Feasibility Study on Cryogenic Irradiation Facility in JMTR

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Introduction

The Japan Materials Testing Reactor (JMTR) is a testing reactor with first criticality in March 1968. JMTR has been utilized for various neutron irradiation tests on nuclear fuels and materials, as well as for radioisotope production. The operation of JMTR was stopped in August 2006 for the refurbishment and the improvement. The renewed JMTR will be operated from FY 2011.

Aiming at the restart of the new JMTR, the new irradiation facilities, the usability improvement, the target, and the expected roles of the new JMTR have been discussed. As one of the new irradiation facilities, the cryogenic irradiation facility, which is used for the investigation on the low-temperature irradiation behavior of materials such as superconducting magnet materials for fusion reactors, has been desired.

In this study, the feasibility of low-temperature irradiation tests with the cryogenic irradiation facility was investigated.

Irradiation Performance of JMTR

1. Irradiation area of core
   - Simultaneous irradiation positions : about 60
   - Low gamma irradiation area

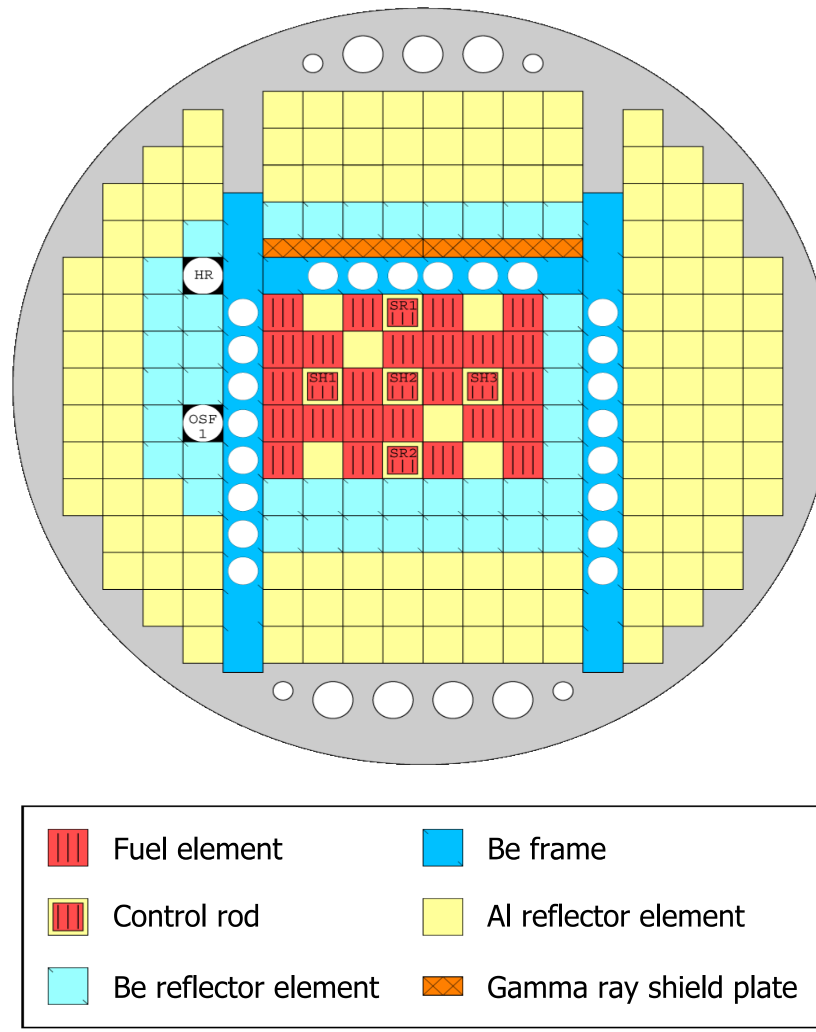
2. Neutron flux
   - Fast : max. 4×10^{18} (n/m^2/s)
   - Thermal : max. 4×10^{18} (n/m^2/s)

3. Neutron fluence/y (at 180 days operation*)
   - Fast and thermal : max. 3×10^{25} (n/m^2)
   - dpa (for Stainless Steel) : max. 4 (dpa)

