Improvement of temperature control of Vertical Irradiation Facility in JRR-3

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Japan Atomic Energy Agency (JAEA)

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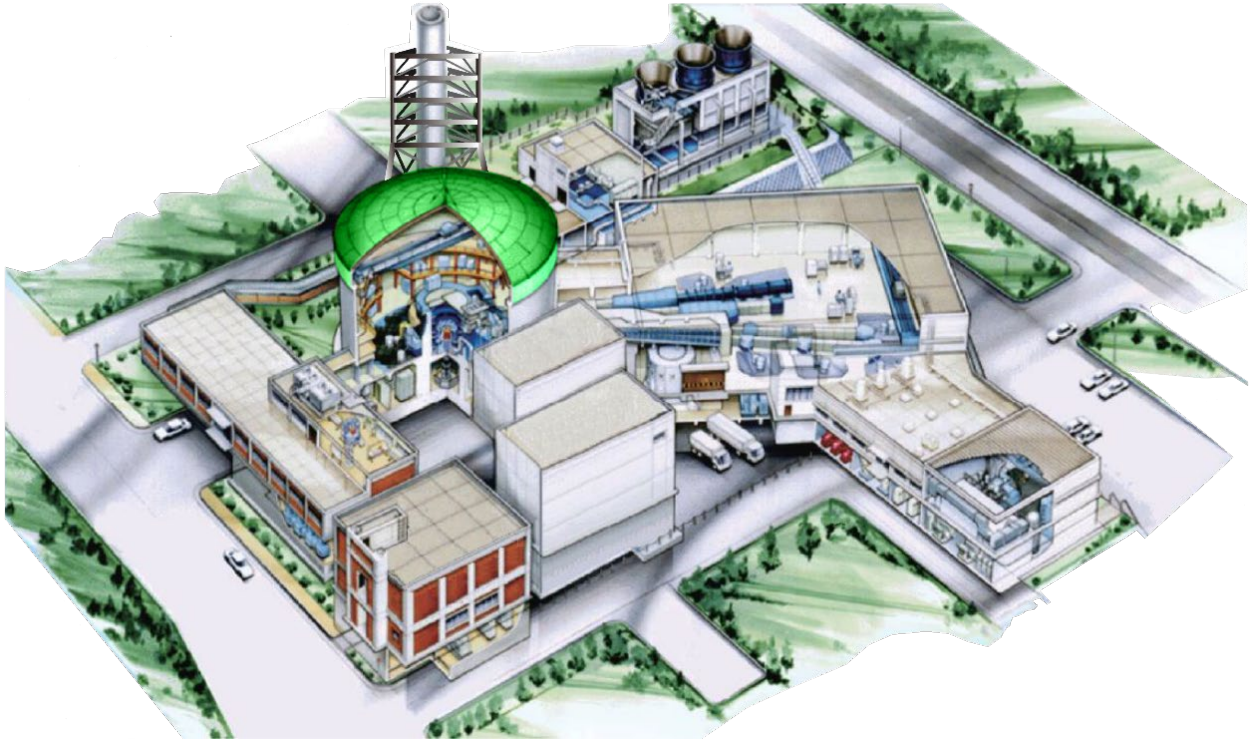


bird’ eye view

Introduction (JRR-3)

2011 The Great East Japan Earthquake happened.

2013 The Japanese regulatory standards were reviewed.

2016 JMTR was decided to be decommissioned.

2018 JRR-3 seismic reinforcement works started.

2021 JRR-3 Inservice operation restarted.

JRR-3 is the only research reactor in Japan that can perform material irradiation test.

