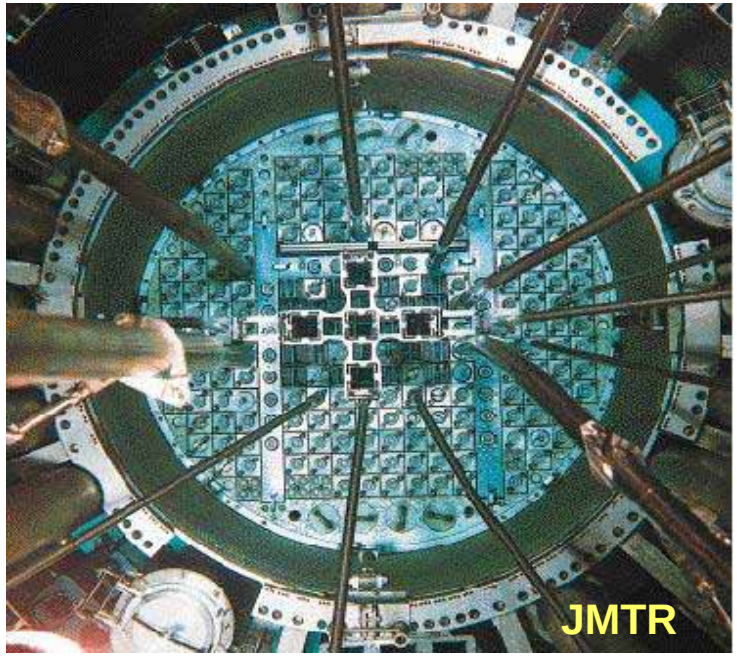
Outlines and Status of Safety Research on Fuels and Materials using JMTR



A part of the program is being conducted under a contract with the Nuclear and Industrial Safety Agency of the Ministry of Economy, Trade and Industry.

Sep. 28 – 30, 2009

2nd International Symposium on Material Test Reactors, Idaho Falls, USA

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Fuel and Material Irradiation Tests in JMTR

To obtain integrity evaluation data of fuel and materials under irradiation conditions for higher performance uses of LWRs, e.g. power up rating, longer operation cycles and modified water chemistries for lifetime extension of the plants.

Fuel Irradiation Tests

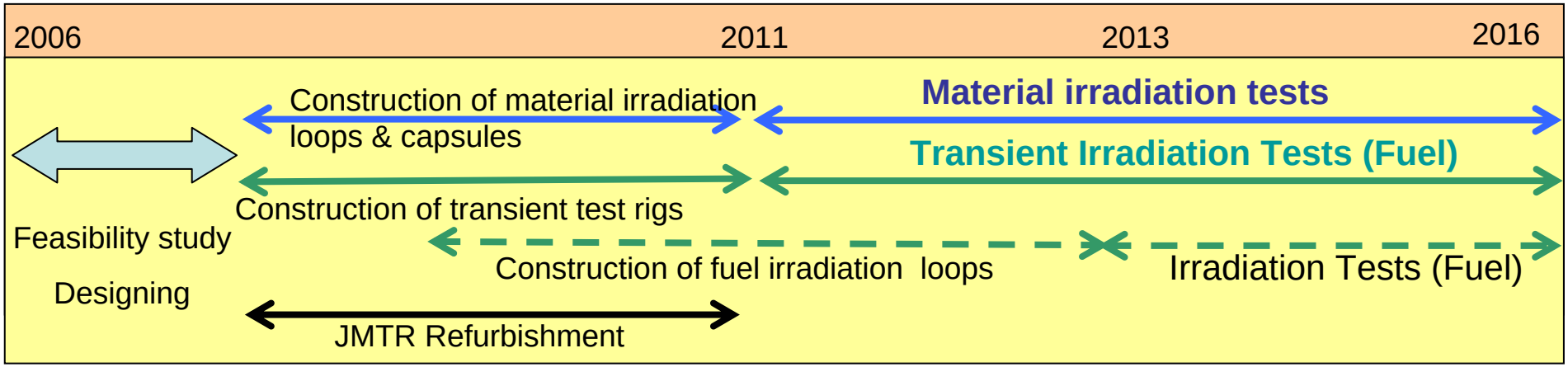
- Transient tests under power ramping conditions (Facility preparation in progress)
- Irradiation tests under high duty conditions, such as high rod internal pressure, uprated power and high burnups (Design finished and proposed)

Material Irradiation Tests

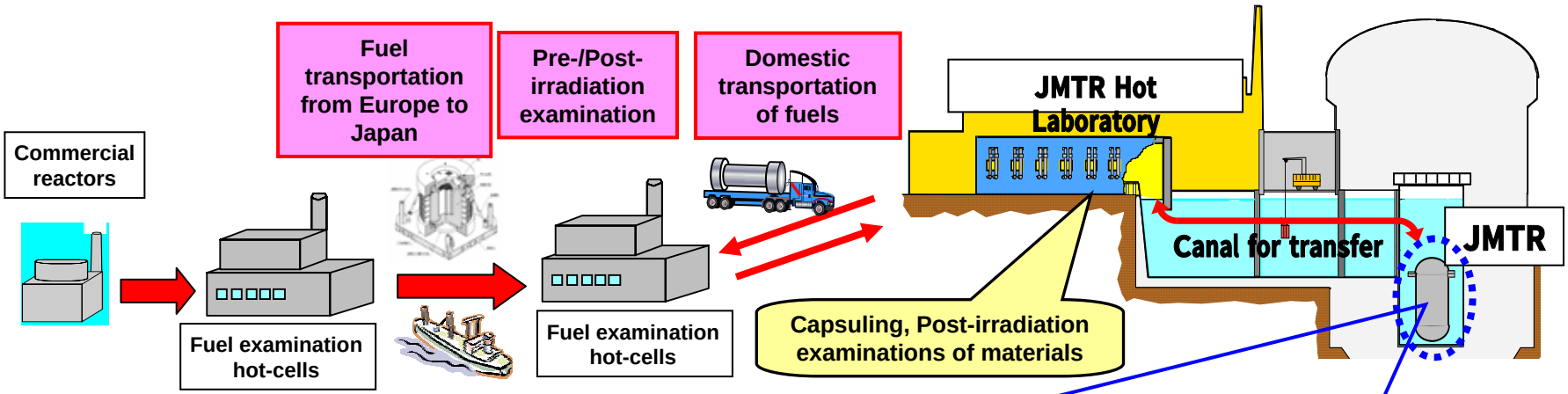
(Facility preparation in progress)

