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Safety Analysis of Prismatic

2026/5/21

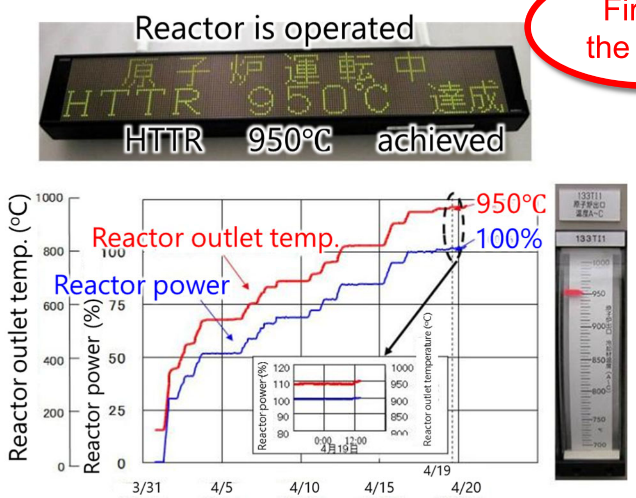
Department of HTTR
Oarai Nuclear Engineering Institute
Japan Atomic Energy Agency

History of HTTR

High temperature engineering test reactor
HTTR

Purpose

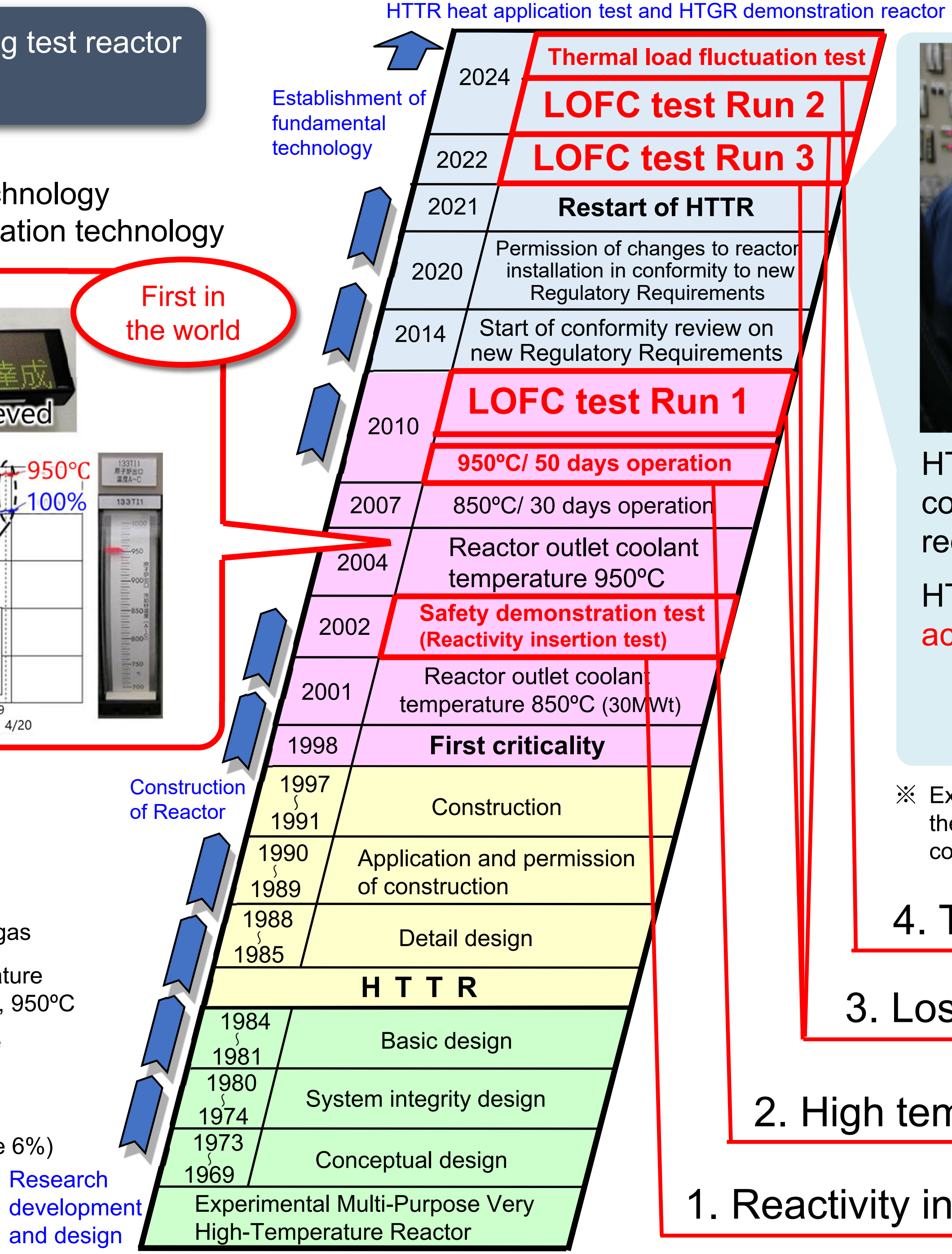
- ☐ Establishment of HTGR technology
- ☐ Establishment of Heat utilization technology



