Nuclear Proliferation Resistance in Feasibility Study on Commercialized Fast Reactor Cycle Systems

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• Status and prospective of the Feasibility Study on Commercialized Fast Reactor Cycle Systems (FS)
• Study on nuclear proliferation resistance for FS
  – Nuclear fuel recycling
• Further approach for future FR fuel recycling
  – Reactor
  – Fuel recycling
• Proposal for future development
Steps of the Feasibility Study

- Domestic collaborations with research organizations, universities, engineering companies, etc.
- International cooperation based on GEN-IV, I-NERI, etc.

Five Goals of the Feasibility Study

**Safety**
- Risks caused by introduction of FR cycle should be small compared with risks that already exist in society.

**Economic Competitiveness**
- Achieve power generation cost comparable to that of future LWRs and other energy resources.
- Ensure cost competitiveness in the global market.

**Reduction of Environmental Burden**
- Reduce the amount of radioactive waste generated in the course of plant operation and maintenance as well as decommissioning.
- Reduce the radiotoxicity of radioactive waste by means of burning or transmuting long lived nuclides.

**Efficient Utilization of Nuclear Fuel Resources**
- Produce sustainable nuclear fuel.
- Respond to diverse needs for energy resources.

**Enhancement of Nuclear Non-Proliferation**
- Reduce burden of nuclear Physical Protection and safeguards (no pure plutonium in any FR cycle process and increase radioactivity of fuel materials).
- Effectively operate non-proliferation system (remote process and monitoring system.)
<table>
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<tr>
<th>Design requirement</th>
<th>Criteria for evaluation</th>
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<tr>
<td>Design which is considered on physical protection (PP) and safeguards (SG)</td>
<td>Efficient application of system for PP and SV by utilizing remote surveillance and automation</td>
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<tr>
<td>No isolated Plutonium</td>
<td>No plutonium isolated through whole processes</td>
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<tr>
<td>Limited access by high exposure from lower decontaminated and/or TRU fuel</td>
<td>Realize limited access to obtain and utilize lower decontaminated and/or TRU fuel</td>
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### Nuclear Proliferation Resistance of Fuel Recycling – Design with consideration on PP and SV –

**Technical requirement on PP**
- Installing barrier and detection system for invasion

**Technical requirement on SV**
- Confirmation of material balance and inventory change by determining area of material balance and points for analysis and measurement
- Corresponding to inspection
- Acting sealing, confinement by surveillance and surveillance

- Investigated on application of current SV system including NRTA (Near Real Time Accounting)
- Applicable to Advance Aqueous Reprocessing
- Investigated on potential for rationalization of SV

- Considered current system
Advanced Aqueous Reprocessing
What is the “NEXT” Process?

Plutonium partitioning for Advanced Aqueous Reprocessing

- No Pu partitioning in solvent extraction
  - Increased technical difficulty to isolate Pu
- Adjustment of ratio of U : Pu by uranium crystallization
  - Major part of U is separated as solid uranyl nitrate
  - Inherently difficult to isolate Pu from U and fission products, practically impossible to separate Pu from dissolver solution of spent fuel

Practically impossible to isolate Pu

Disassembling/decladding
Dissolution/clarification
Crystallization
Extraction chromatography
Co-extraction
Co-stripping (U/Pu/Np recovery)
Solvent regeneration

High level liquid waste
Concentration
Adjusting Pu content

New technologies
Conventional technologies

U/ TRU (product)
U (product)

Criteria of Evaluation for Nuclear Proliferation Resistance

Values in parenthesis are weight.

Extrinsic Resistance
- Export control
- Safeguards
- Physical protection

Intrinsic Resistance
- Access difficulty
- Handling difficulty
- Conversion difficulty (Pu)
- Nuclear weapon unattractiveness

Investigating reprocessing which co-recovers whole actinides
Investigating production of low grade Pu in reactor

The International Nuclear Nonproliferation Science and Technology Forum, Tokyo, 2006
A study on enhancement of nuclear proliferation resistance in a reactor system

Target: No weapon-grade plutonium in a system

Spec. of a large MOX-fueled core

- Thermal power: 3570 MW
- Electric power: MW
- Operation cycle length: 800 day
- Fuel exchange batch: 4
- Average fuel burnup: 147 GWd/t
- Breeding ratio: 1.1

Pu isotopic composition (239Pu/240Pu)
- Fresh fuel (Core): 57% / 34%
- Discharged fuel:
  - Core: 54% / 35%
  - Radial blanket: 95% / 5%
  - Axial blanket: 90% / 9%

Addition of low grade Pu fuel to the blankets
A case of 5% addition

Pu isotopic composition in discharged fuel (239Pu/240Pu)
- Core: 55% / 35%
- Radial blanket: 69% / 24%
- Axial blanket: 71% / 23%

Change of Power Share
- Core: Blanket
  - 93% : 7%
  - 88% : 12%

Influence
- Plutonium inventory: +14%
- Breeding ratio: -0.03
- Average fuel burnup: -5.5%
Addition of low-grade Pu into blankets is effective for the degradation of discharged Pu from blankets.

Pu in blankets becomes reactor grade by more than 3% of the addition.

The deterioration in breeding ratio could be endurable with design changes.

Further evaluation is necessary on the impact to the fuel fabrication cost.

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Pu composition in discharged blanket with low grade Pu addition

- Pu isotopic composition at discharge (%) vs. content of low-grade Pu in fresh blanket (%)

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Proposal for Improving Proliferation Resistance

- Acnides Co-recovery Reprocessing
- Advanced Aqueous Reprocessing
- PUREX type reprocessing

Axis for proliferation difficulty:

- H: High
- M: Medium
- L: Low

Axis for safeguards:

- L: Low
- M: Medium
- H: High
Study of Improved Reprocessing Considering Non-Proliferation by Means of Actinides Co-recovery

**Conclusion**

- For FS (FR cycle development in Japan), proliferation resistance shall be an important goal of development and R&D will be conducted to enhance “intrinsic” resistance.
- “Extrinsic” proliferation resistance will be enhanced by investigating methods for safeguards and by its application to design study although its stage is at conceptual design.
- International cooperation with IAEA and countries concerned is essential for suitable adaptation to changing circumstance of nuclear proliferation.