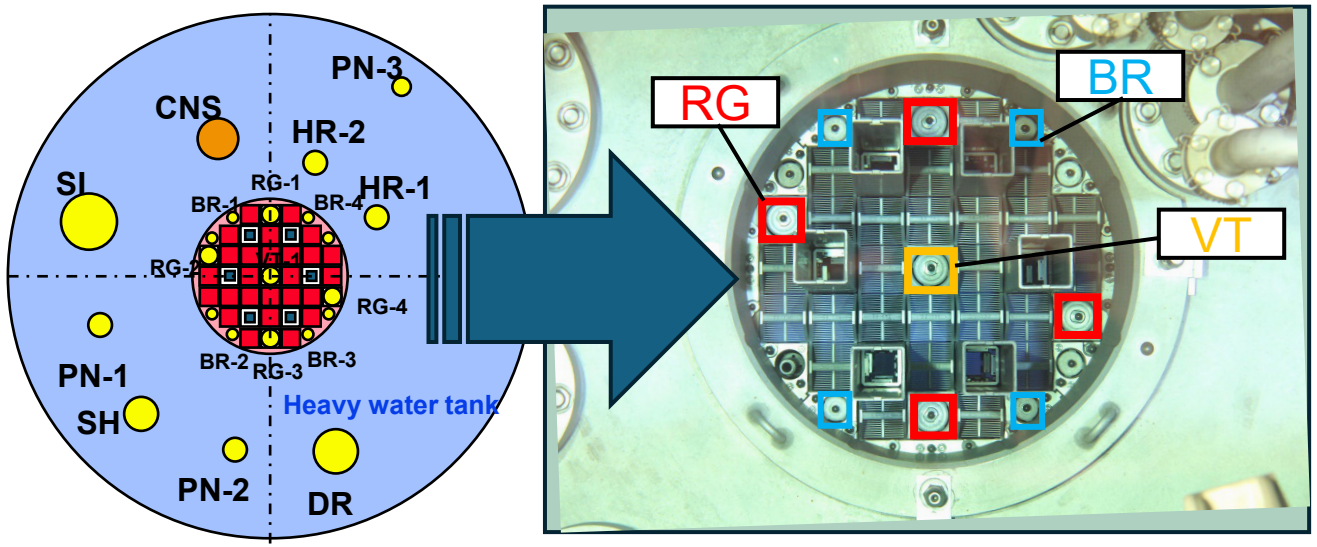
To expand irradiation embrittlement data and assist in the long-term operation of reactors, we have resumed the tests.

Introduction (Vertical Irradiation Facility)

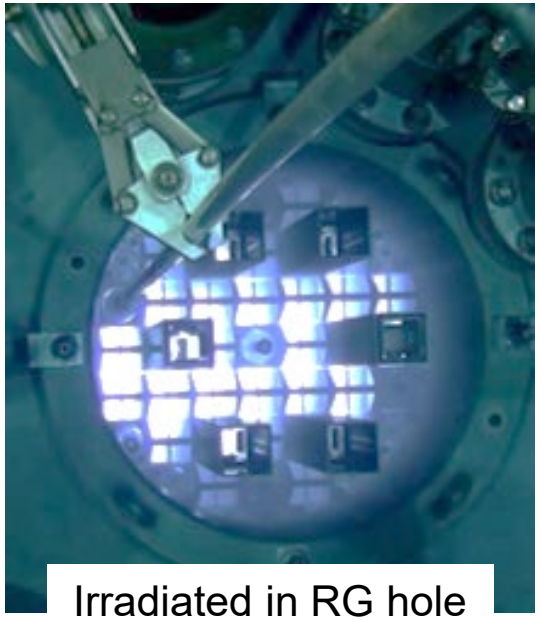
- 9holes in reactor core are valid.
- Capsules are irradiated for 26 days (1 cycle~).
- VT hole is suitable for RI production.
- RG and BR holes can be temperature controlled.

Suitable for material irradiation test

fast neutron flux[n/cm^2/sec]
VT : 2*10^{14}
RG : 1*10^{14}
BR : 1*10^{14}
thermal neutron flux[n/cm^2/sec]
VT : 3*10^{14}
RG : 2*10^{14}
BR : 2*10^{14}



Fuel elements Irradiation holes Reactor core



Irradiated in RG hole

Introduction (Irradiation requirements)

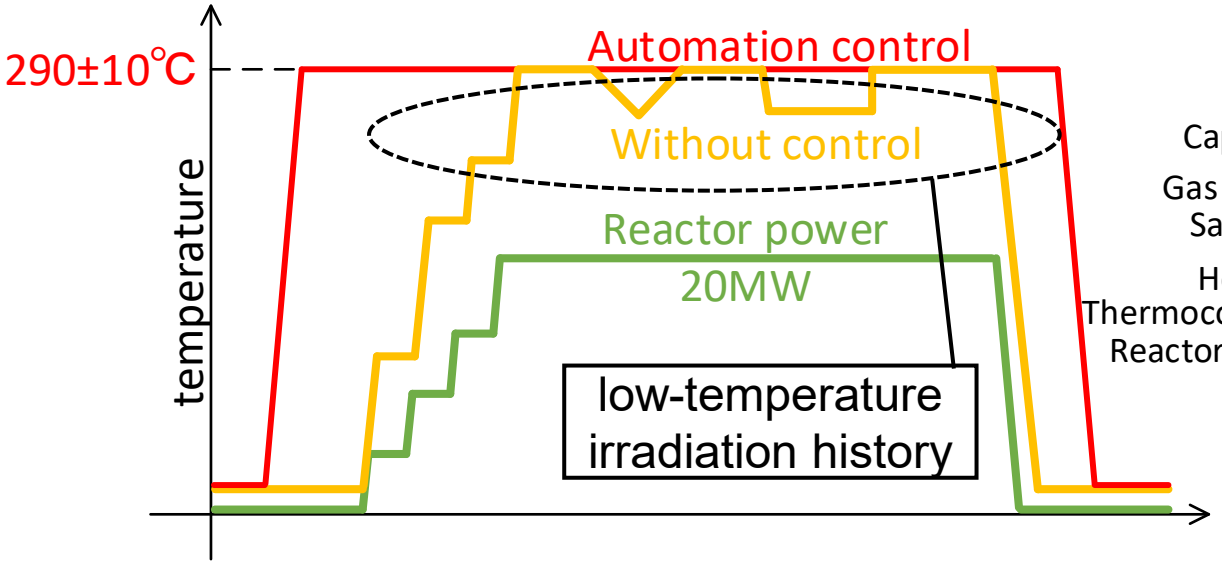
- Keep a temperature within ±**10 ℃** of the target temperature.
- Removing low-temperature irradiation history

