

Safeguards for Pyroprocessing Plants



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To read

- ❑ **Radioactive Waste Management in Korea**

Tae-Jin Park and Jong-Won Choi, Korea Atomic Energy Research Institute (K A ERI), May, 2012.

- ❑ **Current Status of Pyroprocessing Development at KAERI,**

Hansoo Lee, Geun-IL Park, Jae-Won Lee, Kweon-Ho Kang, Jin-Mok Hur, Jeong-Guk Kim, Seungwoo Paek, In-Tae Kim, and IL-Je Cho, Science and Technology of Nuclear Installations, Volume 2013.

- ❑ **Development of Safeguards Approach for Reference Engineering-scale Pyroprocessing Facility,**

Ho-dong Kim, 29 August 2009.



To read

- **Advanced Safeguards Approaches for New Reprocessing Plants**, P. C. Durst, I. Therios, R. Bean, A. Dougan, B. Boyer, R. Wallace, M. H. Ehinger, D. N. Kovacic, K. Tolk, PNNL-16674, June 2007.
 - **South Korean Reprocessing: Unnecessary Threat to the Nonproliferation Regime**,
Frank von Hippel, Arms Control Today, March 2010.
-



Pyroprocessing is reprocessing

- Pyroprocessing differs from PUREX (plutonium-uranium extraction) reprocessing, which has been traditionally used in nuclear energy and weapons programs around the world, because the plutonium separated from spent fuel by pyroprocessing remains mixed with other elements.
 - ROK officials have argued that this difference makes pyroprocessing more proliferation resistant than traditional reprocessing.
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Why Concerns about Reprocessing

- ❑ Separated plutonium reduces substantially time required to sprint for nuclear weapons.
 - ❑ Conversion time from pure plutonium compounds to plutonium metal is 1-3 weeks.
 - ❑ However, it still takes time another few weeks to manufacture components and assemble a nuclear weapon.
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Why pyroprocessing – ROK arguments

- At the end of 2008, there were 10,083 tons of spent fuel in South Korea with an additional 700 tons generated each year
- As of December 2011 69 % of the spent fuel storage capacity at reactor sites was used.
- By the end of the century, the cumulative amount is expected to exceed 110,000 tons.
- An underground repository (and an exclusion zone surrounding the site) would need to cover as much as 80-square kilometers, an area of the size of Manhattan.
- Finding that much free space in South Korea would be enormously difficult; the country is roughly the size of Virginia with about six times as many people.





The ROK Solution to spent fuel problem

- In December 2008, The ROK Atomic Energy Commission a's Atomic Energy Commission suggested a next-generation domestic nuclear system.
- Pyroprocessing and fast reactors that operate in "burner" mode and can use such recycled spent fuel to generate electricity.
- A demonstration of the technical and economic viability of both technologies be completed by 2028.



