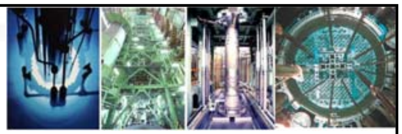
Japan Atomic Energy Agency



NSRR ROSA/LSTF NUCEF JMTR

Safety Research in Japan: Current Priorities and Future Perspective

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Presented at
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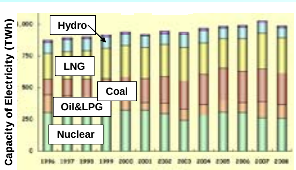
Washington, March 2011

Outline

- Current Status and Future of Nuclear Power in Japan
- Safety Research with High Priority
  - Material Degradation and Aging
  - Behavior of High-Burnup Fuel under RIA
  - HLW Geological Disposal
- Safety Research for Future
  - Advanced LWRs: "Next Generation LWRs"
  - FBR
  - HTGR
- Summary: Safety Research Needs and Challenges

Current Status and Future of Nuclear Power in Japan



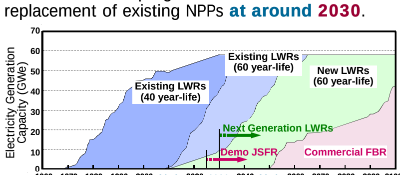
JNES, Current Status of Nuclear Facilities in Japan (2009)

- Currently, **54 NPPs** in operation.
- Nuclear power supplies ca. 30% of total.
- 3 out of 7 units in Kashiwazaki-Kariwa NPS have restarted after the earthquake in 2007.

As of end of 2009

	BWR	PWR	GCR	Total
In operation	30	24	0	54
Under construction	2	0	0	2
In preparation for construction	9	3	0	12
Under decommisioning	2	0	1	3

- Development of "**Next Generation LWRs**" in progress in industries supported by METI/ANRE for replacement of existing NPPs **at around 2030**.
- "**FaCT Project**" also in progress in JAEA jointly with industries targeting:
  - Start operation of "**Demo-JSFR** (~750MWe)" in **2025**.
  - **Commercial use of FBRs** (~1,500MWe) from **~2050**.

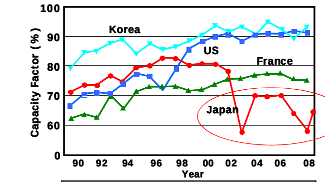


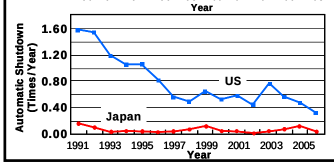
Current Topics: Revised "Basic Energy Plan"

3

(Cabinet, June 2010)

- Basic concept, **"3E"** : **E**nergy Security, **E**nvironment, **Economic Efficiency**
  - Nuclear power: a principal energy source satisfying "3E" concurrently.
  - Build **9 units till 2020** and **at least 5 more till 2030** with a target to achieve **90% of capacity factor**.





- Strong initiative of industries to "**Maximum Use of Current Fleets**"
  - **LTO**: plant life beyond 60 years
  - Power Uprate (not done yet)
  - Longer Operating Cycle*
    - Burnup Extension
    - On-line Maintenance, etc.
- High expectation from developmental side toward more "effective and efficient" regulation:
  - **Risk-informed**,
  - Performance-based, etc.

* NISA has started a new inspection system since Jan. 2009. Now, the periodic inspection is to be done every 13, 18 or 24 months (previously 13 months only).

Safety Research with High Priority (1)
- Material Degradation and Aging -

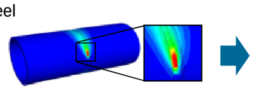
4

- **Aging Management Technical Evaluation (AMTE)** is required before entering **30-year operation** and following every 10 years.
- **19** units completed 30th year AMTE, among which **3** completed 40th year AMTE.
- In AMTE, all the safety related SSCs are evaluated by **assuming 60 year-operation**, focusing on the following **6 phenomena**:

1. **Neutron irradiation embrittlement of RPV**	2. **Irradiation assisted SCC** (IASCC)
3. Low cycle fatigue	4. Thermal aging of duplex stainless steels
5. Insulation degradation of electric cables	6. Defradation of strength / shielding capabilities of Concrete

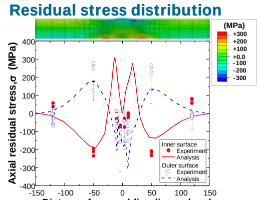
- **Study on structural integrity at JAEA**
  - **Residual stress** simulation for piping welded joint related to SCC in low-carbon stainless steel