4. Dimensions of irradiation capsule
   - φ40mm × 750mm (outer diameter : max. 65mm)

5. Irradiation temperature
   - Controlled from 50 to 2000°C

*: results from Oct.2003 to Spt.2005



Configuration of standard core

Applicable Irradiation Technology of JMTR

IASCC test of LWR core internals

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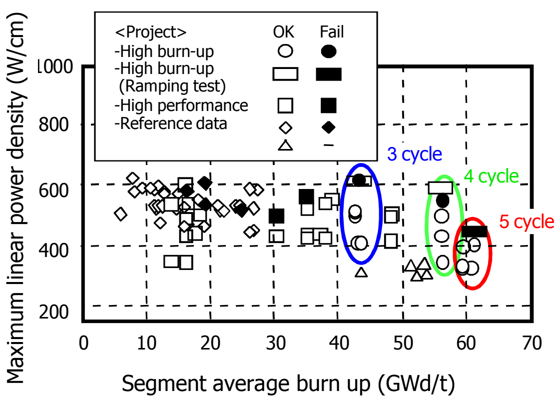
Life time extension of LWR

shroud

Power ramping test of LWR fuels

↓

Burn up extension



Irradiation Technology

Temp. control

- Saturation temp.
- Automatic constant temp.
- High temp.

Environmental control

- Water chemistry, load

Special instrumentation

- Displacement, crack propagation
- Re- instrumentation (temp., pressure)

Power ramping

- Fuel power control by ^{3}He gas

Neutron control

- Spectrum adjustment
- Pulse irradiation

Re-irradiation

- Assembling in hot cell

High accuracy temp. control

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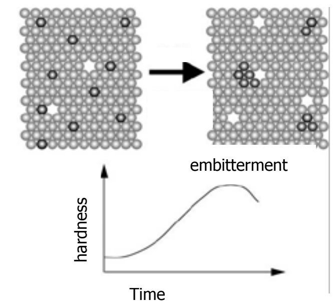
Research of radiation damage



High temp. irradiation

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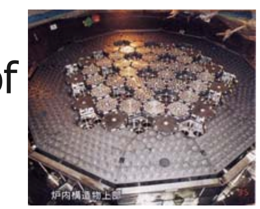
Development of HTTR



ITER operation, He production rate/dpa simulation

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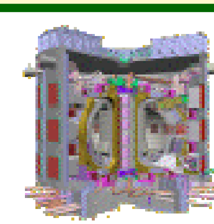
Development of fusion reactor



Target of new JMTR

- **Proposal of attractive irradiation tests**

  Proposal of the irradiation data with high technical value through the development of the new technology, the cooperation with the various nearby post irradiation examination facilities, etc.

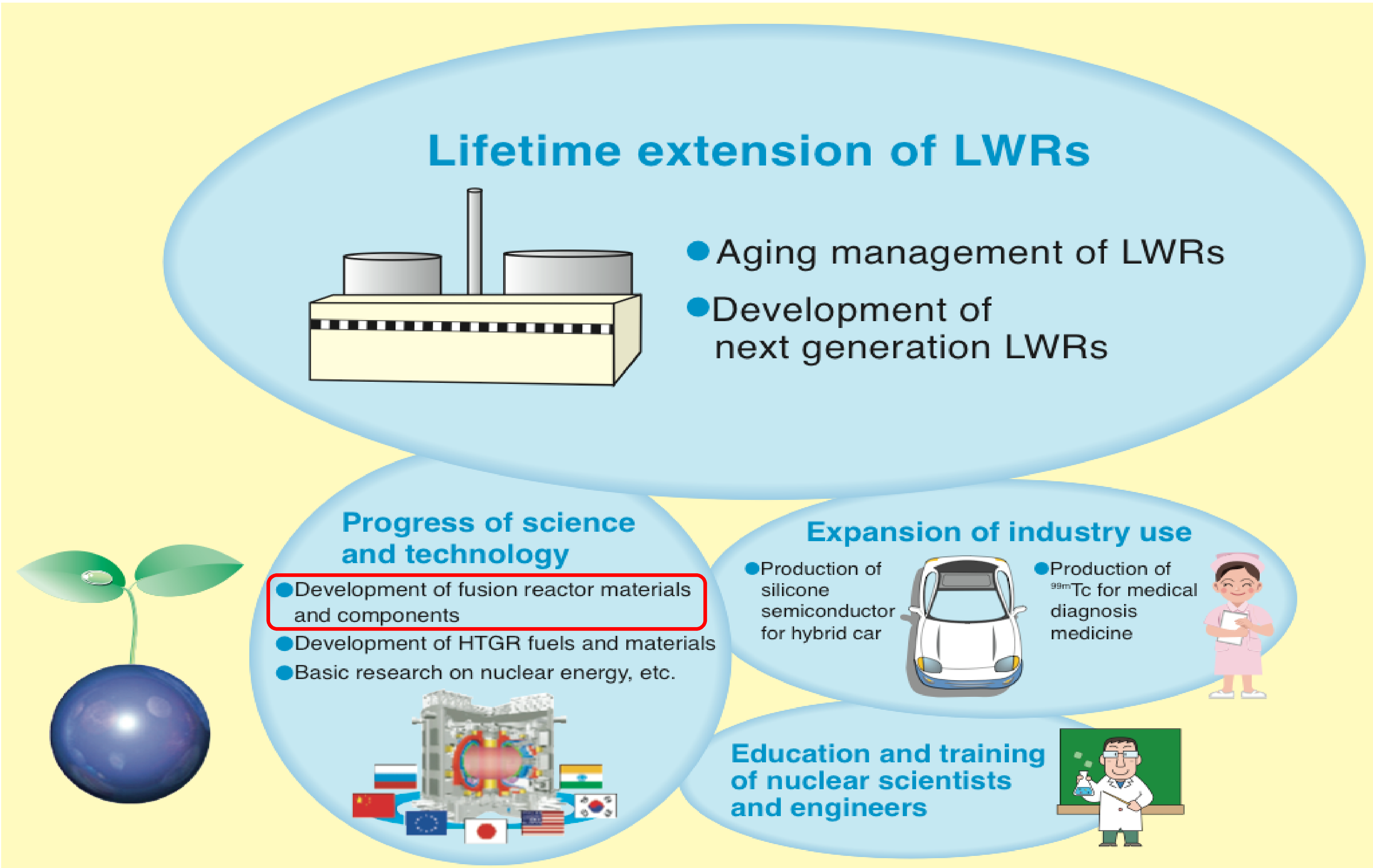
- **Establishment of international center**

