be ground or shredded to recover the material but it would also need to be chemically dissolved. This waste form may also be overpacked for disposal, storage, handling or shipment. Surface contaminated items may be considered microencapsulated if the nuclear materials are firmly affixed to the matrix and aggressive techniques have been used to remove them.

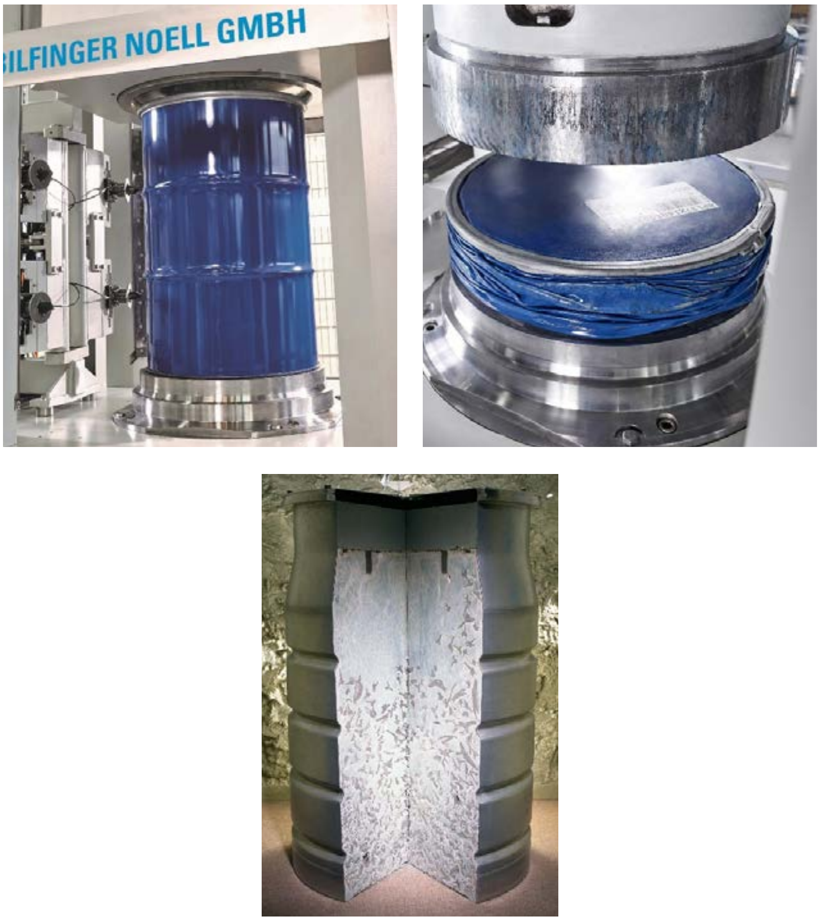

FIG. 16. Macroencapsulated waste examples. Top row: 200-L drum prior to (left) and after (right) supercompaction (image courtesy of Bilfinger Noell); bottom: Lillyhall 500-L ILW waste drum with cutaway (image courtesy of the Nuclear Decommissioning Authority, United Kingdom).

FIG. 17. Photo of a cementitious waste form (containing simulated waste) with a "lost paddle" design which has been cut in half to determine the homogeneity of the dispersed simulant material (tungsten); (image courtesy of United States Department of Energy/Idaho National Laboratory).

FIG. 18. *Stainless steel–Yttrium–Uranium–Thorium metallic waste form, sectioned for characterization (image courtesy of United States Department of Energy/Savannah River National Laboratory).*

FIG. 19. *Vitrified glass waste form in steel cannister with cutaway to show interior glass (image courtesy of the Japan Atomic Energy Agency (JAEA)).*

(e) Vitrified

Vitrification of radioactive materials is a well-studied process for conditioning radioactive liquids and certain solids for disposal. The vitrification process combines the waste material with a glass frit and then heats the entire batch to a temperature high enough to obtain a homogenous amorphous solid with the waste material incorporated at, or nearly at, the atomic level (small particles may remain as separate phases for some products). The final product is a very durable monolith that requires very aggressive processes to recover the material contained within, e.g. the use of hot hydrofluoric acid. A vitrified waste form may also be overpacked for disposal, storage, handling or shipment and is generally stored in a metallic primary container as can be seen in Fig. 19.

FIG. 20. ANSTO Synroc canisters, pre and post the hot isostatic pressing process (image courtesy of ANSTO).

(f) Ceramic

Ceramic waste forms are crystalline materials that incorporate radioactive elements directly into a crystalline phase (or phases) at the atomic level. Ceramic waste forms may be used to condition waste materials (liquids or solids) that have a known chemical composition (e.g. mixed oxide fuel or LEU oxide trimmings) and incorporate their components into tailored crystalline matrices. A typical procedure for creating a ceramic waste form involves mixing, cold-pressing, and sintering at high temperatures or using a hot isostatic press to create a ceramic waste form; an example ceramic waste form is shown in Fig. 20. Ceramic waste forms tend to be refractory, durable and typically require a large effort to break down or leach materials from them, generally requiring a complete dissolution to recover the materials contained within. Ceramic waste forms may also be overpacked for disposal, storage, handling or shipment.

3.3.7. Safeguards awareness for non-nuclear material handling facilities

While waste facilities and processes that are specifically set up to deal with waste streams that likely contain nuclear materials are encouraged to include safeguards concepts at an early stage, it is unreasonable for facilities designed only to handle radioactive wastes (i.e. non-nuclear material wastes) to have to meet the same standards. That being said, there are situations where a radiological waste facility may need to deal with trace or unknown amounts of nuclear material that have been delivered to the facility, sometimes unknowingly. These materials can come in the form of trace level volumetric wastes (e.g. ion exchange resins or sludges), discrete inclusions (such as deposits within pipes or machinery) or surface contamination. Nuclear material that may have been too dilute or dispersed to directly measure may be measurable after certain decontamination procedures, such as scrabbling or laser etching, which concentrate surface contamination, thus necessitating that now-measurable materials are dealt with appropriately. Additionally, the increased use of scaling factors may include nuclear material isotopes that will need to be dealt with even if they are not concentrated enough to warrant transportation or safety restrictions.

Ideally prior to commissioning of the waste facility, procedures can be implemented at the facility that clearly outline the steps that need to be taken if nuclear materials are determined to be present on the site. The waste facility should understand if the facility falls within a defined LOF in the State or within an existing MBA at a declared nuclear facility. The waste facility is encouraged to work with the SRA, and to consult with the IAEA if needed, to determine how to deal with accidental gain materials and what information is required for declaration. Also, provisions can be made to potentially store nuclear materials separate from non-nuclear waste streams; this can be as simple as having a designated ISO container for short term storage of the materials while the status of the waste is resolved, or as complex as having a dedicated, sealable storage facility. Finally, understanding how to terminate safeguards on nuclear materials and how the on-site waste processes can be used for this, if at all, is required; at times, it may be necessary to collect the nuclear material and ship it to a dedicated waste facility that handles nuclear material.

In many cases, the levels of nuclear material may be low enough to warrant termination as unconditioned wastes or as conditioned waste forms after processing, especially for domestic wastes. For wastes received from another State, there may be a takeback agreement in place which would require the site to declare the material as an accidental gain within a LOF (or facility if the waste site is co-located with a nuclear site) and then ship that material back to the originating State as safeguarded material. In both situations, having facility procedures that recognize the possibility of nuclear materials being present and maintaining regular communication with the original owners of the material, the SRA and the IAEA (if needed) is recommended.

Knowledge of, and planning for these scenarios at non-nuclear material waste facilities can save significant time and effort when, or if, nuclear materials are encountered on-site. In these cases, institutionalizing safeguards concepts into operating procedures is one of the best ways to ensure that these situations are recognized early and dealt with appropriately.

3.4. EXAMPLES OF WASTES THAT MAY BE ASSOCIATED WITH SAFEGUARDS OBLIGATIONS

Radioactive waste can be generated throughout the nuclear fuel cycle, from uranium mining operations, through enrichment processes to nuclear fuel production, irradiation in reactors and spent fuel management and/or reprocessing operations. Depending on the material type and purity, the materials may be placed under safeguards (early in the fuel cycle) or be safeguarded from the moment of their production (i.e. reactor produced plutonium).

In general, wastes can be thought of as belonging to one of five sources:

- Operational wastes;
- Decommissioning wastes;
- Accident wastes;
- Waste from past activities;
- Industrial and other wastes.

These wastes range from planned to unplanned, from frequent to infrequent; the relationship between these waste origins and their volumes and frequencies are shown in Fig. 21. All of these wastes may contain nuclear materials and as such may have safeguards obligations associated with them. The goal of this section is to list potential wastes from various parts of the fuel cycle and life cycle of nuclear facilities. This section is meant to be illustrative and not definitive as any level of nuclear materials may have safeguards or reporting obligations.

Some of the more common waste types from research and industrial laboratories, research reactors, nuclear power plants and nuclear fuel cycle facilities are listed here [26]:

- Dry active waste;
- Ion exchange resins;
- Filters;
- Concentrates;
- Contaminated metal components;
- Concrete rubble;

- Disused sealed sources;
- Ashes;
- Soils;
- Excess pure reagents;
- Combustibles;
- Organics (plastic, paper, wood, filters (HEPA, bag) etc);
- Sludges;
- Graphite;
- Metals;
- Insulation materials (e.g. asbestos);
- Discarded equipment (e.g. glovebox, fume hood, HEPA filters in metal frame);
- Halogenated organics (e.g. > *x*% polyvinyl chloride);
- Uranium contaminated metals (i.e. UF_6 cylinders).

While this list is illustrative, significantly more individual waste streams can exist. The following sections will give some information on the various waste streams from the large waste categories displayed in Fig. 21. After that, common waste treatment options will be discussed, followed by waste packages and storage options.

There is a difference between raw waste from fuel manufacturing or reprocessing facilities and raw waste from other nuclear facilities. Raw waste produced from fuel and reprocessing facilities are known to have nuclear material contamination; accordingly, the focus is on quantification and declaration of the nuclear materials. Facilities such as nuclear power plants and other facilities with contaminated waste have the potential to include nuclear material contamination, particularly surface contaminated wastes and other solid waste. Therefore, the focus is typically on general radiological management and only if nuclear material is detected would the waste be re-evaluated for safeguards concerns. As the use of scaling factors (or nuclide vectors, radionuclide fingerprints) continues to increase across in the nuclear industry, the possibility exists to have a calculated nuclear material content in practically all waste packages and items. As these values may be very low, radiological waste facilities would be advised to discuss this possibility with their SRA and the IAEA, to determine a standardized path forward in the event a scaling factor indicates the presence of nuclear material. Several administrative mechanisms, including termination, are available to States and appropriate planning for these eventualities may be conducted as early as possible.

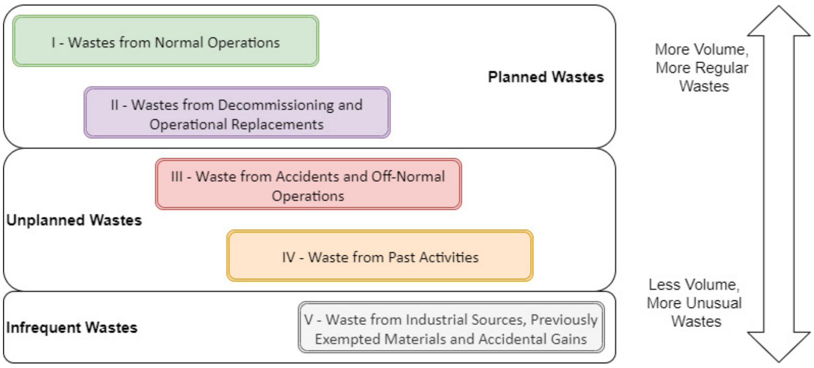

FIG. 21. General origins of radioactive wastes.

3.4.1. Source I — waste from normal operations

Waste from normal operations includes the most regular wastes and will likely contain some of the largest volumes of waste. This category is one of the planned waste origins that can be evaluated prior to generation where mitigation and reduction strategies can be put in place. In addition, policies regarding the safeguards checks on these waste streams can be planned out in advance with the SRA and the IAEA.

Wastes from normal operations will span all classifications of radioactive waste (VLLW through HLW). However, the vast majority of the radioactive waste produced from normal operations are solid VLLW or LLW, primarily from routine operation of fuel cycle facilities and nuclear power plants (exclusive of spent fuel declared as waste, which is not covered in this publication). This waste includes items such as contaminated personal protective equipment, disposable laboratory supplies, glassware, pumps, piping and tubing. At bulk handling and research facilities, operational wastes are more likely to contain nuclear materials than at item facilities due to the types of activities common to those facilities.

ILW tends to be produced during replacement of neutron facing components (i.e. reactor internals) and ion exchange resins from the primary coolant loop. The presence of a leaking fuel rod may introduce small nuclear material concentrations into the reactor coolant or storage pond. In both of these situations, either volumetric in the case of ion exchange resins or via surface adhesion and contamination [27], a small amount of uranium and actinides will be present that needs to be appropriately managed.

High-active wastes tend to be produced from nuclear power production and reprocessing spent fuel; France and the United Kingdom continue to reprocess spent nuclear fuel, although the plan is to cease reprocessing Magnox fuel by the mid-2020s. Sellafield (United Kingdom) and La Hague (France) are the main reprocessing facilities in Europe, with each facility producing large quantities of HLW as well as ILW and LLW. In the United Kingdom, liquid, high-active waste, mainly in the form of first cycle PUREX-style raffinate, are stored in cooled tanks and then conditioned via vitrification or cementation to produce a passive solid waste product encased in stainless steel. Solid ILW is also produced from reprocessing plants, usually from spent fuel metallic components (cladding, assembly hardware, hulls, etc.) plus failed equipment from the hot cells used to safely handle and prepare the spent fuel for dissolution. These processes also produce a large amount of secondary waste streams, typically LLW [28].