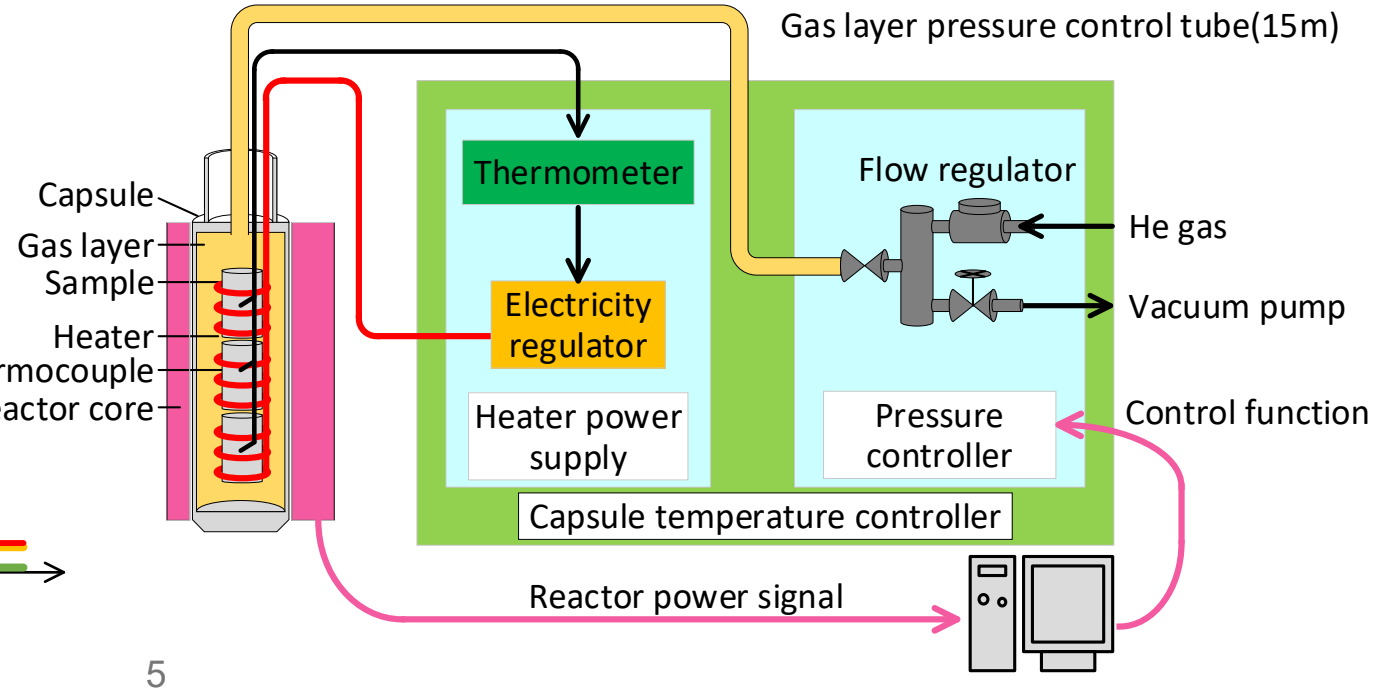
To answer the request…

- Heating with electric wire
- Thermal conductivity control

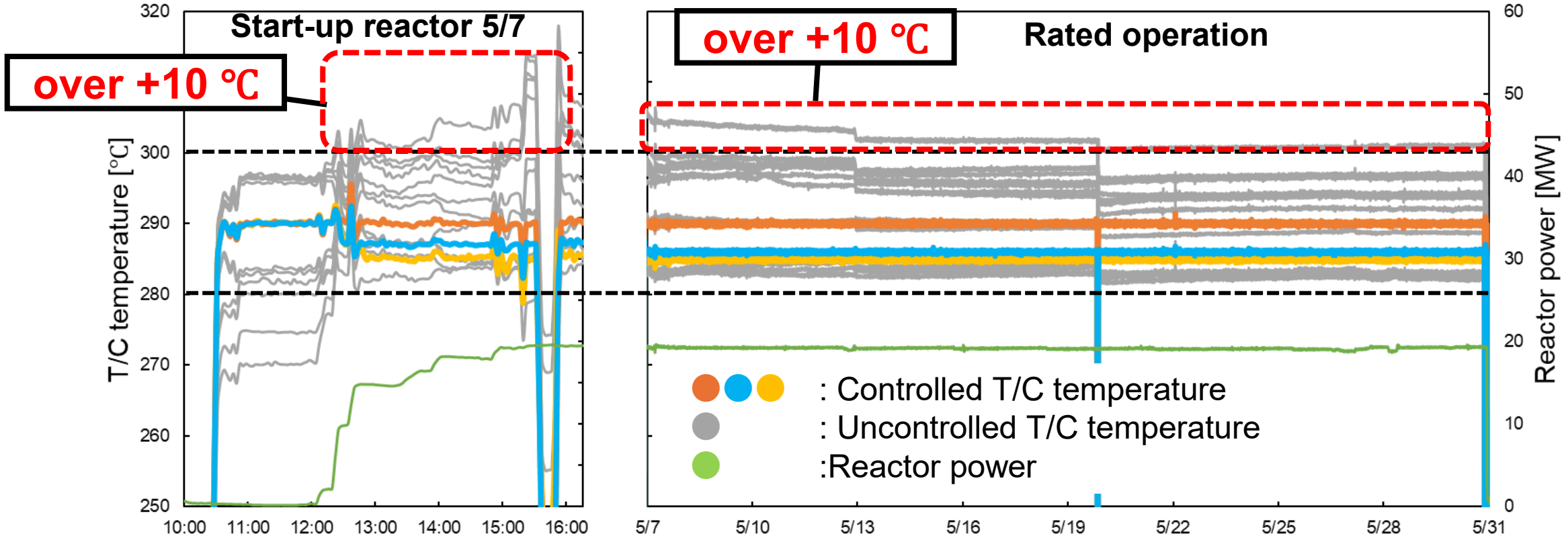
→ Automation

→ **Reactor power linked**





First irradiation test



- The controlled T/C temperatures were maintained within ±10℃.
- During start-up, the response time of the thermal conductivity adjustment was slow, which caused the uncontrolled T/C temperature to overshoot.