First in the world

Specification of HTTR

Reactor thermal power	30 MW
Reactor coolant	Helium gas
Reactor inlet/outlet coolant temperature	395/850, 950°C
Reactor material	Graphite
Fuel	UO_2
Uranium enrichment	3 - 10% (average 6%)



HTTR heat application test and HTGR demonstration reactor

Establishment of fundamental technology

Construction of Reactor

Research development and design

2024	**Thermal load fluctuation test** **LOFC test Run 2**
2022	**LOFC test Run 3**
2021	**Restart of HTTR**
2020	Permission of changes to reactor installation in conformity to new Regulatory Requirements
2014	Start of conformity review on new Regulatory Requirements
2010	**LOFC test Run 1** **950°C/ 50 days operation**
2007	850°C/ 30 days operation
2004	Reactor outlet coolant temperature 950°C
2002	**Safety demonstration test (Reactivity insertion test)**
2001	Reactor outlet coolant temperature 850°C (30MWt)
1998	**First criticality**
1997 ～ 1991	Construction
1990 ～ 1989	Application and permission of construction
1988 ～ 1985	Detail design
	H T T R
1984 ～ 1981	Basic design
1980 ～ 1974	System integrity design
1973 ～ 1969	Conceptual design
	Experimental Multi-Purpose Very High-Temperature Reactor

HTTR restarted in July 2021 and completed conformity to the new regulatory requirements in September 2021.

HTTR has no possibility of the severe accident

- ➢ Core melt is precluded.
- ➢ The evacuation of inhabitants is not necessary at the accidents.*

※ Except for the case of natural phenomenon to be far beyond the safety design and the terrorism to destroy the confinement function of radioactive materials.

