The utilization of the research reactors and associated facilities to support the innovative power reactor and related fuel cycle

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JAPAN ATOMIC ENERGY AGENCY
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Background

• Maintain or increase nuclear power’s present share of 30-40% of Japan’s total power generation beyond 2030 (The time of replacement for the existing plant)
  - Life extension and/or replacement of existing LWR
  - Aim for the realization of demonstration fast breeder reactors and other related facilities by around 2025

• Fix the construction site for International thermonuclear experimental reactor (ITER)

Irradiation study for fuels and materials development is one of the key issues to maintain the present share of nuclear power generation
The role of Oarai Research and Development Center

Provide the irradiation field to support the following items

• Lifetime extension and replacement of the existing plants
• Realization of demonstration plant for FBR
• Fundamental study including the materials research for fusion reactor
Outline of Research Reactor Complex

• Research reactor
  Japan Materials Test Reactor (JMTR), Japan Experimental Fast Reactor “JOYO”, High Temperature Test Reactor (HTTR)

• Post-irradiation examination facilities
  JMTR Hot Laboratory, Fuels Monitoring Facility, Alpha Gamma Facility, Materials Monitoring Facility

• Fuel research facility
  Plutonium Fuel Research Facility

• Other facilities
  International Research Center for Nuclear Materials Science, Tohoku University
# Specification of research reactors

<table>
<thead>
<tr>
<th>RR</th>
<th>JMTR</th>
<th>JOYO</th>
<th>HTTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutron Flux(n/m^2\cdot s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast Neutron</td>
<td>(4 \times 10^{18})</td>
<td>(4 \times 10^{19})</td>
<td>(7 \times 10^{17})</td>
</tr>
<tr>
<td>Thermal neutron (Total)</td>
<td>(4 \times 10^{18})</td>
<td>-</td>
<td>(2 \times 10^{17})</td>
</tr>
<tr>
<td>Coolant temperature (C)</td>
<td>(light water)</td>
<td>(sodium)</td>
<td>(helium)</td>
</tr>
<tr>
<td>Inlet</td>
<td>49(max.)</td>
<td>350</td>
<td>395</td>
</tr>
<tr>
<td>Outlet</td>
<td>56</td>
<td>500</td>
<td>950</td>
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</table>
Neutron Spectrum of Research reactors in ORDC
Research activity of ORDC
- major activity -

- For existing reactor (LWR)
  - IASCC research of aging problem for LWR
    - focus to in-situ experiment
  - Safety research for high burnup fuels of LWRs

- For innovative reactor (such as FBR)
  - In-pile creep rupture test for FBR cladding materials
  - Advanced fuel behaviour under neutron field
  - Investigation of minor actinide containing MOX fuel

- For other activities
  - high temperature materials for HTTR
  - fundamental study including fusion materials research
Re-assembling work of irradiation capsule for in-situ IASCC test
Specimens for In-situ IASCC Experiment
(Work is conducted in the hot cell)

Measurement of crack length using the DC-PDM
Irradiation Test Subassemblies for JOYO
Irradiation field of JOYO

1. Fuel region (450~750°C)
2. Reflector region (400~700°C)
3. Upper core region (550°C~)
4. Irradiation hole outside reactor vessel (200~600°C)

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<thead>
<tr>
<th></th>
<th>Unit: n/cm²·s</th>
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<tbody>
<tr>
<td></td>
<td>Total neutron flux</td>
<td>Fast neutron flux (E ≥ 0.1MeV)</td>
</tr>
<tr>
<td>1</td>
<td>(4~5) × 10^{15}</td>
<td>(3~4) × 10^{15}</td>
</tr>
<tr>
<td>2</td>
<td>10^{14} ~ 10^{15}</td>
<td>3 × 10^{13} ~ 2 × 10^{15}</td>
</tr>
<tr>
<td>3</td>
<td>10^{11} ~ 10^{12}</td>
<td>10^{10} ~ 10^{11}</td>
</tr>
<tr>
<td>4</td>
<td>~ 10^{12}</td>
<td>~ 10^{10}</td>
</tr>
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</table>
Irradiation Technology of JOYO

- **Noninstrumental irradiation vehicles**
  - Neutron dosimetry
  - Off-line temperature monitor
    
    (TED, Melt wire, SiC etc.)