  Construction of the research base utilized internationally as the Asian center of testing reactor

- **User-friendly management**

  Realization of the environment which is easy to use for many users due to the fulfillment of the technological support system, etc.

Contribution Areas of New JMTR



Technology Development for JMTR Re-operation

Items / Fiscal year	'09	'10	'11	'12	'13	'14
JMTR (Refurbishment, Operation)	**Refurbishment**		**Operation**			
Building for Irradiation Technology - Setting of Equipment						
Development for Fuel and Material for LWR - Design and Establishment for Irradiation Facility - Elementary Development - Fuel and Material Irradiation Tests	Establishment for IASCC and BOCA		Consideration of Water Loop Facility			
Development of Advanced Irradiation Tests - Elementary Development (Instrumentation) Multi-paired T/C for High Temperature Ceramic Sensor (H_2, O_2, OH) - Design of New irradiation Facility	**Conceptual Design of Cryogenic Irradiation Facility**					
Development of RI Production - Design and Establishment for Irradiation Facility - ^{99}Mo Production by Molybdenum Target						
Development on Reactor Facility - Recycling and Lifetime Expansion of Be Reflector - Reactor Monitoring System						

Key Points to Realization of Cryogenic Irradiation Facility

Key points for the realization of the cryogenic irradiation facility at specimen temperatures below 20 K by using helium as a cooling medium.