4. Thermal load fluctuation test

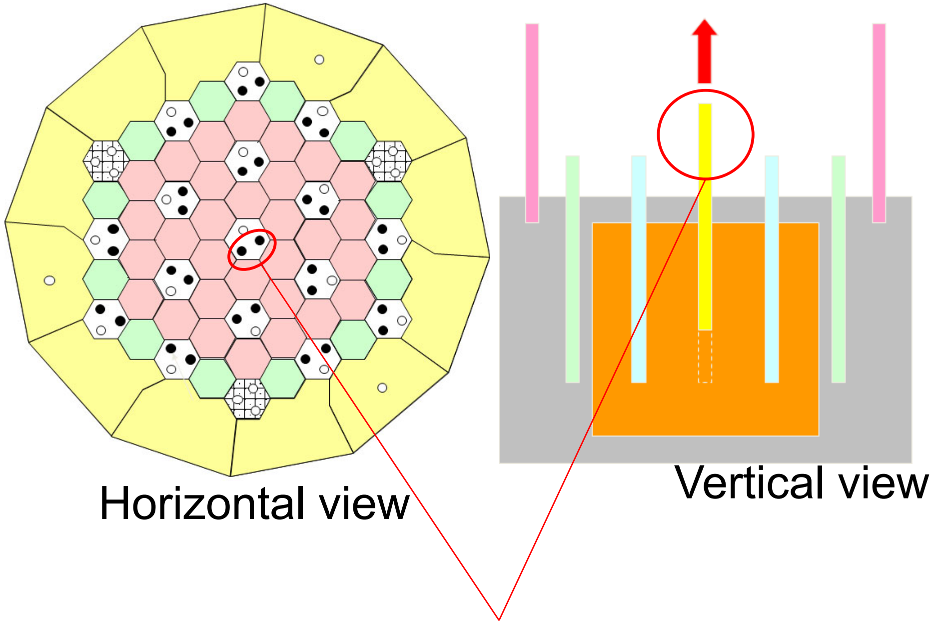
3. Loss of forced cooling tests

2. High temperature continuous operation

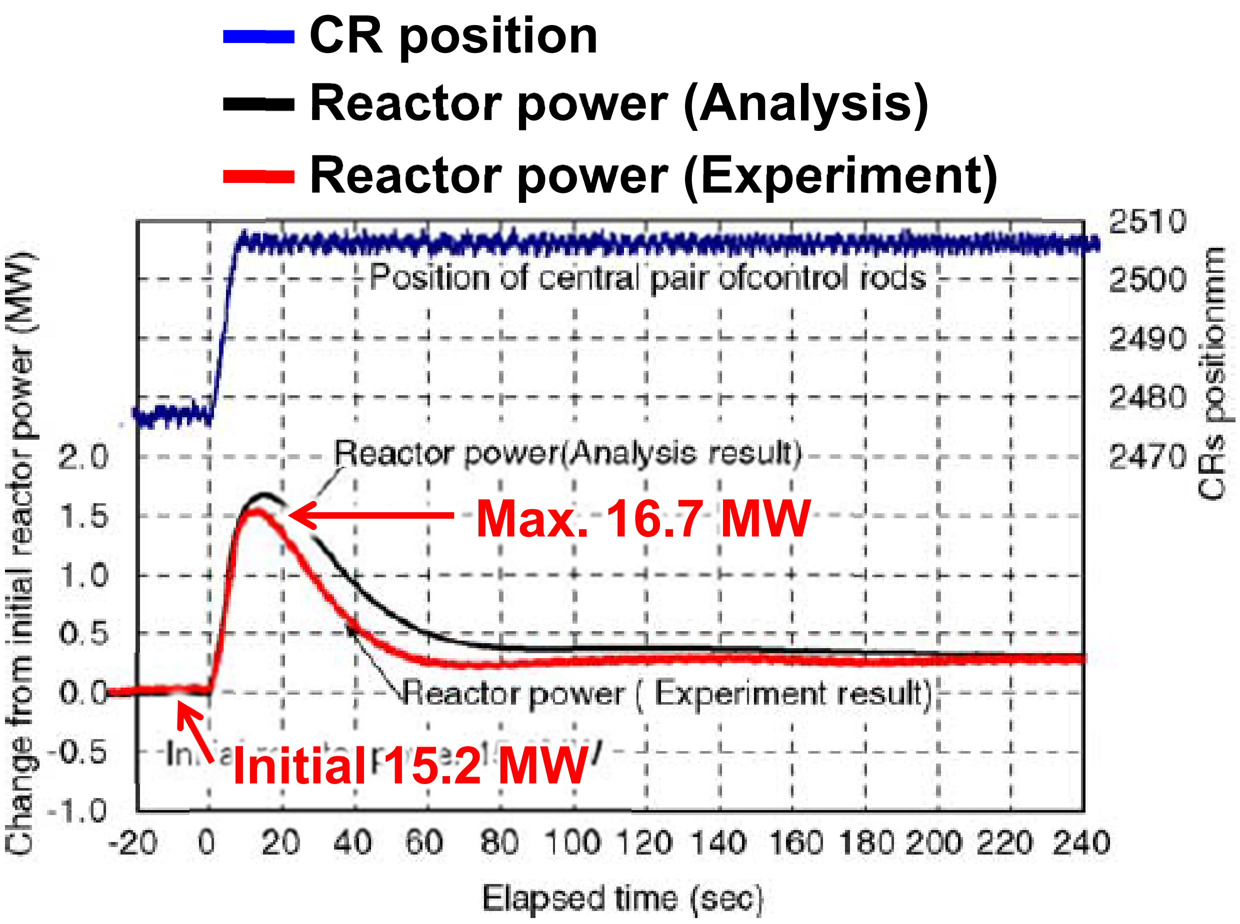
1. Reactivity insertion test

1. Reactivity insertion test (CR withdrawal test)

- **Test conditions**
- Initial reactor power : 30% - 80%
- Withdrawal speed: 1 or 5 mm/s
- Withdrawal distance: < 40 mm



