Progress on reactor system technology in the FaCT project toward the commercialization of fast reactor cycle system

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- Outline of FaCT Project
- Current Status of FaCT Project
- Development Schedule of FaCT Project
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Long Term Forecast of Nuclear Energy in Japan

* The installed capacity is assumed to reach saturation at 58GW, for illustrative purpose.
History of Fast Reactor Development in Japan

- 2025 Demonstration
- 2050 Commercialization

Innovative Technology for Economics and Reliability

- Design Study of Demonstration Reactor
  - Development of Element Technologies
    - Power: 1,600MWe/660MWe
    - Temperature: 550°C

- Demonstration of Reliable Operation
- Establishment of Sodium Handling
  - Power: 714MWe/280MWe
  - Temperature: 529°C

- Confirmation of FR Basic Technologies
- Verification of Safe and Stable Operation
  - Power: 50MWe → 100MWe → 140MWe (Mk-III Core)
  - Temperature: 435°C → 500°C → 500°C

*1: study performed
*2: initial criticality attained
Framework of Promoting the FaCT Project

Atomic Energy Commission (AEC)

Ministry of Economy, Trade and Industry (METI)

Electric Utilities

MHI (Core Company: since April 2007)

JAEA

MFBR (FR Development Company: since July 2007)

Advisory Committee

Council for Science and Technology Policy (CSTP)

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

Manufacturer

Universities, Research Organizations, etc.

- Submit R&D results
- Loan engineers
- Partial injection of capital
- Places orders with manufacturers, universities, research organizations, etc.

- Bundling orders
- The core company injects most of capital
- Checking functions
- Advice for advancing the project

Place orders with manufacturers, universities, research organizations, etc.
# Development Targets for FaCT Project

## Safety and Reliability

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-1</td>
<td>Ensuring safety equal to future LWR and related fuel cycle facilities</td>
</tr>
<tr>
<td>SR-2</td>
<td>Ensuring reliability equal to future LWR and related fuel cycle facilities</td>
</tr>
</tbody>
</table>

## Sustainability

### Environment Protection

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP-1</td>
<td>Radioactive influence through normal operation no more than future LWR cycle</td>
</tr>
<tr>
<td>EP-2</td>
<td>Emission control of environment transfer substances which can restrict in safety limits</td>
</tr>
</tbody>
</table>

### Waste Management

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WM-1</td>
<td>Reduction of an amount of radioactive waste compared with future LWR cycle</td>
</tr>
<tr>
<td>WM-2</td>
<td>Improvement of waste manageability equal to or more than future LWR cycle</td>
</tr>
<tr>
<td>WM-3</td>
<td>Reduction of radio-toxicity compared with future LWR cycle</td>
</tr>
</tbody>
</table>

## Efficient Utilization of Nuclear Fuel Resources

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UR-1</td>
<td>Breeding performance to enable transition to fast reactor, and its flexibility</td>
</tr>
</tbody>
</table>

## Economic Competitiveness

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC-1</td>
<td>Electric generation cost which can compete with other power plants</td>
</tr>
<tr>
<td>EC-2</td>
<td>Investment risks no more than future LWR cycle</td>
</tr>
<tr>
<td>EC-3</td>
<td>External costs no more than future LWR cycle</td>
</tr>
</tbody>
</table>

## Nuclear Non-Proliferation

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP-1</td>
<td>Adoption of institutional measures and application of technical features which can enhance non-proliferation</td>
</tr>
<tr>
<td>NP-2</td>
<td>System design of physical protection and its development to prevent theft of nuclear materials and sabotage</td>
</tr>
</tbody>
</table>
Innovative Technologies for JSFR

**Economic Competitiveness**

- **Reduction of Mass & Volume**
  - 1. Shortened piping with high chromium steel
  - 2. 2 loop cooling system
  - 3. Integrated pump-IHX component
  - 4. Compact reactor vessel
  - 5. Simplified fuel handling system
  - 6. CV with steel plate reinforced concrete building
  - 7. Advanced fuel material