Enrichment, conversion, fuel fabrication, and nuclear power plants will have safeguards applied routinely to their inventories, including all associated waste packaging and storage facilities. Bulk handling facilities, such as fuel fabrication, produce remnants which can be processed to recover the nuclear material content if economic. For example, this was carried out for many years at Dounreay (United Kingdom) where Materials Testing Reactor fuel was fabricated and exported to several Member States. The uranium was recovered from the fuel remnants by dissolving the fuel then separating the uranium from the other elements via solvent extraction. The purified uranium was then processed to produce solid metal billets which were then incorporated in the fuel manufacturing process. All of this was carried out under safeguards, including the collection, treatment and packaging of waste materials [27].

3.4.2. Source II — waste from decommissioning and operational replacements

Waste from decommissioning and operational replacements includes those items that have reached the end of their serviceable lifetimes. The largest generator of these wastes is the decommissioning process, including demolition, where a facility has reached the end of its lifetime or due to closure for other reasons (technical, economic, etc.). Prior to decommissioning, much or all of the item or bulk nuclear materials will have been removed. However, especially in bulk handling facilities, there will be some degree of contamination of portions of the facility structure, equipment, piping, etc. Any of these materials coming from the facility or its surroundings that are contaminated with nuclear material has to be evaluated and the safeguards obligations on them determined.

Decommissioning wastes may seem inconsequential in terms of activity and safeguards significance compared with the inventories that the facility processed when it was operational, sometimes just months prior. The volume of waste produced, especially during subsequent demolition activities, can be significant. However, the small scale of the residuals does not relieve the State of the obligations agreed to in their safeguards agreement or agreements. Therefore, all wastes need to be evaluated for nuclear material content. The management of these wastes can be at least partially planned for depending on the facility type. It is important that the State make appropriate estimates of the volumes and types of potentially safeguardable wastes that may arise during decommissioning, including demolition, and consult their SRA and the IAEA to ensure appropriate metrics (for nuclear material concentration and physical form) and pathways (measured discards, retained wastes, etc.) have been identified.

The second component of this broad category is wastes from operational replacements, such as when components are replaced inside the activated or contaminated area of a facility. These wastes are typically not those that are considered routine operational wastes as they are not regularly generated. However, that does not mean that they are not anticipated or expected; the planned lifetimes of certain components are well known and planned for. Others may need to be replaced in an ad hoc fashion during breakdowns. In either scenario, States and operators are encouraged to internalize the need to screen these wastes for nuclear materials and then apply any appropriate measures. Once the materials will be sent for waste treatment or decontamination, the measures applied to the wastes are typically reviewed.

One important trend that needs to be emphasized is the use of scaling factors during decommissioning operations to determine the radioisotope inventory present in a given class of waste. Due to the methods used to create the radioisotope scalars, there exists a chance to declare a waste material with only a calculated amount, but not verified amount, of nuclear material present. Despite the potentially theoretical nature of the nuclear material, these wastes will also need to be dealt with appropriately through discussions between the generating facility, the waste facility, the SRA and the IAEA. The practical levels in these cases are typically quite dilute and termination can be a logical pathway. Care should be taken with termination in cases where the follow-up treatment may concentrate the nuclear material to such a degree that the “theoretical” vector component is now a measurable quantity of material contained in a much smaller mass; in these cases, it may be more appropriate to request termination of safeguards only after all treatments have been performed.

3.4.3. Source III — waste from accidents and off-normal operations

Wastes from accidents are certainly well documented in contemporary accounts of the accidents, especially large ones. The accidents at the Chernobyl nuclear power plant in the former Soviet Union and at the Fukushima Daiichi nuclear power plant in Japan are prime examples, if very rare. In the case of such accidents, large amounts of infrastructure and the surrounding environment can be contaminated with both fission products and nuclear materials. While the vast majority of the radioactive wastes are effectively disseminated into the environment (which allows for termination of active safeguards on the materials), efforts to remediate and clean up those same areas may require the reapplication of some level of safeguards to the debris, soil and other materials gathered for disposal. The fact that the materials were not safeguarded in their dispersed state does not mean that they will not have safeguards applied to them when collected.

However, these rare events do not encapsulate the whole of these wastes. Fuel cladding failures, and subsequent release of nuclear materials, and residual uranium on fuel surfaces, can happen in a variety of reactor types. These failures can be very small and only release small quantities of fission products and noble gases or they can be very large breaks exposing the fuel to the coolant. An example of these types of failures can be seen in Fig. 22. The effects of having a break in the fuel can be myriad; cooling water and ion exchange beds can be contaminated with fission products and trace actinides; pumps and pipes can gather activated particles on their surfaces; fuel assembly components, normally only activated, will show alpha contamination indicative of nuclear materials. Regarding residual uranium on fuel surfaces, while each assembly may have a small absolute amount of residual surface uranium, over the life of a reactor and thousands of fuel assemblies, this can sum to a non-negligible number. All of these situations will require that the operators and waste facility managers work closely with their State’s safeguards infrastructure to ensure appropriate measures are implemented.

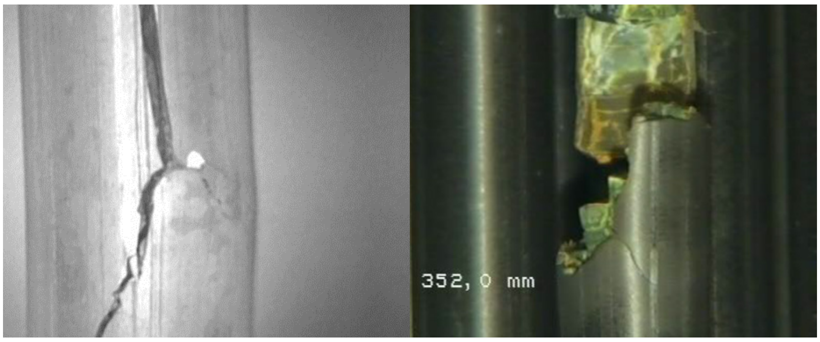

FIG. 22. Examples of boiling water reactor fuel rods with secondary defects (long cracks or breaks) due to fretting. These types of breaks can release nuclear material into the coolant water (image courtesy of Svensk Kärnbränslehantering).

3.4.4. Source IV — waste from past activities

Waste from past activities is waste forms, materials and in situ contamination that either has not been treated, including found items, or treated in such a manner that it requires additional treatment to meet current standards for storage or disposal. These wastes may indeed show the presence of nuclear materials that were previously unknown or were not previously terminated prior to emplacement. Whenever States work to recondition or clean up previous wastes, they need to be conscious that there may be safeguards concerns. The more likely scenario is that the materials were never formally terminated and would have to be declared and terminated in the correct order. Communication with the SRA would be recommended during the planning phase for this work as there are many small facets to this situation to take into account, particularly around repackaging or retreating wastes with no intent to recover nuclear materials (related to conditions for termination, see Section 3.3.6).

3.4.5. Source V — waste from industrial sources, previously exempted materials and accidental gains

Waste from industrial sources, previously exempted materials and accidental gains are some of the least common wastes that States are still likely to encounter. One of the more common versions are accidental gains, such as those that happen when waste is shipped from one State to another (e.g. for treatment) and nuclear materials, albeit at low levels, are detected by the receiver but not declared by the shipper. Another example are materials that were physically located within the State but exempted from safeguards in that State which subsequently have lost that exemption (e.g. a DU shield previously owned and exempted by another State but now belonging to the State in question). There may also be cases of nuclear materials never added to the declared inventory due to innocent omissions (e.g. excess uranyl acetate stains used in biology and never added to a declared inventory as it was in non-nuclear use but never formally terminated or located in a non-facility location prior to adoption of an AP). A final subcategory is industrial sources that contain nuclear material declared as waste in the State and not eligible for repatriation.

All of these wastes tend to be uncommon and are unplanned. Generally, the best recommendation to deal with the safeguards obligations on these wastes, if they exist, is to incorporate check points into procedures and processes to determine (1) whether nuclear materials are present and (2) what their status is with respect to safeguards.

3.4.6. Waste treatment

Treatment of the different waste forms will, in many cases, result in a concentration increase (as the volume decreases) of the radioactive materials which, in some cases, will allow the detection of nuclides that are subject to safeguards or indicate the presence of nuclear material, e.g. ^{241}Am from plutonium decay. However, in some situations, the treatment process will distribute the nuclear material throughout the matrix resulting in a homogenization rather than a concentration. Due to the variety of treatment options available, a complete list cannot be compiled here; however, a representative list of common treatments has been prepared with the appropriate safeguards concerns listed.

3.4.6.1. General considerations

In general, there are three major types of waste treatment, with respect to nuclear material concerns. Those treatments that aim to reduce the volume of the waste to minimize disposal, disperse the waste within a matrix for disposal, or to decontaminate the main waste stream in order to reclassify the waste (e.g. from ILW to LLW, LLW to VLLW, etc.). In two of these categories, volume reduction and decontamination, some amount of concentration will occur. For the latter case, two streams are typically produced — a large volume, low activity stream and a small volume, high activity stream. As a consequence of the increased specific activity, determining the content of nuclear materials will likely be easier than before treatment. This increased activity also means that waste items that were not subject to safeguards before treatment, as the nuclear materials were below detection, may be subject to safeguards after treatment. For example, incineration of a large volume of waste will result in a smaller volume of ash waste that is much easier to measure and, while the nuclear materials were below detection limit prior to this, they are now detectable. The opposite is true when materials are dispersed in a matrix, such as concrete or glass, where detection of the nuclear materials may be very difficult. Therefore, knowledge of the inputs to these processes are very important.

Solid LLW is often packaged in drums, soft packages or directly into full- or half-height ISO containers. On occasion, the waste is not conditioned through encapsulation means (e.g. in-drum compaction on containerization only), but that will depend on disposal WAC. Conditioning solid ILW also depends on the appropriate storage or repository WAC. In some cases, conditioning ILW may not be permitted until a disposal site is ready, due to ALARA (as low as reasonably achievable) concerns surrounding treatment. Similarly, conditioning of wastes by encapsulation in concrete, bitumen or other matrices may be delayed for similar reasons as they are difficult to reverse and potentially foreclose other options.

Liquid waste is often conditioned by evaporation and then solidification in concrete or another matrix. This is carried out in many Member States, including Sweden and the United Kingdom. Untreated ion exchange resin may be solidified in concrete or bitumen but also stored or disposed directly if sufficiently dried before disposal. Concentrated evaporator sludges may also be solidified in concrete or bituminized but, as there are limitations regarding the durability of the concrete product, approval needs to be gained beforehand.

How the wastes are declared depends on the regulations for the waste producer. For example, a fuel factory declares according to agreed IAEA guidance with respect to nuclear material content as it is the largest component of the radiological profile when fresh; conversely, a power plant may only declare the measurable gamma emitting nuclides as they typically dominate and are an important consideration for safe transport. The plant may have had one or more fuel failures but normally the specific activities of transuranic elements are not high in LLW, such as scrap or dry active waste, and therefore are normally declared only in Bq and not in grams.[12]

Waste arriving as safeguarded material in a processing State is typically handled so that the waste batch is kept together during treatment. In some instances, the determination of nuclear material content is easier in the secondary waste rather than the raw waste. This is of particular interest if the raw waste is declared below detection limit or has had safeguards terminated on it before treatment. Then, new measurements need to be applied and safeguards may have to be reapplied to the secondary waste after

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[12] When nuclear materials in these wastes are declared, the amounts are normally in the range of tens of Bq per 1 g waste, which results in a very small total material amount, which is measured in grams. As the normal reporting threshold is typically in grams, the nuclear material in these wastes may not be declared when received from nuclear power plants.

treatment. Typically, terminated wastes that are to be treated will have safeguards reapplied to them prior to shipment or treatment; however, those items that were below detection limits may have never had safeguards applied in the first place. These examples demonstrate that there are a wide variety of possible waste treatments that can be applied to waste streams. Not every State will utilize the same or even similar processes to treat essentially similar wastes. Regarding safeguards measures for the following treatment techniques: the information given below are general statements based on experience and ultimately will be decided for each process and waste stream in each State as the processes are being set up. However, for all treatments, adherence to nuclear material accountancy requirements will always remain a vital component of the safeguards measures applied to the wastes.

3.4.6.2. Thermal treatment of solid LLW

Thermal treatment such as incineration/pyrolysis and metal melting are often used to treat LLW in order to minimize the volume of waste for storage and/or disposal. Normally, as raw waste is received for treatment, the activity is declared by the waste owner. As it is the responsibility of the waste owner to declare the content of the waste — both the radiological content and the chemical and physical content — the waste treatment facility normally does not re-measure incoming waste except to demonstrate the compliance with applicable WAC. It is also the waste owner who is responsible to declare nuclear material inventory information, if appropriate.

When the waste has been treated and the secondary waste, e.g. ash, dust, slag, measured, the specific activity has increased and the detection of nuclear materials now becomes possible. Normally, if ^{235}U or ^{241}Am (as a correlation nuclide for Pu) is detected in the secondary waste that was not declared before treatment, the waste's status has to be clarified in the processing State prior to any eventual repatriation or further processing.

For thermal treatments, safeguards measures may be applied to the input or output materials (e.g. unattended gamma monitors). Depending on the type of materials being processed, the system might be monitored via camera, and random verifications may be used.

3.4.6.3. Treatment of liquid or semi-liquid LLW waste

If wastes are liquids (aqueous and/or organic), sludges or ion exchange resins, the measures for monitoring and verifying them and any nuclear materials is the same as for solid wastes (see above). However, any increase in specific activity depends on the treatment process. For example, incineration or pyrolysis of these waste will increase the specific activity whereas solidification techniques (see below) will most likely reduce the specific activity.