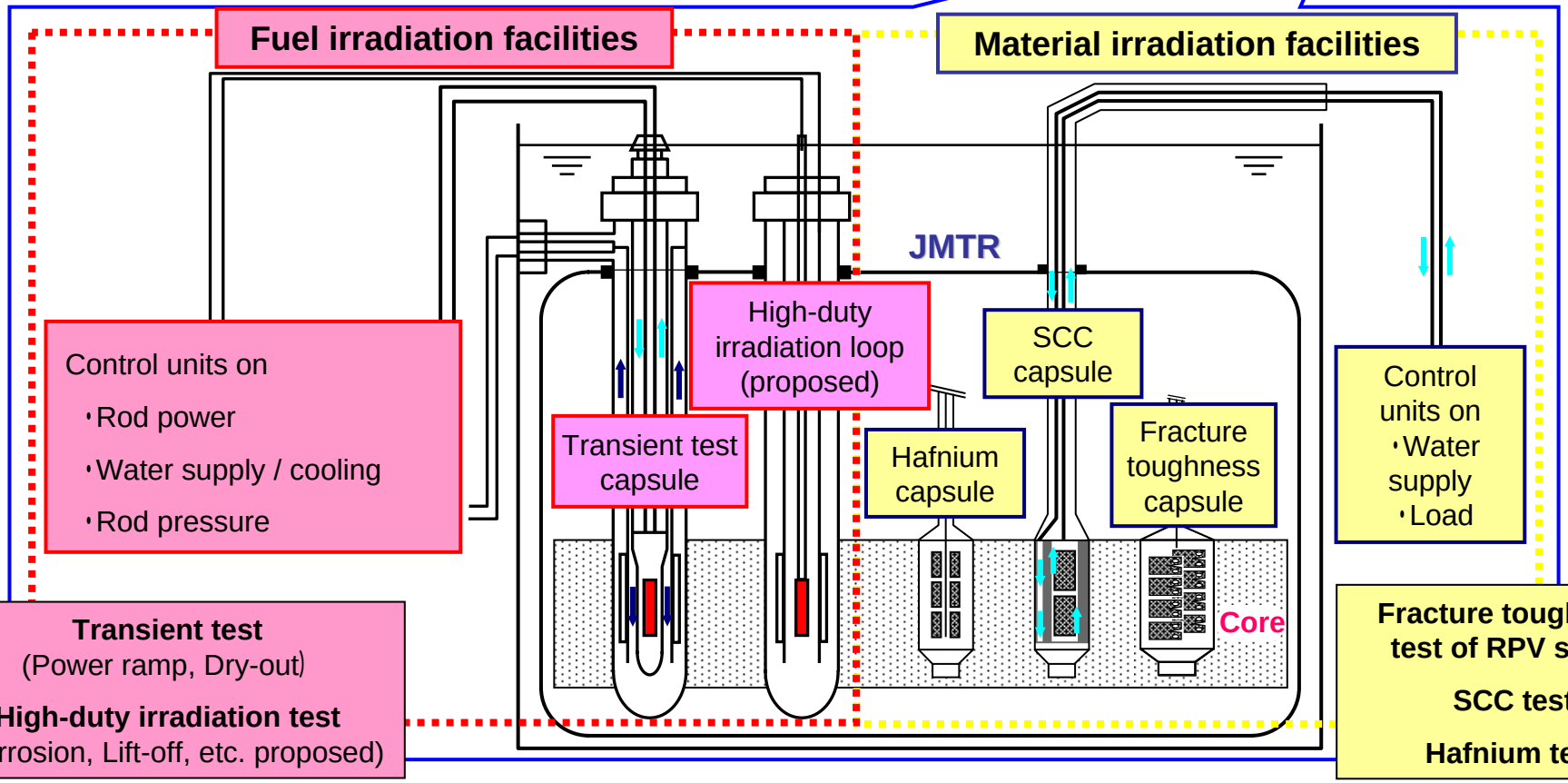
- Fracture toughness tests of reactor vessel materials
- Stress Corrosion Crack growth and water chemistry tests under irradiation conditions
- Irradiation stability tests of Hafnium plates for control rods

Schedule

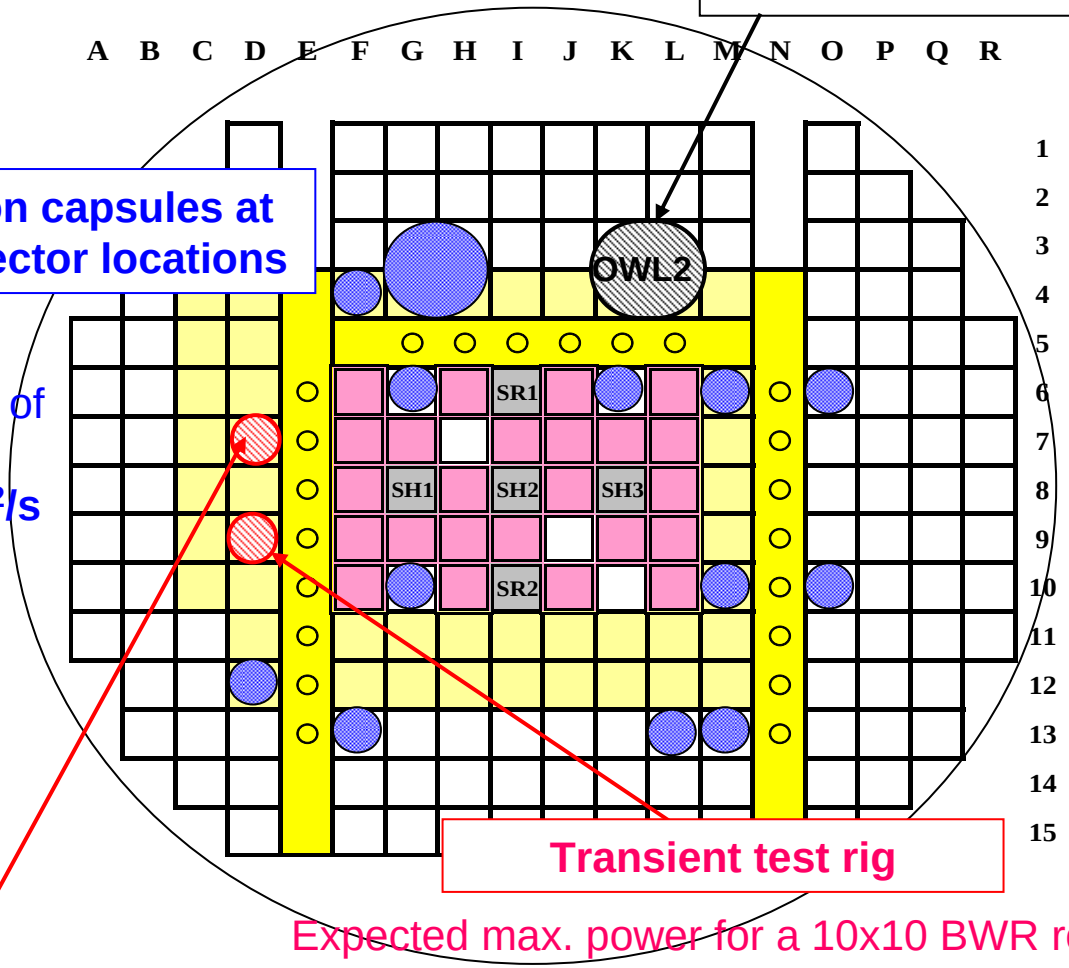


New Fuel and Material Irradiation Tests in JMTR





JMTR core configuration and test capability



Old fuel irradiation loops at lower flux

Expected max. power for 10x10 BWR rods (70GWd/t) in 2x2 bundle configuration:

about 15kW/m

Material irradiation capsules at various Be/Al reflector locations

Low to High flux irradiation in a range of about
$1x10^{16}$ - $1x10^{18}$ $n/m^2/s$ (E >1MeV)

Driver fuel
Control rods
Be frame
Be reflector
Al reflector

Transient test rig

Expected max. power for a 10x10 BWR rod (70GWd/t) :**about 55kW/m**

Expected max. power for 10x10 BWR rods (70GWd/t) in 2x2 bundle configuration : **about 25kW/m**

Candidate location for high duty fuel irradiation test rig

Fuel Irradiation Tests in JMTR

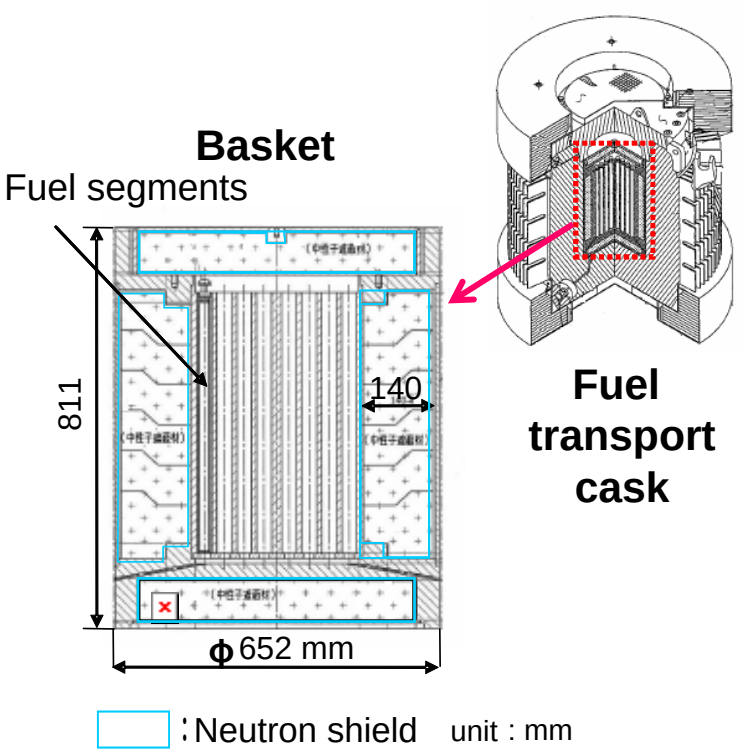
Transient Test (preparation on going)