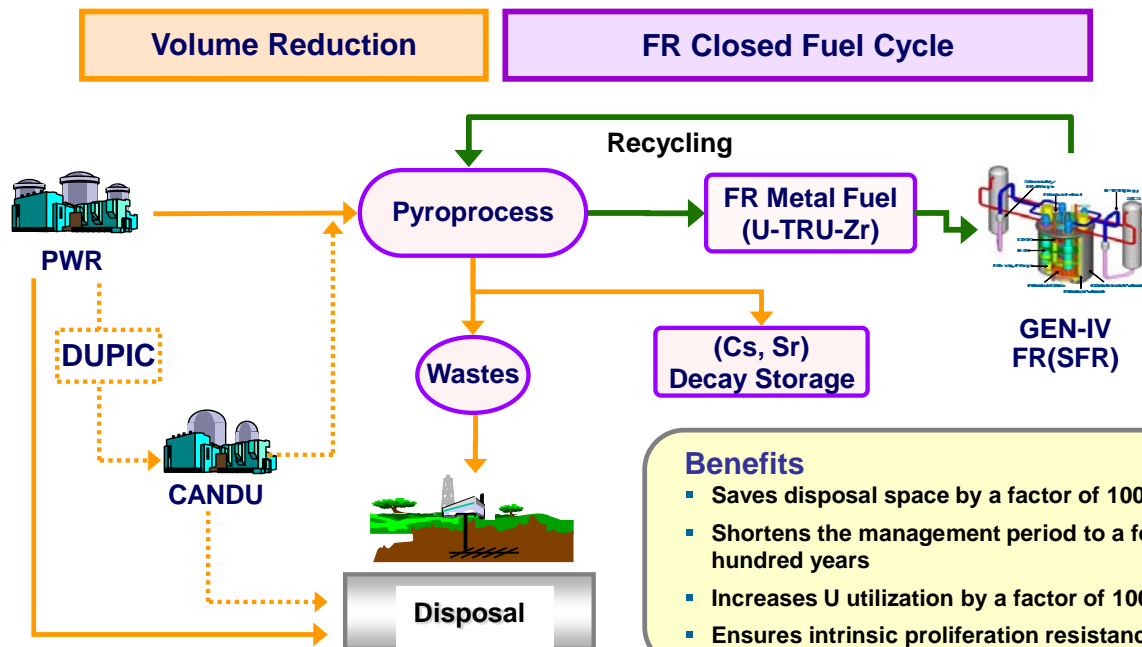
No change in the nuclear policy

- Ms. Park Geun-hye continues support, as her predecessor, nuclear energy policy with stringent safety and safeguards.



The ROK Fuel Cycle Concept

Korean, Innovative, Environment-Friendly, and Proliferation-Resistant System for the 21st C (KIEP-21)



Timeline for the development of technology

2002

2007

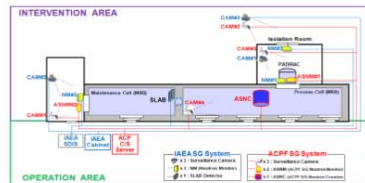
2012

2017

2022

Milestone

ACPF
Safeguards Implement.



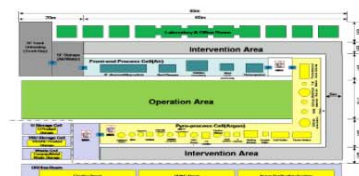
ACPF (Lab. Scale, SF)

PRIDE
SG System Dev.



PRIDE (Eng. Scale, Simfuel)

REPF
3S by Design



REPF (Eng.-scale, SF)

KAPF
3S by Design



KAPF (Prototype)