3.4.6.4. Decontamination of solid ILW

When solid ILW is decontaminated in order to reclassify the waste as LLW, the nuclear materials can be divided between two waste fractions: the main part in the decontamination liquid or solid fraction and the residual attached to the original waste. The mass of nuclear material in each waste fraction needs to be determined, either by mass balance calculations or by direct measurements. Both fractions may be treated differently with respect to their safeguards obligations. For example, the main waste volume may be eligible for termination and clearance from radiological control while the decontamination liquid will have to be incorporated into an engineered waste form or retained in a safeguarded inventory for further treatment.

3.4.6.5. Secondary waste

Processes that concentrate or separate waste fractions will typically generate a secondary waste stream. In radioactive waste management, this stream is typically the wastes that are separated from the input wastes (e.g. a washing solution) or the actual waste form itself in a new form (e.g. ash). Secondary waste from thermal treatment (e.g. ash and dust) will contain the bulk of the activity (with the exception of any gaseous species) and heavy nuclides will likely be retained in the ash, depending on the thermal treatment process and the design of the facility. However, some heavy radionuclides might partition into other waste streams, depending on the specific design features, such as airflow and/or choice of materials in the furnace. Experience shows that leaching uranium from ash can be difficult if silica is present in the furnace as uranium forms insoluble silica compounds.

From the metal treatment processes, the main nuclide-containing wastes are blasting residues, slag and to some extent filters and filter-dust. Depending on the metal placed in the melting process, the slag produced looks very different; for example, aluminium and lead slag are more dust-like than steel slag. Examples of slag waste being removed and collected in drums is shown in Fig. 23, along with blasting residues, while ashes from combustible wastes are shown in Fig. 24.

Extracting nuclear material from most slag is possible but rarely economically feasible due to the physical and chemical features of slag. Most heavy elements spontaneously partition to ferritic but not to aluminium slags during melting. Conversely, for aluminium the heavy elements prefer the chemistry of the metallic phase such that they are hard to separate. This is a counterpoint to blasting residues and liquid decontamination solutions where the physical form (finely divided solids and solutions) makes extraction of heavy elements easier than from metallic phases. These wastes in particular will need other treatments to prevent easy recovery of heavy elements. The generation of these secondary wastes poses an accountancy task to be completed and an evaluation will need to be made as to the extent of safeguards measures to be applied. Due to the low volume, relatively low activity content and irregular radioisotope content, administrative measures and State DA are likely to be recommended.

3.4.6.6. Compaction

Compacting solid waste will not change the nuclide inventory or the specific activity as the volume decreases because the overall mass of material remains unchanged. For standard in-drum compactors, the volume can be reduced by a factor of ~10, allowing the resulting waste to be more efficiently stored in standard drums. In-drum compactors only compact the waste, not the primary waste package. As the mass of the waste does not change, the mass concentration of nuclear materials does not change; care should be taken with inventory if multiple additions are made to the drum or container.

Supercompactors are used in many facilities worldwide to compress primary waste packages, including the container, to increase the amount of waste that can be placed in a secondary or overpack container. These facilities can process large volumes of waste and can use systems to characterize and compact the waste containers (Fig. 25). The raw wastes are typically loaded in the equivalent of a 200-L metallic drum and compressed with several hundreds of tonnes of force (Fig. 26). The resulting puck will have from 10% to 50% of the original volume; multiple pucks are usually overpacked in the same secondary container, typically with stabilizing grout (see Figs 27 and 28).

Due to the ability to mix multiple waste streams in either compression scenario, the inventory and accounting system needs to be able to account for and track all additions to the primary or secondary waste package. Depending on the type and extent of nuclear materials present, random verification checks, unattended monitors or surveillance may be agreed upon between the IAEA and the State.

3.4.6.7. Cementation

Direct immobilization of nuclear materials in cementitious materials can be common for both the treatment of pure nuclear materials and to stabilize or overpack other waste forms. Pure materials are typically directly mixed with the dry or liquid components of the concrete, after chemical adjustment (e.g. adjusting the pH of the system) and then poured into a waste package. The concrete is typically well mixed and allowed to cure. As long as the nuclear materials are homogenously distributed throughout the concrete, the entire mass of concrete can be used for concentration calculations.

Slag from melting

Slag from cutting

Dust from blasting & melting

FIG. 23. Top: Foundry worker in the process of de-slagging the ladle at the Cyclife France facility (image courtesy of Robert Fhal, Cyclife-EDF); bottom: Management of the main residual waste stream categories generated at the Cyclife Sweden facility (image courtesy of Cyclife-EDF).

FIG. 24. Simulated incinerator ashes typical of combustible wastes (image courtesy of the University of Sheffield and the EU PREDIS Project).

FIG. 25. LLW Drums entering the Dounreay Waste Receipt, Assay, Characterisation and Supercompaction (WRACS) facility (image courtesy of Dounreay Site Restoration, Nuclear Decommissioning Authority, United Kingdom).

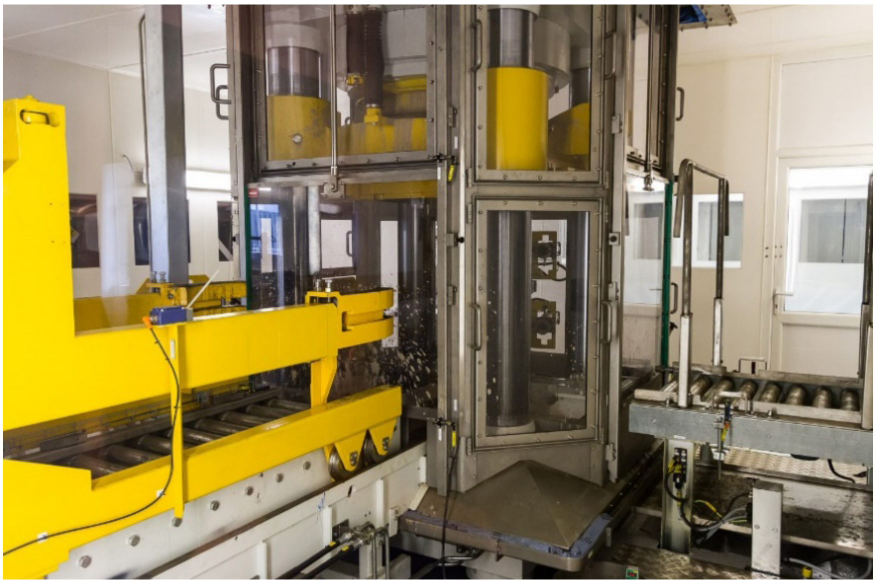

FIG. 26. LLW drum compacted into a puck in the supercompactor (image courtesy of Dounreay Site Restoration, Nuclear Decommissioning Authority, United Kingdom).

FIG. 27. *LLW pucks loaded into a half-height ISO container overpack (image courtesy of Dounreay Site Restoration, Nuclear Decommissioning Authority, United Kingdom).*

FIG. 28. *Supercompacted primary drums overpacked in a secondary drum and immobilized with grout (image courtesy of ONDRAF/NIRAS).*

3.4.6.8. Vitrified and ceramic waste forms

Immobilization of waste in glass or mineral-like phases has been a topic of intense interest and research, especially for liquid HLW and pure, direct use materials. Several vitrification plants exist worldwide to deal with liquid wastes. While not as widespread, there are multiple programmes actively developing ceramic waste forms as well. These waste forms are highly durable and resistant to radiation and chemical attack. This makes them suitable for highly radioactive wastes and to immobilize nuclear materials for geological disposal.

For vitrification plants, the input materials are typically dried and mixed with glass frit prior to heating. Once they are heated to a glassy phase, the waste materials dissolve into the liquid and the liquid is then decanted into a primary canister. This canister is sealed with a lid (welded at times) and allowed to cure for anywhere from 5 to 30 days. These glass slugs are typically thought to be suitable for geological disposal despite the lack of WAC at the time of writing.

Ceramic waste forms are a related type of engineered waste form that takes nuclear material and encases it in a synthetic mineral phase. This is accomplished by mixing the precursor materials, typically with a formula that is highly tailored to the materials being treated, and exposing the materials to high heat, pressure or, typically, both. This produces a waste form that is a fully hardened ceramic phase where the nuclear material is incorporated at the atomic level in the ceramic matrix. These waste forms are highly refractory and show good geological performance with respect to weathering and erosion.

Ceramic wastes are made in batches and typically utilize a hot isostatic press to exert the temperatures and pressures required to form the ceramic phase. The precursors are typically mixed in can or in a hopper that delivers the final material to the final can. The primary packages are in themselves highly specialized to deform correctly without failing at the pressures and temperatures required for this process.

3.4.7. Storage

Waste package storage is set up in practice using three different categories: engineered storage, area storage and subsurface storage [29]. All of the structures described here would need to have comprehensive inventory and accountancy measures in place. Methods for sealing individual containers or overpacks while still under full safeguards would need to be included (see Section 3.3.4) and, depending on what the IAEA and State agree to, other provisions for containment and surveillance, such as cameras, may need to be installed. For more information on storage of spent fuel, declared as waste or otherwise, please refer to the publication on International Safeguards in the Design of Facilities for Long Term Spent Fuel Management [30].

An engineered storage facility is a fully contained building or structure specifically designed for storage of waste packages. Designs are based on handling large waste volumes (e.g. drums or boxes). Surface dose rates may be high from these packages. Engineered stores may range from simply constructed enclosures to highly engineered storage facilities with substantial shielding, remote handling equipment, ventilation and effluent collection. Control is generally handled at the facility level in such stores. Engineered stores are mainly located at or near the nuclear facility site and may operate separately or close to other waste management premises. Engineered stores can be placed on the surface, near surface or underground (e.g. bedrock in Finland). In most cases, the facility offers the possibility to verify the declared nuclear data. These measures can be carried out by facility specific, standard procedures. In the case where the engineered storage is at the same time the disposal repository, the conditioning part of the facility offers the last possibility for verifying measures. After backfilling the disposal facility, possible safeguards measures (particularly verification) may become significantly difficult if safeguards have not been terminated on the materials prior to emplacement.[13]

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[13] The safeguards approach to disposal facilities has not been implemented to date and is an area of active policy research and development.

Area storage or open vault storage consists of the emplacement of waste packages on the ground or a constructed base, either in the open air, with an engineered structure with walls and ceilings, or with a simple open sided covering. In these facilities, packages may be stacked and some packages may be inaccessible. Packages are stored in containers that are suitable for both area storage and transport. Possible safeguards measures may include nuclear material verification throughout the operation of the storage. Re-verification of the nuclear materials and data is possible.

Subsurface storage during its operation allows most of the general safeguards measures. In this option, waste packages are placed in a space where the design is based on shallow excavation. Subsurface storage often has a solid asphalt or concrete base. This option is encouraged to be considered only when the storage time is very short. Subsurface storage needs appropriate environmental monitoring measures. This monitoring may be used also for safeguards purposes. Subsurface storage by this means is not designed and built as engineered storage and/or disposal repository for the wastes, as described in the above.

For long-lived wastes that will be disposed in a repository that has not yet been completed, WAC will likely not exist. To ensure future conditioning or treatment options are not removed as options, States may prohibit these waste packages from being conditioned in such a way that they cannot be repackaged or re-conditioned if the final WAC differs from what was expected. In practice, this usually means that solid waste is not allowed to be embedded into concrete or bitumen, but liquid wastes are still being conditioned through solidification as the hazard reduction associated with solidification is greater than the effort to process the waste for disposal. In these cases, States are encouraged to consider whether keeping these wastes in their retained waste inventory would be beneficial or if the interim wastes can be terminated if no further processing will be undertaken. For wastes that will be stored until final WAC are established, States are encouraged to investigate whether moving the materials to a retained waste inventory will be beneficial (see Section 3.3.5).

3.4.8. Common waste packages

Worldwide, there are several standard solid waste packages which have been approved for use by many Member States. These packages may have approval for either long term storage or for disposal in existing LLW facilities. Some of these waste packages have been granted permission to store more radioactive waste forms allowing them to be used for storage of ILW and HLW while their State pursues an appropriate disposal facility. The purpose of this section is to give some examples of common waste packages used in the Member States. As they pertain to safeguards, it should be noted that these packages may have to be placed under seal while they are safeguarded to prevent any diversion of the materials within. Therefore, it is very important to ensure that the waste packages to be placed under seal described in this section have appropriate anchor points or other features that would be required to apply IAEA safeguards measures. It is important to ensure the design of anchor points minimize the risk of accidental removal/damage to seals and this can be included as part of the package approval process.

3.4.8.1. Soft sided bags

Typically used for VLLW, contaminated soils and other lightly contaminated items, soft sided bags can be a flexible and useful way to dispose of large volumes of waste without having to purchase costly metallic overpackages (see Fig. 29). The bags allow the material to be safely contained within them and the hazard of a spill or leak is mitigated by the very low level of radioactive material present in the bags. The waste materials in the bags are expected to meet the post-closure requirements of their disposal site as is, without any additional structural components.

3.4.8.2. Drums

Most solid radioactive waste (typically VLLW, LLW and ILW) is placed in 200-L drums (Fig. 30), which may be further treated through various means, including supercompaction, and then conditioned,

FIG. 29. Very low level waste placed in soft sided bags (image courtesy of the Japan Atomic Energy Agency (JAEA)).

FIG. 30. Conditioned LLW in 200-L drums in an interim storage facility (image courtesy of Nuclear Engineering Seibersdorf).

FIG. 31. A 200-L drum being placed inside a drum counter.

for example via cement encapsulation in an overpack; this process is shown in Figs 25–28. The drum shown in Fig. 17 contains what is referred to as a “lost paddle”, which allows liquid waste to be mixed with the cement recipe and then to cure within the drum without removing the mixer (which becomes part of the waste). For example, the United Kingdom’s Dounreay site has conditioned the majority of its liquid raffinate inventory produced from reprocessing spent reactor fuel through this route [31]. Many drums are a standard size and proportion that lend themselves to use of standard treatment or characterization techniques, e.g. the use of a drum counter that requires a fixed geometry as shown in Fig. 31.