Welding simulation



- Development of highly-accurate thermal-elastic-plastic **analysis tool**
- **Experiments** for V&V

Residual stress distribution



Material Degradation and Aging
- Neutron Irradiation Tests with Refurbished JMTR -

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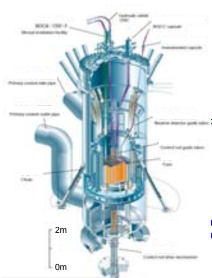
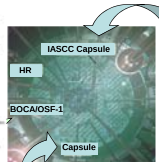
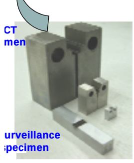
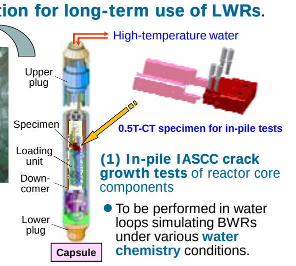
- **JMTR** (Japan Materials Testing Reactor) will be restarted in **2011**.
- Tests will be started on **aging degradation for long-term use of LWRs**.



JMTR
- Power: 50 MW
- First criticality: March 1968
- Tank type LWR







(1) In-pile IASCC crack growth tests of reactor core components
- To be performed in water loops simulating BWRs under various **water chemistry** conditions.

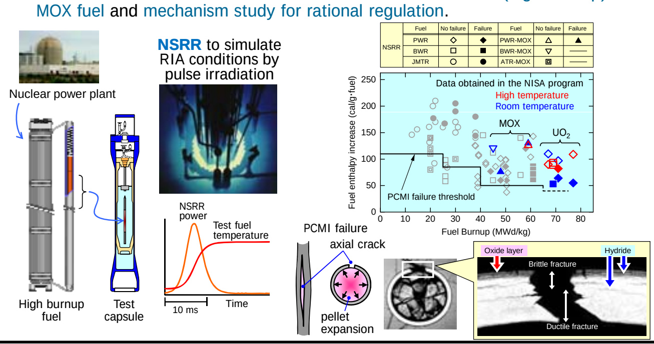
(2) RPV high-neutron irradiation tests
- Up-to1 inch thickness-CT specimens of Japanese A533B and A508 steels
- Verification of fracture toughness **Master Curve** issues, e.g., specimen size effect.

Safety Research with High Priority (2)

- Behavior of High-Burnup Fuel under RIA:Reactivity Initiated Accident -

6

- Urgent research needs exist to confirm safety in **burnup extension** which enables effective implementation of long cycle operation and power uprate.
- JAEA also contributes to data accumulation for extensive use (high burnup) of MOX fuel and mechanism study for rational regulation.



Safety Research with High Priority (3)

- High-level Radioactive Waste (HLW) Geological Disposal -

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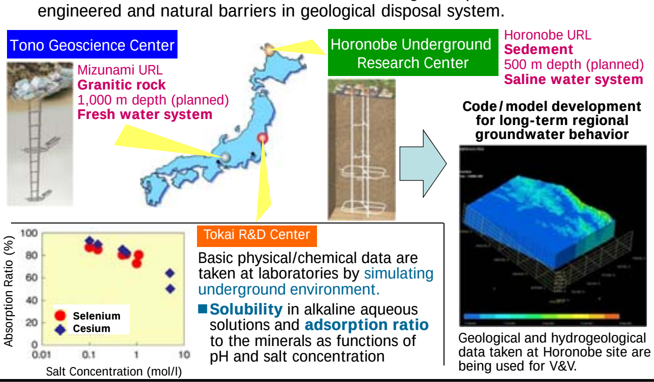
- Research on HLW in JAEA has focused on the long-term performance of the engineered and natural barriers in geological disposal system.

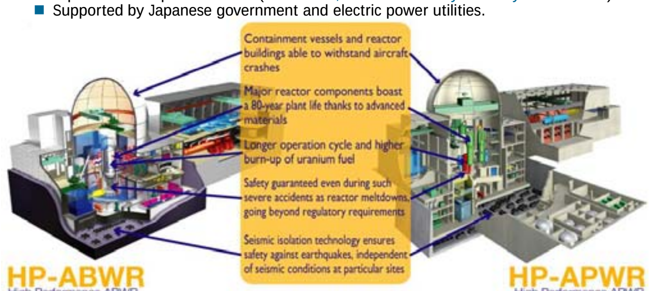


Safety Research for Future (1)

- High-Performance (HP) Next Generation LWRs -

8

- Top-level safety and most economical efficiency featured by:
  - Safety design with **hybrid of passive and active**
  - **Shortened construction period** and **reduced power generation costs**
- Electric output of **1,800 / 800 - 1,000 MWe** depending on user needs
- Conceptual design through collaboration of Institute of Applied Energy and Japanese three plant vendors (Hitachi-GE, Mitsubishi Heavy Industry and Toshiba)
- Supported by Japanese government and electric power utilities.



