International Nuclear Safeguards and Molten Salt Reactors

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Nuclear Security and

Isotope Technologies

International Safeguards

Oak Ridge National Laboratory

ORNL is managed by UT-Battelle
for the US Department of Energy

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Objectives

- How safeguards is distinct from security
- How IAEA safeguards are applied to nuclear facilities
- Reasons why Designers should care about safeguards
- The basic concepts of safeguards by design
- Some potential challenges of safeguarding MSRs

What are International Nuclear Safeguards?

- Technical means for the IAEA to verify that States are meeting their legally binding undertaking not to use nuclear material or other items for illicit purposes
- Provide credible assurance to the international community that nuclear material and other specified items are not diverted from peaceful nuclear uses

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Specificity of the Nuclear Industry

NPP operation

Inventory of radioactive materials

Radiation hazards to workers, public and the environment

Proliferation Issues

Nuclear Safety ***Nuclear Security*** **3S** ***Safeguards***

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Safety

Risks arising from unintended events:

Natural occurrences

Hardware Failures

Internal Events

Human Error

System

Security

Risks arising from malicious acts with the intent to steal material or cause damage (sabotage)

Non-State Actors (Terrorists)

Safeguards

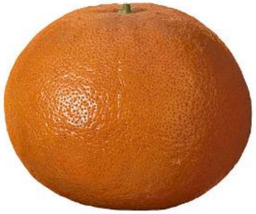
Avoid the diversion of nuclear materials for nuclear weapons purposes

Host State

Fundamental Safeguards Concepts

- …the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.
- …use of material accountancy as a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures.
- …the Agency…may…verify the design information [of a facility]…"

Paragraphs 28, 29, and 48 model comprehensive safeguards agreement (INFCIRC/153)



SQ = 25 kg of HEU; 8 kg of Pu

Significant Quantities, Form of Material and IAEA Detection Timeliness Goals

Used for determining frequency of inspections

Type of Nuclear Material + Form of Material = IAEA Timeliness Goals

Significant Quantity (SQ)

- Pu: 8 kg
- U-233: 8 kg
- HEU: 25 kg
- LEU: 75 kg

Classification *Direct use **Indirect use	Pu, HEU, U-233 unless stated	Conversion time	Timeliness Goal
1*	metal	7-10 d	1 m
2*	oxides, nitrates	1-3 w	1 m
3*	irradiated fuels	1-3 m	3 m
4**	<20% U-235/ U-233, Th	12 m	12 m

Type of Nuclear Facilities

- **Item Facilities**: Reactors
  - Materials are kept in item form and the integrity of the item remains unaltered
  - Ex: Fuel assemblies, fuel pins, waste/storage containers
- **Bulk Facilities**: Conversion, Enrichment, Fuel Fabrication, Reprocessing
  - Nuclear material can get held up, processed, or used in bulk form
  - Batch processes
  - Ex: Pellets, Powders (in containers), Solutions (in tanks), Gases (in cylinders)

Facilities Placed Under IAEA Safeguards

State informs IAEA of intention to construct a nuclear facility when the decision is made

Facility operator completes a Design Information Questionnaire (DIQ)

Negotiations between State and IAEA take place

A Facility Attachment is created which describes the safeguards implementation for that facility

Safeguards approach is determined by the type of facility, form of nuclear material, and probability of detection of diversion

Key IAEA Safeguards Facts in 2015

- Safeguards were applied in 181 States
- Additional Protocols in force in 127 States
- 200,110 SQs of NM under safeguards
- 1,286 nuclear facilities and LOFs under safeguards
- 2,118 inspections, 623 DIVs and 64 CAs conducted = 13,248 calendar days in-field verification
- Almost 800,000 NM accountancy reports received
- Approximately 23,300 seals verified that had been installed on NM, facility equipment or safeguards equipment
- 1,416 cameras connected to 863 systems operating at 266 facilities in 35 States
- Almost 1,000 samples were collected for analysis by the Agency to verify operators' declarations

Considerations for How Safeguards are Applied to a Reactor Facility

- Accessibility to the nuclear material
- Whether the reactor facility is operated continuously
- How the reactor facility is refueled
- Location and mobility of the reactor facility
- Existence and locations of other nuclear facilities in the state

Nuclear Material Accounting - Fundamental to International Safeguards

- NM must be accounted for at each stage of operations
- Design of Material Balance Areas
  - Allow a Mass Balance to be achieved
  - Determine Material Unnaccounted For (MUF)
  - Allow Physical Inventory Verification
- Design of Inventory and Flow Key Measurement Points (KMPs) to measure nuclear material
- Design of containment and surveillance systems

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Unique Design Features of MSRs from a Safeguards Perspective

- MSRs share characteristics of both reactors (transmutation) and spent fuel reprocessing plants (change in chemical and physical material forms)

With the added complication of the intense heat and radiation arising from active nuclear fissioning.

