Japan ADS Project

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• Summary
National Policy for Nuclear Energy
Current status of the NPPs in Japan

- Before March 2011, 54 units (48.8GWe) were operated in Japan.
- After March 2011, 6 units excluding Fukushima Daiichi 6 units were decided to be decommissioned.
- Nuclear Regulatory Authority (NRA) was newly established on 2012 and new safety regulations were issued by NRA.
- NRA approved basic design of 10 units and 5 units were restarted.

“Strategic Energy Plan” issued in Apr. 2014
- Nuclear power is an important base-load power source.
- Dependency on nuclear will be decreased.
- Future volume of nuclear capacity will be carefully examined.
“Strategic Energy Plan” in Japan

- **Position of Nuclear Power**
  Nuclear power is an important base-load power source as a low carbon and quasi-domestic energy source, contributing to stability of energy supply-demand structure.

- **Steady approach for key issues to be solved without putting off implementing measures into the future**

  1. **Spent fuel management**
     - Drastic reinforcement of measures for final disposal of high-level radioactive waste
     - Expanding storage capacity of spent fuels
     - Promotion of technology development on volume reduction and mitigation of degree of harmfulness of radioactive waste
     - Promotion of R&D for technologies including nuclear transmutation technology using fast reactors and accelerators

  2. **Nuclear fuel cycle**
     - The basic policy of Japan is to promote a nuclear fuel cycle that reprocesses spent fuels and effectively utilizes the plutonium retrieved.
Partitioning and Transmutation Technology
R&D on P&T in JAEA

Partitioning and Transmutation (P&T) technology is expected to be effective to mitigate the burden of the HLW disposal by reducing the radiological toxicity and heat generation.

JAEA has been studying this technology for more than 20 years.

**Homogeneous cycle**

- Commercial FBR Fuel Cycle
  - Fuel fabrication
  - Reprocessing
  - HLW
  - U, Pu, MA
  - Geological disposal

**Double-Strata (ADS)**

- Commercial Fuel Cycle
  - Fuel fabrication
  - Reprocessing
  - Partitioning
  - HLW (MA, FP)
  - U, Pu
  - Geological disposal

- Dedicated transmuter
  - MA, LLFP

- I-129

**Partitioning and Transmutation (P&T) technology** is expected to be effective to mitigate the burden of the HLW disposal by reducing the radiological toxicity and heat generation.

- JAEA has been studying this technology for more than 20 years.

- MA is homogeneously mixed to FBR fuel with small amount up to 5 wt.%.  
- MA transmutation is performed in all electricity generating FBR plant.

- Dedicated (second) transmutation fuel cycle with Accelerator-Driven System (ADS) is added to commercial fuel cycle.
- MA recovered from commercial fuel cycle is confined in the compact transmutation cycle.
Accelerator Driven System (ADS)

Characteristics of ADS:
• Chain reactions stop when the accelerator is turned off.
• LBE is chemically stable. ➔ **High safety can be expected.**
• High MA-bearing fuel can be used.
• MA from **10 LWRs** can be transmuted.
R&D for ADS in JAEA
Purpose : MA transmutation

- Proton beam : 1.5GeV ~30MW
- Spallation target : LBE
- Coolant : LBE
- Subcriticality : $k_{\text{eff}} = 0.97$
- Thermal output : 800MWt
- Core height : 1000mm
- Core diameter : 2440 mm
- Fuel inventory : 4.2t (MA:2.5t)
- Fuel composition :
  \[(\text{MA} + \text{Pu})\text{N} + \text{ZrN} \text{ (Mono-nitride)}\]
  - Inner : 70%MA+30%Pu
  - Outer : 54%MA+42%Pu
- Transmutation rate :
  250kg(MA) / 300EFPD
Technical Issues of ADS

- **Accelerator**
  - R&D of SC-LINAC
  - Reliability Assessment
  - Construction of J-PARC accelerator

- **Structure**
  - Design study on reactor vessel, beam duct, quake-proof structure, etc.