- During rated operation, the expected gamma heating was different from the actual heating. As a result, there was a wider temperature difference in the capsule axial direction.

Improvement for the second test

During start-up

To prevents T/C temperature overshoot, the thermal conductivity control was improved.

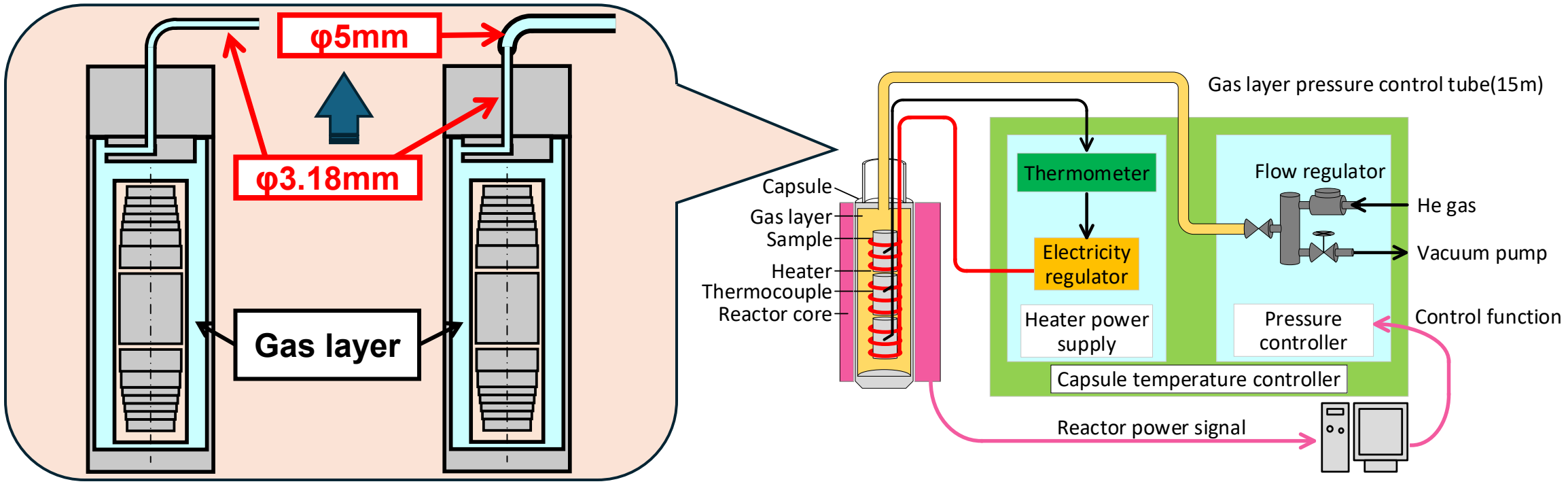
- ✓ Extended diameter of the gas tube
- ✓ Adjust the control function of thermal conductivity parameter