Central pair of control rods was withdrawn



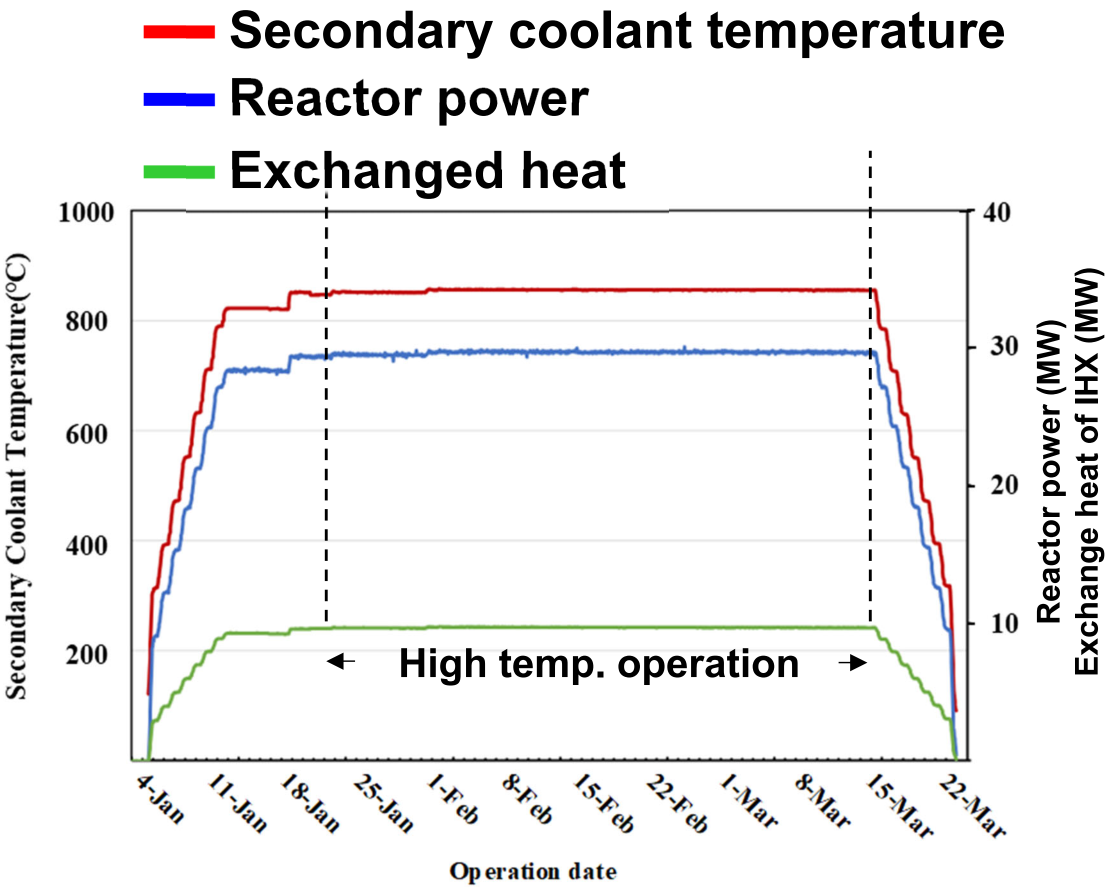
Results of control rods withdraw test

Demonstrated that rapid increase of reactor power due to CRs withdrawal is restrained by only the negative reactivity feedback of the core.

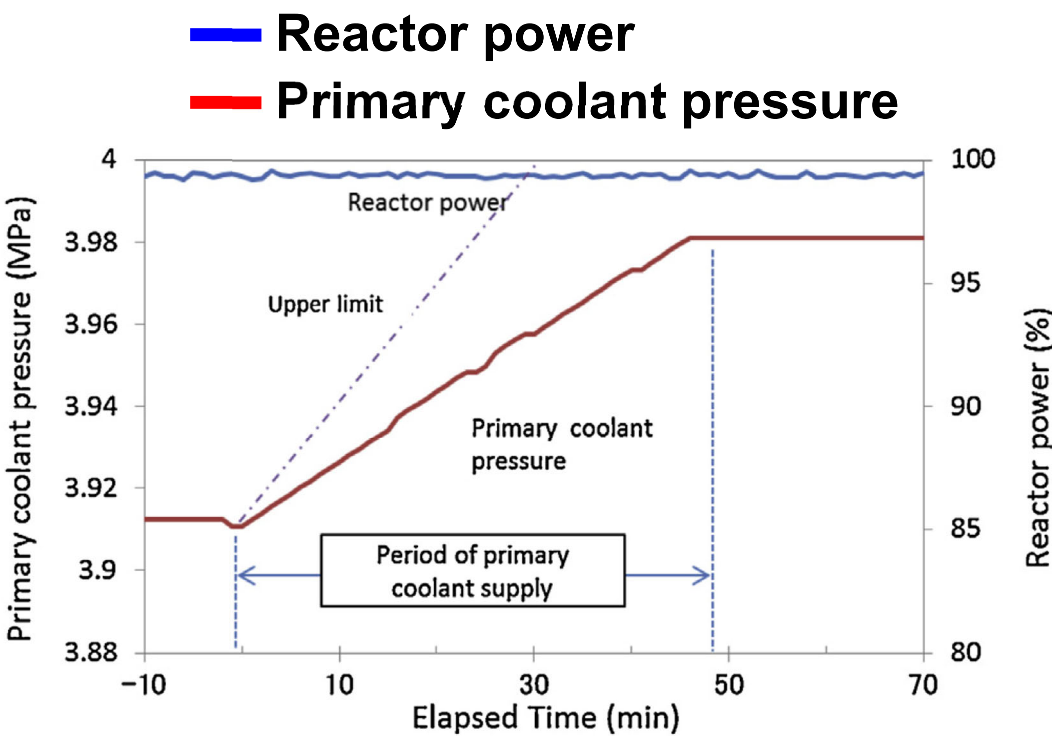
Y. Tachibana *et al.*, Nuclear Engineering and Design 224, 179–197 (2003).
S. Nakagawa, *et al.*, Nuclear Engineering and Design 233, 301–308 (2004) .

2. High temperature continuous operation

High-temperature operation at a reactor outlet coolant temperature of 950 ℃ was conducted for 50 continuous days.



Historical trends of secondary coolant temperature and exchanged heat of IHX



Change in the reactor power and the primary coolant pressure at the time of helium gas supply

Stability and reliability of the components and facility special to HTGRs were demonstrated through the long-term high temperature operation.

A. Shimizu, T. Kawamoto *et al.*, Nucl. Eng. Des. 271, 499–504 (2014).

3. Loss of forced cooling tests

- A series of **"Loss of Forced cooling(LOFC)"** tests have been conducted to confirm inherent safety features of HTGR using HTTR under OECD/NEA framework.