- **Fuel**
  - Fabrication, irradiation and reprocessing tests

- **R&D of Pb-Bi technology**
  - Construction of TEF-T in J-PARC

- **Spallation Target, Material**
  - Operation of Pb-Bi system

- **Experiments in existing facilities and analyses**
  - Construction of TEF-P in J-PARC

- **Reactor Physics**
  - Control of Subcritical System

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J-PARC: Japan Proton Accelerator Research Complex
TEF-P: Transmutation Physics Experimental Facility
TEF-T: ADS Target Test Facility
SC-LINAC: Superconducting LINAC
Increase Beam Reliability

• Beam-trip is one of the critical issues for ADS
• To reduce the beam-trip frequency, double-accelerator concept is proposed
• By running two accelerators (50% of rated power/acc.), reliability requirement for ADS can be satisfied
k_{eff} adjustment by SAR

• To reduce the proton beam current, ADS with Subcriticality Adjustment Rod (SAR) was investigated
  • Install 3 B_{4}C SARs (Total Worth: 1.5%dk/k)
  • Possible to keep proton beam current around 10mA during the burnup cycle

![SAR Layout (Green)](image)

### Change of proton beam current

- **Reference**
- **ADS with SARs**

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A workshop on the Status of ADSs Research and Technology Development, 7-9 Feb 2017, CERN
Improvement of passive safety

- Reflecting the Fukushima Accident, conceptual design of DRACS (Direct Reactor Auxiliary Cooling System) is investigated.
- PLOHS with DRACS was analyzed by RELAP5-Mod3.
- It was confirmed the coolant temperature can be kept below 400°C even in the case of Station Black Out.

![Graph showing temperature over time](image-url)
Subcritical core arrangement

- Layout of reactor components including newly added equipment (ex. SAR) was performed
- The scheme to replace beam window and fuel is confirmed
Research Plan at J-PARC
Transmutation Experimental Facility (TEF)

Jan. 28, 2008

Site for Transmutation Experimental Facility

Materials and Life Science Experimental Facility

3 GeV Synchrotron

30 GeV Synchrotron

To neutrino detector

400 MeV LINAC

A workshop on the Status of ADSs Research and Technology Development, 7-9 Feb 2017, CERN
**Image View of TEF**

**Transmutation Physics Experimental Facility: TEF-P**
- Purpose: To investigate physics properties of subcritical reactor with low power, and to accumulate operation experiences of ADS.
- Licensing: Nuclear reactor: (Critical assembly)
- Proton beam: 400MeV-10W
- Thermal power: <500W

**ADS Target Test Facility: TEF-T**
- Purpose: To research and develop a spallation target and related materials with high-power proton beam.
- Licensing: Particle accelerator
- Proton beam: 400MeV-250kW
- Target: Lead-Bismuth Eutectic (LBE, Pb-Bi)
Transmutation Physics Experimental Facility (TEF-P)

- TEF-P is designed to take over the experiences and functions of FCA to minimize the cost and risk for newly developed equipment.
- Low power critical facility for reactor physics and nuclear data of transmutation systems including ADS and FBR.
- By replacing central partial matrix tubes with pin-type assembly, MA fuel can be used with cooling and remote handling.
ADS Target Test Facility (TEF-T)

- Experiments for irradiation damage of material by protons and neutrons
- Material irradiation test for material for beam window of ADS, structure material for FBR, and material for fusion reactor
- Development of database for engineering feasibility of ADS by experiments in various condition (ex. temperature and velocity of flowing LBE)

Candidate concept for LBE target in TEF-T

Test device for flow visualization by PIV method (Full-scale transparent acrylic model of target vessel)
Development of ADS Transmutation System

实验ADS⇒MYRRHA
〜2.4MW-beam, 50〜100MW\(_{th}\)
・Engineering feasibility of ADS and fuel irradiation

Basic research (LBE loop test, KUCA experiments)

Power

*Experimental ADS⇒MYRRHA*
- 2.4MW-beam, 50〜100MW\(_{th}\)
- Engineering feasibility of ADS and fuel irradiation

*ADS without MA fuel (LBE coolant, Accelerator, Operation of ADS)*

*ADS Transmutation plant*
- 30MW-beam, 800MW\(_{th}\)
  - Transmute 250kg of MA annually

*Reactor physics of MA transmutation system and material development for spallation target material*

