2012 International Pyroprocessing Research Conference, The Abbey Resort, August 26-29, 2012

Development of Safeguards Approach for Reference Engineering-scale Pyroprocessing facility

August 29, 2012

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KAERI Korea Atomic Energy Research Institute

Contents

I. Overview

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Requirements of Advanced Fuel Cycle

❖ Minimization of Repository Space

- Reduction of heat load > 99 % (needed repository space < 1/100)

❖ Reduction of Environmental Burden

- Reduction of radiotoxicity < 500 yrs

❖ Economic Compatibility with the Current Options

- 1-2 mills/kWh

❖ Enhancement of Proliferation Resistance

- “Dirty fuel, clean waste” with homogeneous recycling of all TRUs

Combination of Pyro and FR meets all these criteria

Introduction

- Pyroprocess produce Pu with actinides together
- The product is handled in shielded area
  - Have a good intrinsic barrier of proliferation resistance
  - Easy to use C&S

- No pyro. facilities other than laboratories under international safeguards
- No IAEA safeguards criteria and IAEA authenticated safeguards technology
- Pu-bearing materials in the pyro. facility are very different from reprocessing facility
- A new safeguards technology is required for the pyro. facility

- IAEA recommends “Safeguards-by-Design” for the implementation of the effective and efficient safeguards to the new nuclear facility

SG R&D for Pyroprocessing

❖ The IAEA made a contract 3-year MSSP for the 'Support for Development of a Safeguards Approach for a Pyroprocessing Plant' with ROK in 2008

❖ We are, for the pyroprocessing facility,

- developing some nuclear material accounting and surveillance technologies.
- designing a safeguards system based on the concept of Safeguards-by-Design.
- investigating the safeguardability of a pyroprocessing facility.

We try to see if it is viable for a pyroprocessing facility to be safeguardable

II. Status of SG R&D for Pyroprocessing

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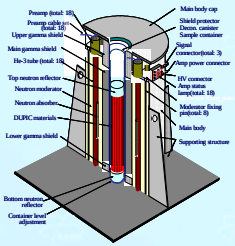
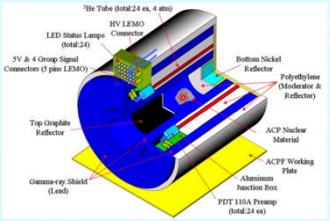
History of SG R&D for NFCF at KAERI

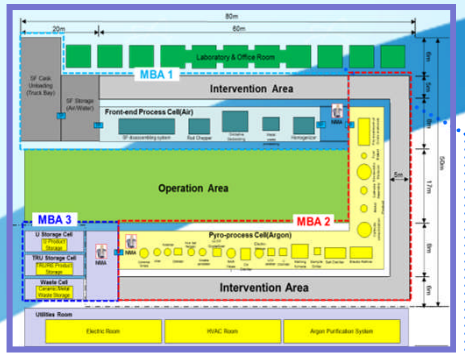
- DUPIC (Direct Use of PWR spent fuel in CANDU Reactors)
- ACP (Advanced spent fuel Conditioning Process)
- Pyro. MSSP for REPF(Reference Engineering Pyroprocessing Facility)
- PRIDE (PyRoprocess Integrated inactive Demonstration)



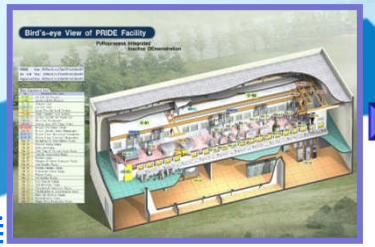
DSNC



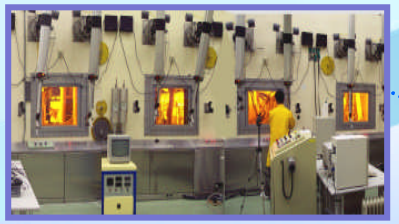
ASNC



Development of Safeguards Approach for REPF (IAEA MSSP)