- Unlike reactors, the nuclear material may not be solid and fixed and would therefore considered bulk facilities
- Unlike reprocessing plants, MSRs are not throughput facilities, i.e., comparatively little material is being added or withdrawn - such that it can be considered a “closed loop”

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MSRs are unique, tightly-coupled, and dynamic nuclear energy systems

LWR (Traditional)	MSR (Non-Traditional)*
Safeguards routinely applied	**Traditional safeguards techniques may not be applicable**
Reactor and fuel cycle **facilities are distinct**	Reactor and fuel cycle essentially may be combined in a **single facility**
Fuel assemblies are **discrete items** – with **offline refueling**	Fuel can be a **mixture** of fuel salt, coolant salt, fission products, and actinides – some with **online refueling**; continuous feed and removal of salt
Monitor transfers in/out: monitor core and power level. Bar code reader I.D. and item counting of individual units (fuel assemblies)	**Additional monitoring will be required that doesn't exist today.** Item counting and visual accountability of fuel may not be possible

Safeguards issues should be considered during design phase

Some Safeguards Challenges for MSRs

- Measurement uncertainties associated with bulk facilities can make application of safeguards more difficult
- Material Unaccounted For may become large
- Example: Japan's Tokai and Rokkasho facilities, these two facilities alone have accounted for 20% of the total IAEA safeguards inspection effort
- Design options should be considered that would facilitate the application of safeguards:
  - Measurements - challenging in a MSR for equipment due to high temperature, high radiation, tritium production
  - Remote sampling capability (item counting and visual accountability may not work)
  - Reduce quantities of fuel outside the containment/ vessel
  - Consider accessibility for IAEA inspections

Why Should Designers/ Vendors Take Note?

- IAEA Safeguards will be required if MSRs are deployed in non-nuclear weapons states
- New technologies will stress the IAEA International Safeguards system and this may have consequences on MSR deployment
- Also possible negative public perception if MSRs are perceived to have safeguards/ nonproliferation issues
- The application of safeguards for MSRs may face technology challenges and new safeguards approaches

New IAEA Safety Standard - 2012

<u>Requirement 8</u>: Interfaces of safety with security and safeguards:

"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."

…This is a "3S" approach


IAEA Safety Standards
for protecting people and the environment

Safety of
Nuclear Power Plants:
Design

Specific Safety Requirements
No. SSR-2/1

IAEA
International Atomic Energy Agency

Safeguards by Design

- Safeguards by design (SBD) refers to the process of including international safeguards considerations throughout all phases of a nuclear facility life cycle; from the initial conceptual design through facility construction and into operations, including design modifications and decommissioning
- This concept needs to be stated because, unlike safety, safeguards has traditionally been something that has been “bolted-on” after the design has already been completed
- This is consistent with the “3S” approach and considers safeguards issues during the design phase along with safety and security

Resources from NNSA on SBD

https://nnsa.energy.gov/aboutus/ourprograms/nonproliferation/programoffices/officenonproliferationinternationalsecurity-0-0

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NGSI Safeguards By Design

NNSA's Next Generation Safeguards Initiative (NGSI) sponsors a project promoting international Safeguards by Design (SBD). The International Atomic Energy Agency (IAEA) has described the SBD concept as an approach in which "international safeguards are fully integrated into the design process of a new nuclear facility from the initial planning through design, construction, operation, and decommissioning." SBD has two main objectives: (1) to avoid costly and time-consuming redesign work or retrofits of new nuclear fuel cycle facilities and (2) to make the implementation of international safeguards more effective and efficient at such facilities.

The NGSI SBD project works with the IAEA, industry partners, and likeminded countries. NGSI is working towards transforming SBD from a slogan into standard practice by making SBD guidance documents available to industry users, engaging with industry and the IAEA, and promoting the SBD concept among stakeholders (e.g., industry and state regulatory authorities).

As part of this effort, NGSI has developed a series of facility-specific guidance for designers and operators to be used as reference documents.