1. Irradiation temperature rise of specimens

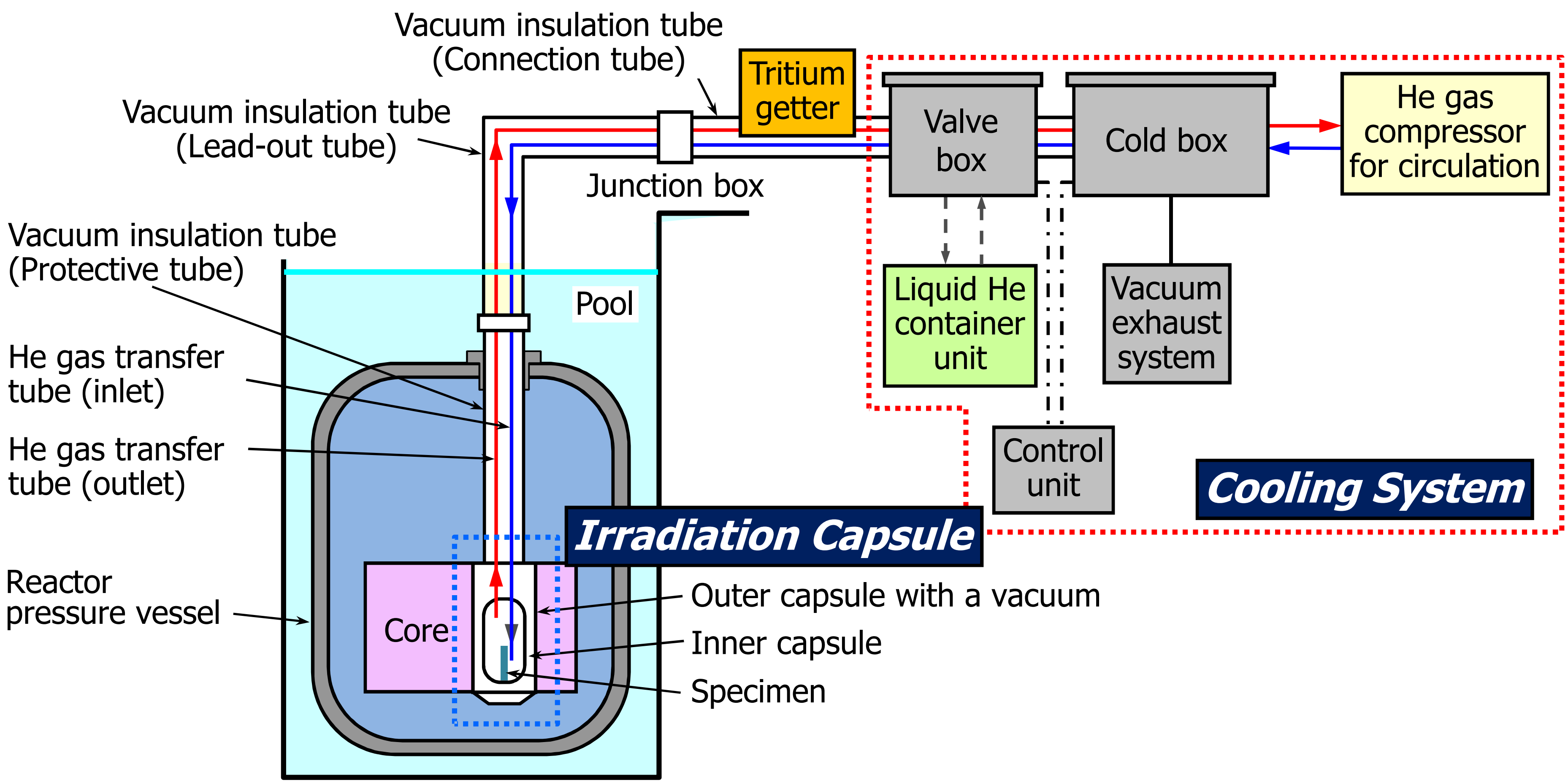
Selection of the irradiation hole to install the irradiation capsule connected with the cryogenic irradiation facility, considering a heat balance between neutron flux and gamma heating.

2. Invasion heat to helium transfer tubes

Application of vacuum thermal insulation to the helium transfer tubes.

Conceptual Design of Cryogenic Irradiation Facility

The cryogenic irradiation facility consists of two major components; an irradiation capsule and a cooling system. The two components are connected with vacuum insulation tubes. In addition to them, a tritium getter is installed in order to remove the tritium generated from the helium gas irradiated with neutron.



Irradiation Hole for Cryogenic Irradiation Facility

In order to investigate the mechanisms of irradiation damage of the superconducting magnet materials, a neutron fluence of 10^{22} n/m^2 is required.

[Irradiation Conditions]

Irradiation Hole : G-1

Max. thermal neutron flux

: 1×10^{17} n/(m^2·s)