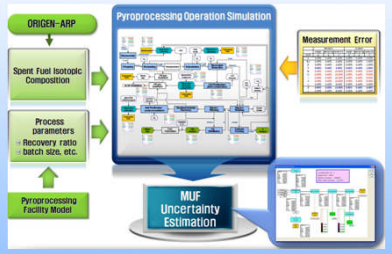


Establishment of PRIDE Safeguards System

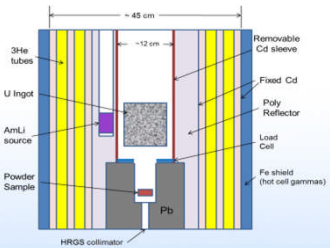


Development of NMA Technology for DUPIC Facility

Development of NMA Technology for ACP Facility



Safeguards Concepts



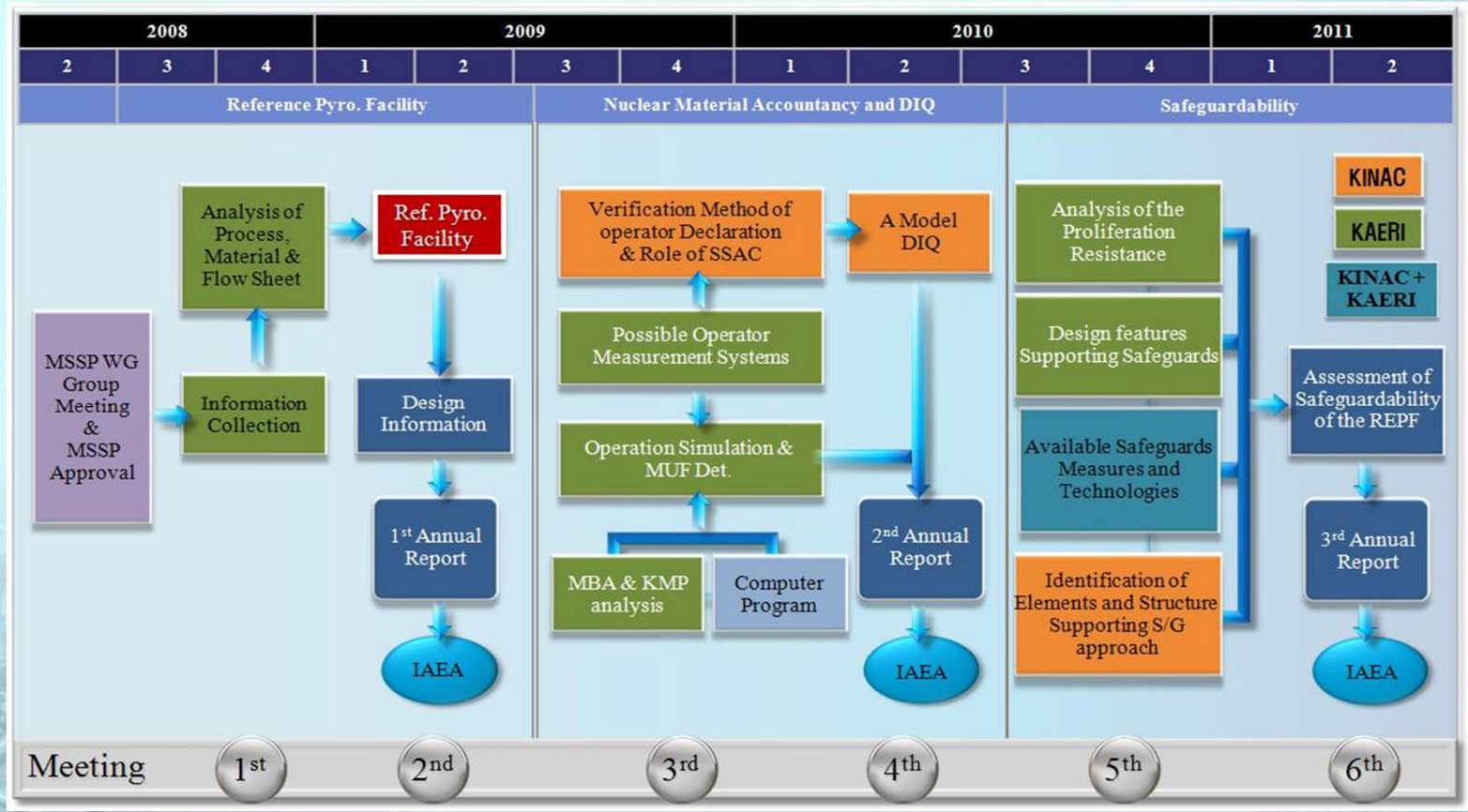
Neutron-Gamma Unified NDA

'97 '01 '07 '11

ROK-IAEA MSSP (Member State Support Program)

Title: Support for Development of a Safeguards Approach for a Pyroprocessing Plant

- **Collect and analyze various pyro. concept → Determine a Reference Pyro. Facility(REPF)**
- **Design the reference facility and safeguards system models → MUF Uncertainty Analysis**
- **Assess safeguardability of the reference pyro. facility → Model DIQ (example FA)**



MSSP Status

Title: Support for Development of a Safeguards Approach for a Pyroprocessing Plant (C01761)

- Duration
  - Aug. 2008 – July. 2009 : Determination of a Reference Engineering-scale Pyroprocessing Facility
  - Aug. 2009 – Sep. 2010 : Identification of possible NMA system and MUF determination for the REPF
  - Oct. 2010 – : Assessment of safeguardability of the REPF

1st WG Meeting in KAERI, June 2008

2nd WG Meeting in KAERI, May 2009

5th WG Meeting & Pyro. Workshop in IAEA, Sept. 2010

6th WG Meeting & SSWG meeting in KAERI, May. 2011

3rd WG Meeting in IAEA, Sept. 2009

4th WG Meeting in KAERI, May 2010

7th WG Meeting in IAEA, Sept. 2011

8th WG Meeting in KAERI, June. 2012

Milestone for MSSP

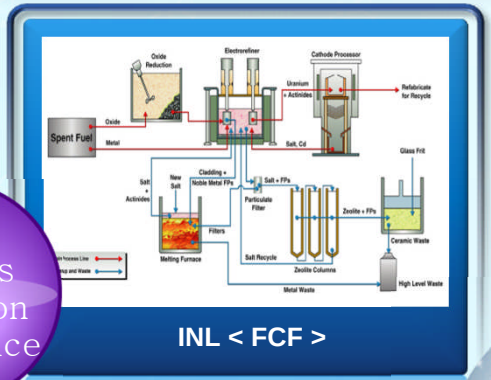
- **REPF (Reference Engineering-scale Pyroprocess Facility) Model (2010)**
  - Based on design information for the PRIDE facility and equipments
  - Based on the flowsheet for the ESPF (Version 2.4, 2009. 12. 10)

- **Safeguards Approach (2010-2011)**
  - Safeguards system consisting of conventional technologies
  - Supplemented intense surveillance and monitoring
  - Near-real time accounting for every campaign by NDA and DA

- **Assessment of safeguardability (2011)**
  - Estimating reliable measurement uncertainties and evaluating MUF
  - Diversion pathway and PR analysis to investigate safeguards system performance
  - Drawing recommendations to enhance safeguards performance