Participating countries

Japan
(Operating Agent)
US
France
Germany
Korea
Czech Republic
Hungary

- **Project duration**: 31 March 2011 ～ 31 March 2027
- **Test data**: Obtained by using JAEA's HTTR and shared with participants.
- **Objective**:

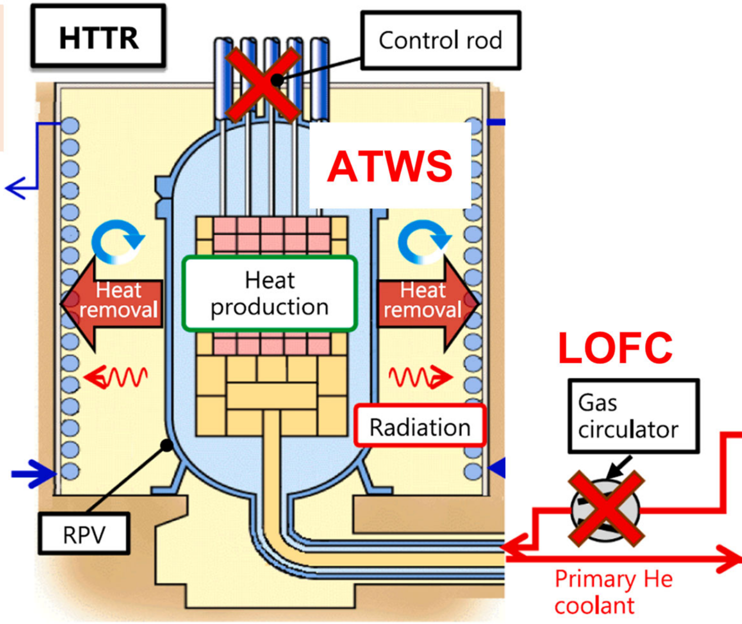
1. To provide data useful for verifying and improving analysis codes.
2. To understand the reactor physics phenomena following a LOFC event.

- By utilizing the HTTR, which has a maximum coolant outlet temperature of 950 ℃, we can cover the temperature ranges of other HTGRs currently at the design stage.
- Therefore, the collected LOFC test data will benefit not only Japan but also OECD/NEA member countries engaged in HTGR development.

Scope of experimental work of LOFC project

The LOFC tests were conducted with **HTTR under both the ATWS and LOFC situations.**

- The LOFC tests were **conducted to collect data, clarifying the transient characteristics** of the reactor and its surrounding equipment.
- These tests were carried out **without inserting control rods or restarting the HGCs.**



By following three tests, it was investigated how different the initial reactor power and the state of the VCS affect the transient characteristics.

Run 1	Standard case to be compared with Run 2 and Run 3. Reactor power of 30 % with the Vessel Cooling System (VCS*) operation
Run 2	**Reactor power of 100 % with the VCS operation**
Run 3	Reactor power of 30 % **without the VCS operation** (All cooling systems are down.)