During rated operation

To keep all T/C temperature within 290 ± 10 ℃

- ✓ The design of the heat transfer medium was optimised to ensure uniform gamma heating value.

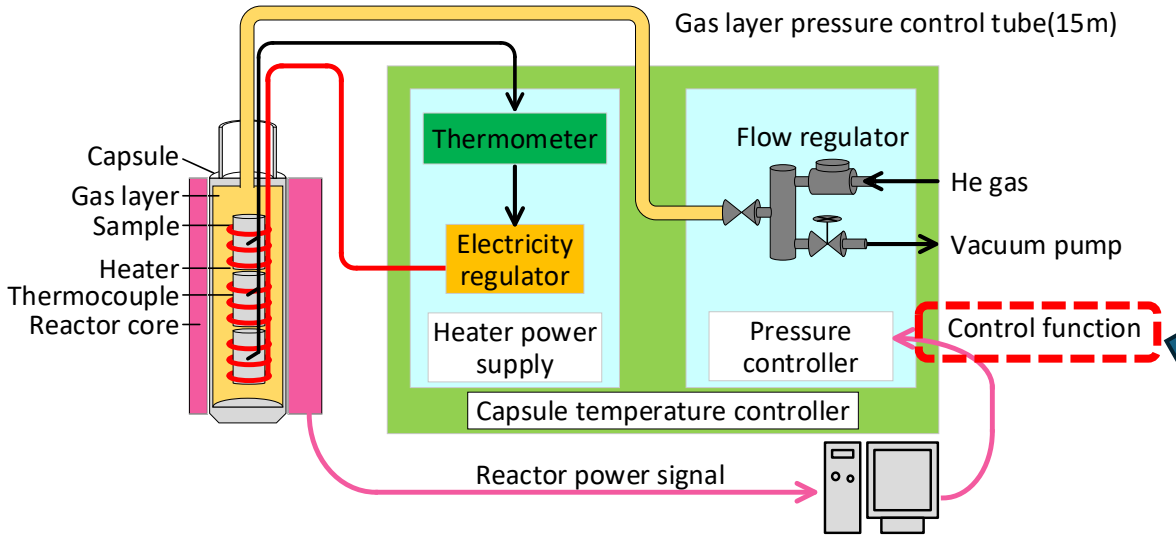
Improvement (Responsivity)