Pyroprocessing scheme

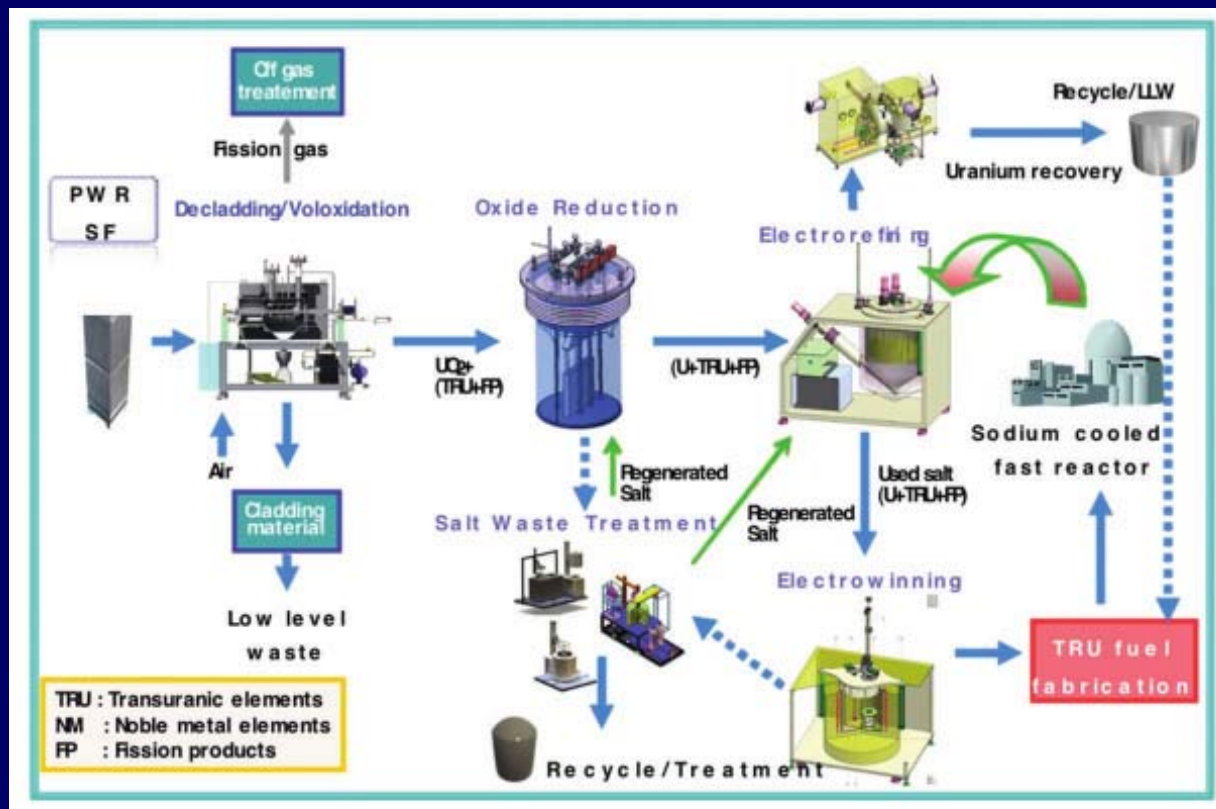


Fig. 1. Flow Diagram of Pyroprocessing (KAERI).



Pyroprocessing has wider implications

- ❑ Denuclearization of the Korean Peninsula, The Joint Declaration in 1992.- no reprocessing and enrichment.
 - ❑ US- ROK 1-2-3 agreement – Golden Standards – forego enrichment and reprocessing.
 - ❑ Proliferation of sensitive technologies
 - ❑ Neptunium, Americium and Curium are fissile.
 - ❑ Spent fuel alternatives:
 - Reprocessing abroad
 - Multinational reprocessing
 - Direct disposal of spent fuel
 - Additional storage capacity needed anyway
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What is pyroprocessing ?

- Spent fuel is cut into pieces, heated, and turned into a powder.



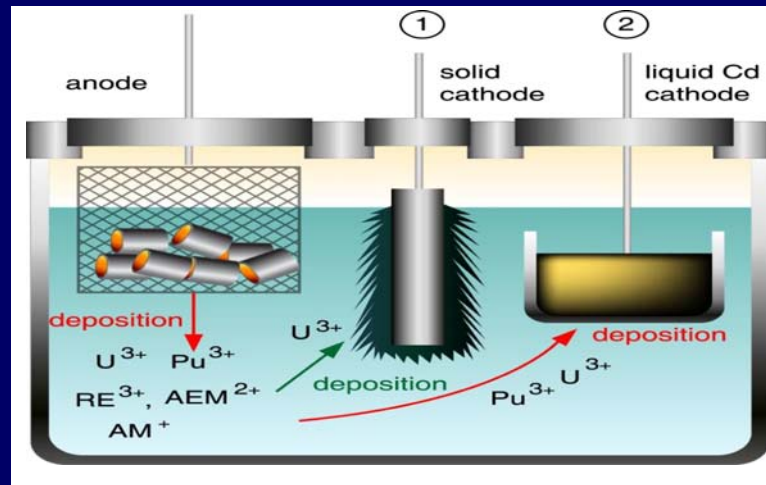
What is pyroprocessing ?

□ The process removes volatile fission products such as krypton and xenon as well as some semi-volatile fission products such as iodine and cesium.



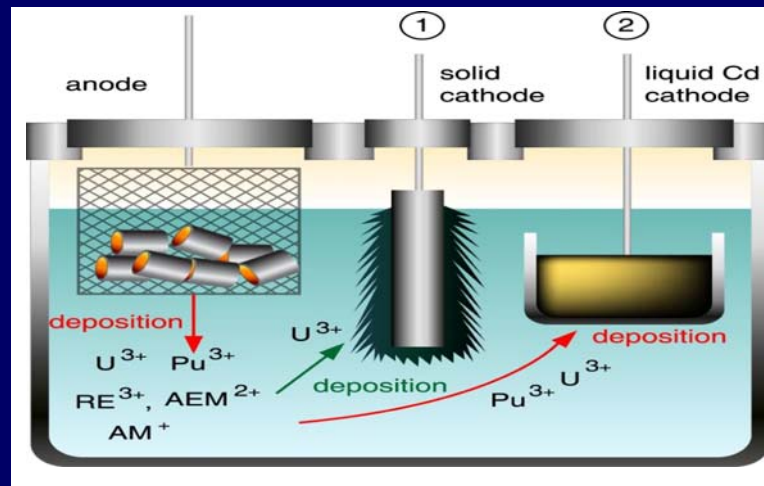
What is pyroprocessing ?