3.4.8.3. Boxes

A common container is a cement box known as a caisson constructed through the use of reinforced cement panels that form the bottom and sides of the box. Solid ILW or conditioned drums of waste are placed into the box and then it is filled with cementitious grout. The lid is placed onto the filled and grouted box and more cement is poured to reinforce the lid once the cement cures. The renderings of concrete boxes shown in Fig. 32 were designed for used by ONDRAF/NIRAS for various types of radioactive waste, and similar boxes are produced in many Member States.

As an alternative to concrete boxes, a stainless steel box can be used with a sealable lid. As an example, a stainless steel box may hold four 500-L drums within its cavity, or it can be directly filled with solid ILW such as irradiated reactor fittings or other highly radioactive components (Fig. 33). Stainless steel boxes have some ability to shield wastes and can be used for temporary storage; additional shielding can be added as needed to the box design. Due to the removable lid, there is an option to defer filling the box with grout, which would restrict future waste treatments. Therefore, this material would not be typically eligible for termination of safeguards, and would likely be placed in retained wastes, until treatment of the wastes is completed as determined by the disposal WAC. Stainless steel boxes have also been developed with shielding added into the box itself where it is possible to have tens of centimetres of cement poured between the outer and inner box skins.

FIG. 32. Rendering of concrete boxes (caissons) showing various filling modes prior to final grouting. Examples include: multiple medium drums (left); one larger drum (centre); and large, loose components contained in an inset basket (image courtesy of ONDRAF/NIRAS).

FIG. 33. Stainless steel box of 3 m^3 in size (image courtesy of Sellafield Ltd).

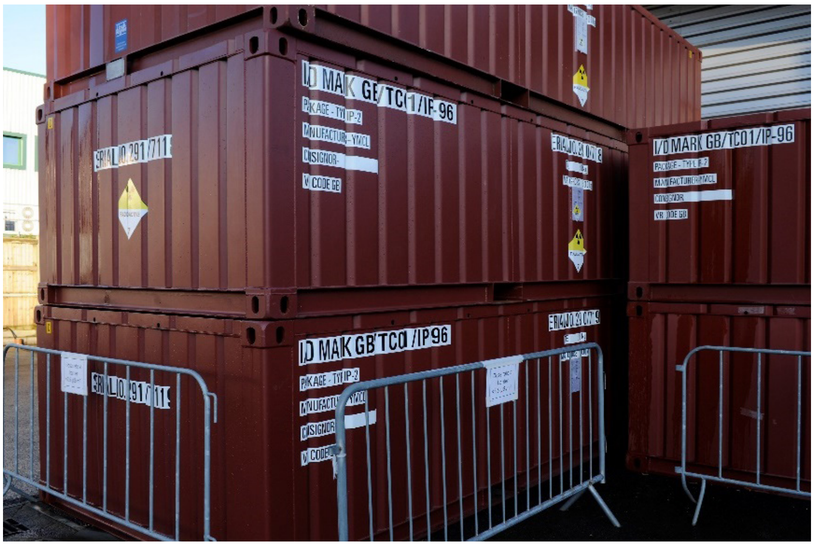

FIG. 34. Half-height ISO container marked for transport of radioactive wastes.

3.4.8.4.   ISO containers

One of the more common overpacks used throughout the world is the intermodal container, many versions of which meet the International Organization for Standardization (ISO) standards and thus are referred to as ISO containers. These containers are commercially available in several sizes, have compatible gross weight limits and adequate structural integrity to survive post-closure in a disposal facility (see Fig. 34). Typically these are used for VLLW and LLW that will be placed in a near surface disposal facility, as they can be easily transported and moved by crate or truck and are highly adaptable. These containers are generally filled with primary (or secondary) packages and then backfilled with either soil or grout to make a solid disposal form that can be emplaced. For many waste operations, top loading half-height ISO containers are used.

Larger box type waste containers are used either as waste packages or as overpacks containing several large drums. The boxes may contain some shielding but, depending on the radionuclide inventory, they may be required to be stored within a shielded waste store. All boxes are generally stackable, but the stack loading of the facility will determine the number of boxes that are allowed within a stack. A full height ISO container may contain upwards of seventy 200-L drums without compaction or 250–300 pucks if the drums are processed through a super compactor facility (see Figs 25–27).

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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 glossary offers simple definitions for terminology used in the field; many, but not all of the terms, are used in this publication. In some cases, the industry use of the terms may differ from what is presented here; note that these terms are used in association with the safeguards measures applied within a State. All safeguards terms have been taken from INFCIRC/153 (Corrected)[1]*, INFCIRC/66/Rev. 2*[2]*, INFCIRC/540 (Corrected)*[3] *or the IAEA Safeguards Glossary*[4]*. Terms in the waste management section are taken from the IAEA Nuclear Safety and Security Glossary*[5].

NUCLEAR AND NON-NUCLEAR MATERIAL

direct use material.[4] Nuclear material that can be used for the manufacture of nuclear explosive devices without transmutation or further enrichment. It includes plutonium containing less than 80% ^{238}Pu, high enriched uranium (HEU) and ^{233}U. Chemical compounds, mixtures of direct use materials (e.g. mixed oxides (MOX)) and plutonium in spent reactor fuel fall into this category. Unirradiated direct use material is direct use material which does not contain substantial amounts of fission products; it would require less time and effort to be converted into components of nuclear explosive devices than would irradiated direct use material (e.g. plutonium in spent reactor fuel) that contains substantial amounts of fission products.

hold-up.[4] Nuclear material remaining in and about process equipment, interconnecting piping, filters and adjacent work areas after shutdown of a plant. It may also be referred to as ‘material held up in process’ or ‘in-process material’ for plants in operation. Hold-up is difficult to measure and may be a contributor to material unaccounted for, and therefore is important to minimize prior to conducting a physical inventory taking. Some material in hold-up is recovered through periodic maintenance such as filter exchanges and cleaning of process equipment, often in preparation for conducting a physical inventory, while other material in hold-up may be recovered only during the decommissioning of the plant, such as material plated onto the walls of fixed piping. The IAEA nuclear material accountancy principles require that hold-up be declared as part of the physical inventory and/or inventory changes if the related equipment is transferred between material balance areas. Hold-up is mainly estimated on the basis of plant or equipment specific models; these models are associated with uncertainties larger than those typically observed for accountancy measurements. Therefore, hold-up should be minimized as much as possible prior to conducting a physical inventory. Developing hold-up models may involve dedicated theoretical and experimental studies combined with the use of operational data available through periodic maintenance (e.g. filter exchange, cleaning of process equipment) and of information on the amount of hold-up material recovered during the decommissioning of similar plants or equipment.

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low enriched uranium (LEU).[4] Enriched uranium containing less than 20% in weight per cent (wt%) of the isotope ^{235}U. LEU is considered a special fissionable material and an indirect use material.

mixed oxide (MOX).[4] A mixture of the oxides of uranium and plutonium used as reactor fuel for the recycling of plutonium in thermal nuclear reactors (‘thermal recycling’) and for fast reactors. MOX is considered a special fissionable material and a direct use material.

retained waste.[4] “[N]uclear material generated from processing or from an operational accident, which is deemed to be unrecoverable for the time being but which is stored” (para. 107, INFCIRC/153 Corr.). The actual inventory change used in accounting records and reports is termed ‘transfer to retained waste’. Nuclear material transferred to retained waste is stored in the material balance area (MBA) and continues to be subject to IAEA safeguards but is not included in the inventory of the MBA. See also waste.

scrap.[4] Recyclable nuclear material rejected from the process stream. Clean scrap comprises rejected process material that can be reintroduced into the process stream without the need for purification, while dirty scrap may require separation of the nuclear material from contaminants, or chemical treatment to return the material to a state acceptable for subsequent processing.

waste.[4] In the context of IAEA safeguards, this refers to waste containing nuclear material in concentrations or chemical forms which make the nuclear material no longer usable for any nuclear activity relevant from the point of view of safeguards, or which has become practicably irrecoverable. Reporting requirements to the IAEA for nuclear material contained in waste are specified under the relevant safeguards agreement and additional protocol (AP) thereto, as applicable. The termination of IAEA safeguards on nuclear material in waste is based on a determination by the IAEA that certain of the relevant technical conditions are met. Under an INFCIRC/153-type safeguards agreement, where these conditions are not met but the State considers that the recovery of safeguarded nuclear material from residues is not for the time being practicable or desirable, para. 35 of INFCIRC/153 (Corrected) provides that the IAEA and the State shall consult on the safeguards measures to be applied, in which case the nuclear material remains subject to IAEA safeguards but is reported to the IAEA as transferred to retained waste and is no longer included in the inventory of the material balance area (MBA).

NUCLEAR INSTALLATIONS AND EQUIPMENT

bulk handling facility.[4] A facility where nuclear material is held, processed or used in bulk form. Where appropriate, bulk handling facilities may be organized into multiple material balance areas (MBAs) for safeguards purposes, for example by separating activities relating only to the storage and assembly of discrete fuel items from those involving the storage or processing of bulk material. In a bulk MBA, flow and inventory values declared by the facility operator are verified by the IAEA through independent measurements and observation. Examples of bulk handling facilities are conversion plants, enrichment (isotope separation) plants, fuel fabrication plants and spent fuel reprocessing plants, and storage facilities for bulk material.

essential equipment list (EEL).[4] A list of equipment, systems and structures essential for the operation of a facility. The EEL is facility specific and is established during the design information examination (DIE). It identifies those items that may influence the facility’s operational status, function, capabilities and inventory.

item facility.[4] A facility where all nuclear material is kept in item form and the integrity of the item remains unaltered during its residence at the facility. In such cases, IAEA safeguards are based on item accountancy procedures (e.g. item counting and identification, non-destructive measurements of nuclear material, verification of the continued integrity of the items). Examples of item facilities are most reactors and critical assemblies (critical facilities), and storage installations for reactor fuel.

reprocessing plants.[4] Any plant especially designed for or containing essential equipment capable of reprocessing nuclear material.

NUCLEAR MATERIAL ACCOUNTANCY

continuity of knowledge.[6] Assurance that the safeguards relevant data (e.g. identity and integrity of the item, item contents or flow and inventory of nuclear material) remain valid.

declarations. Information submitted to the IAEA by a safeguards authority.

design information.[4] Information concerning nuclear material subject to IAEA safeguards under the relevant agreement and the features of facilities relevant to safeguarding such material (see para. 8 of INFCIRC/153 Corr.; see also para. 32 of INFCIRC/66). Design information includes the facility description; the form, quantity, location and flow of nuclear material to be or being used; facility layout and containment features; and procedures for nuclear material accountancy and nuclear material control. This information is used by the IAEA, inter alia, to design the facility safeguards approach, to determine material balance areas (MBAs) and select key measurement points (KMPs) and other strategic points, to develop the design information verification (DIV) plan and to establish the essential equipment list (EEL) […].

destructive analysis (DA).[4] Determination of nuclear material content and, if required, of the isotopic composition of chemical elements present in the sample. DA normally involves destruction of the physical form of the sample. In the context of IAEA safeguards, determination of the nuclear material content of an item sampled usually involves the following:

- Measurement of the mass of the item;
- The taking of a representative sample;
- Sample conditioning (if necessary) prior to shipment to the IAEA Safeguards Analytical Laboratories (SAL) for analysis or to the location of on-site analysis;
- Processing of the sample to the chemical state required for the analysis (e.g. dissolution in nitric acid);
- Determination of the mass fraction (also called concentration) of the nuclear material (i.e. uranium, plutonium or thorium) present in the sample (i.e. elemental analysis) […];
- Determination of the isotopic abundance ratios of uranium or plutonium isotopes (i.e. isotopic analysis) […].

diversion path analysis.[4] A structured method used to analyse the paths by which, from a technical point of view, nuclear material subject to IAEA safeguards could be diverted from a facility, or by which facilities or other items subject to safeguards could be misused. Diversion path analysis is used to establish technical objectives for States with an item-specific safeguards agreement and States with a voluntary offer agreement (VOA). For States with a VOA, the path analysis includes consideration of the withdrawal from safeguards of nuclear material subject to safeguards without notifying the IAEA.

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[6] This usage is illustrated in the IAEA Safeguards Glossary, but not explicitly defined.

exemption from IAEA safeguards. Under para. 37 of INFCIRC/153 (Corrected) and para. 21 of INFCIRC/66/Rev. 2, a State may request exemption for nuclear material up to certain specified limits.

Under para. 36 of INFCIRC/153 (Corrected), a State may also request exemption for nuclear material related to the specific use as follows:

(a) Special fissionable material, when it is used in gram quantities or less as a sensing component in instruments;
(b) Nuclear material, when used in non-nuclear activities in accordance with para. 13 of [153], if such nuclear material is recoverable;
(c) Plutonium with an isotopic concentration of ^{238}Pu exceeding 80%.

Under para. 38 of INFCIRC/153 (Corrected), if exempted nuclear material is to be processed or stored together with safeguarded material, reapplication of IAEA safeguards on the exempted material is required. Accordingly, exempted nuclear material is required to be de-exempted if such material is to be stored together with safeguarded nuclear material or processed.

In certain circumstances there remain some reporting obligations on exempted nuclear material.

Under Article 2.a.(vii) of INFCIRC/540 (Corrected), the State is required to provide the IAEA with information regarding the quantities, uses and locations of nuclear material that has been exempted from IAEA safeguards under para. 36(b) or para. 37 of INFCIRC/153 (Corrected).