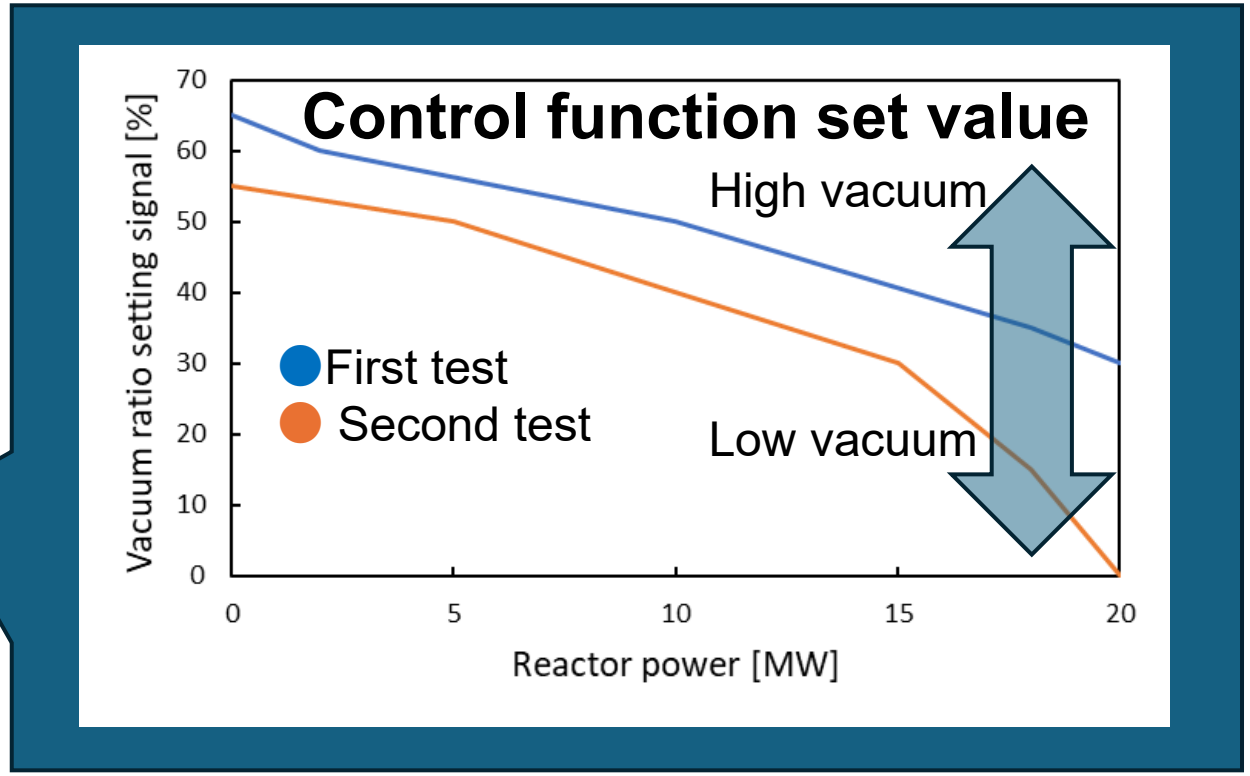


- The responsiveness of the thermal conductivity adjustment facility, which is adjusted by Helium gas pressure, has been improved.
- To enhance control response, the diameter of the gas tube was extended(φ3.18mm→φ5mm).

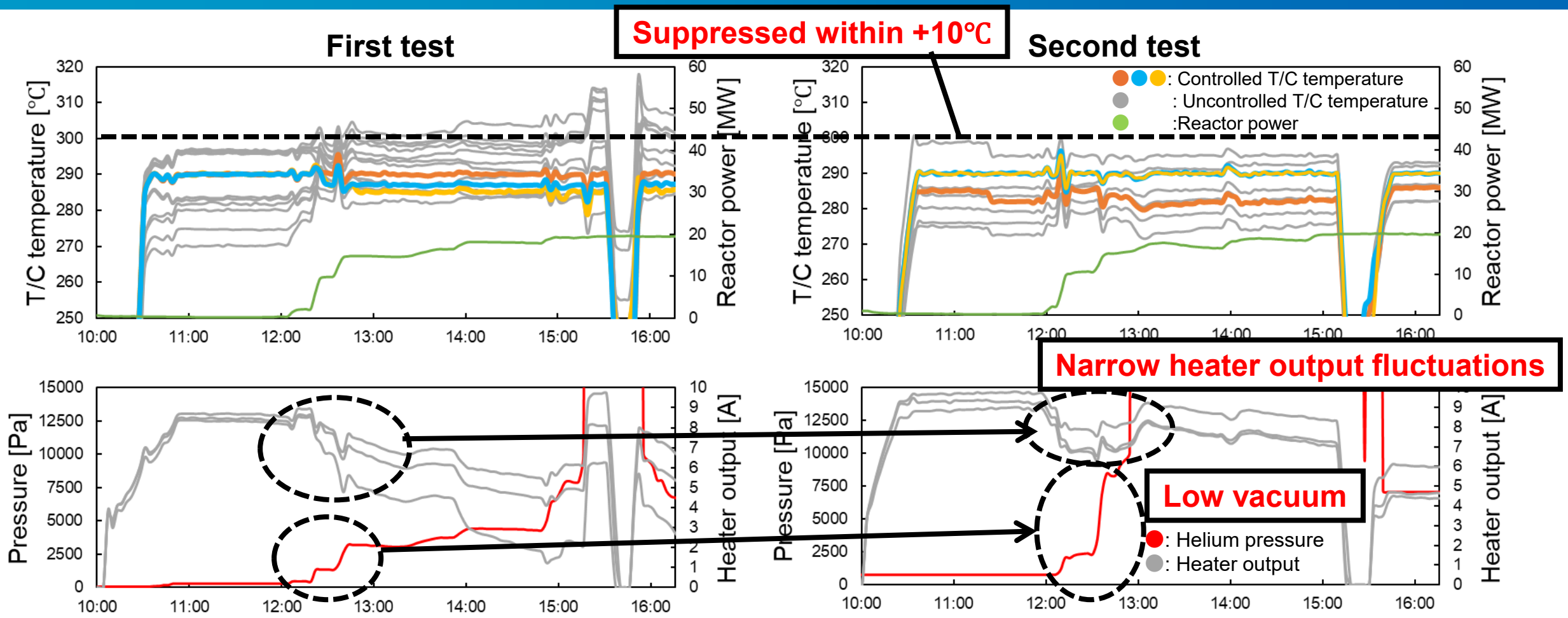
Improvement (Overshooting)

- The vacuum is controlled to set the vacuum ratio to the reactor power.
- If the vacuum is too high, the T/C temperature overshoots when the gamma heating increases.
- To prevent overshooting of the T/C temperature, the control function to adjust the vacuum level was modified.