- Fuel integrity data under abnormal transients, e.g. power ramps, and performance data for model development and safety analyses
- Online measurement of fuel temperature, rod internal pressure, etc.
- Effective capsule handing in the canal-connected hot laboratories followed by detailed pre/post-test examination

Candidate fuel rods

Cladding	Pellet	Burnup
Zry-2 GNF-Ziron NFI-HiFi	Standard additive	～75GWd/t

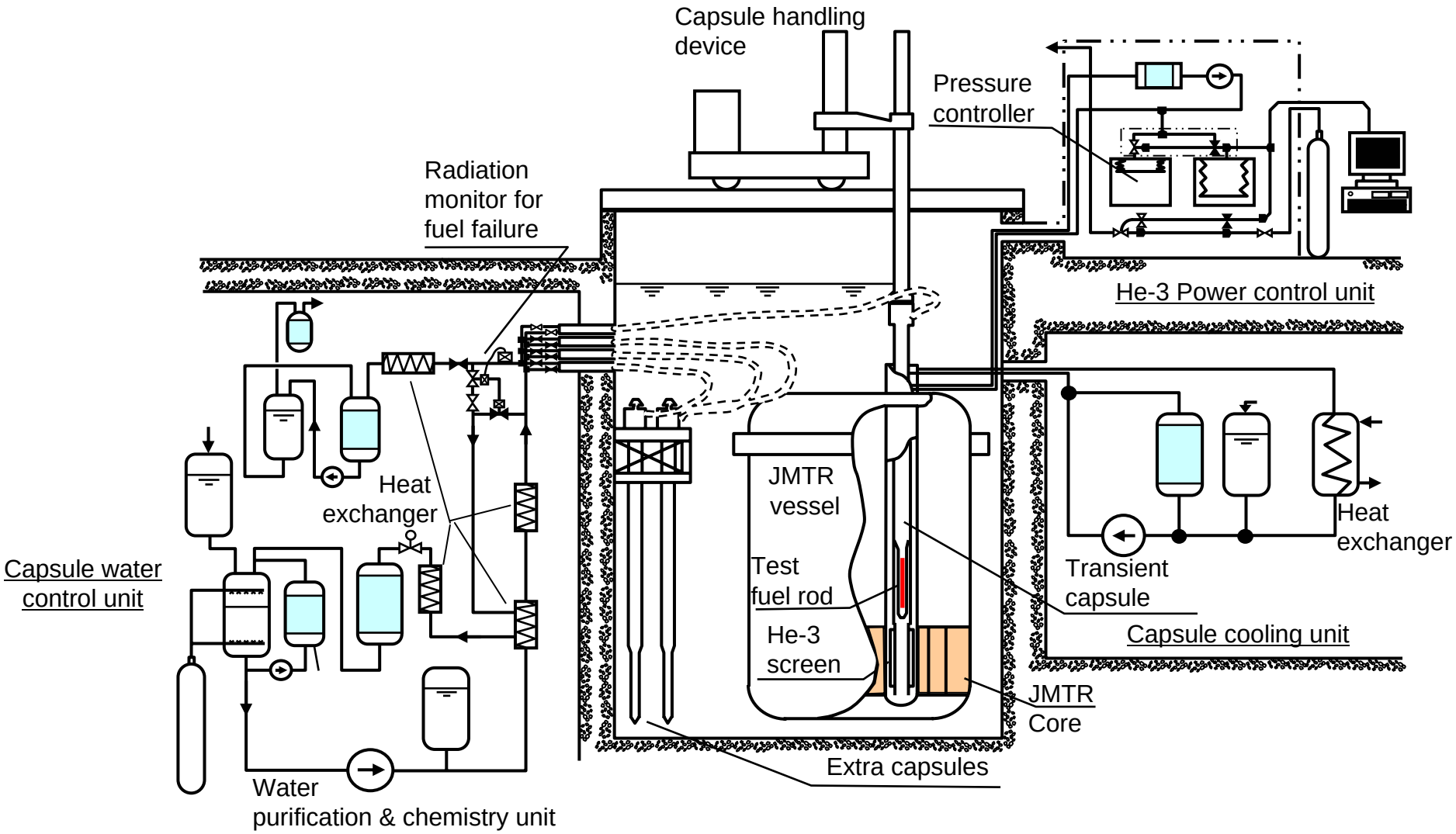
BU type cask, which is capable of containing 50 segments(50 cm long, is being prepared for expected international transportation from Europe in 2010 and 2013



Transient Tests (Preparation on going)

Types of capsules for power and cooling transients are being designed. (Natural and forced convection capsules for power transients)

On-power handling and independent power control system for effective operation



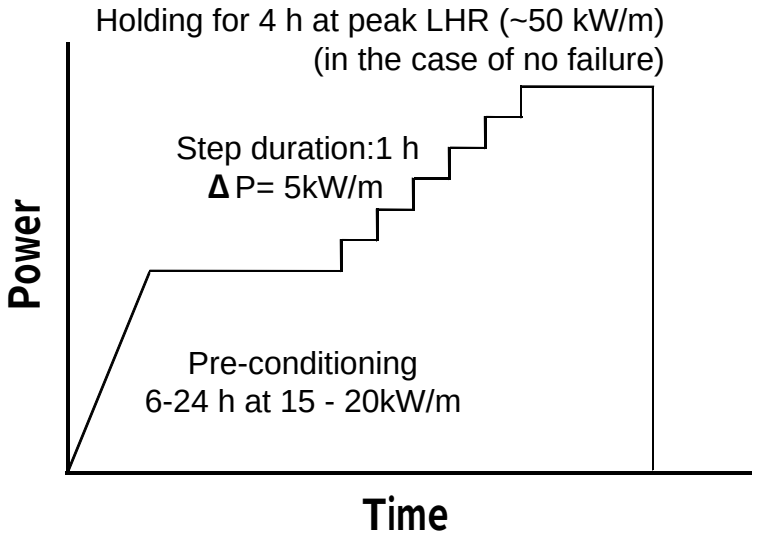
Power transient tests under LWR conditions

[Cooling conditions]

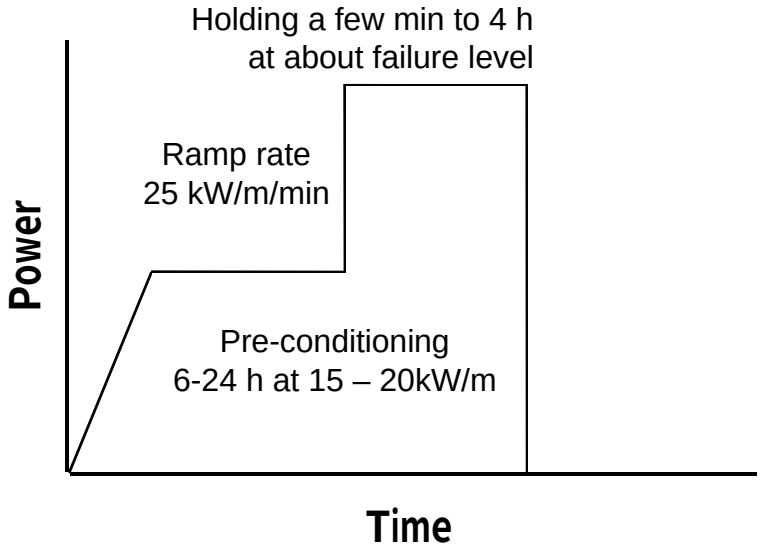
- ✓ Natural circulation capsule, well experienced for BWR tests (preparation on going)
- ✓ Forced convection capsule (proposed for future tests)

[Power ramping mode]

- ✓ Power ramping 1 : Multiple step ramp mode for scoping tests
- ✓ Power ramping 2 : Single step ramp mode to obtain the fuel failure threshold.