Paragraphs 22 and 23 of INFCIRC/66/Rev. 2 also provide for exemptions related to reactors.

interim inventory verification (IIV).[4] An IAEA inspection activity that takes place within a material balance period (MBP). Such verification is for timely detection or, for example, for reestablishment of the inventory of nuclear material.

mailbox declaration.[4] The near real time submittal, into a secure electronic mailbox, of information on operational activities of safeguards relevance, as agreed in advance with the IAEA. Mailbox declarations are not used for submitting State reports to the IAEA, but are used for collecting and transmitting operator data, typically to facilitate inspections on short notice (e.g. through the use of short notice random inspections (SNRIs)).

The contents of the information submitted in mailbox declarations are agreed between the IAEA and the State or regional authority responsible for safeguards implementation (SRA) in coordination with the facility operator on a case by case basis. For example, a fuel fabrication facility operator might submit mailbox declarations with information on receipts, material in process, product and shipments of nuclear material on a daily basis. Provision of a mailbox declaration may also be provided in connection with declarations submitted pursuant to Article 2.a.(ii) of [540], although an additional protocol (AP) is not required for mailbox declarations to be provided to the IAEA.

material balance period (MBP).[4] The time between two consecutive physical inventory takings as reflected in the State's material balance report (MBR). Under some item-specific safeguards agreements, the term is used to refer to what more accurately should be called the book balance period, since the beginning and the ending dates of the period are not linked to physical inventory takings or to the inspection dates.

near real time accountancy (NRTA).[4] A form of nuclear material accountancy, particularly for bulk handling material balance areas (MBAs) with large throughput, in which detailed inventory and inventory change data are maintained by the facility operator for each item containing nuclear material and are made available to the IAEA on a near real time basis. Associated measurement uncertainties of every measurand used to establish the accountancy data are also included in these data. This enables inventory verification to be carried out and material balances to be established more frequently than, for example, at the time of the annual physical inventory taking by the facility operator. When the in-process inventory cannot be determined by measurement, NRTA requires that an estimate, including its uncertainty, be made of the inventory in each piece of equipment containing nuclear material, on the basis of documented techniques.

non-destructive assay (NDA).[4] A measurement technique applied to nuclear material and other items of safeguards interest to confirm their isotopic composition and quantity without destroying the items. NDA measurements can be conducted in attended mode — if an inspector or a technician has to be present for operating the device — or in an automated manner with unattended monitoring systems (UMSs). There are two broad categories of NDA based on ionizing radiation:

- Passive analysis (assay), in which the measurement refers to spontaneous emissions of neutrons or gamma rays, or to the total decay energy;
- Active analysis (assay), in which the measurement refers to a stimulated emission (e.g. neutron or photon induced fission).

NDA of many other physical quantities of interest — including mass, temperature or non-ionizing radiation such as Cerenkov glow — can be used for the verification of nuclear material.

nuclear material accountancy.[4] The practice of nuclear material accounting by the operator of the facility or location outside facilities (LOF) and the State or regional authority responsible for safeguards implementation (SRA) through the State (or regional) system of accounting for and control of nuclear material (SSAC/RSAC), inter alia, to satisfy the requirements of safeguards agreements. The IAEA independently verifies the correctness of the nuclear material accounting information in the facility records and the reports provided by the SRA to the IAEA […].

physical inventory verification (PIV).[4] An IAEA inspection activity that closely follows, or coincides with, the physical inventory taking which closes the material balance period (MBP). The basis for a PIV is the list of inventory items (IIL) prepared by the operator. The data are reconciled with the physical inventory listing (PIL) reports submitted by the State to the IAEA.

practicably irrecoverable.[5] The IAEA's determination that a waste form's characteristics and nuclear material concentration place the nuclear material in a state or condition where it would be more economical to produce similar material from scratch than to recover the material itself (at a certain point in time).

remote data transmission (RDT).[4] A technique whereby safeguards data, collected by RDT systems, are transmitted in a secure and reliable way off-site to IAEA Headquarters, a regional office or another IAEA location for review and evaluation purposes. RDT enables better utilization of equipment, more optimized planning of inspections and a reduction in the inspection effort needed to meet verification requirements. It also allows the implementation of more efficient and timely equipment maintenance driven by the analysis of equipment state of health data, and even remote maintenance in certain cases.

safeguards approach.[4] An internal document developed by the IAEA describing the practical implementation of IAEA safeguards. A safeguards approach consists of a set of safeguards measures and safeguards activities, along with their corresponding intensity and frequency […].

short notice random inspection (SNRI).[4] A routine inspection performed by IAEA inspectors both at short notice and randomly. SNRIs are part of a safeguards approach developed for fuel fabrication plants under IAEA safeguards to provide 100% verification coverage of domestic transfers of nuclear material and borrowing scenarios. The SNRI is based on near real time submittal of mailbox declarations containing the operator's operational data. SNRIs may also be used at other facility types where the safeguards approach calls for unpredictably scheduled short notice inspections.

State or regional authority responsible for safeguards implementation (SRA).[4] The term 'SRA' was introduced by the IAEA in 2012 to denote the authority established at the national (or regional) level to ensure and facilitate the implementation of IAEA safeguards in a State or States of a region. One of the primary responsibilities of an SRA is to establish and maintain a State (or regional) system of accounting for and control of nuclear material (SSAC/RSAC). Such responsibility may also extend to the implementation of the State's obligations under an additional protocol (AP) (INFCIRC/540).

The responsibilities of the SRA related to the implementation of IAEA safeguards may include nuclear material accountancy and the reporting of imports and exports of nuclear material as well as facilitating IAEA inspections. Where the SRA is responsible for activities associated with the implementation of an AP [540], such responsibilities may include, for example, coordinating the collection of information required to be reported to the IAEA in AP declarations, responding to IAEA requests for clarification and facilitating complementary access by the IAEA at relevant locations.

If established within a broader nuclear authority, the SRA may have additional responsibilities associated with nuclear safety, security, radiation protection and export/import controls separate from and in addition to its safeguards functions.

termination of IAEA safeguards. Termination of IAEA safeguards on nuclear material pursuant to paras 11, 13 and 35 of INFCIRC/153 Corr.

unannounced inspection.[4] A routine inspection performed by IAEA inspectors at a facility for which no advance notice is provided by the IAEA to the State before the arrival of IAEA inspectors. Paragraph 84 of INFCIRC/153 Corr. provides that, "as a supplementary measure, the Agency may carry out without advance notification a portion of the routine inspections...in accordance with the principle of random sampling." Paragraph 50 of INFCIRC/66 Rev. 2 makes provision for the IAEA to carry out unannounced inspections.

unattended monitoring system (UMS).[4] A tamper indicating system that operates continuously and autonomously to perform measurements without inspector intervention. UMSs are employed in applications of nuclear material accountancy using non-destructive assay (NDA), containment/surveillance devices or a combination thereof. UMSs consist of radiation detectors and/or sensors for physical and electrical properties connected to an industrial cabinet containing data acquisition equipment, power management components, and communication and other support devices […].

CONTAINMENT AND SURVEILLANCE

containment.[4,7] Structural features of a facility, containers or equipment which are used to maintain the continuity of knowledge of items by preventing undetected access to, or movement of, the items. The continuing integrity of the containment is usually ensured by complementary containment/surveillance measures.

seal.[4] A tamper indicating device used to join movable segments of a containment in a manner such that access to the containment's contents without opening the seal or breaking the containment is prevented. A sealing system comprises the containment enclosing the material to be safeguarded, the means of applying the seal and the seal itself. All three components must be examined in order to verify that the sealing system has fulfilled its function of ensuring continuity of knowledge of the identity and integrity of the material concerned.

surveillance.[4] The collection of information through direct inspector observation or recording devices for use in maintaining continuity of knowledge of nuclear material, containment, IAEA assets and site activities.

system of containment/surveillance measures.[4] A combination of containment and/or surveillance measures that are used to maintain continuity of knowledge of nuclear material, IAEA assets and site activities. Each containment/surveillance (C/S) system is designed to meet a purpose specified in the IAEA's safeguards approach. To increase reliability, a C/S system can include one or several C/S devices. Dual C/S measures are normally applied if verification of nuclear material is difficult, in order to increase confidence in the C/S results and reduce the requirements for re-verification.

tamper indication.[4] Physical or electronic evidence of any unauthorized or undeclared attempt, physically or electronically, to access or alter IAEA equipment or to compromise the confidentiality, integrity or authenticity of equipment, containment or data.

WASTE MANAGEMENT TERMS

containment.[5,8] Methods or physical structures designed to prevent or control the release and the dispersion of radioactive substances.

exemption.[5] The determination by a regulatory body that a source or practice need not be subject to some or all aspects of regulatory control on the basis that the exposure and the potential exposure due to the source or practice are too small to warrant the application of those aspects or that this is the optimum option for protection irrespective of the actual level of the doses or risks.

clearance.[5] Removal of regulatory control by the regulatory body from radioactive material or radioactive objects within notified or authorized facilities and activities.

high level waste (HLW).[5] The radioactive liquid containing most of the fission products and actinides present in spent fuel — which forms the residue from the first solvent extraction cycle in reprocessing — and some of the associated waste streams; this material following solidification; spent fuel (if it is declared as waste); or any other waste with similar radiological characteristics.

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[7] This definition differs from that defined in the IAEA Nuclear Safety and Security Glossary.

[8] This definition differs from that defined in the IAEA Safeguards Glossary.

intermediate level waste (ILW).[5] Radioactive waste that, because of its content, in particular its content of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal.

low level waste (LLW).[5] Radioactive waste that is above clearance levels, but with limited amounts of long lived radionuclides.

nuclear material.[9] "[N]uclear material" means plutonium except that with isotopic concentration exceeding 80% in plutonium-238; uranium-233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore-residue; any material containing one or more of the foregoing.

radioactive material.[5] Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.

scaling factor (SF).[10] A factor or parameter derived from a mathematical relationship used in calculating the radioactivity of a difficult to measure nuclide from that of an easy to measure key nuclide as determined from sampling and analysis data.

very low level waste.[5] Radioactive waste that does not necessarily meet the criteria of exempt waste, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in landfill type near surface repositories with limited regulatory control.

waste.[5] Material for which no further use is foreseen.

waste acceptance criteria.[5] Quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for the waste form and waste package to be accepted by the operator of a waste management facility.

waste from past activities. Waste forms, materials and in situ contamination that either have not been treated, including found items, or treated in such a manner that they require additional treatment to meet current standards for storage or disposal.

MISCELLANEOUS

diversion of nuclear material.[4] A particular case of non-compliance that would include: (a) Under an INFCIRC/153-type safeguards agreement, the undeclared removal of declared nuclear material from a safeguarded facility; or the use of a safeguarded facility for the introduction, production or processing of undeclared nuclear material, e.g. the undeclared production of high enriched uranium in an enrichment plant, or the undeclared production of plutonium in a reactor through irradiation and subsequent removal of undeclared uranium targets; (b) Under an INFCIRC/66-type safeguards agreement, the use of the nuclear material specified and placed under safeguards in such a way as to further any military purpose.

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[9] Convention on the Physical Protection of Nuclear Material, INFCIRC/274/Rev. 1, IAEA, Vienna (1980). Note that nuclear materials are designated by isotope while radioactive materials are designated by regulation. Therefore, an item can be a nuclear matenandsrial but not a radioactive material if it has a low enough activity to not be regulated with respect to safety.

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Determination and Use of Scaling Factors for Waste Characterization in Nuclear Power Plants, IAEA Nuclear Energy Series No. NW-T-1.18, IAEA, Vienna (2009).

INFCIRC. A document circulated by the IAEA in order to provide information on matters of general interest to all its Member States.

misuse.[4] a particular case of non-compliance under an INFCIRC/66-type safeguards agreement that would include the use of the non-nuclear material, services, equipment, facilities or information specified and placed under safeguards to further any proscribed purpose.

safeguardability. The degree of ease with which a nuclear energy system or facility can be effectively and efficiently placed under international safeguards.

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.

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.
- Opportunities for synergies with security requirements may be identified during this phase.

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.

FIG. II–1. Facility life cycle stages.

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 (DIV).
- 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 DIV;
- The SRA, IAEA and operator cooperate to install and test safeguards equipment.[1]

II–5. COMMISSIONING (INACTIVE AND ACTIVE)

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

- The IAEA continues DIV.
- 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. PREPARATION

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 DIV and reviews the facility and associated systems.
- The IAEA performs inspections, e.g. verifies the facility nuclear material accounting system, records and measurement systems.

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[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.

- The IAEA confirms the operability and function of safeguards equipment, calibrates equipment, cooperates with the 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.

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 DIV 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 DIE and DIV;
- 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.

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

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

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

TABLE III–1. FACILITY SAFEGUARDABILITY ASSESSMENT (cont.)

Facility safeguardability assessment screening questions	
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

INFORMATION FOUND IN THE DESIGN INFORMATION QUESTIONNAIRE FOR RADIOACTIVE WASTE MANAGEMENT FACILITIES

The following information is written at an introductory level for an audience unfamiliar with the IAEA design information questionnaire. Official templates are available from the IAEA. This questionnaire is intended for waste facilities that would be expected to process more than 1 effective kilogram of nuclear material. If the facility is not expected to process that quantity, then the waste facility would typically fall under the definition of a location outside a facility.

IV–1. GENERAL INFORMATION

- Name of the facility (including any usual abbreviation);
- Location and postal address;
- Owner;
- Operator;
- Description of main features;
- Purpose (include type of facility — processing, storage, etc.);
- Status (planned, under construction, in operation, shutdown, closed-down, decommissioned for safeguards purposes);
- Construction schedule dates (if not already in operation);
- Normal operating mode (days only, two-shift, number of days per annum, etc.);
- Facility layout (including routes followed by nuclear material);
- Siting of the facility (including other buildings, roads, railways and rivers);
- Names and/or title and address of responsible officers (for nuclear material accounting and control and contact with the IAEA; if possible, include organizational charts).