- The powder is then transformed into a metal and placed in a molten bath of lithium and potassium chloride salts.



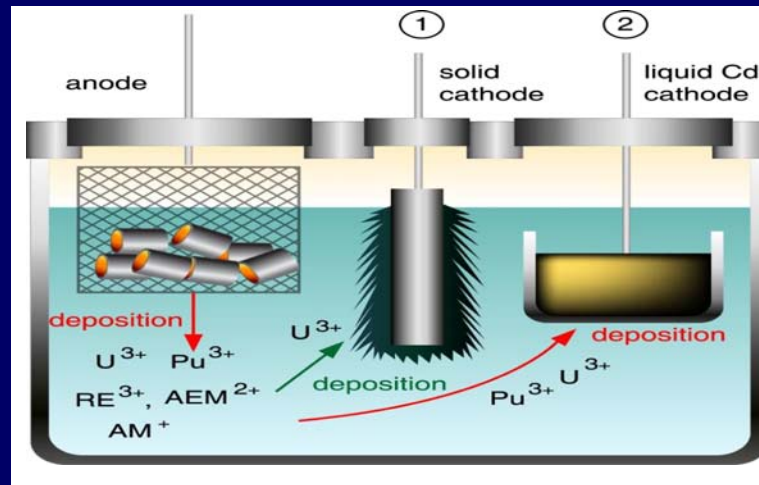
What is pyroprocessing ?

- An electric current is run through the bath to dissolve the radioactive metal and to separate its elements in several stages, beginning with the recovery of uranium



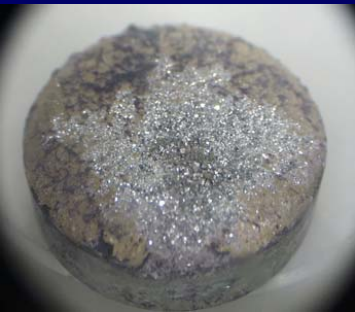
What is pyroprocessing ?

□ This operation continues with separation of transuranics (plutonium, neptunium, americium, and curium) in the molten salt from the bath, along with a significant amount of fission products (cerium, neodymium, and lanthanum).



What is pyroprocessing

- It then can be directly refabricated into metallic fuel for use in fast reactors without any further processing or purification.
- The process is able to drastically reduce the volume and heat load of the spent fuel it pyroprocesses and reuses in fast reactors, allowing it to make a future spent fuel repository up to 100 times smaller than a repository filled with spent fuel that doesn't undergo such a treatment.





REPF (Reference Engineering-scale Pyroprocess Facility)