Analysis of Six Pyroprocessing Facility Concepts

Metal Process Operation Experience



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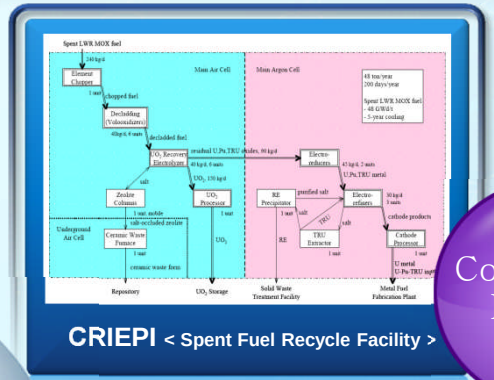
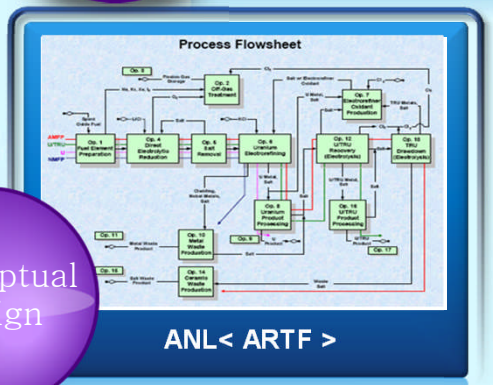


CRIEPI < Spent Fuel Recycle Facility >

Conceptual Design

Conceptual Design



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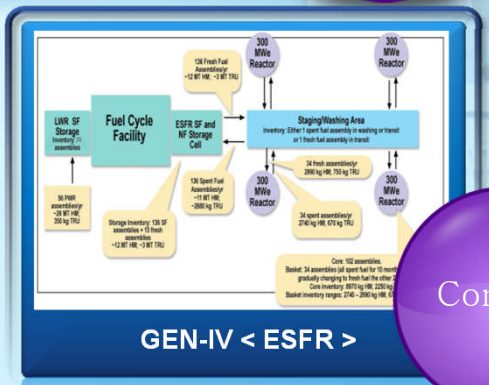
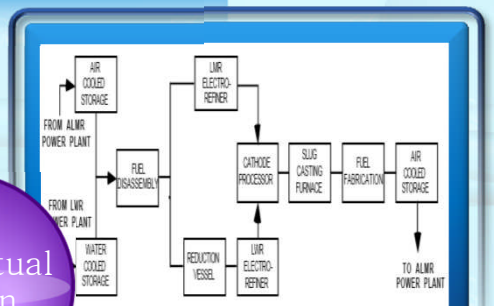
Process Flow Sheet