IV–2. OVERALL PROCESS PARAMETERS

- Facility description (indicating important items of equipment which process nuclear material);
- Design capacity;
- Anticipated annual throughput and inventory for processing;
- Licence information (and any restrictions);
- Location and method to retrieve all waste acceptance criteria (WAC) relevant to facility;
- Storage capacity.

IV–3. NUCLEAR MATERIAL DESCRIPTION AND FLOW

- Nuclear waste material description:
  - Major contributions (sources);
  - Type/description of waste;
  - Chemical and physical form (liquid, solid, etc.);
  - Uranium and its enrichment range / plutonium content;

- Waste processes (describe waste treatment/conditioning processes with details of equipment and flow chart);
  - Indicate expected end state for each process and waste type (termination, disposal, storage, clearance);
  - Criticality considerations.

IV–4. HANDLING OF NUCLEAR MATERIAL (FOR EACH ACCOUNTABILITY AREA)

- Containers, packaging and storage area description;
- Methods and means of transfer of nuclear waste and/or materials;
- Shielding (for storage and transfer).

IV–5. PROTECTION AND SAFETY MEASURES

- Basic measures for physical protection of nuclear material;
- Specific health and safety rules for inspector compliance.

IV–6. NUCLEAR MATERIAL ACCOUNTANCY AND CONTROL

- Nuclear material accountancy control system description:
  - General;
  - Receipts;
  - Shipments;
  - Physical inventory;
  - Operational records and accounting records.
- Features related to containment and surveillance measures.
- For each measurement point of accountability areas:
  - Description of location, type, identification;
  - Anticipated types of inventory change and possibilities to use this measurement point for physical inventory taking;
  - Physical and chemical form of nuclear material;
  - Nuclear material containers, packaging;
  - Sampling procedures and equipment used;
  - Measurement method(s) and equipment used;
  - Source and level of random and systematic errors (weight, volume, sampling, NDA);
  - Technique and frequency of calibration of equipment used;
  - Method of converting source data to batch data;
  - Means of batch identification;
  - Anticipated batch flow rate per year;
  - Anticipated number of inventory batches;
  - Anticipated number of items per flow and inventory batches;
  - Type, composition and quantity of nuclear material per batch;
  - Features related to containment surveillance measures;
- Ability to terminate safeguards, per the facility attachment, at this measurement point.

IV–7. POST-OPERATIONAL INFORMATION

- Decommissioning schedule date.
- Facility decommissioning plan:
  - Key events of the decommissioning plan;
  - Removal and recovery of nuclear material;
  - Removal and rendering inoperable of essential equipment.

IV–8. OPTIONAL INFORMATION

- If possible, give reference location and method to retrieve all WAC relevant to facility.

Annex V

TECHNICAL EXAMPLES FOR TERMINATION OF SAFEGUARDS

This annex contains a collection of technical examples, which are fictional scenarios that incorporate real world experiences and current good practice on the treatment of wastes and application of safeguards. They could also be described as non-State-specific case studies. This is due to the fact that deficiencies (if present) which may have occurred in a State's processes, even if those deficiencies led to a beneficial change in practice, may not be publicly known. In addition, the details of safeguards applications at an identifiable facility may be sensitive information. Therefore, the technical examples given here should not be viewed as representative of any given State and should be viewed as amalgamations of several States' experiences. The safeguards measures identified for these fictitious facilities should be viewed as fictions themselves (though rooted in current good practice) and should not be construed as safeguards advice or guidance for any State. These examples are intended to illustrate various concepts presented in this publication under realistic circumstances. A total of nine technical examples are contained here and each illustrates a slightly different situation that is found in common practices surrounding the application of safeguards to wastes and the common questions directed to the IAEA on this topic.

V–1. CREATION OF GLASS WASTE FORMS

V–1.1. Summary

A glass waste facility is processing liquid HLW into glass waste forms. The facility was designed according to safeguards-by-design principles and incorporates several features to reduce the inspection burden. Finished waste glasses from this facility are stored on-site, a termination of safeguards is petitioned for, and items with successfully terminated safeguards are transferred to a long term store on-site prior to emplacement in a geological repository suitable for HLW.

V–1.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a comprehensive safeguards agreement (CSA) in force with an additional protocol (AP).
- The facility was designed with safeguards concepts in mind due to the amounts of direct use material being processed and the eventual need to petition for termination of safeguards:
  - The application of safeguards by design led to the identification of the need for an input accountancy tank, destructive analysis (DA) requirements and the positive benefits of unattended monitoring systems for product cannisters.
  - Inline monitoring and unattended verification systems are both in use.
- An interim storage facility for terminated wastes is co-located with the waste facility.
- The facility attachment gives details of termination process for the vitrified wastes.
- Design information verification (DIV) was easier to perform due to early inclusion of the IAEA.

V–1.3. Narrative

The State has a partially closed fuel cycle where approximately 50% of the State's spent fuel is reprocessed to recover uranium and plutonium for new fuel. This process produces a highly active liquid waste stream that is highly acidic, with large amounts of fission products, and trace amounts of nuclear material (~0.01% by mass in the liquid composed of ^{235}U, ^{238}U, ^{239}Pu). This liquid is stored at the reprocessing facility in criticality safe tanks. The tanks are capped and placed under safeguards seal at the reprocessing facility after filling and verification of the contents. The tanks are then placed in the retained waste inventory at the facility.

The tanks are then re-transferred from retained waste, in batches, placed under full accountancy and shipped to the on-site waste processing facility. The glass waste equipment is located within a multicell hot cell with remote manipulation equipment due to the high intrinsic radiation field associated with the liquid waste. The first step is transferring the liquid HLW to a dedicated input accountancy tank that allows for a DA sample to be taken for compositional testing. This testing is threefold: to determine solution composition for material balances, determine necessary pre-treatments and determine and add appropriate glass frit materials. This information is logged against the waste tank identification number, which is on the exterior of the tanks and machine-readable. The sampling equipment can also be used to draw an on-demand sample during verification activities. The tank uses level monitors and flow meters (input and withdrawal) to measure the amount of solution in the tank.

At this point, the liquid waste / glass frit mixture is loaded into the glass melter and vitrified. The molten glass is poured into a final waste cannister and once cooled, it is welded shut. The final cannister has an identifying, machine-readable, inscribed label. The cooled and sealed cannister is then moved to a decontamination cell, visually inspected, and measured with an unattended monitoring system that verifies the gamma activity of the cannister and the machine-readable inscribed label. The cannister is then moved to a transfer cell for interim storage.

Once per month, termination of safeguards is requested for the nuclear material in any cannisters that are in storage. The physical characteristics of the glass waste form, the nuclear material concentrations and total amount of material to be terminated is transmitted to the IAEA. When the termination of safeguards is approved, the cannisters are removed from the transfer cell, any seals are removed and saved for return to the IAEA, and the cannisters are emplaced in the interim storage vault of the facility pending development of a geological repository. The wastes are managed as HLW requiring isolation from the biosphere but not as safeguarded wastes. The location of these wastes will continue to be tracked as the plutonium content within the glasses makes them AP declarable and subject to CA.

The waste processing facility was designed with safeguards needs in mind. The presence of the input accountancy tank, the protocol and design for the unattended monitoring system, and the material tracking processes were all designed with input from the IAEA. This collaboration led to decisions that:

- The State is providing isolated electrical and data transmission channels for IAEA equipment inside the facility and within the glass processing hot cell.
- The design of the hot cell incorporated the physical requirements of the cabling required for IAEA equipment to ensure compliance with local electrical and construction standards.
- The design of the monitoring system was altered to include heavy shielding due to the high radioactivity levels:
  - The combination of the monitoring system, which measures spontaneous neutrons from ^{244}Cm, and the DA taken from the accountancy tank, which gives the Cm:U and Cm:Pu levels, gives the total nuclear material content in the waste package.
  - This process requires close cooperation between the State and the IAEA to share data for verification purposes.

V–2. MOLYBDENUM PROCESSING WASTES

V–2.1. Summary

A molybdenum-99 production facility co-located at a research reactor facility routinely irradiates low-enriched uranium (LEU) targets and generates, in addition to the molybdenum product, several highly active waste streams including uranium cake (the uranium solid that is filtered as part of the chemical process to separate molybdenum), liquid wastes from the washing and molybdenum recovery lines and operational wastes. The liquid wastes are concentrated, characterized and cemented for stability and eventual disposal as non-safeguarded wastes. These wastes are placed in a non-safeguarded storage facility. The uranium cake is placed in storage containers, dried, sealed and placed in safeguarded storage for repatriation to the supplier State; the State has expressed an interest in reusing the uranium cake.

V–2.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a CSA in force with an AP in place.
- The State is responsible for its residual wastes that will be disposed of in the State in a near surface disposal facility and an intermediate depth disposal facility (not yet built).
    - The State will keep irradiated uranium targets created by the process in safeguarded storage until a final decision is made on disposal.
- The facility and State consulted with the IAEA at the start of the project and a comprehensive plan was developed for all waste streams, which is captured in an updated facility attachment for the research reactor facility.
- Due to LEU (target) and plutonium (neutron capture) present at the facility, and the need to terminate lower level wastes, additional safeguards measures are applied.
- Per national regulations, non-geological disposal can only be used for non-Safeguarded wastes.
    - The facility must ensure that the nuclear material content in each waste stream is determined and that it is clearly understood that there is always some residual nuclear material content in each waste stream.
    - Transfers to a retained waste inventory is available for pre-termination/non-terminable materials.
- Significant recovery operations have decreased residual LEU in waste streams; the remaining material is difficult to recover.

V–2.3. Narrative

The State receives safeguarded 19.5% LEU targets that are irradiated in their research reactor with thermal neutrons. Some of the ^{235}U targets absorb the neutrons, which causes them to fission. After irradiation, the samples are removed from the reactor, cooled slightly and sent to a co-located processing facility. The movement of the targets is noted as they move from the reactor MBA to the processing MBA of the facility and monitored by camera since the target now contains ^{239}Pu, which is a direct use nuclear material.

The targets are dissolved in an alkaline dissolution process and the molybdenum recovered. The process produces several waste streams that contain trace levels of uranium and significant levels of short-lived fission products. The operational waste streams include surface contaminated personal protective equipment and disposable items, the highly active fission product stream and the bulk LEU waste product. This final product will either be shipped back to the supplier State or kept and reprocessed into new targets. The State conditions the bulk uranium by drying the material into a uranium hydroxide solid. The uranium content is verified using an active neutron coincidence counter in campaigns by

IAEA inspectors after some of the short-lived nuclides have decayed (at least two years after irradiation). This material is placed under seal and stored until the material can be transferred to the safeguarded storage vault on-site.

Per the termination process specified in the facility attachment, low level waste (LLW) with trace level contamination is placed in soft bags, gamma counted and in-drum compacted based on the waste acceptance criteria (WAC) in place. The drums are closed, labelled and stored until further processing (e.g. transportation or overpackaging). The intermediate level waste (ILW) is sampled for radionuclide content and, after a cooling period of more than six weeks, grouted in a drum per the termination plan specified in the facility attachment. At this point, the wastes are placed in the retained waste inventory until termination of safeguards is approved. The State requests terminations once per year. The LLW are treated as overpacked/compacted wastes while the ILW is treated as a microencapsulated waste. After approval, they are transferred from retained waste back to the facility, terminated and transferred to the a near surface disposal site; the IAEA is notified of the movement.

The long term prognosis for the wastes is as follows:

- The compacted drums are evaluated for termination as compacted wastes:
  - Drums that have a high nuclear material concentration are placed in the retained waste inventory pending further processing.
  - Acceptable drums will be shipped to a near surface disposal facility.
- The grouted materials are also prepared according to the termination plan such that they can be terminated, i.e. the ratio of grout to fission product waste is adjusted to keep nuclear material concentrations below the agreed upon limit for termination. These will likely be placed in a near surface disposal facility.
- Concentrated LEU wastes will either be repatriated to the supplier or cleaned for reuse:
  - If ownership is transferred to the State, the wastes will need to be placed in an ILW / high level waste (HLW) disposal site within the State, likely under safeguards.

V–3. PROCESSING OF LOW LEVEL Pu CONTAMINATED WASTE

V–3.1. Summary

A waste treatment facility that deals with radioactively contaminated, solid, LLW waste is being operated. The facility uses an incinerator to reduce combustible items (such as plastics, paper and cloth) to ash, which is then cemented. A melting furnace recycles any low level metallic waste into ingots and produces a slag by-product containing the now concentrated contamination. The clean metal ingots are then sold for use in manufacturing. The waste by-products (incinerator ash and melting slags) are sampled, analysed, conditioned and packaged for disposal to landfill or a near surface disposal facility as appropriate for the measured radionuclide content.

V–3.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a CSA and AP in force.
- The facility is set up to treat both radioactive and nuclear material containing wastes:
  - Waste received may be under safeguards and the facility declares receipts for these items on their monthly reports.
  - Waste that contains nuclear material that was not declared (or was not detectable) is declared as an accidental gain.

- The facility segregates combustible and metallic waste streams:
  - Ashes are cemented for emplacement in a near surface disposal facility (off-site) after termination of safeguards has been approved.
  - Metal ingots may be freely released for other uses; slags are shipped to a landfill after being cleared from regulatory control and safeguards on any nuclear materials are terminated.
- Termination of safeguards on waste materials sent for near surface disposal is requested at the point where the wastes are ready to be transferred to the disposal site per the approved termination practice and procedure.

V–3.3. Narrative

The State operates a small mixed oxide fuel fabrication facility and a U-Pu mixed oxide fuelled demonstration reactor in addition to three older pressurized water reactors. The fuel fabrication facility generates operational wastes contaminated with plutonium and uranium residues as well as minor amounts of fission products. These materials are typically personal protective equipment such as gloves and disposable clothing, paper and plastic. Metallic wastes, such as replaced valves and operational supports, are segregated and sent to an induction furnace. Most of the wastes processed in this facility are LLW with minimal contact contamination. The wastes are bagged, nuclear material concentrations are estimated and these amounts are recorded when the waste bags are transferred to the waste processing MBA.