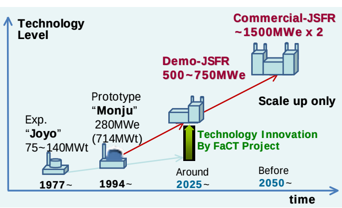
High-Performance (HP) Next Generation LWRs
- R&D for Use of 5-10wt% Enrichment Fuel -

9

- **Advantages toward Sustainability of Nuclear Power**
  - **Reduction of spent fuel** (30 ~35%) and **saving of natural uranium** (~10%) through efficient burning of uranium of high enrichment fuel
  - **Reduction of fuel cycle cost** (~10%) by implementing longer cycle operation and power uprate together with burnup extension to 70GWd/t (90GWd/t for PWR SUS cladding)
- Expectations for International Partnership
  - Broad issues related to all fuel cycle process for practical use of 5-10% enrichment fuel
  - Encourage international discussions within **NEA Framework** on relevant issues (such as design requirements for fuel cycle facilities, international standards for UF_6 cylinders, impact on reprocessing, etc.)
  - First step: Establish safety database
    - Acquisition of new criticality experimental data in 2015 in Japan, and
    - Co-operation with **NEA criticality safety database** (International handbook of evaluated criticality safety benchmark experiments)

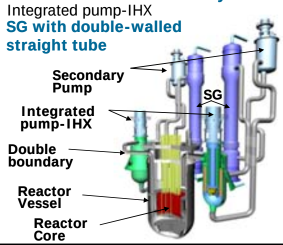
Safety Research for Future (2)
- Toward Commercialization of FBR -

10



Items	Specifications
Power	3,570MWt (1,500MWe)
Number of loops	2
Primary sodium temp. and pressure	550 /395 ℃ Atmospheric Pressure
Secondary sodium temp.	520 / 335 ℃
Fuel type	TRU-MOX
Breeding ratio	Break even ~ 1.2

- **Major Design Characteristics**
  - Compact reactor system with **two loops** of large piping
  - **Double boundary** against sodium leak
  - **Steel plate reinforced concrete containment vessel (SCCV)**
  - **Passive shutdown system and re-criticality free core**
  - Advanced **seismic isolation system**
  - Integrated pump-IHX
  - **SG with double-walled straight tube**



Toward Commercialization of FBR
- R&D for **SCCV** Aiming at Compact CV (Containment Vessel) -

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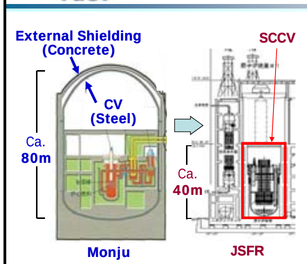
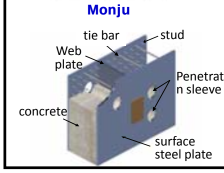
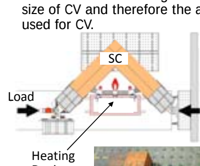
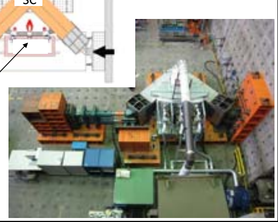


- In Monju, CV was designed to cope with sodium fire caused by re-criticality during CDA (Core Disruptive Accident).
- "Re-criticality free" design of JSFR enables to reduce the design load to CV.
- Double coolant boundary also allows to suppress the challenge on CV
- **R&D for SCCV** is being done to drastically reduce the size of CV and therefore the amount of materials to be used for CV.



SC: Steel plate reinforced concrete



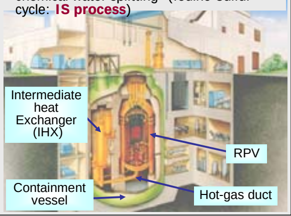


Safety Research for Future (3)
- R&D for Industrial Applications of HTGR -

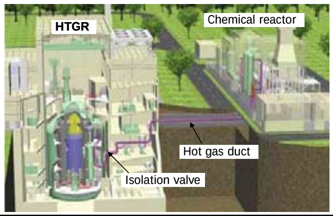
12

- **HTGR** is a promising high-temp. energy source for various industrial applications including **hydrogen production**.