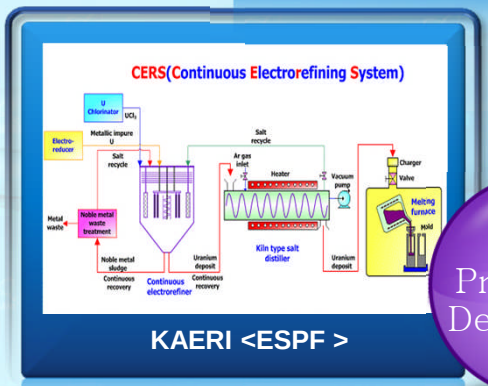
GEN-IV < ESFR >

Concept

Conceptual Design



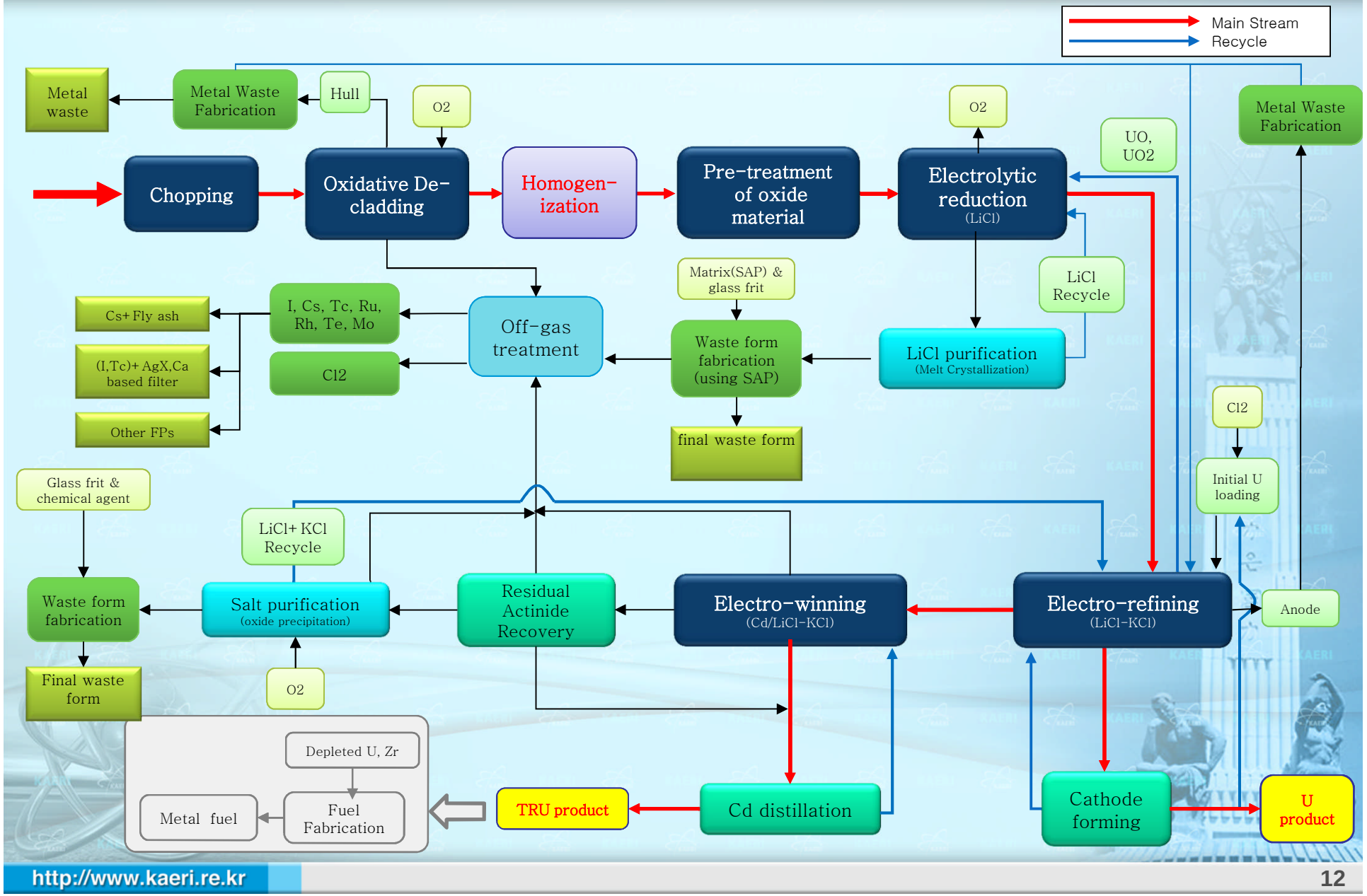
GE-Hitachi < SFRF >



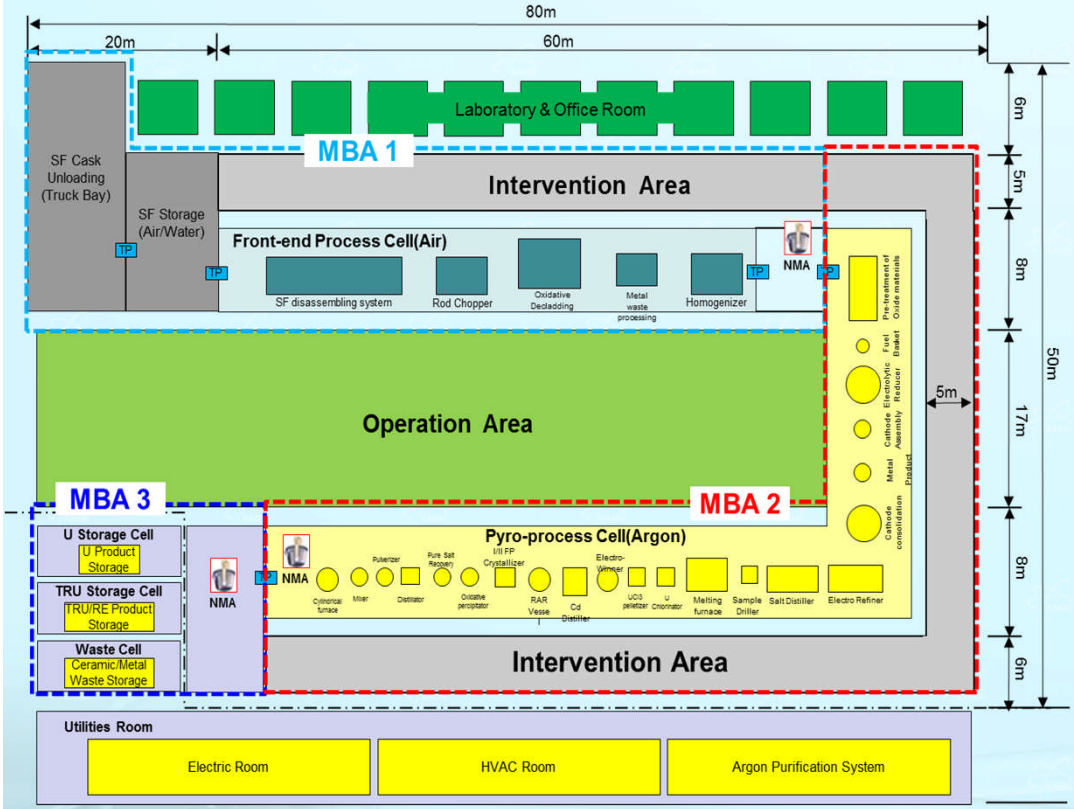
KAERI <ESPF >

All Processes Developing

Material Flow Model



REPF Model



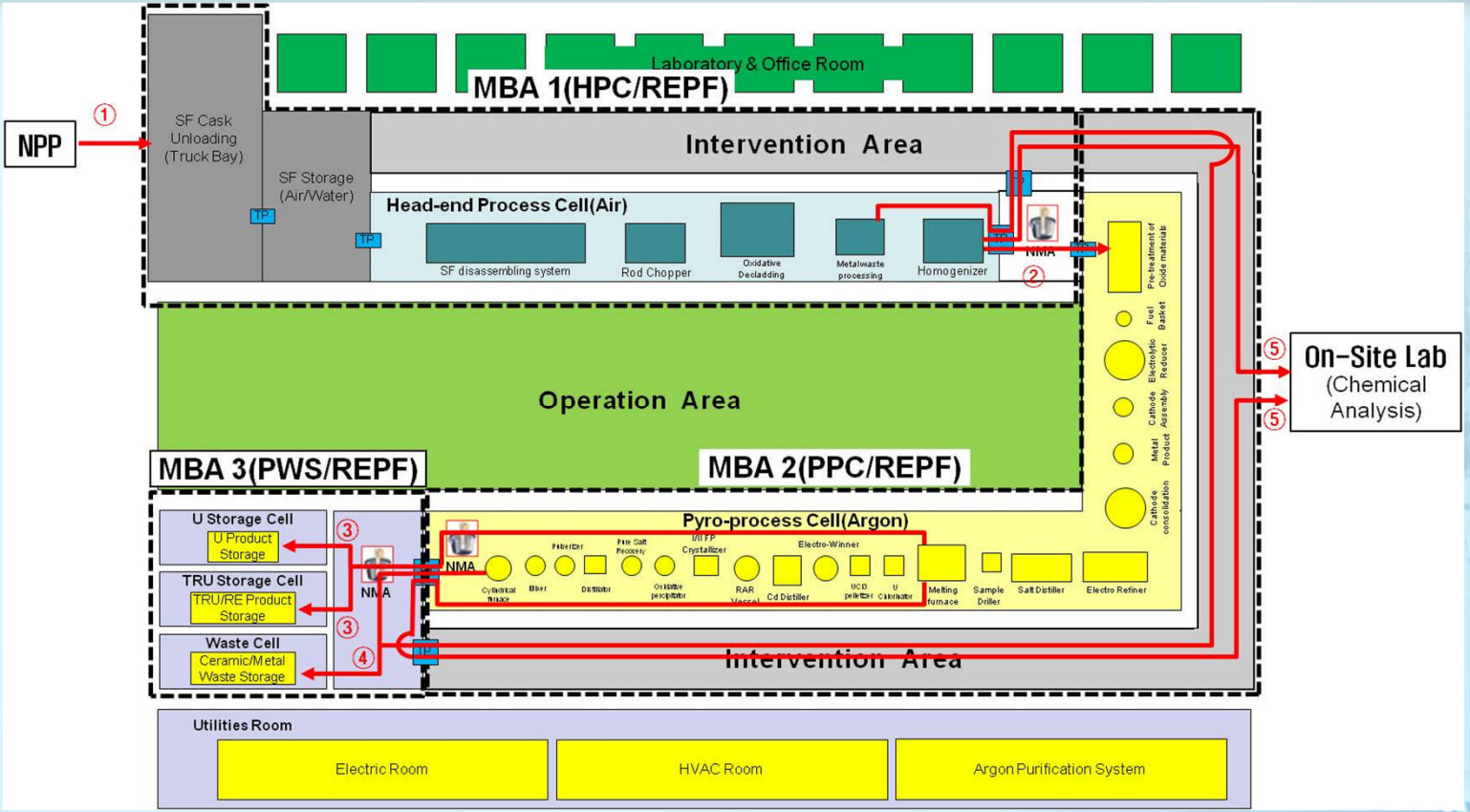
Key Features of REPF

- Throughput: 10 MtHM/yr
- Campaign capacity: 500 kgHM (PWR SF 1 Assembly)
- Batch capacity: 50 kgHM
- Operation days: 250 days/yr
- Output: U ingot, U/TRU ingot