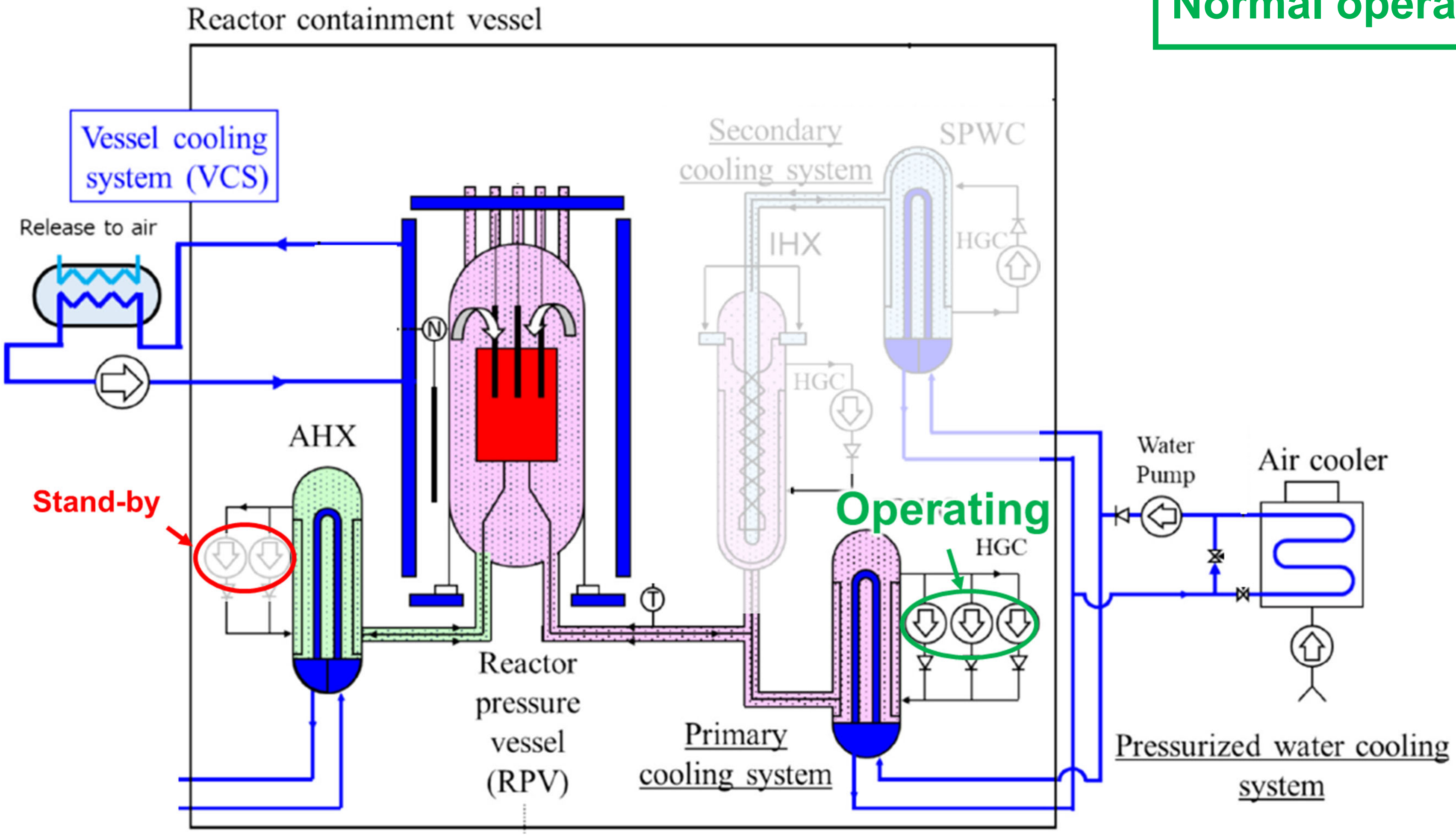
*VCS: cooling system to remove radiant heat from the surface of the reactor pressure vessel (RPV)

K. Nagatsuka *et al.*, Nucl. Eng. Des. 425, 113338 (2024).

Condition of Cooling system of HTTR (1/2)

- Condition before the LOFC tests

Normal operation mode



i. Confirmed the reactor initial conditions

ii. Switched the operation mode from normal to test mode

iii. Tripped All HGCs (primary coolant flow rate is lost)

iv. Tripped All VCS pumps [Run 3 only]