SBD Guidance for Independent Spent Fuel Storage Installations [PDF]
SBD Guidance for Natural Uranium Conversion Plants [PDF]
SBD Guidance for Research Reactors and Critical Assemblies [PDF]
SBD Guidance for Pebble Fuel High Temperature Gas Reactors [PDF]
SBD Guidance for Prismatic Fuelled High Temperature Gas Reactors [PDF]
SBD Guidance for Gas Centrifuge Enrichment Plants [PDF]
Overview of the Facility Safeguardability Analysis [PDF]

GIF - GEN IV International Forum: PRPPWG
https://www.gen-4.org/gif/jcms/c_9365/prpp

The Generation IV International Forum

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  - Risk & Safety

Related links >>

PRPP Bibliography

FAQ on Proliferation Resistance and Physical Protection

A Technology Roadmap for

Proliferation Resistance & Physical Protection Working Group (PRPPWG)

The Generation IV Roadmap defined the following Proliferation Resistance and Physical Protection goal for future nuclear energy systems:

> *Generation IV nuclear energy systems will increase the assurance that they are a very unattractive and the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.*

Evaluation methodology

This report presents an evaluation methodology for proliferation resistance and physical protection (PR&PP) of Generation IV nuclear energy systems (NESs). For a proposed NES design, the methodology defines a set of challenges, analyzes system response to these challenges, and assesses outcomes. The challenges to the NES are the threats posed by potential actors (proliferant States or sub-national adversaries). The characteristics of Generation IV systems, both technical and institutional,

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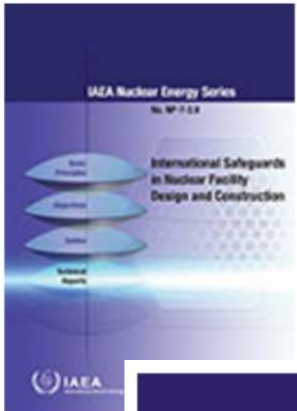
IAEA Nuclear Energy Series - SBD



International Safeguards in Nuclear Facility Design and Construction

IAEA Nuclear Energy Series No. NP-T-2.8

Subject Classification: 0800-Nuclear fuel cycle and waste management

English STI/PUB/1600; (ISBN:978-92-0-140610-1); 22 pp.; € 19.00; Date Published: 2013

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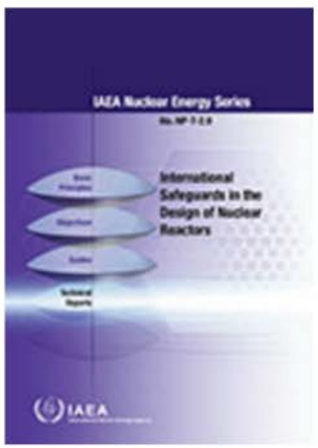

International Safeguards in the Design of Nuclear Reactors

IAEA Nuclear Energy Series No. NP-T-2.9

Subject Classification: 1000-Safeguards

English STI/PUB/1669; (ISBN:978-92-0-106514-8); 50 pp.; 17 figures; € 30.00; Date Published: 2014

Download PDF (1.81 MB)

- **General Guidance**
- **Nuclear Reactors**
- **Conversion Plants**
- **Fuel Fabrication Plants**
- **Enrichment Plants**
- **Reprocessing Plants**
- **Spent Fuel Management**

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IAEA Nuclear Energy Series - SBD

- Basic principles document provides general information suitable for management, higher levels of nuclear regulatory bodies
- Facility-specific guidance focuses on issues of interest to the designer, vendor, and operator
  - Terminology and basic safeguards concepts
  - Legal basis
  - Verification objectives, measures and activities
  - Technical objectives, tools and measures
  - In-field activities, surveillance, seals
  - Practical implications

Purpose of IAEA Energy Series SBD

- Familiarize a new audience (designers) with international nuclear safeguards
- Define equipment and infrastructure requirements
- Identify roles of stakeholders
  - IAEA/ designers/ contractors/ owners/ operators/ regulators/ suppliers/ technology developers
- Discuss material flow and routes, diversion pathways
- How to establish material balance area(s), key measurement points…
- Discuss safeguards technology options

Benefits of SBD

Understanding and addressing safeguards needs at early stages of design:

- More efficient safeguards implementation at facility
- Supports IAEA safeguards effectiveness
- Minimize safeguards impact on facility operation
- Use of world-wide lessons learned
- Improves international acceptance of MSRs
- Avoid costly and time-consuming redesign work in facilities

Retrofitting can be costly!

Thank you for your attention!

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