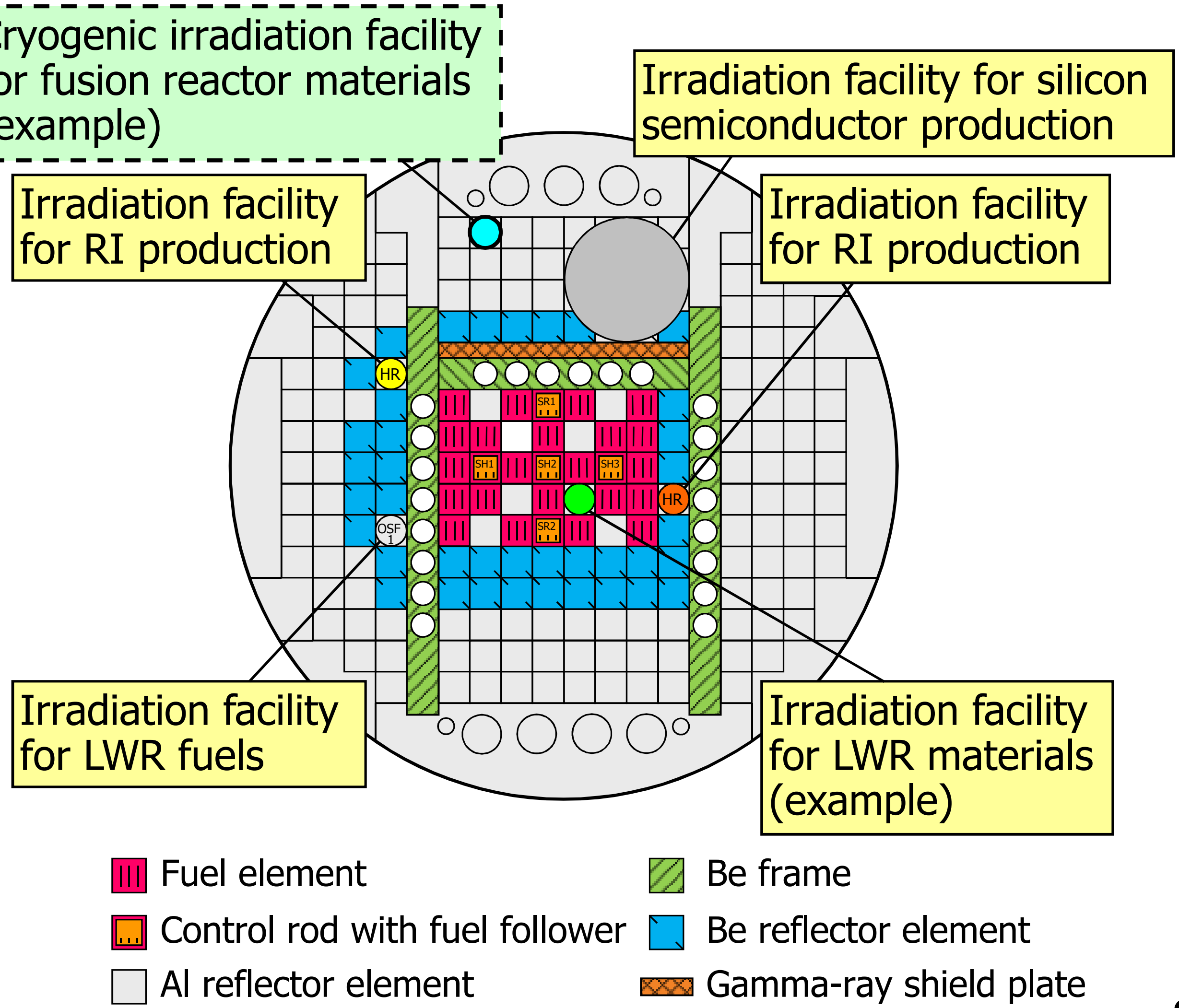
Max. fast neutron flux

: 1×10^{16} n/(m^2·s)

Av. γ-heating rate

: 0.1 W/g

The maximum fast-neutron fluence can reach to 2.6×10^{22} n/m^2 by the irradiation during 30 days, which is the one operation cycle of JMTR.