The combustible wastes are sent to an incinerator. The resulting batches of ashes are gamma counted and then sampled for DA (alpha spec, gamma) to determine nuclear material content. Batches that have a low enough nuclear material concentration (as defined in the subsidiary agreements to the State's CSA) and are acceptable for the disposal site (per the disposal WAC) are sent to be compacted. It is then requested for each compacted drum to have the safeguards applied to it terminated as an overpacked/compacted conditioned waste form. Multiple compacted drums are then placed in an ISO container overpack and immobilized with grout for shipment to a low activity LLW permitted landfill. Batches that are too radioactive for landfill disposal are prepared according to the WAC for near surface disposal and then transferred to that facility for subsequent emplacement. In this case, batches are reported to IAEA as measured discards, after approval, when they are ready to be transferred to the waste site for disposal.

Metallic components are sent to a metal melting system that produces two product streams: a low level, purified metal ingot and a slag fraction that contains most of the radioactive and nuclear materials. In every batch, the metal fraction is sampled to perform a DA to determine the residual nuclear material content. Per an agreement between the State and the IAEA, those ingots that are below radioactive waste clearance limits are able to be released for further industrial reuse. The slag fraction is cooled, placed in drums and gamma counted. The slag is then crushed and analysed for radioactive material content and then, depending on the radioactive material content, termination is requested for and the slag sent to a landfill or a near surface repository for disposal. The slag, as a mixed metal oxide fraction, would likely be considered a microencapsulated waste for calculations related to termination as a measured discard.

V–4. POST-IRRADIATION EXAMINATION FACILITY WASTE AT A RESEARCH REACTOR SITE

V–4.1. Summary

A research reactor provides commercial post-irradiation examination (PIE) services including fuel testing and investigation of commercial fuel pin failures (pinhole, crack, etc.). The facility offers services for both novel or conventional fuel performance and cladding performance. The facility generates trace level wastes streams that are treated on-site. Separately, the irradiated test elements are placed in a sealed container and sent back to the customer for disposition. The wastes treated on-site typically contain small amounts of fission products and nuclear material (depleted uranium (DU), HEU and Pu). The wastes are placed in primary containers that cannot be sealed thus requiring them to be overpacked into drums that could be sealed while the safeguards termination request is processed.

V–4.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State operates a commercial PIE facility as part of their research reactor.
- The State has item-specific safeguards agreements in place (based on INFCIRC/66/Rev. 2):
  - Code 10 reporting has been adopted in the State.
  - The State has opted to use design information questionnaire (DIQ) forms for convenience when providing design information.
- The safeguards processes and equipment for the facility needed to be updated during the design and construction of the PIE facility, and the IAEA was involved at an early stage.
- Early incorporation of safeguards by design (SBD) concepts prevented the acquisition of incorrect supplies:
  - Better primary containers were acquired after consultations regarding sealing arrangements and positioning.

V–4.3. Narrative

The State national research laboratory operates a research reactor as part of its nuclear engineering and fuel development programmes. One of the collocated facilities is a PIE facility to examine test fuel plates, alternate fuel matrices and commercial fuel under a variety of reactor conditions. Depending on the services contracted, the facility may perform a variety of non-destructive assay (NDA) and DA on the test specimens. A condition of testing is that the customer agrees to take back all samples and materials.

The PIE facility was constructed after the research reactor was installed. The facility was modified to accept the new equipment by creating a new MBA for the PIE facility with key measurement points (KMPs) located between the reactor and the PIE facility (KMP5) and between the PIE facility and the storage facility (KMP6); new inventory KMPs were established in the PIE facility and the storage facility. The facility was modified to incorporate continuous camera monitoring of the transfer of test material from the reactor to the PIE facility receiving area. This involved modifications to the facility wiring and data transfer cabling. This required updates to the research reactor DIQ to develop the new verification, surveillance and containment measures. In addition, as the facility would generate small amounts of waste material that would have to be conditioned, the annexes to the subsidiary arrangements for the facility were also amended with procedures for creating and verifying waste forms and for requesting termination of safeguards on those wastes.

During the PIE facility construction, the State demonstrated operations (cold) to the IAEA to assist with developing the appropriate verification measures. Facility operations included taking analytical samples for elemental and isotopic analysis (i.e. inductively coupled plasma-mass spectrometry) and de-fuelling cladding mechanically and chemically, which produces liquid wastes. These liquid wastes will be concentrated and grouted into a waste form inside a 100-L drum. Depending on the concentration, they will either be sent to a LLW facility (after receiving approval for termination of safeguards) or they will be placed in the facility's retained waste inventory for disposal with the State's HLW in a safeguarded geological repository. This determination will be made based on the nuclear material content in each drum, though the goal is to place as many as possible in the LLW site.

During the initial cold demonstration, it was noted that the State would be placing the original fuel samples in containers for shipment back to the customers. Each customer's sample or samples would be placed in one or more containers and stored until repatriation. The IAEA representatives noted that the containers that will be used for this, which were different from the original containers as the samples were now cut, were not designed to be easily sealed to maintain continuity of knowledge in storage or shipment. The State and IAEA agreed to place the containers in overpacks that could be sealed if a redesigned primary container could not be procured prior to commissioning.

The facility would declare each return shipment back to the original State, less any estimated work losses. These loses, such as when samples were cut and residual contamination on the saw blade and in the cutting fluid, would be assigned to the hot cell. These working losses were declared as a single item associated with the hot cell and tracked via accountancy measures. When wastes are cleared from the hot cell as conditioned waste forms, the new waste item reduces the inventory in the hot cell.

V–5. REGIONAL WASTE FACILITY WORKS WITH METALLIC REACTOR WASTES

V–5.1. Summary

A reactor site is sending multiple components from several maintenance outages to a commercial recycling facility in a neighbouring State. This includes large metal components (steam pipes, turbine train, containment vessel parts, etc.) that are radioactively contaminated. Due to historical pin breakages, some nuclear material is assumed to be in these wastes, and scaling factors for the total radioactive inventory have been established. Items with known nuclear material are shipped as a safeguarded transfer and added to the vendor's State inventory. Confusion arose for several components with ultra-low level nuclear materials included in the scaling factors.

V–5.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- Both States have CSA with APs in place.
- Large items can be sent for decontamination and disposal/recycle from various points of the fuel cycle prior to and during decommissioning:
    - Safety and economic concerns are dependent on the reliable clearance of materials.
- Wastes that contain nuclear materials may or may not arrive under safeguards.
- Scaling factors may produce unverifiable results.
- Constant communication was used to determine the appropriate accountancy path.

V–5.3. Narrative

Over the course of several years, a reactor site has accumulated a large inventory of large metal components from operational replacements. Some items needed some short term decay storage due to small activities of activation products prior to being eligible for decontamination. From an economic standpoint, the site relies on being able to send these items for decontamination and clearance for recycling or reuse rather than having to dispose of these items. The reactor site agrees to receive any collected radioactive materials from the treatment process. Historically, this reactor had a series of pin breakages that resulted in detectable alpha contamination in the primary coolant. This resulted in potential contamination in all components of the primary heat exchange system including the exchanger, which has many inaccessible areas. The site established scaling factors for a wide selection of radionuclides for these components.

The components that had distinct nuclear material contributions were shipped as safeguarded materials with a shipping declaration to the recycling facility. However, during initial negotiations to develop the work packages to deal with the other materials, the recycling facility raised questions about the components that only had scaling factor based information on nuclear materials. As these materials were calculated but not guaranteed to be present, both facilities were unsure how to report them. As an example, one set of materials were from the turbine train consisting of approximately 200 tonnes of metal components. The scaling factor indicated a ppm U presence (i.e. ~1×10^{-6} Bq uranium per Bq of ^{137}Cs). Given the mass of the metallic components and the measured Cs activity as 15 Bq/g, and the uranium being identified as between 1% and 4.5% LEU, the entire shipment would have a maximum ~40 mg of LEU total. The material, due to the distributed and low activities, would be practically impossible to verify.

The IAEA, the regional authority responsible for both States, and both facility operators worked to determine an appropriate path forward. The end result was that the turbine components would be declared as an unconditioned waste per the guidelines in the reactor site's facility attachment regarding measured discards. The facility would also immediately declare that the wastes would be transferred out of the State but that no processing to recover the nuclear material would be performed.

This information was then proposed to be incorporated in the procedures of both facilities so that undeclared material (in a scaling factor) would not be inadvertently shipped to the recycler. In addition, the IAEA used the situation as an example for future communications regarding these types of wastes.

V–6. CONTAMINATED SOIL AT FORMER URANIUM ENRICHMENT FACILITY

V–6.1. Summary

The State's gaseous diffusion enrichment facility is undergoing decommissioning and has already been decommissioned for safeguards purposes including the dissolution of the facility's MBAs. During the site remediation phase, a large volume of soil contaminated with 4% LEU, at concentrations ranging from 1–100 Bq/g was accumulated. The State is already running an automated soil gamma analysis system to reduce the volume of waste that will be sent to a LLW disposal site. The State and IAEA agreed to a plan where soils with higher concentrations of nuclear material would be declared as accidental gains and then terminated as unconditioned wastes or overpacked conditioned wastes depending on the activity levels in the soil.

V–6.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The facility does not exist within an MBA but within the State-wide location outside a facility (LOF).
- Initial conversations between the IAEA and the State or regional authority responsible for safeguards determined:
  - Whether materials had to be safeguarded;
  - The process for termination of safeguards on the nuclear materials.
- The level of verification measures required and process for requesting termination of safeguards on soil waste were established.
- The soils will be segregated based on activity by an automatic gamma-spectroscopy-based system that will produce a low fraction, < 10 Bq/g, and a high fraction, > 10 Bq/g.

V–6.3. Narrative

During the advanced stages of decommissioning of an enrichment plant site, after the essential equipment had been removed, all bulk material was transferred to another MBA and the facility was decommissioned for safeguards purposes. After several buildings had been partially deconstructed, the site environmental remediation survey identified several areas of contamination that were previously obscured by the buildings and the local geology. The safeguards obligations on these materials need to be resolved with the IAEA as materials under safeguards cannot be placed in the State's near surface disposal facility nor can they be released from regulatory control, neither as restricted nor unrestricted releases. The survey found areas around the building with enriched uranium (maximum of 4% ^{235}U) contamination at levels from 1–100 Bq/g with the vast majority of the soil at less than 15 Bq/g. The State's clearance level for uranium bearing wastes is 10 Bq/g for uranium isotopes. The State has implemented a conveyor belt system with gamma detectors to fractionate the soils based on activity and isotope level. All soils determined by this analysis to be over 10 Bq/g will have to be sent to a LLW disposal site, while those below the 10 Bq/g level can be cleared through existing regulatory processes and freely released to a landfill site. The mass of soil was estimated at > 40 000 tonnes with an estimated 4000 kg of LEU dispersed throughout the soil. The plant capacity was ~ 1600 tonnes of enriched uranium (4% LEU) per year, meaning this level of contamination represents ~ 0.25% of annual throughput.

The SRA contacted the IAEA who, after taking its own environmental samples, which agreed with the operator's findings regarding activity levels and volumes, advised that all materials should be declared as accidental gains to the national LOF (as the facility MBA had closed), the higher activity materials containerized and termination of safeguards is requested for overpacked wastes if they met a negotiated activity level (nominally, higher than the clearance limit of 10 Bq/g). For the lower activity soils, those less than 10 Bq/g, representing approximately 70% of the total soil mass, termination should be submitted as unconditioned wastes; these contained, estimated conservatively, 2800 kg of LEU (though the actual amount is less) representing ~1.5 significant quantities. These wastes would be subject to flow restrictions and capped at a fixed total amount of material. The operator had proposed blending the soils such that the nuclear material content was below 10 Bq/g, and thus suitable for landfill disposal. However, this was rejected by the State authority on environmental grounds as an unnecessary dilution.

The IAEA and State agreed to a system of data sharing and randomized verification activities for each of the waste streams and did not require the wastes to be placed under seal. The termination process was planned to be evaluated on a monthly basis. All drums of materials that were generated were identified uniquely and placed in a temporary storage yard. Successfully terminated drums were removed promptly to a separate storage facility to be released to their respective end points.

V–7. WASTES GENERATED AT A COMMERCIAL MINING FACILITY

V–7.1. Summary

A commercial mining facility generated several litres of uranium bearing solutions separated from potential mining site leachates. The national radioactive waste management operator was contacted to dispose of the materials. Due to their appearance as uranium solutions, the State's safeguards authority was contacted to determine the safeguards status of the materials. After consultations with the IAEA, it was determined that the materials did not meet the criteria for the starting point of safeguards as listed in the State's CSA and could be disposed of as naturally occurring radioactive material waste.

V–7.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a CSA in force with an AP and a small quantities protocol in effect.
- Mining materials do not usually require safeguards verification and accountancy but may be declarable if exported.
- SBD principles were enshrined in waste management procedures that resulted in a check of the safeguards status of the materials.

V–7.3. Narrative

A phosphate mining company's analytical laboratory accumulated several litres of liquid waste which contained natural uranium. These wastes were separated from potential mine leachates and were approximately 50 ppm uranium. The normal chemical waste contractor refused to accept the waste as they did not accept radioactive materials. At this point, the mining company contacted the State radioactive waste management organization for assistance in disposing of the solutions. The radioactive waste management organization was concerned that the chemical separations that produced the solutions may make them eligible to have safeguards measures applied to them.