<table>
<thead>
<tr>
<th>Year</th>
<th>TEF in J-PARC</th>
<th>MYRRHA</th>
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<tbody>
<tr>
<td>2010</td>
<td>R&amp;D for elemental technology (LBE target, Reactor physics)</td>
<td>Fuel irradiation, Accumulation of operation experience of ADS</td>
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<tr>
<td>2020</td>
<td>250kW-beam TEF-P : 500W (max.)</td>
<td>2.4MW-beam Power : 50〜100MW(_{th})</td>
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<td>2030</td>
<td>Mock-up experiments of transmutation system with massive MA (kg order)</td>
<td>Irradiation experiment with small amount</td>
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*Purpose*
- R&D for elemental technology (LBE target, Reactor physics)
- Accumulation of operation experience of ADS

*Power*
- 250kW-beam TEF-P : 500W (max.)
- 2.4MW-beam Power : 50〜100MW\(_{th}\)
Summary

• National Policy for Nuclear Energy
  • “Nuclear power is an important base-load power source”
  • “GOJ will promote development of technologies for reducing the volume and harmfulness of radioactive waste in order to secure a wide range of options in the future.”

• R&D for ADS in JAEA and J-PARC
  • Current status and future plan on R&D of ADS were summarized.
  • Various basic R&D have been implemented, and new experimental facility, TEF, is proposed in the J-PARC project. TEF is expected to play important roles as an international research facility.
Backup
Estimation of Beam-trip Frequency

<table>
<thead>
<tr>
<th>Beam-trip duration</th>
<th>Allowable beam-trip frequency 100% to 0%</th>
<th>100% to 50%</th>
<th>50% to 0%</th>
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<tbody>
<tr>
<td>0 - 10sec</td>
<td>20,000</td>
<td>6,600</td>
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<tr>
<td>10sec - 5min</td>
<td>1,300</td>
<td>12,000</td>
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<tr>
<td>&gt; 5min</td>
<td>42</td>
<td>1,500</td>
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*Due to the necessity to shutdown the system (to prevent the LBE freezing), the allowable beam-trip frequency was determined. However, in the 100% to 50% case, it was not necessary to shutdown the system.

Beam-trip frequency in the double-accelerator concept satisfied the allowable beam-trip frequency.

Reduction of temperature difference

Multiplexing and downgrade of each component

Multiplexing and downgrade of each component

Beam-trip frequency in the double-accelerator concept satisfied the allowable beam-trip frequency.
**Construction Schedule (Tentative)**

JAEA’s current mid- to long-term plan

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<td><strong>TEF-T</strong></td>
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R&D/Design

1 year shifted

Construction

Operation

Licensing

Construction

Operation

Updated in Sep, 2016
Material data taken in TEF-T

- Irradiation data at higher temperature range than existing experiments is required to realize ADS
- TEF-T can provide irradiation data for rated operation condition not only for future ADS but also for MYRRHA

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<tr>
<th>STIP-I,II</th>
<th>Irradiation in Stagnant Pb-Bi performed at PSI MEGAPIE</th>
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<tr>
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<td>World’s first Pb-Bi spallation target with 1MW proton beam performed at PSI SNS</td>
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<td>High power spallation neutron source in USA MLF</td>
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<td>1MW Mercury spallation target of J-PARC</td>
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New Test Equipment for TEF-T Design

**OLLOCHI** Oxygen-controlled Lbe LOop for Corrosion tests in High temperature
- Material corrosion database for various temperature, oxygen potential, LBE flow rate will be collected
- The loop will be operated from next April
- Addition of corrosion test section with mechanical stress are planned

**IMMORTAL** Integrated Multi-functional MOckup for TEF-T Real-scale TArget Loop
- Demonstration of safe operation of LBE loop by reflecting operation condition of J-PARC LBE Spallation target
- Tests for dynamic behavior of heat removal, functional tests of sensors, loop components are underway

**Oxygen Sensor Calibration Device**
- To prevent corrosion by flowing LBE, oxygen potential in LBE should be controlled in appropriate potential range (10^{-5} to 10^{-7} %)
- Development of oxygen potential sensor and loop tests for oxygen potential control mechanism are underway