Configuration of Irradiation Capsule

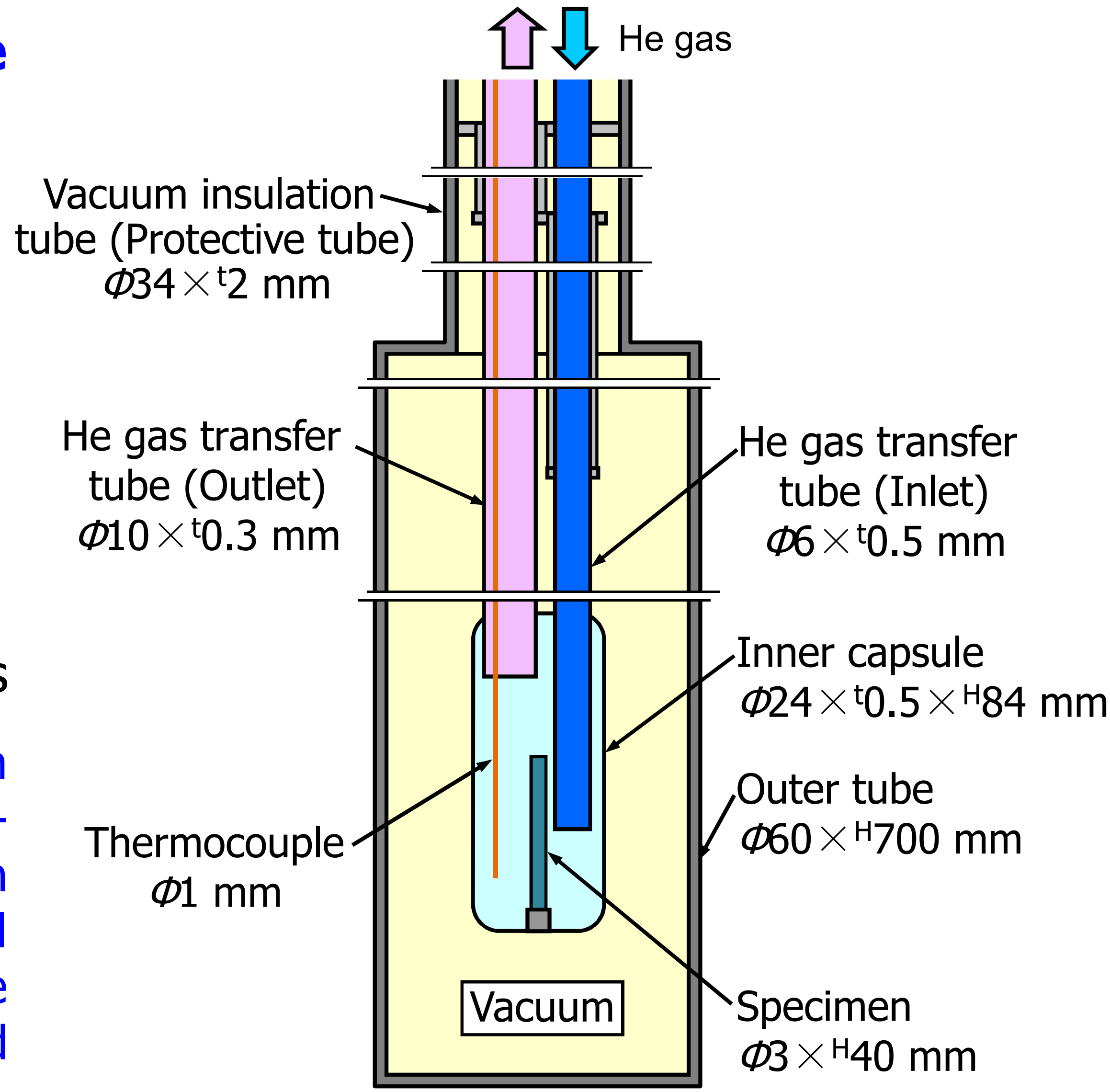
Structure of Irradiation Capsule

- Outer tube : SS316
- Inner capsules : SS316
- He gas transfer tubes : SS316
- Thermocouple : K type (SS316)