Multi step ramp

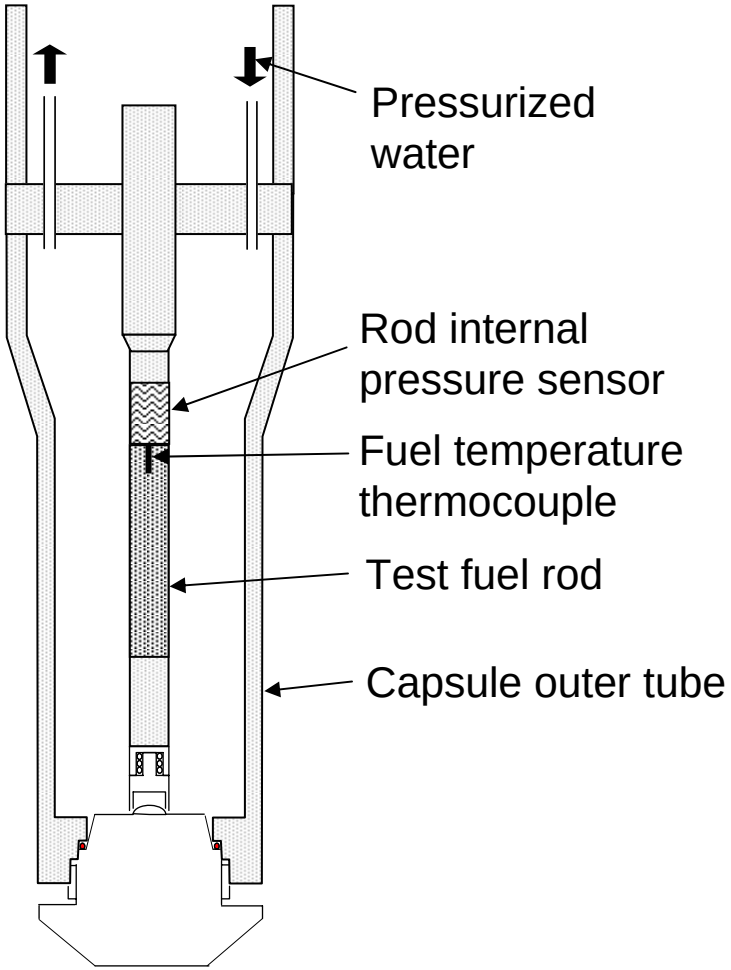


Single step ramp

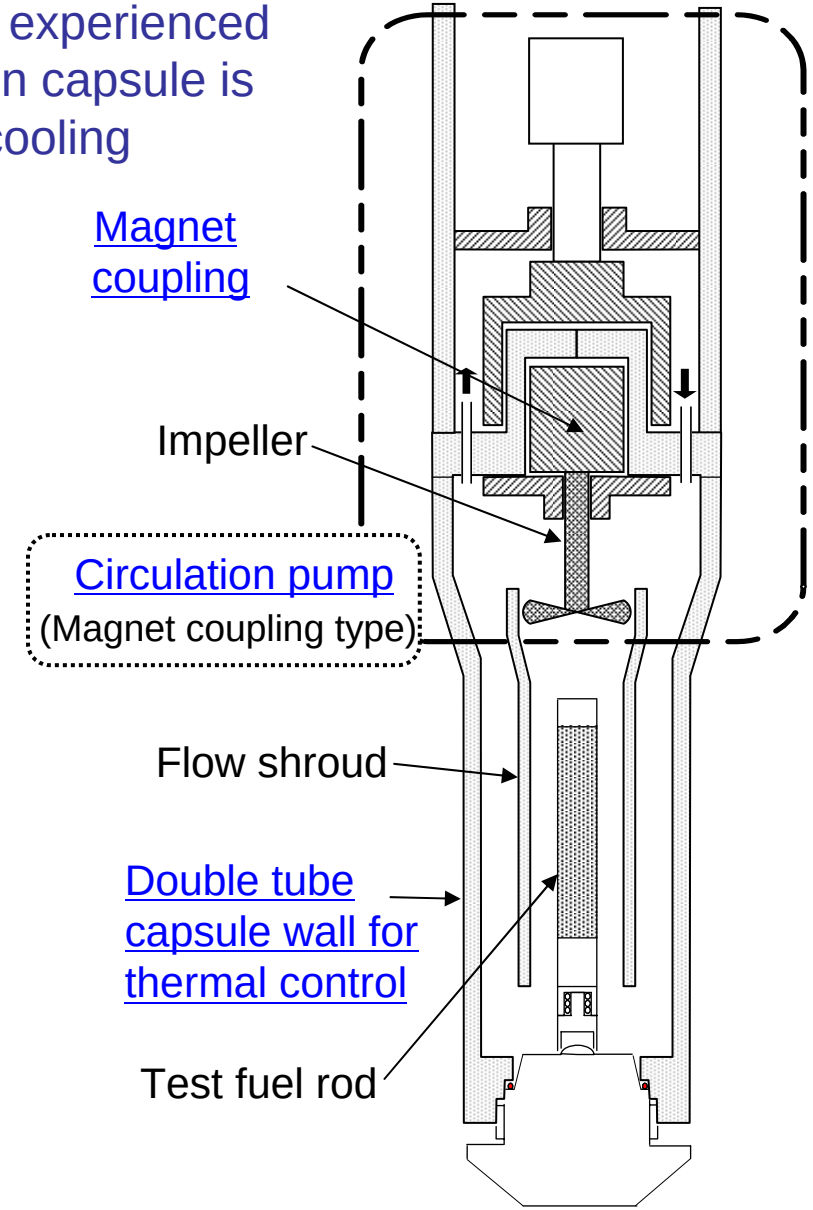
Expected max. liner heat rates for transient tests
about 55kW/m for BWR & PWR fuel rods at 70GWd/t

Schematic configuration of power transient test capsules

In addition to natural convection capsules, well experienced in JMTR for BWR fuel tests, a forced convection capsule is being developed for better simulation of LWR cooling conditions avoiding boiling transitions.

