Experiences of Safeguards Technology Development in JAEA

International Symposium on Technology Development for Nuclear Nonproliferation and Nuclear Security
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Japan Atomic Energy Agency
Nuclear Fuel Cycle Facilities in Japan

- **Tokai**
  - Reprocessing
  - MOX fabrication

- **Rokkasho**
  - Commercial Plant
  - (Enrichment, Reprocessing & MOX fabrication)

- **Tsuruga (Monju)** FBR

- **Ningyo-toge**
  - U Enrichment

1. SG technology development for Nuclear fuel cycle facilities owned by J AEA
   - Enrichment Plant
   - Reprocessing Plant
   - MOX fuel fabrication Facility
   - Fast Breeder Reactor

2. Recent research using innovative technology
   - NDA development program subsidized by MEXT
   - Neutron Detector alternative to He-3
In 1979, Japan, Troika (UK, West Germany, Netherland), Australia, USA, IAEA and Euratom established the hexapartite safeguards project (HSP) to discuss safeguards approach for centrifuge uranium enrichment plant up to 1000tSWU/year.

Main inspection activities:

- Verification of the declaration for NM process flow and inventory
- Verification of the declared enrichment range (e.g. 4-5%) of the product

HSP concluded the maximum enrichment could be achieved by LFUA (Limited Frequency Unannounced Access).
Development of pipe enrichment monitor, in-line enrichment monitor and sample bottle enrichment monitor under Japan Support Program for Agency Safeguards (JASPAS)

Development of Portable Neutron Uranium Holdup Counter (PNUH) to determine the quantity of uranium holdup within the Gas Centrifuges Cascade Halls.

The Advanced Enriched Monitor, which can estimate the enrichment of wall deposits and has unattended safeguards capabilities, is under testing and evaluation.
SG for Reprocessing Plant


Tokai Reprocessing Plant (TRP)

TRP Improvement Plan

SRD
LASW measurement,
Pulse filter measurement

SMMS

K-edge, NRTA

OSL cooperation

Plutonium Conversion Development Facility (PCDF)

HBAS/WDAS/BBAS
Discussion with
IAEA and US

Safeguards System

Upgrade of HBAS

TAMS

iPCAS

LASCAR

Rokkasho Reprocessing Plant
TASTEX (Tokai Advanced Safeguards Technique Exercise)

- TASTEX was conducted from 1978 to 1981 as a collaborative project by Japan, USA, France and IAEA following the US-Japan joint statement for the reprocessing in 1977.
- Their results were provided INFCE (International Fuel cycle Evaluation: 1977-1980) and some tasks were continued under Japan Support program for IAEA.

**TASTEX: 13 tasks**

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<td>γ-scanning for spent fuel</td>
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<td>Pu K-edge densitometer</td>
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<td>High resolution γ spectrometry</td>
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<td>Pu input by Gravimetry</td>
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<td>Input volume by isotope spike</td>
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Surveillance camera, Underwater camera, Crane monitor
Burnup estimation
Measurement for adhered nuclear material
Solution weight at input/output accountability tank and Pu storage tanks
Level measurement at input/output accountability tank
Near Real time Accountancy system
Pu concentration and isotope measurement
Pu concentration and isotope measurement
Continuous surveillance for Pu product flow, tank level, valve opening/closing
Improvement of sampling technique
Verification of measurement data at Input accountability tank
Pu/U ratio at Input accountability tank
Calibration for input accountability tank
Improvement of Safeguards Equipment

1. More accurate Volume measurement

Water manometer

Digiquartz manometer

2. Solution Monitoring

Solution monitor

Sealed box including data collection computer

Sealed box including transformer of pressure to electric signal

Volume measurement system by air flow

Digiquartz Manometer

Input tank
Level Density Temp.
Level Density Temp.
Level Density Temp.
Pu concentration
Pu storage tank
Pu output tank
U concentration
U storage tank
Level

Separation and purification

Solution monitoring system
Measurement area of monitoring system

Flow of nuclear material
3. Nondestructive Assay

K-edge densitometer for Pu solution

Inventory sample counter for Pu solution and MOX powder

Measurement system of hold-up in glove box for MOX

4. Measurement of small amount in waste

Vitrified Waste Canister Counter

Measurement system of waste drum
SG for MOX Fabrication Facilities

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<th>Year</th>
<th>PPFF</th>
<th>PFPPF</th>
<th>Discussion with IAEA and US</th>
<th>WCAS, SBAS</th>
<th>RMS, ENMC, Spike</th>
<th>Safeguards System</th>
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Plutonium Fuel Fabrication Facility
(MOX fuel fabrication for ATR and FBR)

Discussion with IAEA and US

Automated process was introduced.