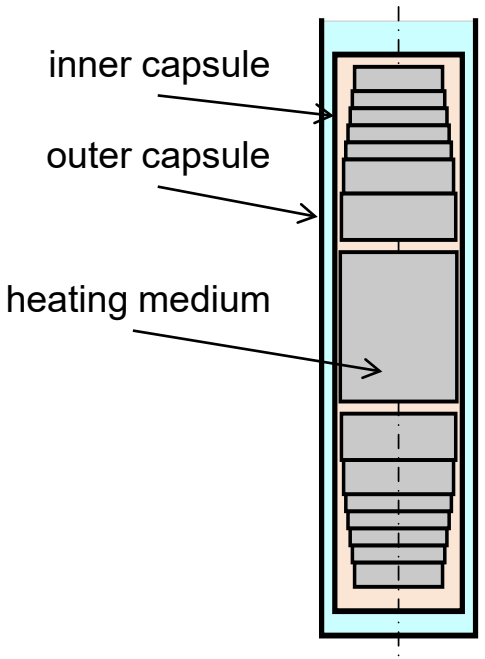
Second irradiation test (start-up)

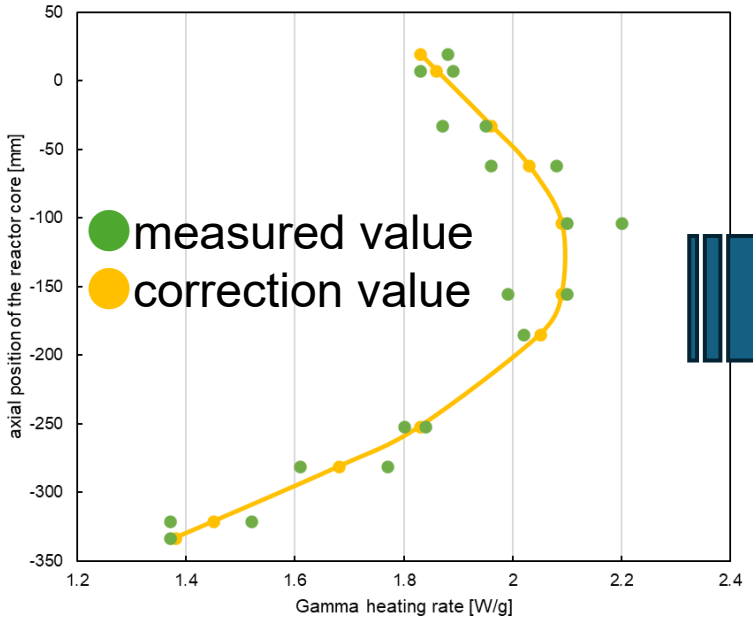


- The T/C temperatures were controlled at a lower vacuum level after the adjustment to the control function.
- The heater was controlled in a low vacuum condition against temperature changes caused by the reactor power increase. This allowed the heater power to be controlled within a narrow range.

➢ As a result, the T/C could be regulated **within +10℃.**

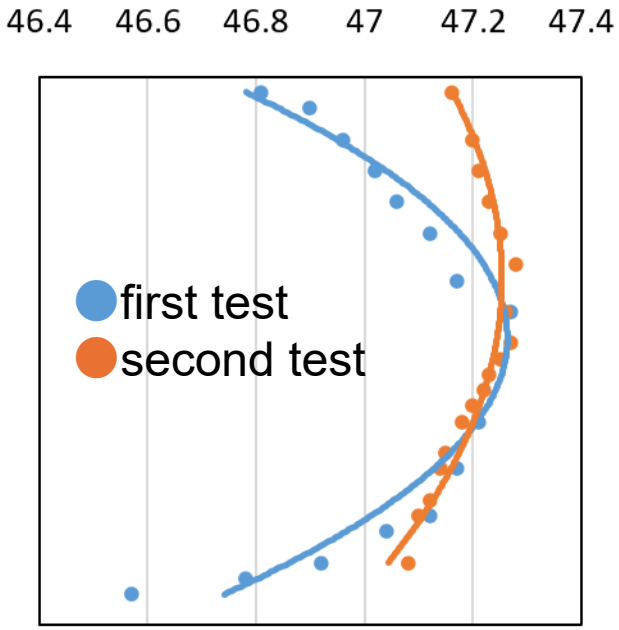
Improvement (Temperature uniformity)