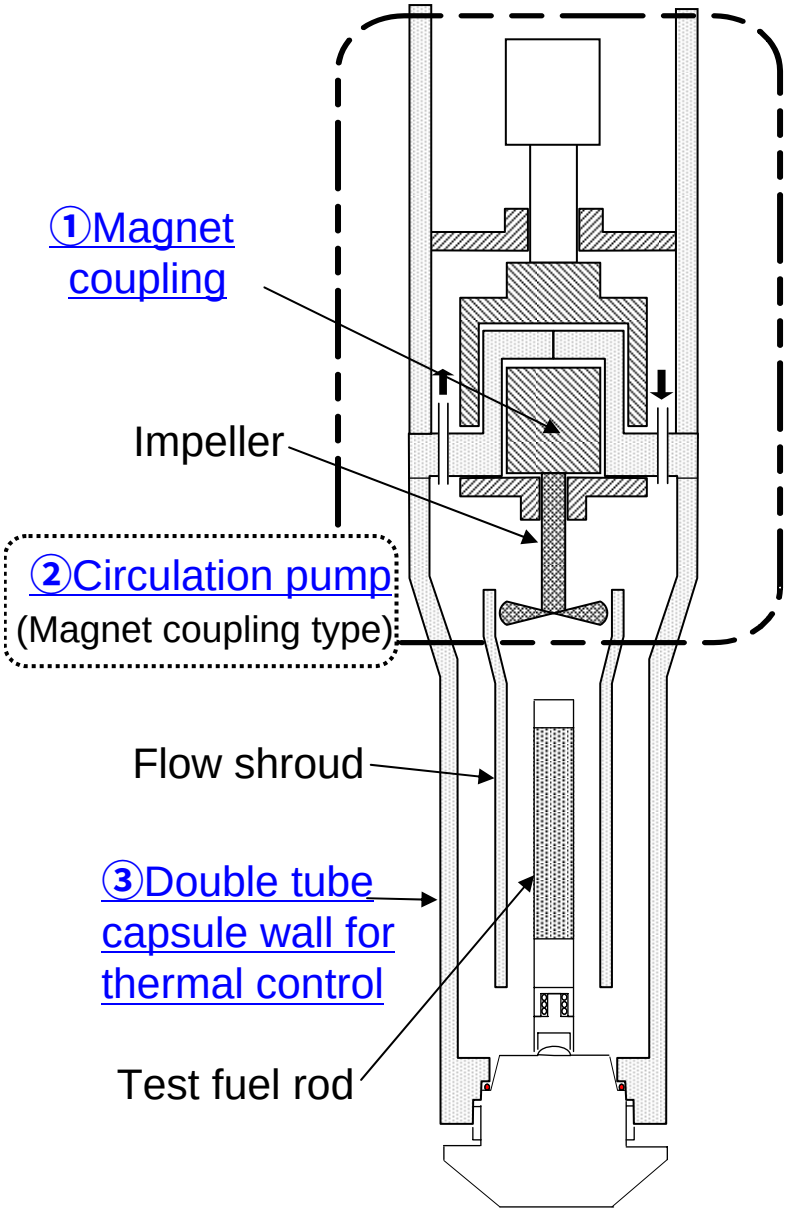


Natural convection capsule



Forced convection capsule (under development)

Development of forced convection capsule



Element tests

① Magnetic coupling torque at high temperatures

Torque of the magnet coupling at high temperatures was examined. Reduction of the torque was limited to be about 35% at 280℃, which was high enough for the pump.

Temperature ℃	Torque N・m
RT	0.45
280	0.29

② Circulation capability of magnet coupling pump

Forced convection as high as about 2 m/s was achieved by small magnetic coupling type pump (Φ40mm, 200mm long, excluding motor) with screw and volute type impellers in a mock-up capsule.

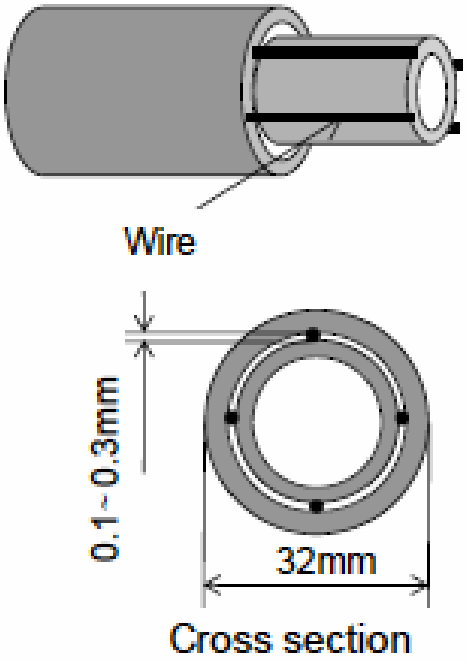
③ Double tube for thermal control

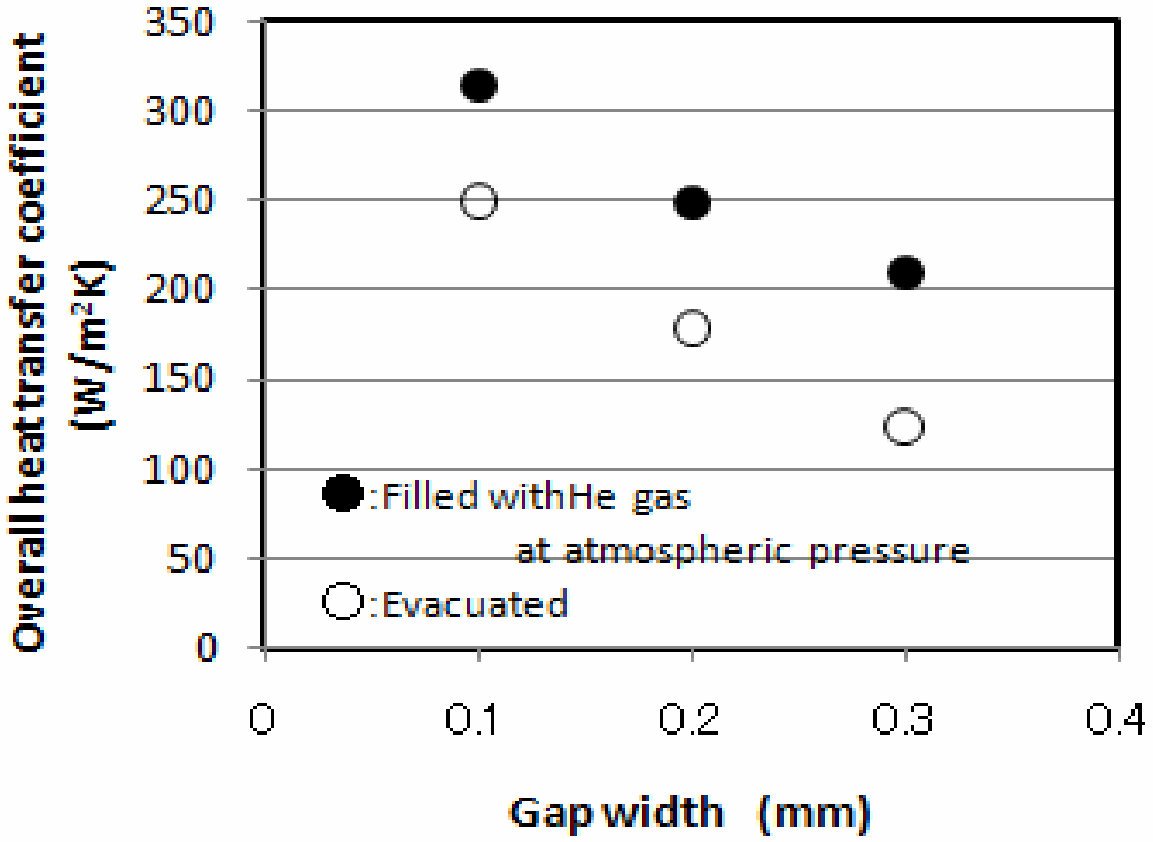
Thermal resistance controllability by gap gas condition in the double tube was examined for coolant temperature control.

Thermal resistance control by double tube

③ Double tube for thermal control

Thin gapped duplex tubes were test pieced by drawing with wire spacing. Overall heat transfer coefficients of the tubes under He filled and evacuated gap conditions were measured, in order to examine thermal controllability with the technique. Results will be used to design the feasible forced convection capsules operated at high temperatures.





Material Irradiation Tests in JMTR

To obtain integrity and aging evaluation data of reactor core components and vessels for high performance and long-term use of LWRs

Fracture toughness tests (preparation on-going)

Fracture toughness of irradiated reactor vessel steel will be examined by the Charpy, 0.4T-CT and 1T-CT specimens, in order to examine specimen size effects on the Master Curve evaluation.