3 MBAs and 11 KMPs

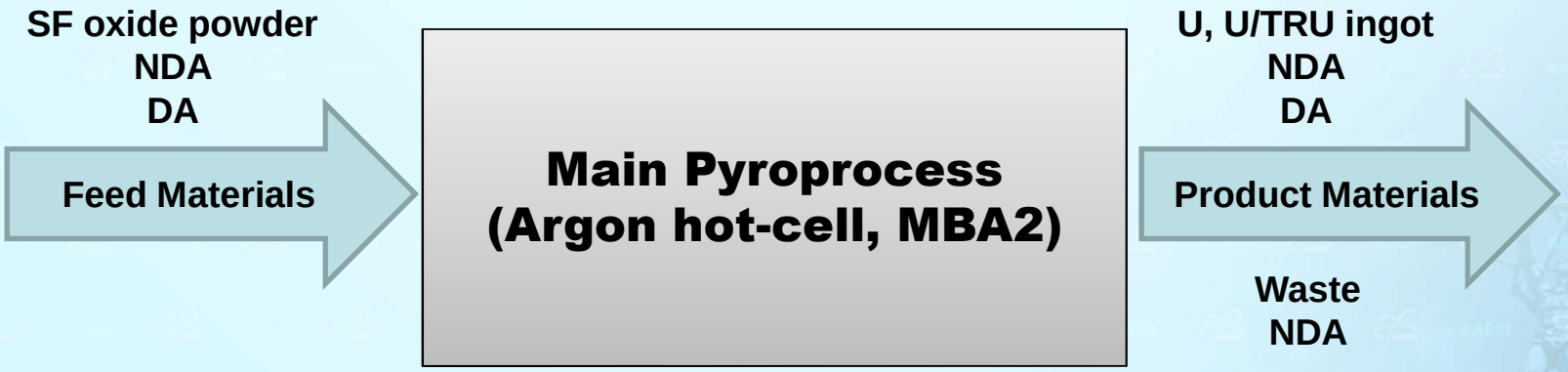
- MBA-1: Spent fuel storage & head-end process
- MBA-2: Main pyroprocess
- MBA-3: Product and waste storage

Material Transfer Scheme



No.	Material type	Container	Transfer Equipment
①	PWR spent fuel assemblies	Cask	Train/Truck/Ship
②	Spent fuel oxide powder	Powder container	Crane/Cart
③	Metal ingot	Ingot container	Crane/Cart
④	Waste	Waste container	Crane/Cart
⑤	Chemical samples	Sample container	Crane/Cart