HTTR (High Temperature Engineering Test Reactor):
- Graphite-moderated and helium-cooled HTGR with **30MWt**
- First criticality achieved in 1998
- Coolant temp. of **950℃** achieved in 2004
- 50days high temp. operation in 2010.
- **Hydrogen production** by "Thermo-chemical water splitting" (Iodine-Sulfur cycle: **IS process**)



- **Intrinsically safe characteristics** of HTGR combined with H_2 production can contribute to realize "CO_2-free Society"
- R&D for **coupling** between HTGR and H_2 production system is in progress:
  - **High temperature isolation technologies** such as isolation valves
  - **Safety design guides** and **safety analysis codes**

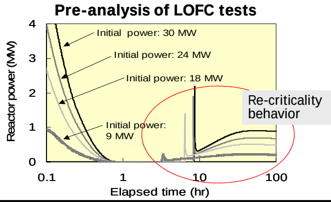


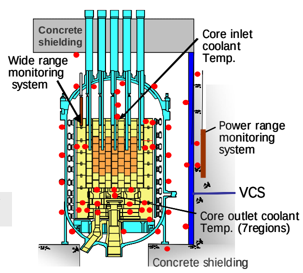
R&D for Industrial Applications of HTGR
- Safety Demonstration Tests at HTTR -

13

- **HTGR** could be proven to be safe enough to realize "**Evacuation -Free**" concept even without containment.
- "**Safety Demonstration Tests**" are being conducted as a **OECD/NEA joint research project** and demonstrate its intrinsic safety characteristics during **total loss-of-forced cooling (LOFC) without scram.**
- Major Areas of interests:
  - Cooling of RPV through conduction, convection, and **radiation**
  - Temperature-**reactivity feedback** during ATWS

Pre-analysis of LOFC tests



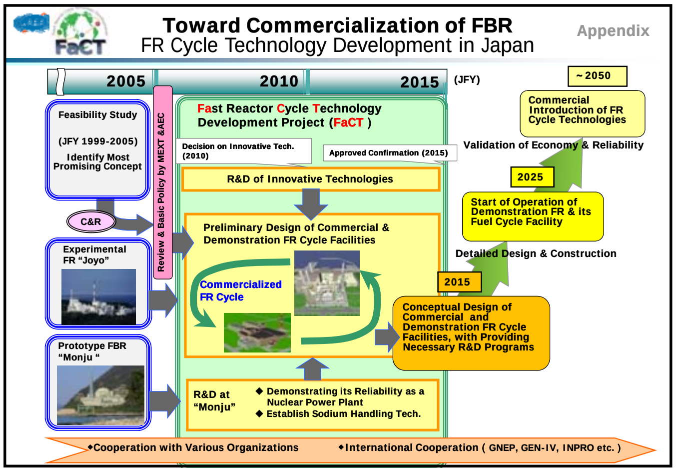


● **Thermo-couple position**

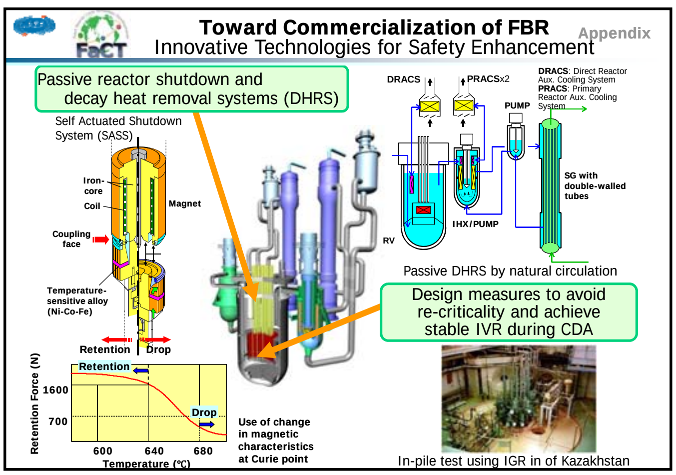
Summary: Safety Research Needs and Challenges