In-pile IASCC test (preparation on-going)

・Irradiation Assisted Stress Corrosion Crack (IASCC) growth tests of type 316L stainless steel
・Water chemistry tests

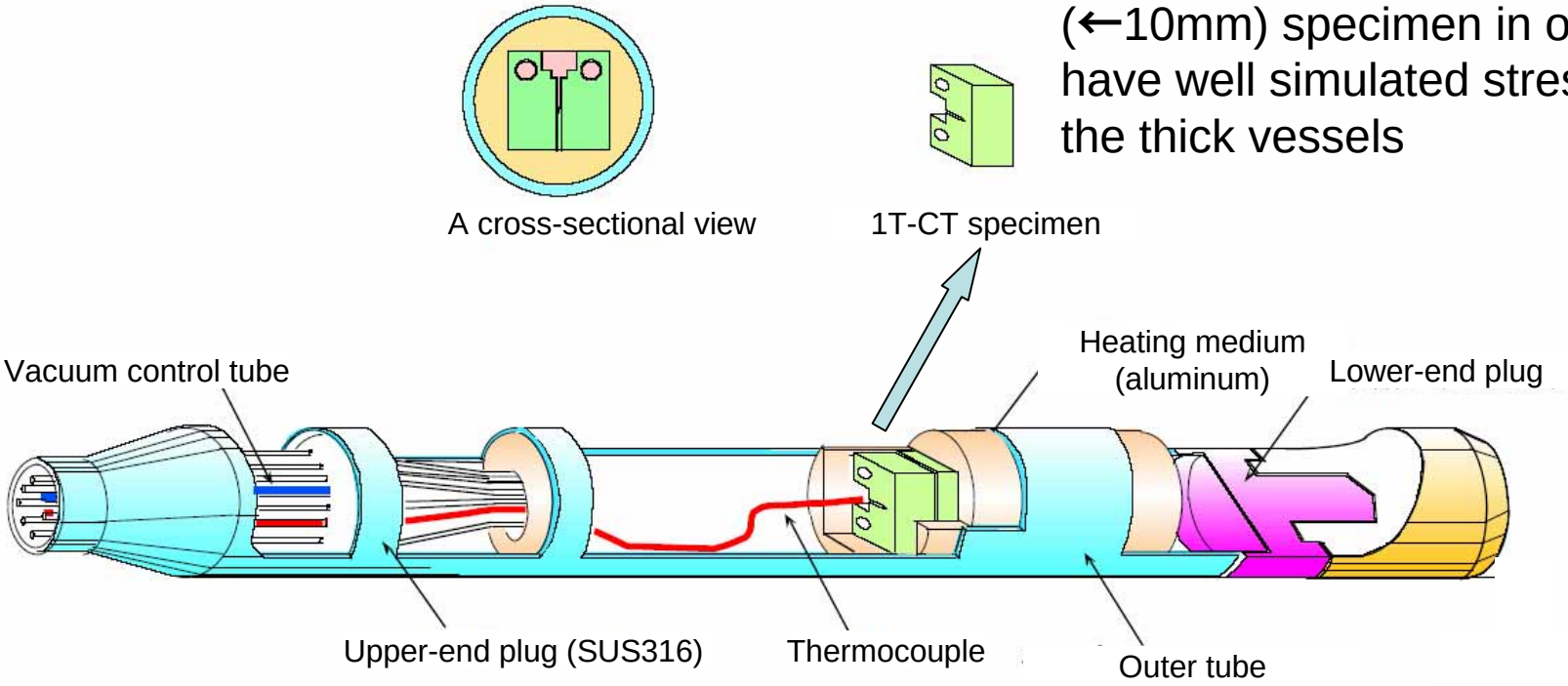
Irradiation stability tests of Hafnium plates for control rods (pre-test on-going)

Irradiation growth of Hf for control rods will be examined. The unexpected corrosion in the gap between stainless steel ad Hf plates and large irradiation growth of Hf caused the SCC troubles of Japanese BWR control rods.

Fracture toughness tests

To evaluate irradiation embrittlement of the reactor pressure vessel steels for long term uses of LWRs, fracture toughness of the vessel material will be investigated with larger-size specimens.

Tests with thicker 1T-CT 25mm (←10mm) specimen in order to have well simulated stress field of the thick vessels