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

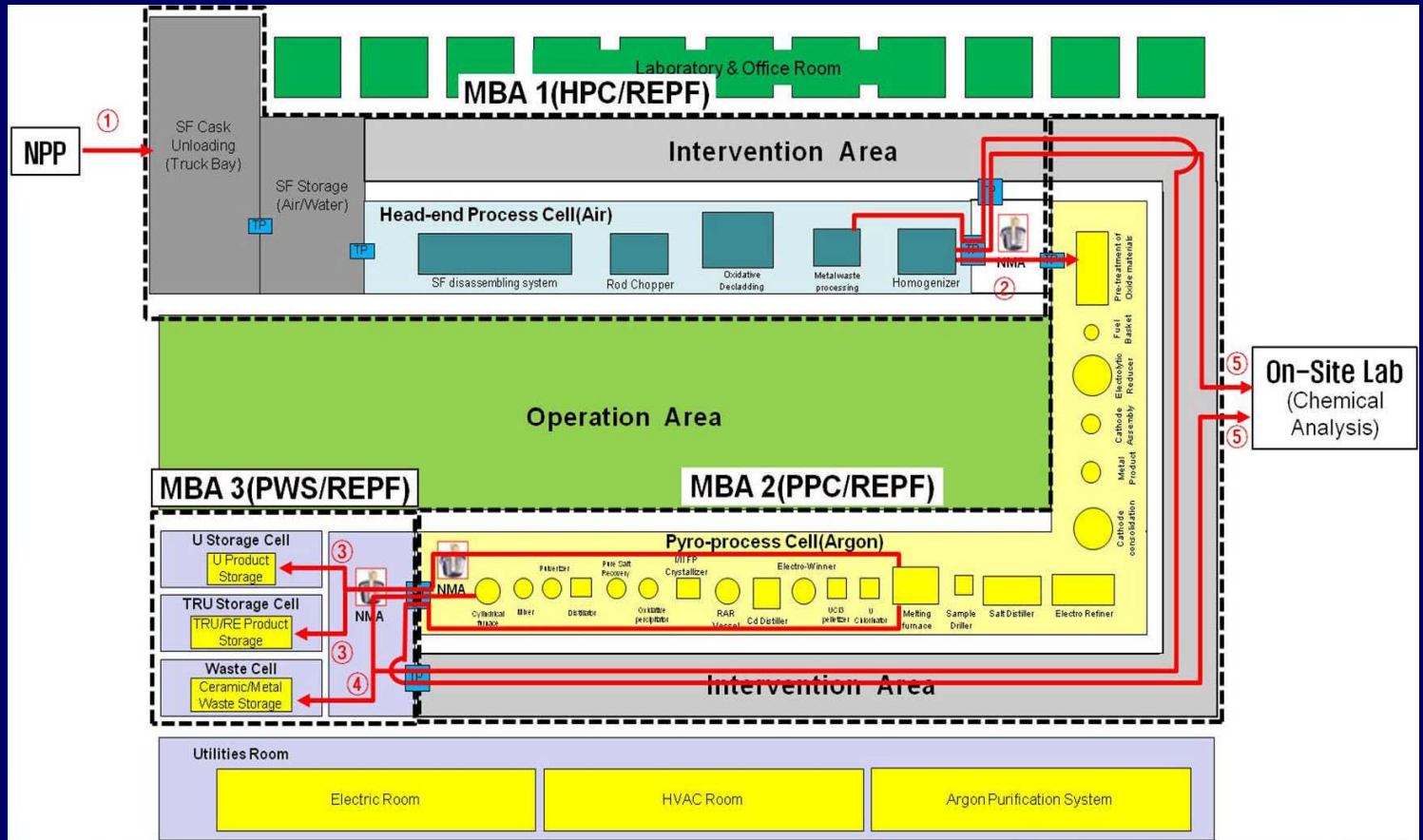
Output: U ingot, U/TRU ingot

Safeguards approach

- Examination of operator records and reports
- Verification of interim inventory for timeliness
- Verification of inventory changes
- Verification of physical inventory (annual) including evaluation of MUF/SRD
- Design information examination / design information verification



REPF safeguards approach





REPF safeguards approach

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
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REPF safeguards approach

Homogenization Process

- Heterogeneous input powder for DA and NDA
- A constant C_m ratio (for each campaign)

Accounting Period

- Accounting and MUF evaluation every campaign (11 – 22 days)
 - Near Real Time Accountancy (NRTA)
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Safeguardability

□ *Draws from past experiences:*

- Large reprocessing and MOX fabrications plants (UK, France, Japan)
 - DUPIC (ROK)
 - PRIDE (ROK)
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Operator Measurement Systems on 3 Major KMPs

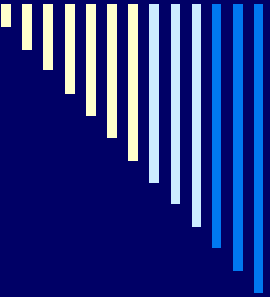
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Safeguardability

□ *Number of challenges:*

- Pyroprocessing safeguards experience only from lab/pilot scale
 - Instrumentation in highly corrosive environment
 - Verification (DA and NDA) of salt and metal solutions and not liquids or powders
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What needs to be done to produce pure plutonium metal?

□ *Steps straight forward:*

- Purification from metal ingots from Np, A, and Cm requires special arrangements, but most of the fission products have been removed.
 - Plutonium metallurgy is part of the fuel production, and contributes to weapon component manufacturing.
 - Recycling of turnings from the rod manufacturing
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In summary

- ❑ Technological and economical feasibility not proven.
 - Pyroprocessing
 - Fuel manufacturing
 - Waste solidification and disposal
 - Fast breeder reactor
 - ❑ Less proliferation sensitive than PUREX, but still concerns.
 - ❑ Need to think also Np, Am, Cm.
 - ❑ Requires development of new safeguards equipment and methods, but safeguardable.
 - ❑ Wider proliferation implications.
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