- **Instrumental irradiation vehicles**
  - loading position
    core, upper plug, ex-vessel
  - measurement object
    temperature, pressure, fission gas etc.
Monitoring of Creep Rupture

**MARICO**
- Core
- Capsule (Temperature Controlled)
- Gas Gap
- Specimen
- Gas Inlet Line
- Gas Exhaust Line
- Thermocouple
- Capsule
- Specimen
- Capsule
- Thermocouple

**Structure of MARICO**

**Loading into Reactor**

**Cover Gas Line (Ar)**
- Gas Sampling for RIMS (tag gas)
- On-line Gamma-ray Monitor (activation nuclide of tag gas)
- Gas Chromatography (He)

**Gas Exhaust Line**
- Gas Gap
- Specimen
- Thermocouple
- Gas Inlet Line
- Gas Exhaust Line

**A-A Section**
Cladding
(6.9 φ × 42.5mm)
End plug
Tagging gas (0.3 φ mm)
Before irradiation
After irradiation
In-pile creep test sample
Leser welding

Material testing rig with temperature control

Put the sample into the canister in irradiation vehicle

RIMS
Breach detection for in-pile creep rupture test by tagging gas analysis and radioactivity measurement of cover gas

Reassemble the capsule in MARICO irradiation vehicle
Fuel Examination Facilities

- JMTR Hot Laboratory
- Canals
- AGF
- JAEA
- FMF
- MMF
- Tohoku University container
- Actinide Examination Facility
- NFD
- Oarai site
- Chemcial processing Facility (CPF)
- Tokai site
- PFRF
- Tohoku University
- RFEF

15 km
Remote fabrication technology for Am-MOX fuel

Operation Area of AGF

Remote fabrication apparatuses in the hot cell

Pre-sintering Furnace
Sintering Furnace
Pin manufacturing and inspection
X-ray inspector
Pellet inspection
Shielded cell
Pressing unit

Grinder
Material feeder
Ball mill

Sintered pellet of Am-MOX

(U_{0.66}Pu_{0.29}Am_{0.05})O_2

O/M: 2.00
O/M: 1.99
Facilities Utilization for MA related Research

- **MMF**
  - PIE of core and structural material

- **FMF**
  - PIE of irradiated S/A
  - Intermediate inspection of S/A
  - Construction of irradiation rig and S/A

- **AGF**
  - PIE and analysis of irradiated fuel
  - Am-MOX fuel fabrication
  - Advanced fuel research

- **PFRF**
  - Pu, MA fuel

- **JOYO**
  - Irradiation for fuels and materials
  - Development of advanced irradiation Vehicle

- **Collaboration**
  - Oarai Branch, Tohoku University

- **CPF**
  - MA supply

- **High purity Ar gas glove boxes**
Application of X-ray computer tomography technology to fuel subassembly inspection
1.0 \times 10^0 \quad 1.0 \times 10^1 \quad 1.0 \times 10^2 \quad 1.0 \times 10^3 \quad 1.0 \times 10^4 \quad 1.0 \times 10^5

4.0 \quad 4.5 \quad 5.0 \quad 5.5 \quad 6.0 \quad 6.5 \quad 7.0

Energy / MeV

Counts

Am-241, Pu-238, Cm-243, 244

Cm-242

Pu-239, 240

Am-243

Cm-243

Operation Area of AGF

Solution of Am Sample in V-capsule irradiated in JOYO

Glove box for sample preparation

Mass spectrometer

Some of equipment for chemical analysis for actinides and burnup

In-cell equipment (EPMA)
Example of transmutation behavior for Np and Am irradiated in JOYO
Actinide research facility
Oarai branch, Tohoku Uni.

Nuclear magnetic resonance spectrometer

SQUID type magnetic fluxmeter

$^{241}\text{Am-MgO}$

MgO

Close collaboration with Orai branch, Tohoku University in the area of actinide related study
Future perspective
Provide the research field for irradiation study include outside researchers
Mutually complementary relationship

Research reactors complex in Oarai site
Research reactor complex for irradiation study
Achieve the user friendly facility

- Increase the operating rate of reactor
- Develop the excellent Irradiation technology and PIE technology suitable for user’s needs
- Shorten the turnaround time
- Realize the reasonable irradiation and PIE cost
- Establish the simple irradiation procedure and satisfied technological support system to use more easily (improve the accessibility and usability)
This vehicle is used for the fuels, which are difficult to conduct under current JOYO license because of uncertainly of their irradiation behavior.

The compartment is equipped with a capsule which has sufficient strength to withstand the stress which arises at fuel cladding failure, and with capability to catch fuel particle which is released from cladding breach.

### Possibility under License

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<td><strong>MA Contents</strong></td>
<td>$\leq 50 %$</td>
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</table>
| **Melting Area of pellet**| Oxide: $\leq 20 \%$
                        | Others: No Melt |
| **Burn up**              | $\leq 200 \text{ GWd/t}$ |
Conclusion

- ORDC provides all sort of research facilities as the research ground for lead researchers in the field of irradiation study, and serves cultivation field as young researchers also.

- Improvement the quality of reactor irradiation technology such as in-situ measurement and coupling irradiation technologies with specially designed irradiation vehicles and the PIE technology are going on under close relationships with university persons as users.

- Investigation to manage the RR complex as an international center of excellence is in progress.