**Long operation by high burn-up fuel**

- 8. Higher reliable SG with double-walled piping
- 9. Higher reliable SG with double-walled tube
- 10. Higher inspection ability inside of sodium boundary

**Enhanced reliability**

- **Sodium technology**
  - 11. Sodium leak tightness with double-walled piping
  - 12. Higher reliable SG with double-walled tube
  - 13. Higher inspection ability inside of sodium boundary

**Enhanced safety**

- **Core safety**
  - 14. Passive shutdown and decay heat removal
  - 15. Re-criticality free core

- **Seismic reliability**
  - 16. Seismic reliability in core assemblies

**Economic Competitiveness**

- Enhanced reliability
- Enhanced safety

**Innovative Technologies for JSFR**

- Plant design study (D-FR/C-FR)
- Large-scale sodium tests
(1) Thermal Hydraulic of Compact RV

Investigation on
* Gas Entrainment
* Thermal Stratification
* Flow around Slit
* etc.

1/10th scaled upper plenum model

FHM arm can go into UIS through the slit.
(2) Two-loop cooling system

Piping under Flow of High Reynolds Number

1/3-scale Water Test
1) Visualization Test (acrylic resin)
2) Vibration Test (stainless steel)

- Flow Pattern
- Velocity Profile
- Pressure Loss of Elbow
- Pressure Fluctuation
- Natural Frequency/Mode
- Vibration Response

Flow Pattern - Velocity Profile - Pressure Loss of Elbow - Pressure Fluctuation - Natural Frequency/Mode - Vibration Response

(Dye Injection from Inlet)

- Existing Data (up to 3.5x10^5)
- Idelchik Present data (Acrylic pipe at ~15°C or 60°C)
- Present data (Steel pipe at ~15°C)

Reactor condition (hot leg)

- Subcritical regime
- Transition regime
- Postcritical regime

Reynolds Number (-)

10^4 10^5 10^6 10^7 10^8

Present data

Present data
(3) Integrated IHX with Primary Pump

- Pump rotor
- Upper plenum
- Heat exchange tubes
- Baffle plates
- Secondary Na
- Primary Na
- Lower plenum

1/4th scaled model

Operating range

Test:
- Analytical accuracy ± 10%

Analysis
(4) Trial Manufacturing for Double-walled Tube SG

**Trial manufacturing:**
- Mechanically bonded double-walled tube with high Cr steel
- Machine worked CSEJ with high Cr steel

**Components:**
- Inner tube
- Outer tube
- Tube-sheet
- Inlet plenum
- Sodium inlet
- Sodium outlet
- Steam outlet
- Water inlet
- Tube bundle
- Shell bellows (CSEJ)

**Additional Information:**
- Thick (t1000) forged high Cr steel for tube-sheet material
FR Cycle Development Program in JAPAN

<table>
<thead>
<tr>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>(JFY)</th>
<th>~2050</th>
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</thead>
<tbody>
<tr>
<td>Feasibility Study</td>
<td>Commercial Introduction of FR Cycle Technologies</td>
<td>Fast Reactor Cycle Technology Development Project (FaCT)</td>
<td></td>
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<tr>
<td>(JFY 1999-2005)</td>
<td></td>
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<tr>
<td>Identify Most Promising Concept</td>
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<tr>
<td>Experimental FR “Joyo”</td>
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<tr>
<td>Prototype FBR “Monju”</td>
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<tr>
<td>Review &amp; Basic Policy by MEXT &amp;AEC</td>
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<tr>
<td>R&amp;D of Innovative Technologies</td>
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<tr>
<td>Preliminary Design of Commercial &amp; Demonstration FR Cycle Facilities</td>
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<tr>
<td>Commercialized FR Cycle</td>
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<tr>
<td>Conceptual Design of Commercial and Demonstration FR Cycle Facilities, with Providing Necessary R&amp;D Programs</td>
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<tr>
<td>2015</td>
<td></td>
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<tr>
<td>R&amp;D at “Monju”</td>
<td></td>
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<tr>
<td>◆Demonstrating its Reliability as a Nuclear Power Plant</td>
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<tr>
<td>◆Establish Sodium Handling Tech.</td>
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<tr>
<td>2025</td>
<td></td>
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<tr>
<td>Start of Operation of Demonstration FR &amp; its Fuel Cycle Facility</td>
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<tr>
<td>Detailed Design &amp; Construction</td>
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<tr>
<td>~2050</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Commercial Introduction of FR Cycle Technologies</td>
<td></td>
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<tr>
<td>International Cooperation (GNEP, GEN-IV, INPRO etc.)</td>
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◆Cooperation with various Organizations
Schedule of the FaCT Project (Phase 1)
Decision on Innovative Technologies