The solutions were transferred to the radioactive waste management organization, which placed them in a storage vault used to hold safeguarded materials. The materials were placed in an overpack and uniquely identified. At this point, per procedure, the waste organization contacted the State safeguards authority for a consultation as the solutions contained nuclear materials. Since the liquids were more chemically pure than typical ore samples, there was some confusion as to their status with regards to the starting point of safeguards. The State authority determined that the material likely did not meet the requirements for the starting point of safeguards (not purified enough) and contacted the IAEA Department of Safeguards for assistance. The IAEA agreed with the analysis that the materials were not required to be placed under safeguards but noted that if the State were to export these solutions, or similar solutions, they would be reportable under the State's AP obligations.

The waste organization then entered the liquid uranium wastes into the radioactive waste system for processing as naturally occurring radioactive material wastes.

V–8. RADIOACTIVE WASTE FACILITY COLLECTING URANIUM MATERIALS

V–8.1. Summary

A State's radioactive waste treatment facility was contacted regarding a recently discovered disused sealed radioactive source that also includes a previously unknown DU shield. Concurrently, the facility is working with a university to arrange for disposal of laboratory chemicals containing natural uranium (NU) and a commercial entity that found a previously unknown drum of DU that was used for ceramics glazing in the 1970s. The facility contacted the State authority for safeguards to determine how to adequately store and account for these materials under the State's safeguards programme. Materials were stored in an ISO container alongside the main facility while their status was clarified.

V–8.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a CSA and an AP in force.
- The radioactive waste facility handles safeguarded materials (placed in storage) and has procedures for storing declared materials.
- The various wastes were old items with few or no records or documentation attached to them.
- Verification of exemption status on the items was challenging:
    - A new area was set up within the facility (using SBD principles) inside the LOF to keep the materials secure and separate from the waste facility while their status was investigated.
    - If items were found to be exempted or already safeguarded, they would be moved to appropriate storage locations.

V–8.3. Narrative

The State radioactive waste operator organized a campaign to identify any excess radioactive material (mainly disused sealed radioactive sources and standards) in the State, collect the materials and dispose of them in their near surface disposal facility. During the campaign three potential safeguarded materials were identified:

- An unused 1 kg bottle of uranyl acetate from the biology department at one of the State universities;
- A previously unknown drum (100-L, approximately half full) of uranium used for glazing ceramics identified when a ceramics company downsized a warehouse;
- An excess DU shield identified in a hospital inventory whose exemption status was unclear.

The waste operator took these items into its inventory but stored them in a separate ISO container alongside the regular waste processing facility until the status and path for the materials was clarified. The ISO container was utilized to keep the materials physically safe and secure as well as to isolate them from the non-nuclear waste streams in the facility.

The materials identified needed to have their exemption and safeguards statuses clarified. Furthermore, as they were pure chemicals (or pure uranium metal), further conditioning was required for all of the materials before they could be disposed of (due to the national LLW WAC having an upper limit of 350 Bq/g total alpha activity). Furthermore, the materials, without further conditioning, were not eligible for termination of safeguards.

For the university's uranyl acetate, it was discovered that the salts predated the adoption of the AP in the State and were not added to the university's LOF during the initial survey of nuclear materials. As such, these materials were treated as an accidental gain of material and declared as a new natural uranium batch. The status of the former uranyl glaze of the ceramics company was less certain. It was unclear if the material had been terminated for use when it arrived at the facility in the 1970s or after the product glaze had been produced. As the State was looking to terminate safeguards on these materials anyway, the decision was made to treat the DU as an accidental gain and then work towards termination and disposal.

The disposition pathway for the uranyl salts was discussed in depth between all interested parties and two pathways were identified:

- Move the items to retained waste and wait for the safeguarded geological repository for disposal;
- Dilute the material into concrete such that it meets the termination criteria of the IAEA.

The facility, State and IAEA determined that the best path forward was to dilute the acetate into concrete at a level suitable for disposal (as a microencapsulated material) in the State's LLW facility. While this increased the volume of the waste, the benefit of removing it from the safeguarded inventory was deemed to be a net positive. The glazing materials, being primarily oxides, were evaluated and the grain size suggested that the materials would qualify for termination as macroencapsulated materials when placed in a grout. Despite the lower concentration permitted in the concrete due to particle size, the DU bearing concrete was able to include more material due to the lower enrichment. Both of these materials were added to the inventory and moved from the temporary storage area to the safeguarded storage area, and plans were started to implement the disposal plan, including working with the IAEA to create a verification plan.

The hospital's DU shield was found to have an active transit exemption in place as it was shipped from an outside State ~7 years earlier but was not listed in the State's sealed source and shielding inventory (which is separate from their nuclear material inventory). The shield was misplaced when the hospital moved all radiotherapy activities from the main facility to a satellite campus; the shield was misidentified as a lead shield and placed in the hospital storage area. As the DU shield held an active exemption in the originating State, the shield was properly handled with respect to safeguards. The shield was now being tracked in the national sealed source and shielding inventory (which also keeps track of exemptions) and new identifying labels were attached. As the material remains exempted it was moved to the non-safeguarded storage area and arrangements were made to attempt to return the shield to the originating State as it is no longer needed in the State.

V–9. WASTE FROM PAST ACTIVITIES UNEARTHED

V–9.1. Summary

A set of drums was unearthed at a research site that contained waste with an unknown providence. There is no detailed information on the chemical or radiological content. Some information is contained in reports from the 1970s that allude to the waste but there is an incomplete history. Initial survey results indicated the presence of alpha radiation and, coupled with the site history, there was a strong likelihood that at least some of the waste containers had nuclear materials in them.

V–9.2. Facility and safeguards information

Relevant facility and safeguards information is as follows:

- The State has a CSA and an AP.
- The waste was ~50 years old.
- An investigation is required to determine the history of the waste.
- There is a need to continue to safely manage the waste including characterization; to process or treat the waste; to prepare the package for clearance, recycling, reuse or storage, awaiting a disposal route.
- Robust procedures for dealing with unknown wastes exist.

V–9.3. Narrative

At one of the State's nuclear laboratories, a radioactive waste trench was located that was estimated to have been filled ~50 years previously. The trench was in poor condition and the waste needed to be recovered, treated, repackaged and sent to a new near surface disposal facility. Approximately 100–150 items (a mix of soft bags, loose items and 200-L drums) were identified in the trench. Initial surveys showed only low levels of radioactive contamination, consistent with laboratory waste. However, in or on several drums, alpha contamination was detected. Due to the site history, there was a possibility of nuclear materials being present in the waste. Known wastes from this period typically contained a mix of ^{137}Cs, ^{90}Sr, ^{60}Co, ^{241}Am, ^{3}H and radioisotopes of plutonium, uranium and thorium.

After the waste was inventoried for repackaging, the following items were identified in the trench:

- Laboratory waste including analytical glassware, personal protective equipment, ceramic/porcelains and various metals;
- Laboratory organic solid waste (e.g. paper, clothing, office furniture);
- Contaminated building rubble and soil;
- Spent resins (both high and low activity);
- Disused sealed radioactive sources;
- A DU shield;
- Vials (some broken) with salt residues.

During the initial planning for the cleanup, it was decided that any wastes with suspected nuclear materials should be isolated for further investigation. The site worked with the State authority to determine the best path forward for properly accounting for the waste materials. It was decided that for nuisance level alpha contamination (<~10–20 Bq/cm^2) no efforts to identify the isotope would be required and the materials could be disposed as radioactive wastes. For higher activity wastes, an effort was made to identify isotopes present via gamma spectroscopy and alpha spectroscopy. If nuclear materials were identified, their masses would be estimated from the measurement, and they would be declared as accidental gains and then repackaged as new waste items. This was an acceptable compromise as all of the materials were going to be repackaged as new waste packages and sent back to a disposal site and only the more significant wastes needed to be safeguarded in the interim. In all cases, the levels of material present were consistent with overpacked wastes. The new drums which required safeguards measures were placed under seal until the request to terminate safeguards on these items was granted. At that point they were transferred to the State's disposal facility. This process was communicated to the IAEA and, after some minor modifications regarding verification of spectroscopy measurements, the process was agreed to by all parties. This process was then added to the facility attachment for the site.

The waste items were evaluated in situ for radioactive materials and initial determination of nuclear materials. On completion of characterization in the field, the items would be placed in a transport container and transferred to a waste facility for processing.

The waste was evaluated on the basis of relevant visual information (e.g. labels, tags) and by basic radiological measurements. The waste containers were first X rayed to understand what was inside each package. In two instances, high-z materials were identified; the first was a lead brick (contaminated) and the second was a DU vial shield. Once opened, the package contents were carefully removed and surveyed for alpha, beta and gamma radiation. Any discrete items (such as the shield) were immediately isolated for further study. The contents of the packages were examined to ensure that there were no non-conforming items in the waste such as explosive organics, liquids or prohibited metals (such as lead or cadmium).

The State declared 41 new discrete items as accidental gains, 3 as separated nuclear materials (the shield plus 2 vials with dried LEU residue) and 39 as higher activity contaminated items. The 39 items were repacked into 200-L drums, and the total nuclear material concentration was evaluated over the mass of the wastes in the drums, backfilled with lower activity wastes from the project. This generated four new 200-L drums, each of which was suitably dilute for the termination of safeguards to be requested. The remaining three items were sent to the laboratory complex to be cleaned, recovered and added to the current nuclear material waste streams.

ABBREVIATIONS

ALARA	as low as reasonably achievable
AP	additional protocol
CA	complementary access
CSA	comprehensive safeguards agreement
DA	destructive analysis
DIE	design information examination
DIQ	design information questionnaire
DIV	design information verification
DU	depleted uranium
EEL	essential equipment list
HEU	highly enriched uranium
HLW	high level waste
IIV	interim inventory verification
ILW	intermediate level waste
LEU	low enriched uranium
LLW	low level waste
LOF	location outside a facility
MBA	material balance area
MBP	material balance period
MOX	mixed oxide
NDA	non-destructive assay
NRTA	near real time accountancy
NU	natural uranium
PIE	post irradiation examination
PIV	physical inventory verification
RDT	remote data transmission
SBD	safeguards by design
SF	scaling factor
SNRI	short notice random inspection
SRA	State or regional authority responsible for safeguards implementation
VLLW	very low level waste
WAC	waste acceptance criteria

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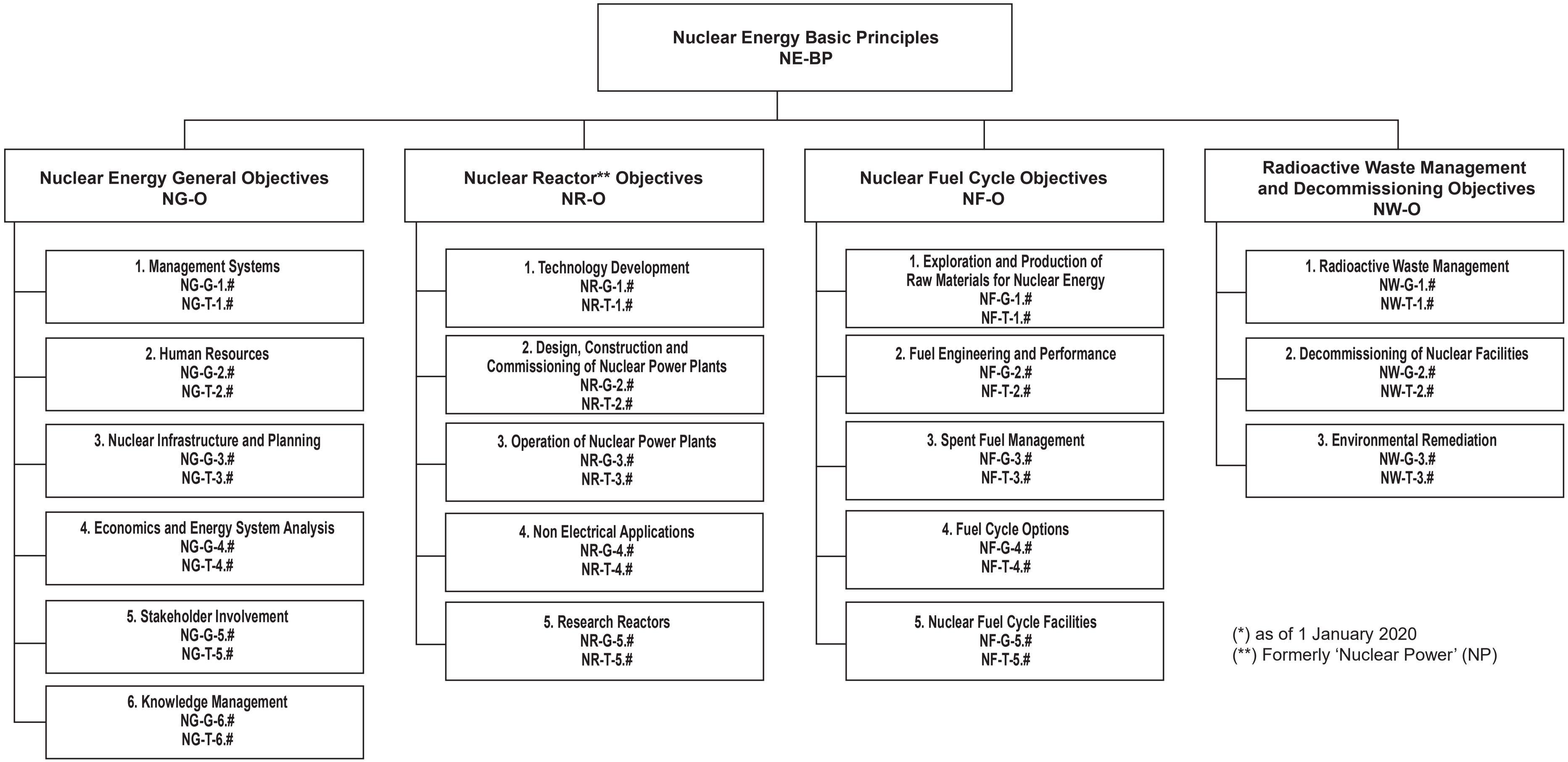

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