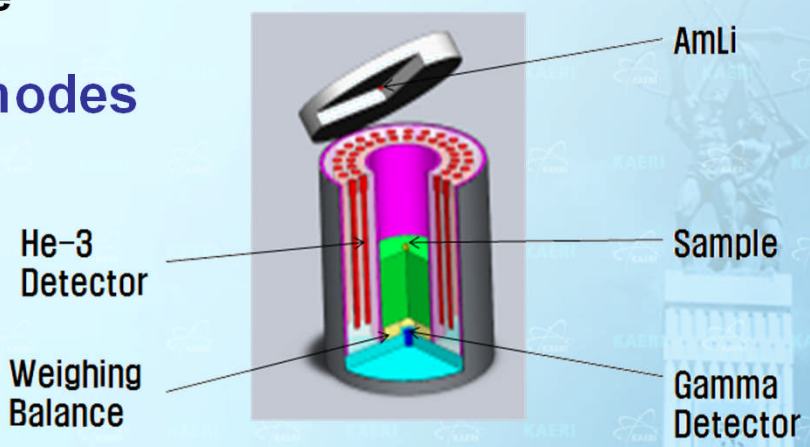
NMA for REPF



Accounting Method	- An assembly-based Nuclear Material Accountancy - Mainly focusing on input and output materials of the main pyroprocess - NDA based on the Cm balance (Cm ratio) - All minor materials (e.g. recycled materials) accounted by NDA - Process and portal monitoring to secure the hot-cell containment
Homogenization Process	- Heterogeneous input powder for DA and NDA - A constant Cm ratio (for each campaign)
Accounting Period	- Accounting and MUF evaluation every campaign (11 – 22 days) - Near Real Time Accountancy (NRTA)

Unified NDA System for NMA

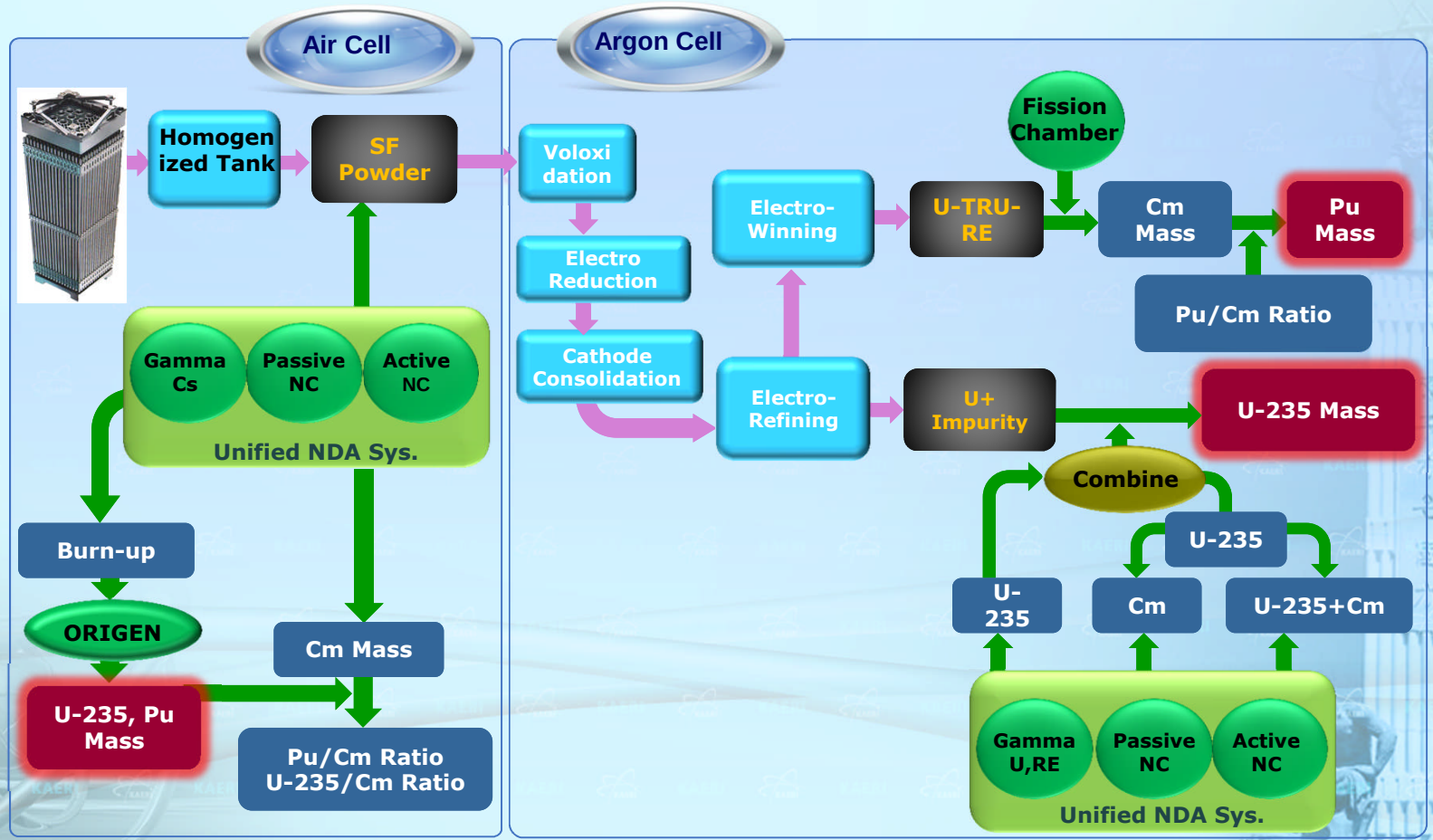
- **Designed the unified NDA system**
  - All-in-one NDA equipment of a well-type neutron counter, AmLi sources, a small-size gamma detector, and a scale
- **This system has three counting modes**
  - Passive neutron counter
  - Active neutron counter
  - Gamma spectrometry



Measurement device	Height: 800mm, Diameter: 800 mm, Inside Diameter: 200mm		
	Passive Neutron Counter Mode (M1)	Active Neutron Counter Mode (M2)	Gamma Spectrometry (M3)
Measurement target	Spontaneous neutron from Cm amount	Induced fission neutrons from fissile material	Burn-up from Cs-134/137 ratio
Accounting target	Pu amount using Cm ratio	U-235 amount	Determination of Pu and U quantity through ORIGEN simulation, Measurement of U enrichment