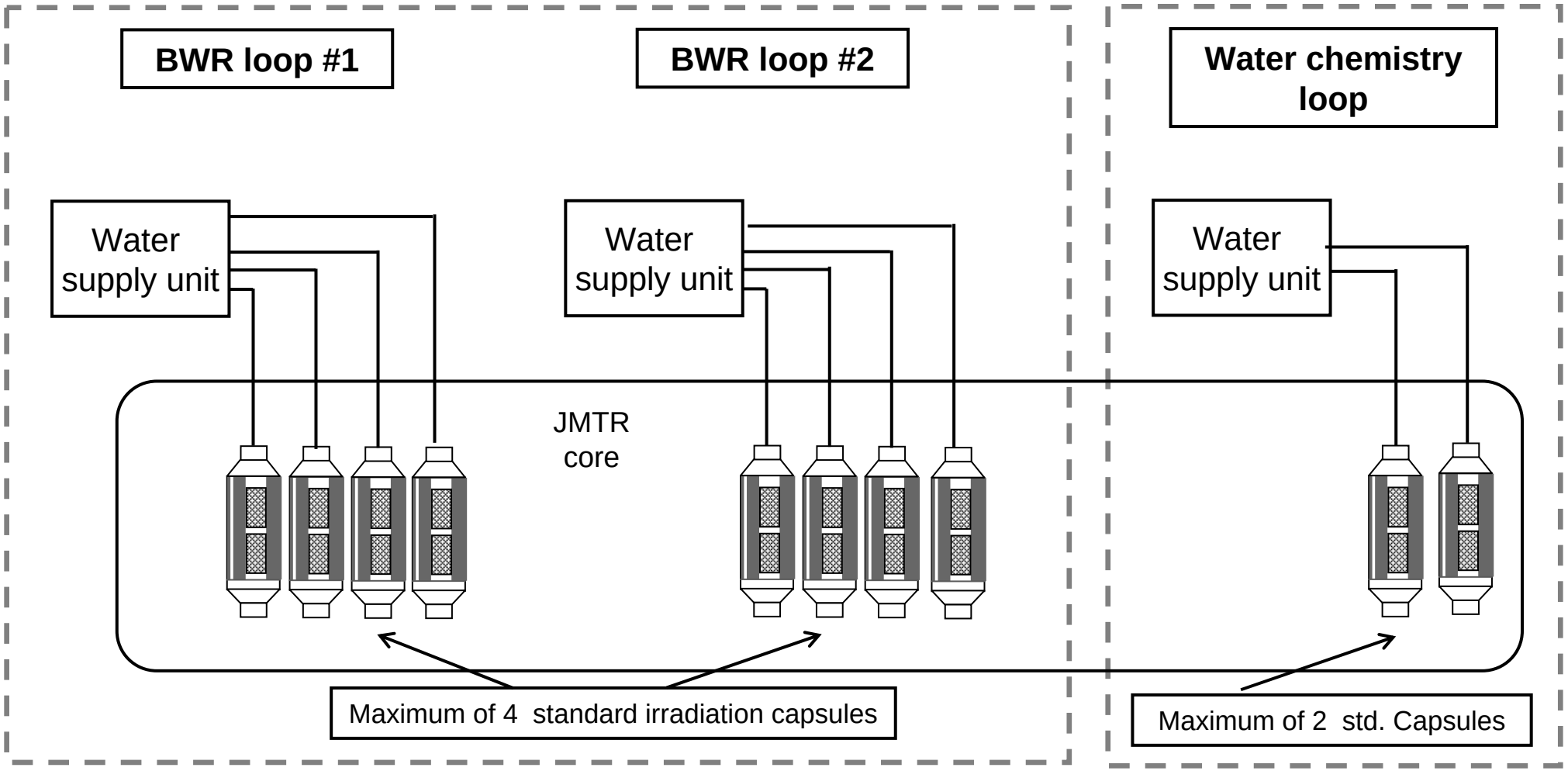


Test capsules to be installed in the JMTR

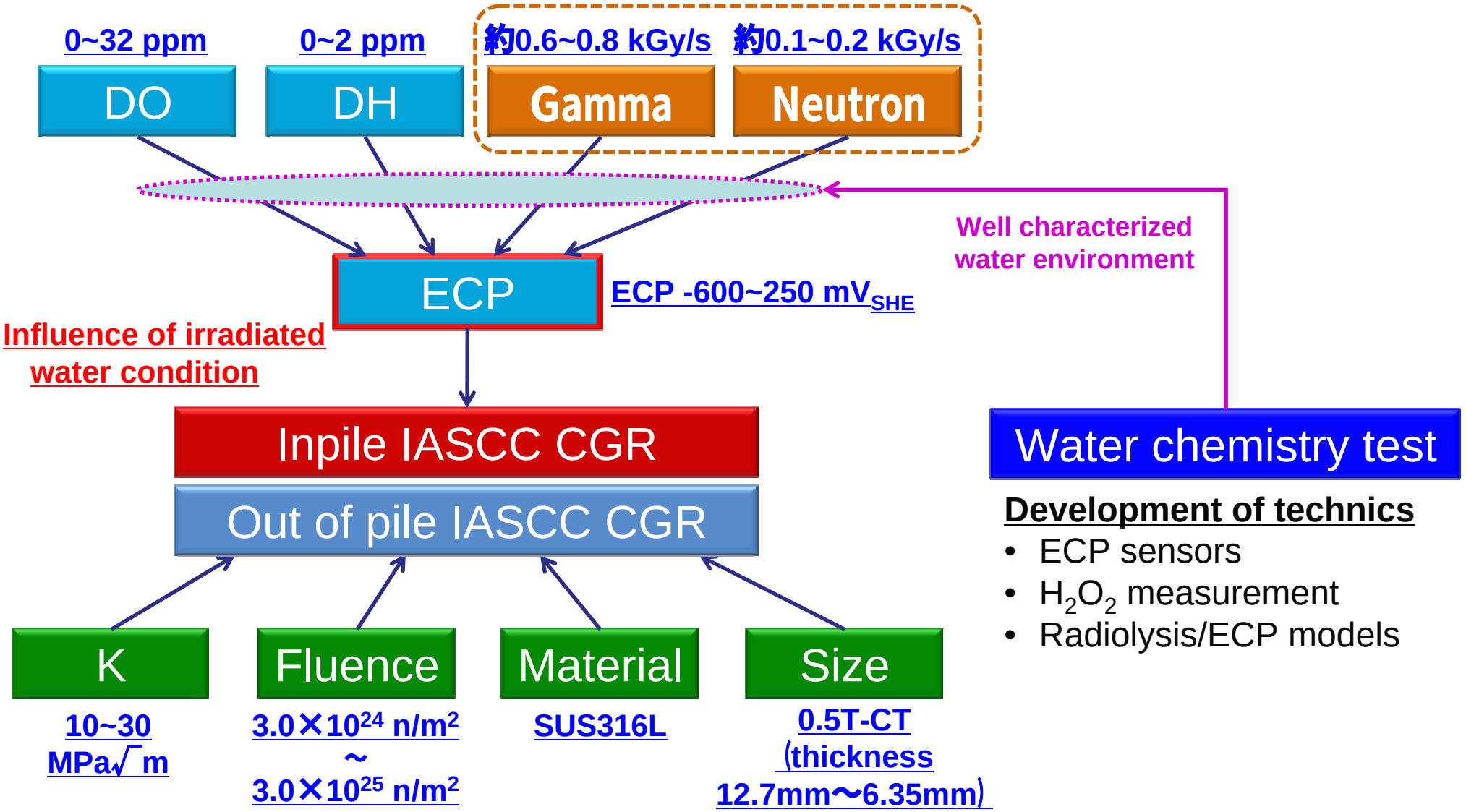
- Fast neutron (E>1MeV) flux : about 4 x 10^{16} n/m^2/s
- fluence : above 5 x 10^{23} n/m^2 for 1T-CT

Crack growth and water chemistry tests

Three loops for material irradiation are being constructed in the JMTR. Two are for IASCC cracking growth study under BWR conditions. One is for water chemistry study under BWR/PWR conditions.



Main test parameters



Development of technics

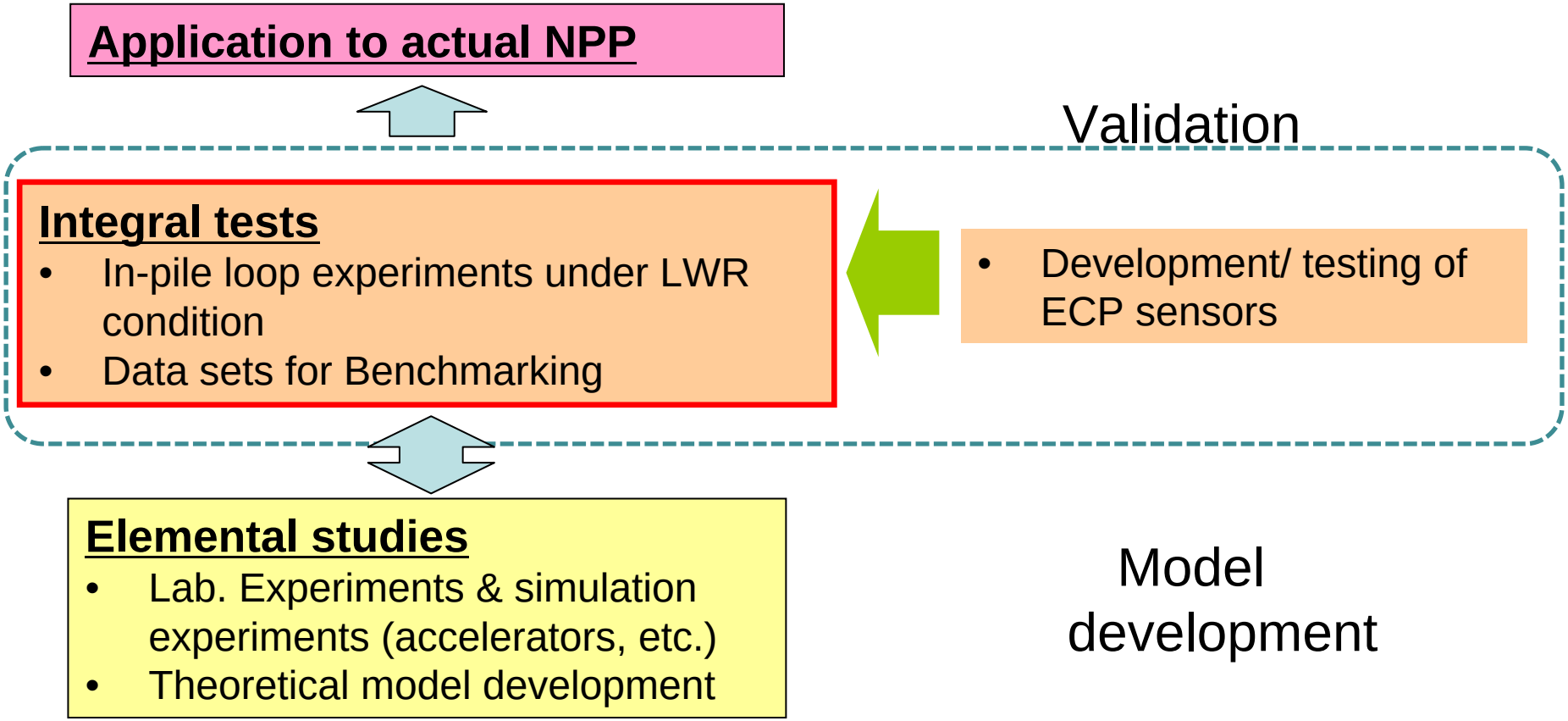
- ECP sensors
- H_2O_2 measurement
- Radiolysis/ECP models

Water Chemistry Tests

Water chemistry related issues on material degradation, such as corrosion/ hydrogen absorption, could be examined with the water loops for material irradiation.
Radiolysis / ECP (Electrochemical Corrosion Potential) model validation program is initiated through the in-pile loop tests

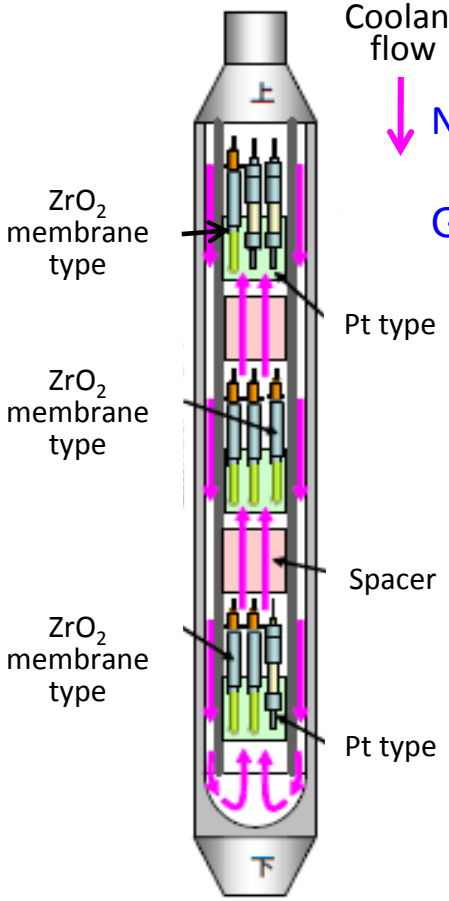
① ANERI project data in LVR15 reactor in NRI Czech