Acceleration is desirable for continuous pursuit of the FaCT Project.
**Decision on Innovative Technologies**

13 innovative technologies are re-classified into 10 items.

<table>
<thead>
<tr>
<th>Equipment Division</th>
<th>Evaluated Technologies</th>
<th>13 Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core, Fuel</td>
<td>1. High Burn-up Fuel with ODS Cladding Material</td>
<td>⑦</td>
</tr>
<tr>
<td></td>
<td>2. Enhanced Safety</td>
<td>⑪ ⑫</td>
</tr>
<tr>
<td>Reactor Structure</td>
<td>3. Compact Reactor Vessel</td>
<td>④</td>
</tr>
<tr>
<td>Primary Loop</td>
<td>4. 2 Loop Cooling System of Large Piping with High Chromium Steel</td>
<td>① ②</td>
</tr>
<tr>
<td></td>
<td>5. Integrated Pump-IHX Component</td>
<td>③</td>
</tr>
<tr>
<td>Secondary Loop</td>
<td>6. Higher Reliable SG with Straight Double-walled Tube</td>
<td>① ⑨</td>
</tr>
<tr>
<td>DHRS</td>
<td>7. Decay Heat Removal by Natural Circulation</td>
<td>⑪</td>
</tr>
<tr>
<td>BOP</td>
<td>8. Simplified Fuel Handling System</td>
<td>⑤</td>
</tr>
<tr>
<td>Building</td>
<td>9. CV with Steel Plate Reinforced Concrete</td>
<td>⑥</td>
</tr>
<tr>
<td></td>
<td>10. Advanced Seismic Isolation System for SFR</td>
<td>⑬</td>
</tr>
</tbody>
</table>
**International Collaboration**

**Trilateral Collaboration**

**JAEA - DOE - CEA**

"COOPERATION ON SFR DEMO/PROTOTYPES"

Jan.2008 MOU → Aug.2008 revised

**Gen-IV International Forum (GIF)**

12 countries, 1 organization

SFR

Parties: Japan, France, US, Korea, EU, China, (Russia)

SFR Project
- System Integration and Assessment
- Safety and Operation
- Advanced Fuel
- CD · BOP
- GACID (Japan-France-US)

**Japan-France Collaboration**

**JAEA-EDF**


**JAEA-CEA**

Framework Arrangement (Dec. 2005)

**Japan-US Collaboration**

**JNEP** (US-Japan Joint Nuclear Energy Action plan)

*Missions and Objectives were reviewed in Apr., 2009

**Fast Reactor WG**

Fuel cycle WG etc.

**INPRO** (International Project on Innovative Nuclear Reactors and Fuel Cycles)

**TWG-FR** (Fast Reactor Technology Working group)

**IAEA**
The FaCT project launched in 2006. JAEA is carrying out the design and R&D of sodium-cooled fast reactor (SFR) steadily, aiming at the realization of demonstration FR in 2025 and the deployment of commercialization FR around 2050.

The development targets of FaCT project is consistent with the Generation-IV goals.

The FaCT project comes near to the milestone of 2010, when we have to examine and decide continuation to investigate individual innovative technologies.

International collaboration plays an important role in the effective development of FR cycle technology. We would like to encourage international collaboration.