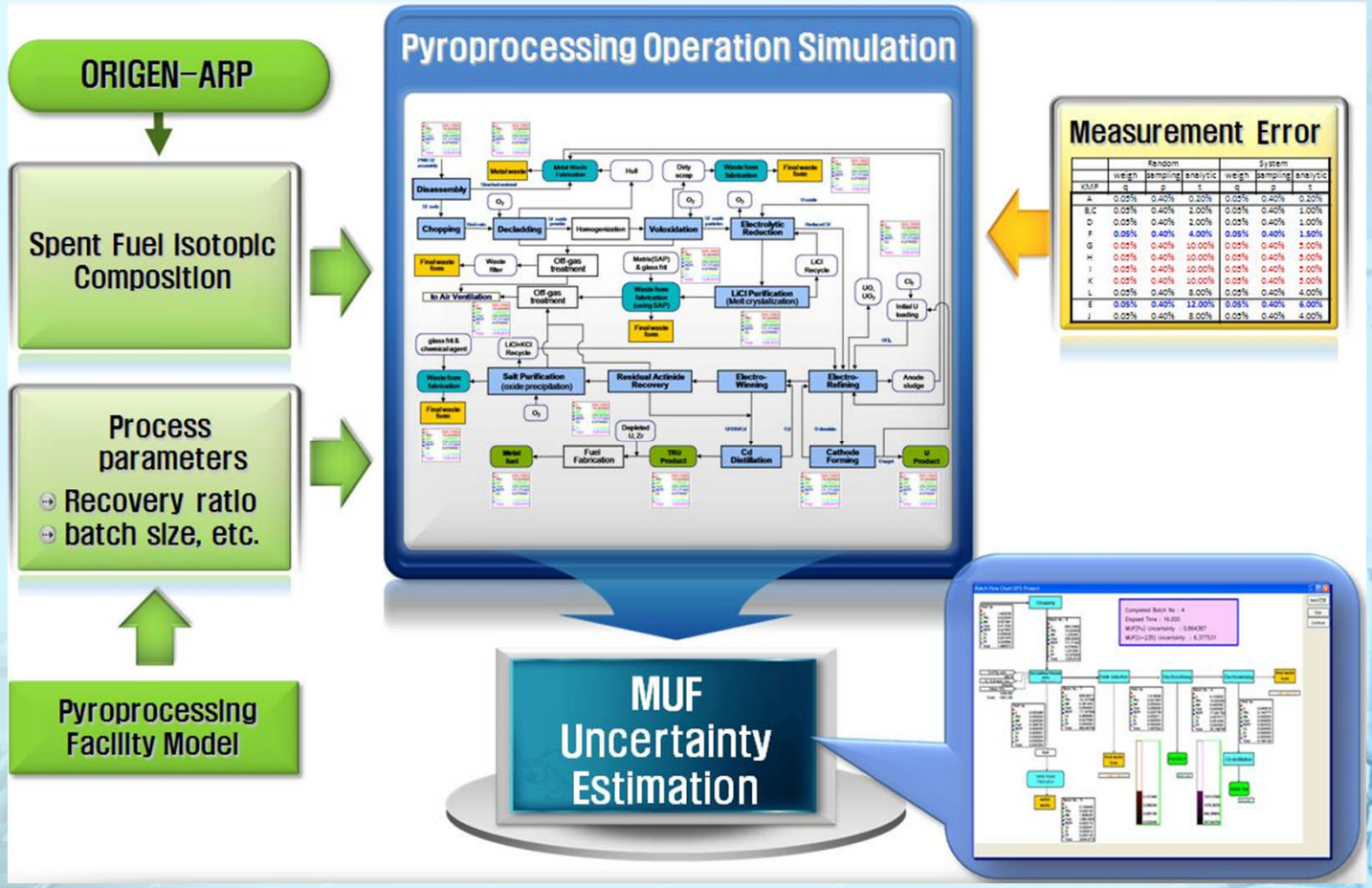
Operator Measurement Systems on 3 Major KMPs

- Three process materials at major KMPs are indicated in black
- The applicable measurement systems and final accounting values are indicated in green circle and red
- These measurements are verified by using DA system with more accuracy



REPF Material Accountability Analysis Tool

- A PYMUS (PYroprocessing Material flow and MUF Uncertainty Simulation) has been developed to analyze nuclear material flow and MUF uncertainty in a pyroprocess facility



III. International Cooperation in future S/G R&D

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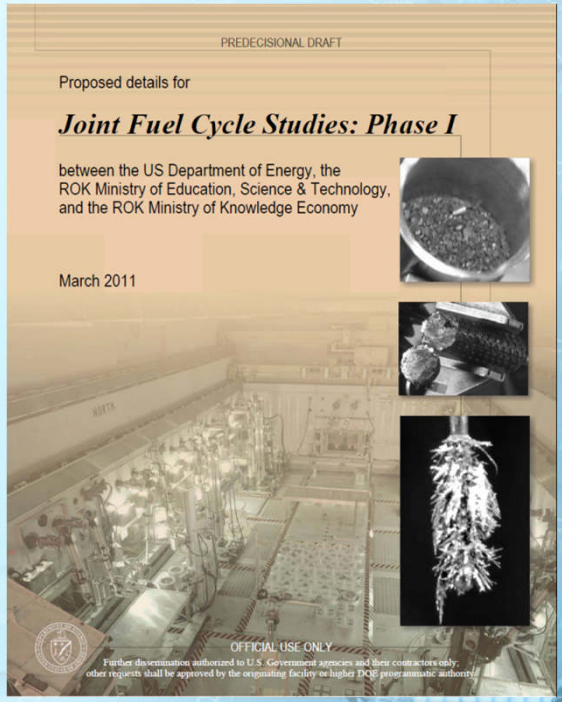
Joint Fuel Cycle Studies Program