Challenges:
- Difficulty of access to nuclear materials
- Increased radiation exposure regarding the inspection activities
How to verify MOX in the process line with NDA?
Automated MOX Fabrication Plant - PFPF

- UNARM: unattended & remote
- PCAS: Input MOX
- MAGB: process MOX
- SBAS: holdup MOX
- FAAS: Fuel assembly
- WDAS: Wastes drums

Unattended NDA system:
- NDA data (moving direction)
- Image data (ID number)
- NDA data (the amount of Pu)

- Raw text:
  "How to verify MOX in the process line with NDA?
  Automated MOX Fabrication Plant - PFPF

- Diagram:
  - UNARM: unattended & remote
  - PCAS: Input MOX
  - MAGB: process MOX
  - SBAS: holdup MOX
  - FAAS: Fuel assembly
  - WDAS: Wastes drums

- Unattended NDA system:
  - NDA data (moving direction)
  - Image data (ID number)
  - NDA data (the amount of Pu)
Safeguards system in the process area

MAGB
Material Accountancy Glove Box Assay System

SBAS
Super Glove-Box Assay System

FPAS
Fuel Pin Assay System

Plutonium Storage

Powder

Hold-up

Pin

Pellet

Scrap material

Waste

HRGS
High Resolution Gamma-ray Spectrometer (Verification for isotope ratio)

PSMC
Plutonium Scrap Multiplicity Counter

WDAS
Waste Drum Assay System

Assembly Storage
Improvement of NDA for MOX facility

- **AMAGB**
  - Polyethylene
  - 16 He-3 tubes per each side
  - Transport container
  - Glove Box

- **ENMC**
  - Cd Liner
  - Graphite End Plugs
  - Sample Cavity: 200mm diameter, 430mm tall
  - 121 He-3 Tubes
Prototype FBR “Monju”
SG equipment for fresh fuel transfer

- Core fuels cannot be observed because FBR uses Na coolant.
- There are fuel transfer routes which are difficult to access.

Dual C/S system (camera and radiation monitor) is introduced

ENGM: Entrance Gate Monitor
EVRM: EX-Vessel transfer machine Radiation Monitor
EVSM: EVST radiation Monitor
MCRM: Monju Core Radiation Monitor
DSOS: Digital Single Camera Optical Surveillance System
DMOS: Digital Multi Camera Optical Surveillance System
ITVM: In-Vessel Transfer Machine
Contribution to Rokkasho safeguards

• Reprocessing Plant
  ISVS: Integrated Spent fuel Verification System
  SMMS: Solution Monitoring and Measurement System
  IHVS: Integrated Head-end Verification System
  RHMS: Rokkasho Hulls Drum Measurement System
  WCAS: Waste Crate Assay System
  WDAS: Waste Drum Assay System
  VCAS: Vitrified Canister Assay System
  PIMS: Plutonium Inventory Measurement System
  iPCAS: Improved Plutonium Canister Assay System
  MSCS: MOX Storage C/S System

  etc.

• J-MOX plant
  GUAM: Glove-box Unattended Assay & Monitoring System
  IPCA: Improved Plutonium Canister Assay system
  AVIS: Advanced Verification for Inventory Samples system
  AMAGB: Advanced Material accountancy Glove Box
  FAAS: Advanced Fuel assembly Assay System
  RSMC: Recyclable Scrap Multiplicity Counter

  etc.

• Enrichment plant
  Pipe Enrichment Monitor
  PNUH: Portable Neutron Uranium Holdup Counter

  etc.