Gamma heating rate in axial direction

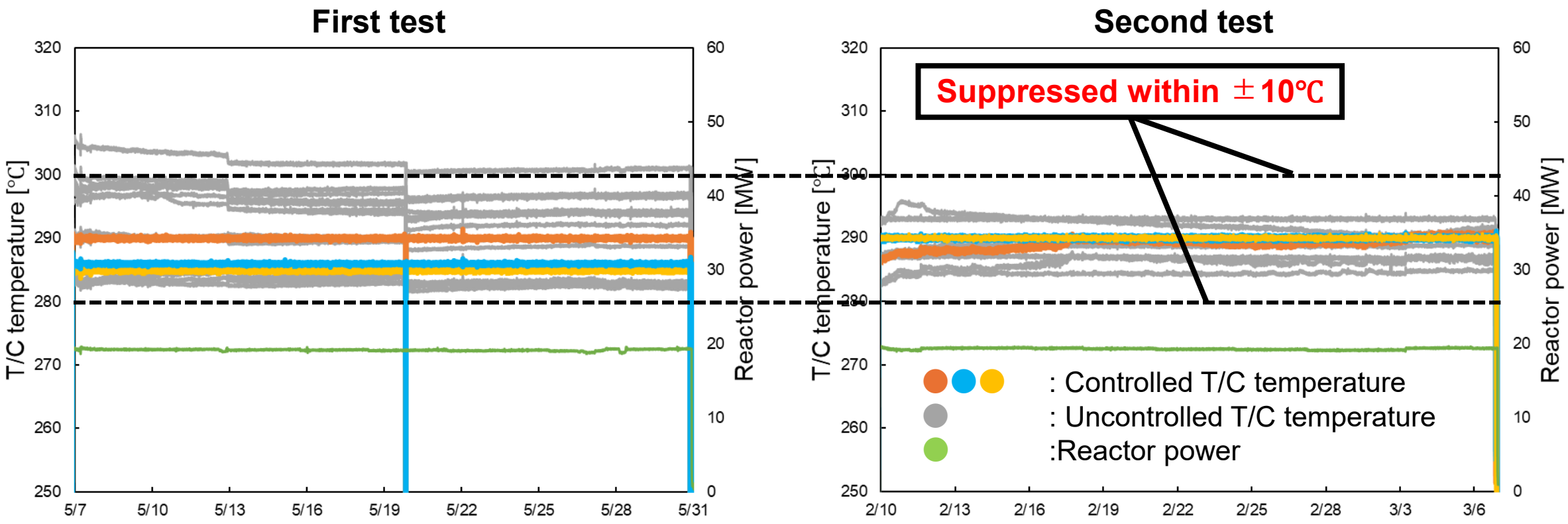
reflected



Heating medium diameter (mm)

- To achieve a uniform gradient of sample temperatures, **the heating medium design was optimised**.
- The gamma heating rate was calculated based on the measured temperatures and reflected in the design of the heating medium.

Second irradiation test (Rated operation)



- The axial temperature variation was suppressed by adjusting the heat transfer medium to ensure uniform gamma heating value.

➢ All T/C temperatures were successfully kept **within ±10℃** of the target temperature at all times during rated operation.

Summary

During start-up

- The overshoot of T/C temperature at start-up was suppressed.

During rated operation

- Axial temperature variation was suppressed within ±10℃.

Vertical Irradiation Facility could

✓**Keep a temperature within ±10 ℃ of the target temperature.**

✓**Removing low-temperature irradiation history**

The challenge for the future is to increase irradiation needs.

- Develop a capsule that can be produced more economically and in a shorter time.

Acknowledgment

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Appendix

JAEA Reactors

	JRR-3	JMTR	Jōyō	HTTR
type	water-cooled reactor	water-cooled reactor	sodium-cooled fast reactor	high-temperature gas-cooled reactor
power (MW)	20	50	140	30
fast neutron ($n/m^2 \cdot s$)	2×10^{18}	4×10^{18}	30×10^{18}	2×10^{17}
thermal neutron ($n/m^2 \cdot s$)	3×10^{18}	4×10^{18}	2×10^{18}	7×10^{17}
purpose	material irradiation RI production scattering experiment activation analysis	material irradiation RI production	development research material irradiation	development research
operation	restarted in 2020	decommission	restart after 2026	restarted in 2021