- ROK and USA agreed to work together to consider the technical and economic feasibility and nonproliferation implications of several approaches to used fuel management

- Three technical working groups of the JFCS are
  - ✓ Electrochemical recycling
  - ✓ Safeguards and security
  - ✓ Fuel cycle alternatives

- JFCS Safeguards Approach
  - ✓ Phase I (2011-2012): Analytical Phase
  - ✓ Phase II (2013-2016): R&D and Process Integration Phase
  - ✓ Phase III (2017-2020): Testing and Evaluation Phase



JFCS – Safeguards & Security Working Group

SSWG Activities

- Provide technical input for evaluation of the acceptability of the electrochemical recycling process on nonproliferation grounds
- Undertake safeguards technology R&D to validate assumptions of measurement capabilities and, where possible, push the state-of-the-art to achieve success.
- Evaluate the integrated safeguards approach with the INL hot-test facility and KAERI PRIDE cold-test facility
- Phase I (2011-2012): Analytical Phase
  - ✓ Undertake safeguards study of REPF (10-ton facility) culminating in technical safeguards report
    - – Evaluate current safeguards technology for application to pyroprocessing
    - – Develop comprehensive list of prioritized safeguards issues needing further investigation
    - – Highlight issues related to scaling
  - ✓ R&D tasks on high priority issues (NMA, C/S, etc.)
  - ✓ Continue cooperation with ROK on dry storage and repository safeguards

IV. Summary

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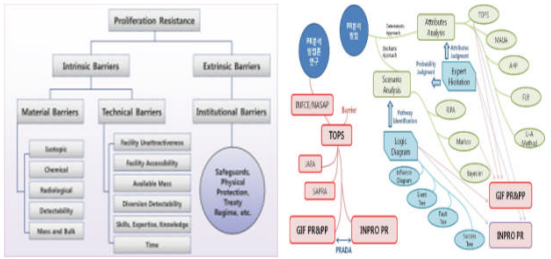
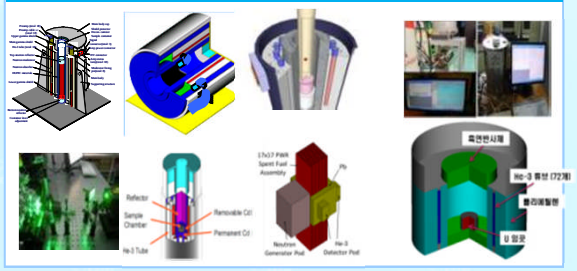
PR-Enhanced Pyro. Safeguards and Hot Cell Design

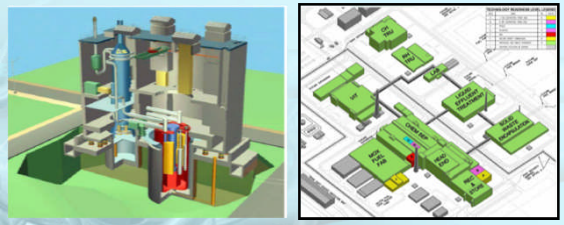
PR/PP Enhancement and Evaluation



Pyro. Safeguards Technology

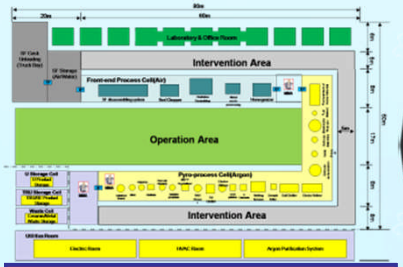


Pyro Hotcell Design Technology



PRIDE : PyRoprocessing Integrated inactive Demonstration facility
KAPF : Korea Advanced Pyroprocessing Facility
PR : Proliferation Resistance, PP : Physical Protection
SF : Spent Fuel

PRIDE (Eng. Scale, Simfuel)



REPF(Eng. Scale, SF)

Non-proliferation System Establishment for Prototype Facility

International Cooperation for PR/PP

- ❖ INPRO : Commencement of PROSA
- ❖ Participation in GIF PR&PP WG

ROK-US Joint Fuel Cycle Study

- ❖ Safeguards technical direction and analysis
- ❖ Safeguards testing with irradiated material
- ❖ Technology for nuclear material accountancy
- ❖ Technology for containment and surveillance
- ❖ Safeguards and security by design
- ❖ Modeling and simulation for analysis of safeguards performance
- ❖ Safeguards for dry storage and repositories (fuel cycle alternatives)

ROK-IAEA Collaboration for SG

- ❖ MSSP for PRIDE test & JFCS
- ❖ MSSP for STR of pyroprocess

GIF : Gen-IV International Forum
INPRO : International Project on Innovation Nuclear Reactors and Fuel Cycle
PROSA : Proliferation Resistance and Safeguards Assessment
NDA : Non-Destructive Assay
SG : Safeguards

Summary

- **ROK has developed the NDA devices and safeguards system for the nuclear fuel cycle facilities such as DFDF, ACPF and PRIDE.**
- REPF concept was established to develop the safeguards approach, and evaluate and assess the safegaurdability of the pyroprocessing facility through the ROK-IAEA MSSP.
- We expect the results of MSSP will make a valuable contribution to the guidance of "Safeguards-by-Design" for pyroprocessing facilities.
- The safeguards approach developed for the REPF is being reviewed through SSWG of Joint Fuel Cycle Study (JFCS) between ROK and US.
- Safeguards R&D for Pyro. will be continued through trilateral MSSP and field testing with irradiated material of pyro facilities.

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Thank you for your Attention

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