Photos: JNFL web site http://www.jnfl.co.jp/
JAEA NDA Development Programs subsidized by MEXT (1/2)
(conducted between 2011JFY-2014JFY)

<table>
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<tr>
<th>(1)</th>
<th>Measurement test of the PNAR-NDA system for Fugen SFAs (2011JFY-2013JFY) (JAEA/USDOE collaboration)</th>
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<td>(2)</td>
<td>Basic development of NRF-NDA technologies using LCS gamma-rays (2011JFY-2014JFY) (using HlgS of Duke University) (JAEA/USDOE collaboration for simulation codes) (Security)</td>
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<tr>
<td>(3)</td>
<td>Development of neutron detector alternative to $^3$He using ZnS/B$_2$O$_3$ ceramic scintillator (2011JFY-2014JFY)</td>
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<td>(4)</td>
<td>NRD using NRTA and NRCA (2012JFY-2014JFY) (JAEA/JRC-IRMM collaboration)</td>
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PNAR: Passive Neutron Albedo Reactivity  
NRF: Nuclear Resonance Fluorescence  
LCS: Laser Compton Scattering  
NRD: Neutron Resonance Densitometry  
NRTA: Neutron Resonance Transmission Analysis  
NRCA: Neutron Resonance Capture Analysis
### Development of the following NDA technologies (for nuclear safeguards and security)

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<th>Description</th>
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<td>(7)</td>
<td>Feasibility study on monitoring technology for Pu solution with fission products in tanks inside cell (2015JFY-2017JFY) (to be JAEA/USDOE collaboration)</td>
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An Organization Diagram of JAEA NDA R&D Programs subsidized by MEXT

(As of February 2016)

MEXT
Ministry of Education, Culture, Sports, Science and Technology

Development of Basic Technologies of Advanced NDA of NM

JAEA

ISCN

QuBS
Program: (5)
Demonstration of NRF Non Destructive Detection of NM

NSEC
Program: (6)
Development of active neutron NDA techniques using a D-T neutron source

TRDC
Program: (7)
Feasibility study on monitoring technology for Pu solution with fission products in tanks inside cell

QuBS: Quantum Beam Science Center
NSEC: Nuclear Science and Engineering Center
TRDC: Tokai Reprocessing Technology Development Center
Overview of a ZnS/$^{10}$B$_2$O$_3$ Ceramic Scintillator Neutron Detector (JAEA)

Alternative neutron detector (JAEA developed)

Neutron Detection using ZnS/$^{10}$B$_2$O$_3$ Ceramic Scintillator

Neutron Detector Head

330 mm

32.5 mm (Regular Square)

ZnS/$^{10}$B$_2$O$_3$ Ceramic Scintillator Sheet

39 x 250 mm, less than 100g
ASAS  
(Alternative Sample Assay System)

Alternative HLNCC type NDA system

System Configuration

Detector

$^{10}\text{B}_2\text{O}_3/\text{ZnS}$ Ceramic Scintillator (24 modules) (Rectangular Area)

Data Processing Unit and Power Supply

Shift Register

Data Acquisition PC
Comparative Demonstration of ASAS with INVS using MOX Samples

Comparative Demonstration using known MOX Samples

<table>
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<th>ASAS</th>
<th>INVS @ PCDF</th>
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<tr>
<td></td>
<td>Passive Cal.</td>
<td>Known-α</td>
</tr>
<tr>
<td>Statistical Uncertainty (30min Meas.(r))</td>
<td>3.2%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Systematic Uncertainty</td>
<td>2.25%</td>
<td>2.62%</td>
</tr>
<tr>
<td>Total Measurement Uncertainty (TMU)</td>
<td>3.91%</td>
<td>4.14%</td>
</tr>
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Comparative Demonstration using a unknown MOX Sample

<table>
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<tr>
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<th>Pu-mass by PSMC (gPu)</th>
<th>Passive Calibration</th>
<th>Known α Calibration</th>
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<tr>
<td></td>
<td></td>
<td>Pu-mass (gPu)</td>
<td>Pu-Mass (σ)</td>
</tr>
<tr>
<td>INVS</td>
<td>1.353</td>
<td>1.343</td>
<td>0.012</td>
</tr>
<tr>
<td>ASAS</td>
<td>1.331</td>
<td>1.331</td>
<td>0.016</td>
</tr>
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→ ASAS can be used in actual safeguards inspection
JAEA initiated to develop SG technologies mainly in order to facilitate operation for their own nuclear fuel cycle facility.

- The background was bilateral or international negotiation.

- JAEA has been improving the technologies via their experiences of the operation for a long time. As the results, The efforts contributed to the reducing PDI of inspection, the design and operation of the commercial plants.

- JAEA is now moving to next stage and should develop a SG technology in order to solve an issue in IAEA safeguards inspection in collaboration with international/domestic partners.