Characteristics of Capsule

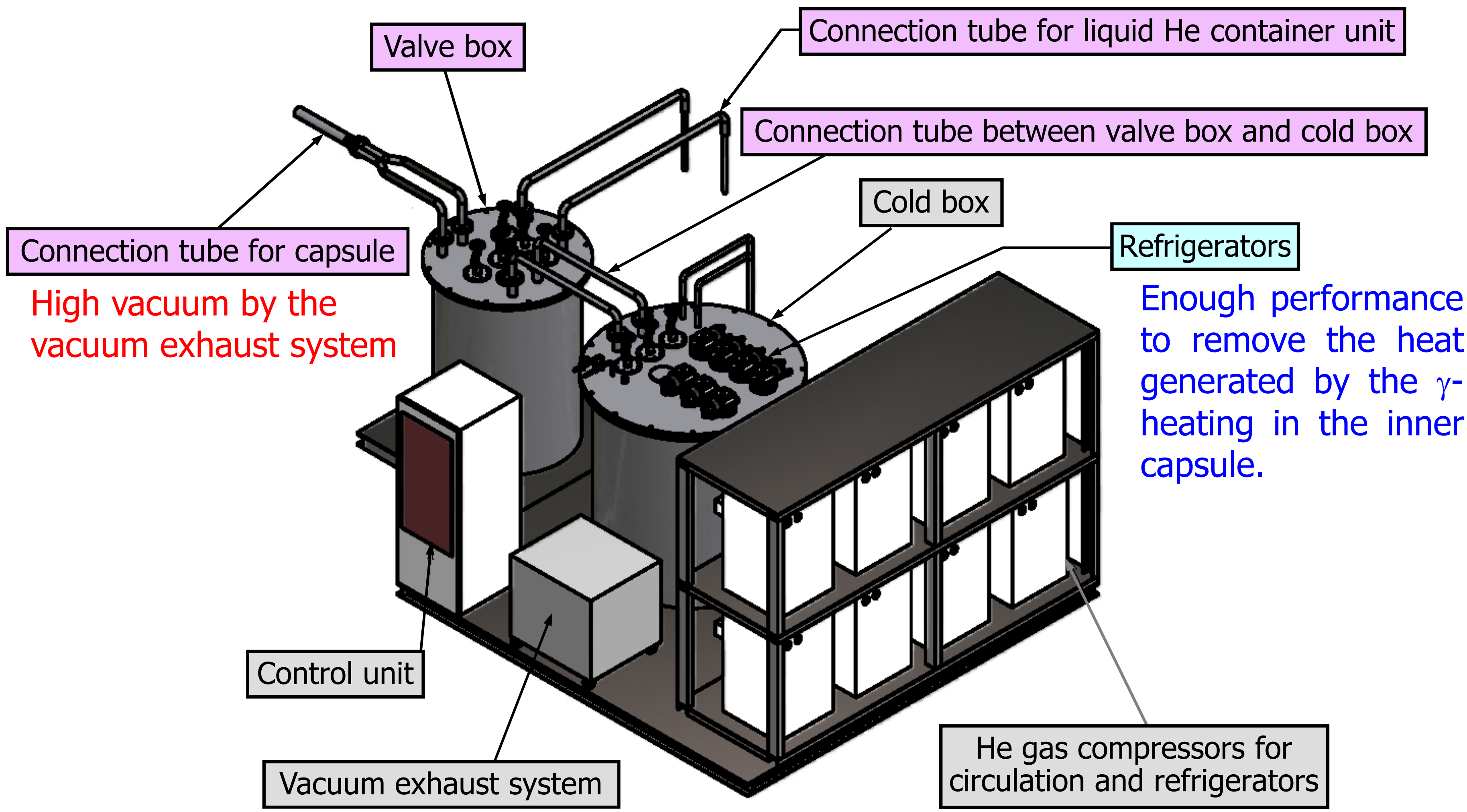
- Space between outer tube and inner capsule : vacuum
- Cooling of specimen : circulating He gas

In order to transfer the helium gas maintained at low-temperature, vacuum insulation tubes are indispensable, and the he gas transfer tubes are inserted into the evacuated protective and lead-out tubes.



Configuration of Cooling System

The cooling system will be established around JMTR reactor and provides the stable cooling of the specimen installed in the capsule for a long time.



Calculation Conditions of Heat Balance

In order to confirm the realization of the irradiation tests at temperatures below 20 K, the heat balance of the helium gas in the helium gas transfer tubes was calculated. A heat load to the helium transfer tube (gas supply line) of 28 W, a heat load to the helium transfer tube (gas return line) of 31 W, a heat load to the thermal shield of 200 W, and a helium gas flow rate of 6.1×10^{-4} kg/s were evaluated from the conditions.

<Conditions assumed in heat balance calculation>

γ-heating rate	0.1 W/g
Material of components	Stainless steel
Emissivity	0.1 to 0.5
Tube length	30 m (one-way)
Invasion heat to tubes	0.3 W/m
Invasion heat to valves	0.5 to 1.0 W
He gas temperature	8 K at refrigerator outlet