14

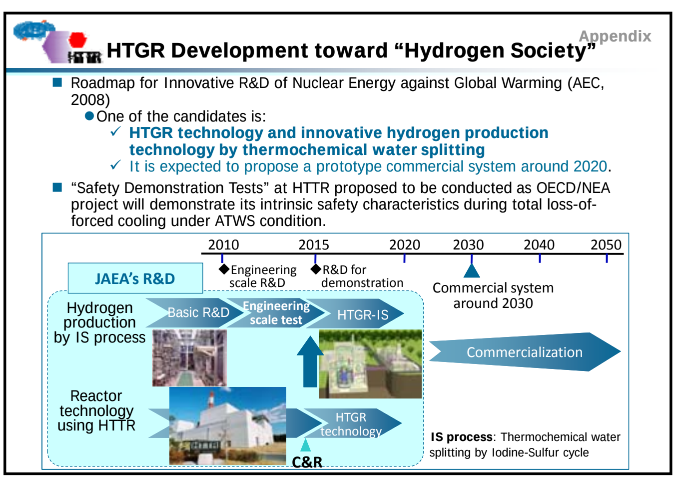
- Initiative of industries to "**Maximum Use of Current Fleets**"
  - Aging evaluation assuming beyond 60-year operation
  - Longer cycle operation, power uprate, burnup extension of UO_2 and MOX fuel, application of burnup credit, etc.
- High expectation toward more "effective and efficient" regulation: **More risk informed approach**
  - On-line maintenance, extension of AOT, RI-ISI, etc.
  - Consensus building on Risk-Informed Decision-Making (RIDM) process
- Introduction of **new systems with new technologies** aiming at higher safety and economic efficiency
  - Safety evaluation of seismic base isolation, higher enrichment fuel, etc.
  - Use of BE/CFD codes: more accurate evaluation of safety margin
  - Safety evaluation of design provisions against severe accidents
- **Public expectation for "Lower Risks"** for future plants
  - R&D for optimum design to reduce risks while enhancing efficiency
- **key for future:** "How to maintain infrastructure for safety research (facilities and human resources)"



Toward Commercialization of FBR
FR Cycle Technology Development in Japan
Appendix
2005
2010
2015
(JFY)
~2050
Commercial Introduction of FR Cycle Technologies
Validation of Economy & Reliability
Feasibility Study
(JFY 1999-2005)
Identify Most Promising Concept
Review & Basic Policy by MEXT &AEC
Fast Reactor Cycle Technology Development Project (FaCT)
Decision on Innovative Tech. (2010)
Approved Confirmation (2015)
R&D of Innovative Technologies
2025
Start of Operation of Demonstration FR & its Fuel Cycle Facility
C&R
Preliminary Design of Commercial & Demonstration FR Cycle Facilities
Detailed Design & Construction
Experimental FR "Joyo"
Commercialized FR Cycle
2015
Conceptual Design of Commercial and Demonstration FR Cycle Facilities, with Providing Necessary R&D Programs
Prototype FBR "Monju"
R&D at "Monju"
◆ Demonstrating its Reliability as a Nuclear Power Plant
◆ Establish Sodium Handling Tech.
◆Cooperation with Various Organizations
◆International Cooperation (GNEP, GEN-IV, INPRO etc.)



Toward Commercialization of FBR
Innovative Technologies for Safety Enhancement
Appendix
Passive reactor shutdown and decay heat removal systems (DHRS)
Self Actuated Shutdown System (SASS)
Iron-core
Coil
Magnet
Coupling face
Temperature-sensitive alloy (Ni-Co-Fe)
Retention
Drop
Retention Force (N)
1600
700
600
640
680
Temperature (°C)
Use of change in magnetic characteristics at Curie point
DRACS
PRACSx2
PUMP
DRACS: Direct Reactor Aux. Cooling System
PRACS: Primary Reactor Aux. Cooling System
SG with double-walled tubes
IHX/PUMP
RV
Passive DHRS by natural circulation
Design measures to avoid re-criticality and achieve stable IVR during CDA
In-pile test using IGR in of Kazakhstan



HTGR Development toward "Hydrogen Society"
Appendix
■ Roadmap for Innovative R&D of Nuclear Energy against Global Warming (AEC, 2008)
●One of the candidates is:
✓ HTGR technology and innovative hydrogen production technology by thermochemical water splitting
✓ It is expected to propose a prototype commercial system around 2020.
■ "Safety Demonstration Tests" at HTTR proposed to be conducted as OECD/NEA project will demonstrate its intrinsic safety characteristics during total loss-of-forced cooling under ATWS condition.
2010
2015
2020
2030
2040
2050
JAEA's R&D
◆Engineering scale R&D
◆R&D for demonstration
Commercial system around 2030
Hydrogen production by IS process
Basic R&D
Engineering scale test
HTGR-IS
Commercialization
Reactor technology using HTTR
HTGR technology
C&R
IS process: Thermochemical water splitting by Iodine-Sulfur cycle