② JMTR water chemistry tests planned to start in 2013

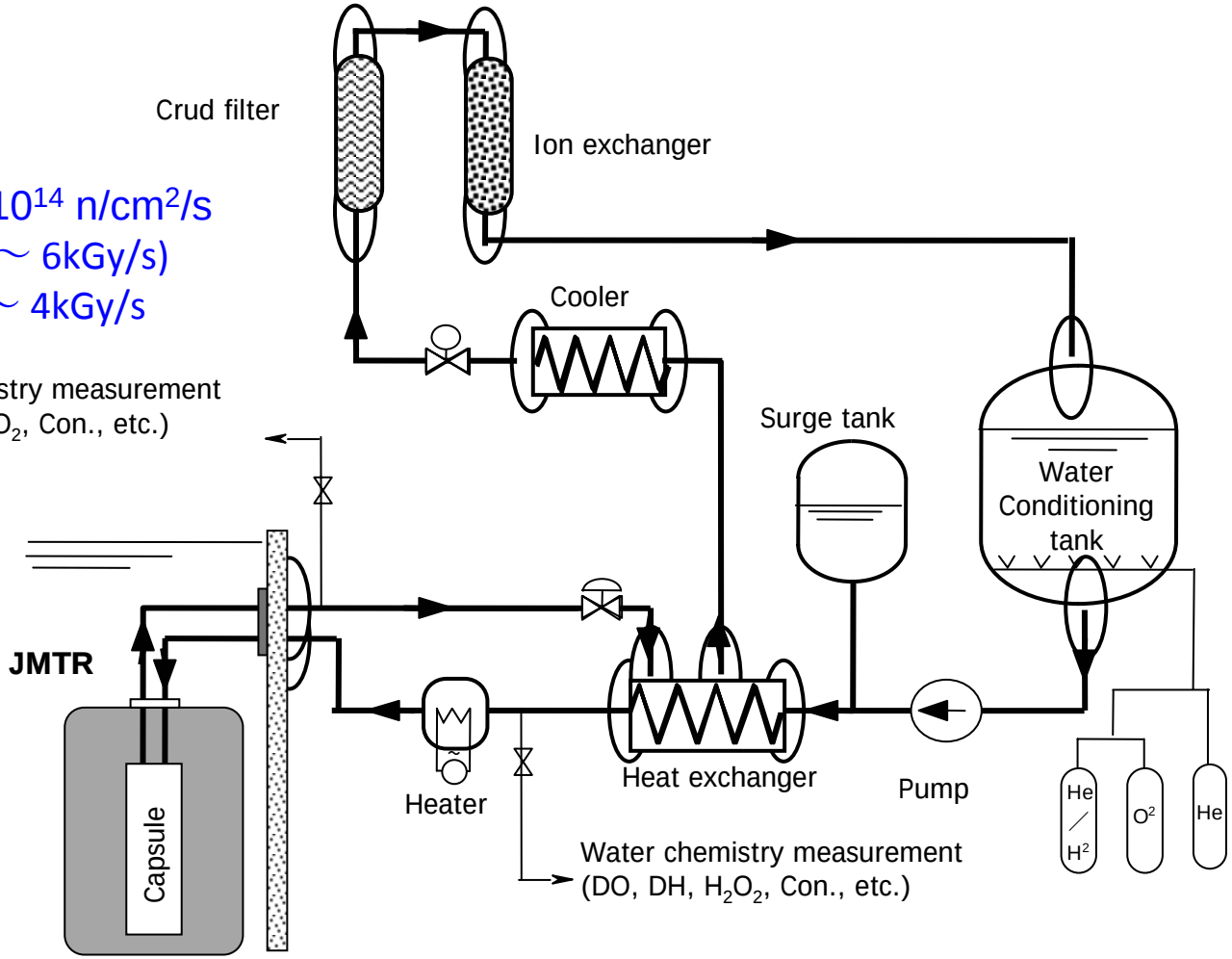


Water chemistry tests in the JMTR

Types of ECP sensors, e.g. Fe/Fe_3O_4 electrodes with ZrO_2 membrane using mechanical/brazing sealing etc, will be tested under irradiation conditions up to neutron flux of 10^{14} n/cm^2/s. Concentration of important species, such as Hydrogen Peroxide(H_2O_2), DO etc. will be measured, to validate radiolysis models.



Schematic of capsule

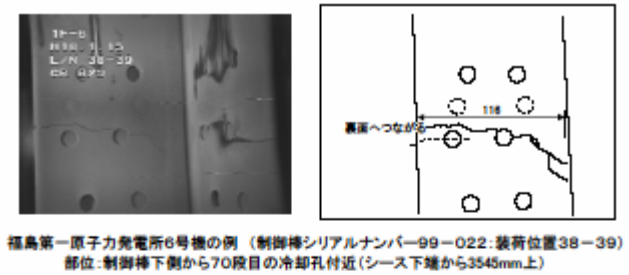


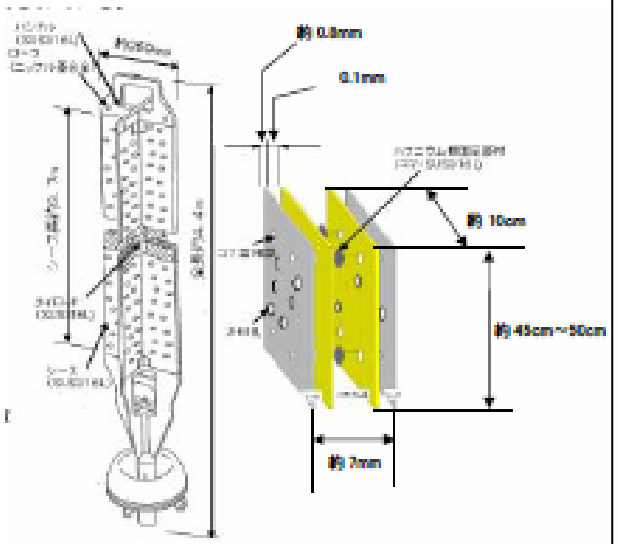
Water chemistry test loop

Hf irradiation test

Stress corrosion cracking on stainless steel sheath and tie rods in numbers of Hf plate type control rods at accumulated thermal neutron irradiation above 4.4×10^{25} n/m^2.

Build up of corrosion products in the narrow gap between the sheath and Hf plates lead loss of mobility between the two parts. Stress by the irradiation growth of the Hf plates seemed to play a large part for the crack initiation and growth.





Investigation report on cracking of Hf plate type control rods in BWRs, NISA/METI May 2009

Behavior of the Hf plates under the irradiation conditions are not well characterized in open literatures.

Irradiation growth test of Hf is being prepared and pre-irradiation characterization tests are being prepared.

Summary

Fuel and Material Irradiation Study at JMTR

- ✓ Refurbishment of the JMTR started in FY 2007, after the last operation ended in Aug. 2006, in order to re-start the reactor in FY2011 in a good shape.

- ✓ Fuel safety research at JAEA will be started in FY2011 to examine fuel integrity under transient conditions using new test rigs designed for JMTR. Preparation of the test facilities and fuel transportation is in progress. In addition, fuel irradiation test loops are proposed for development of next-generation LWR fuels with high duty uses.

- ✓ The new tests would provide fuel failure criteria under the power transients and data to examine evaluation models on the fuel integrity.

- ✓ Material irradiation study will be performed to examine,
  - Fracture toughness tests of reactor pressure vessel steels
  - Stress Corrosion Cracking and water chemistry tests under simulated LWR irradiation field
  - Irradiation growth of Hf,

  The irradiation studies would contribute not only to solve the current problems but also to identify possible seeds of troubles and to make proactive responses.