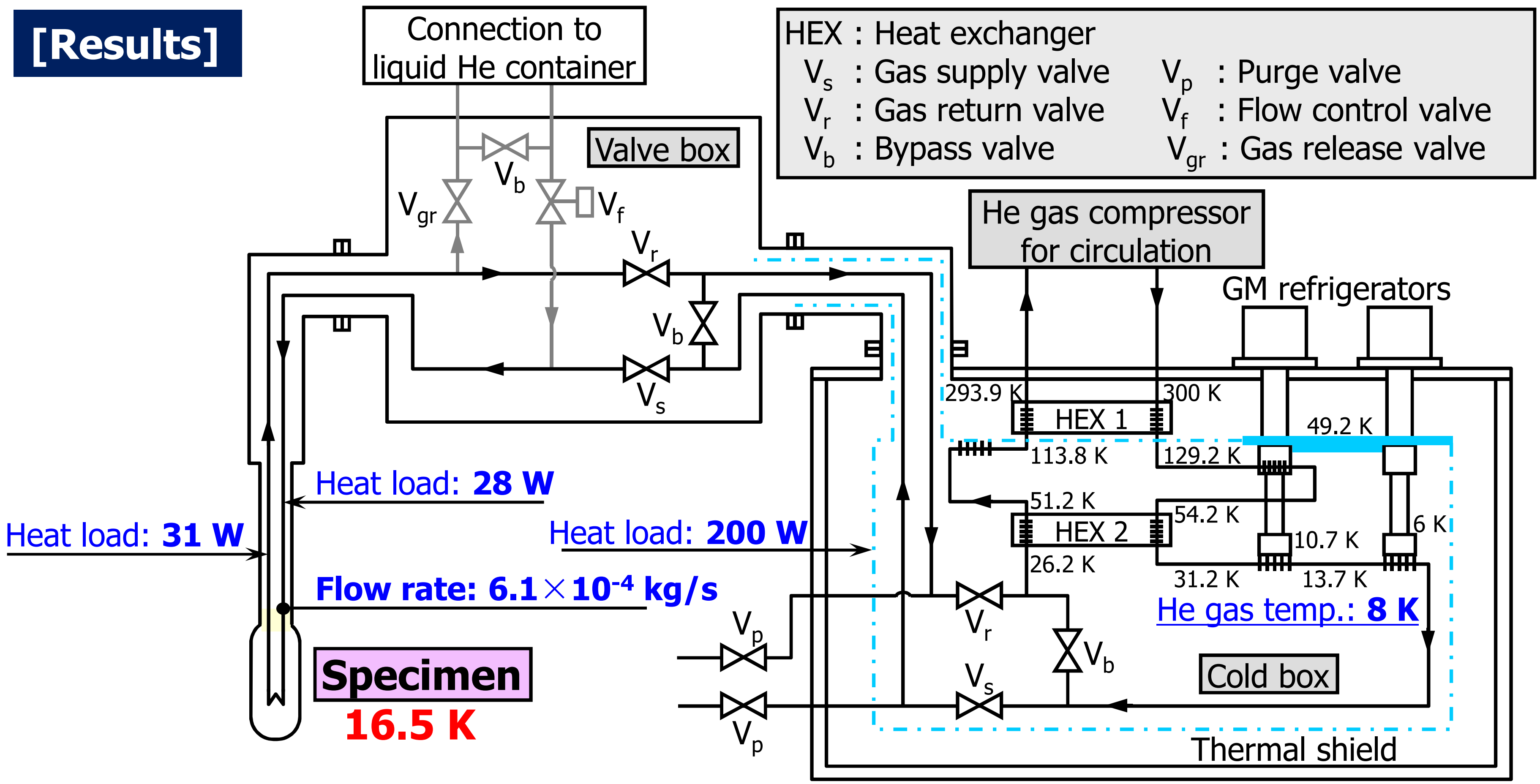
Results of Heat Balance Calculation

[Equation]

$$Q = m\,C_p\,\Delta T$$

Q [W] : Additional heat to the helium gas in the transfer tube
m [kg/s] : Mass flow rate of the helium gas
C_p [J/(kg·K)] : Specific heat of the helium gas
ΔT [K] : Temperature difference between two points in the transfer tube

[Results]



Summary

Aiming at the restart of the new JMTR, a cryogenic irradiation facility for low-temperature irradiation tests has been desired, and then the feasibility of the low-temperature irradiation tests with the cryogenic irradiation facility was investigated.

As a result, it was clarified that irradiation tests at temperatures below 20 K for the development of the superconducting magnets applied to the fusion reactors can be realized by the installation of an irradiation capsule into the irradiation hole with low γ-heating and by the adoption of evacuated protective and lead-out tubes.

In future, technical problems are distilled from this results and detail design of the facility will start for the installation in JMTR.