v. Monitored and collected test data

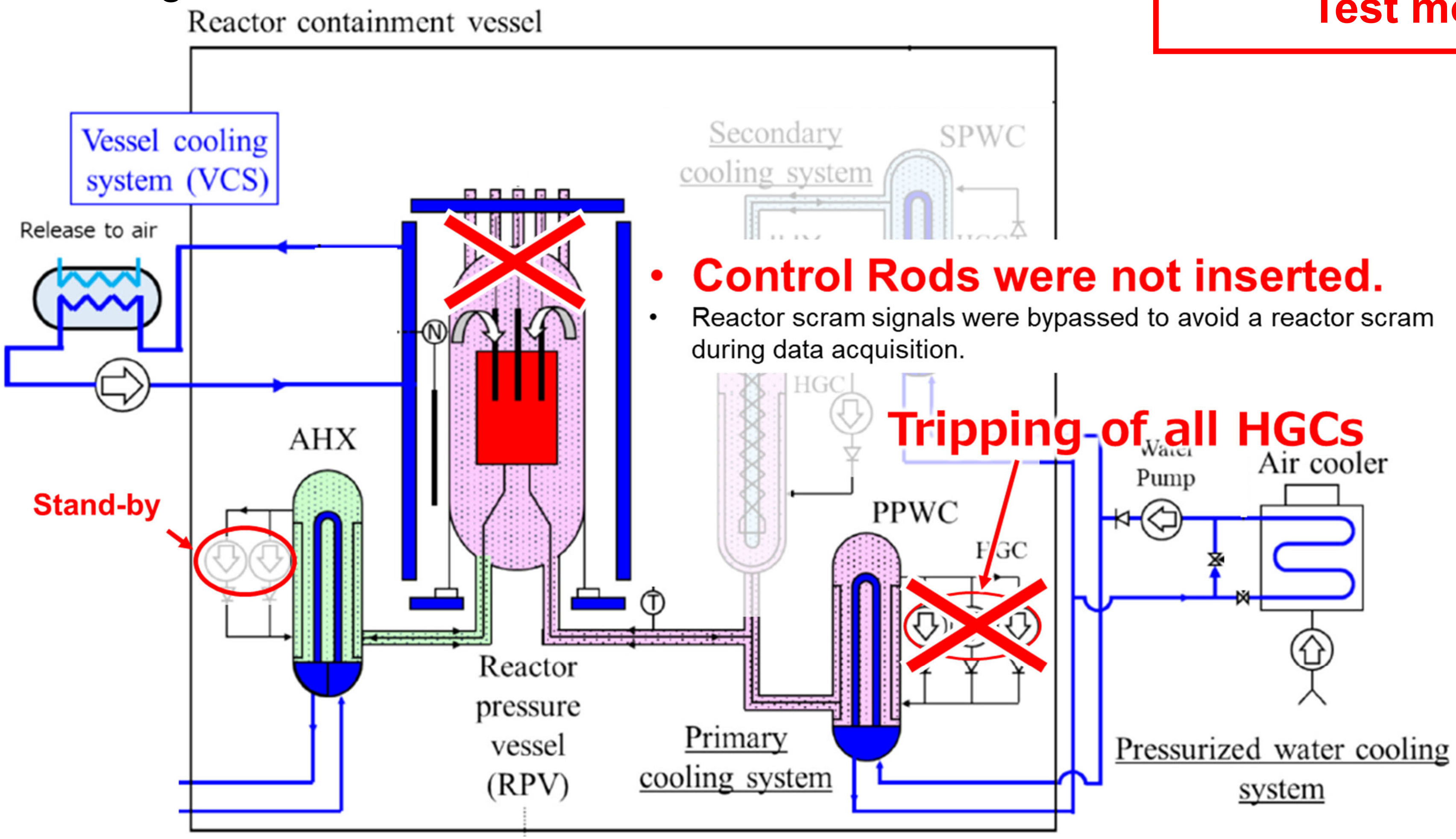
vi. Finished the test

S. Nagasumi *et al.*, Nucl. Eng. Des. 446, 114542 (2026).

Condition of Cooling system of HTTR (2/2)

- Condition during the LOFC tests

Test mode



- **Control Rods were not inserted.**
- Reactor scram signals were bypassed to avoid a reactor scram during data acquisition.

ii. Switched the operation mode from normal to test mode

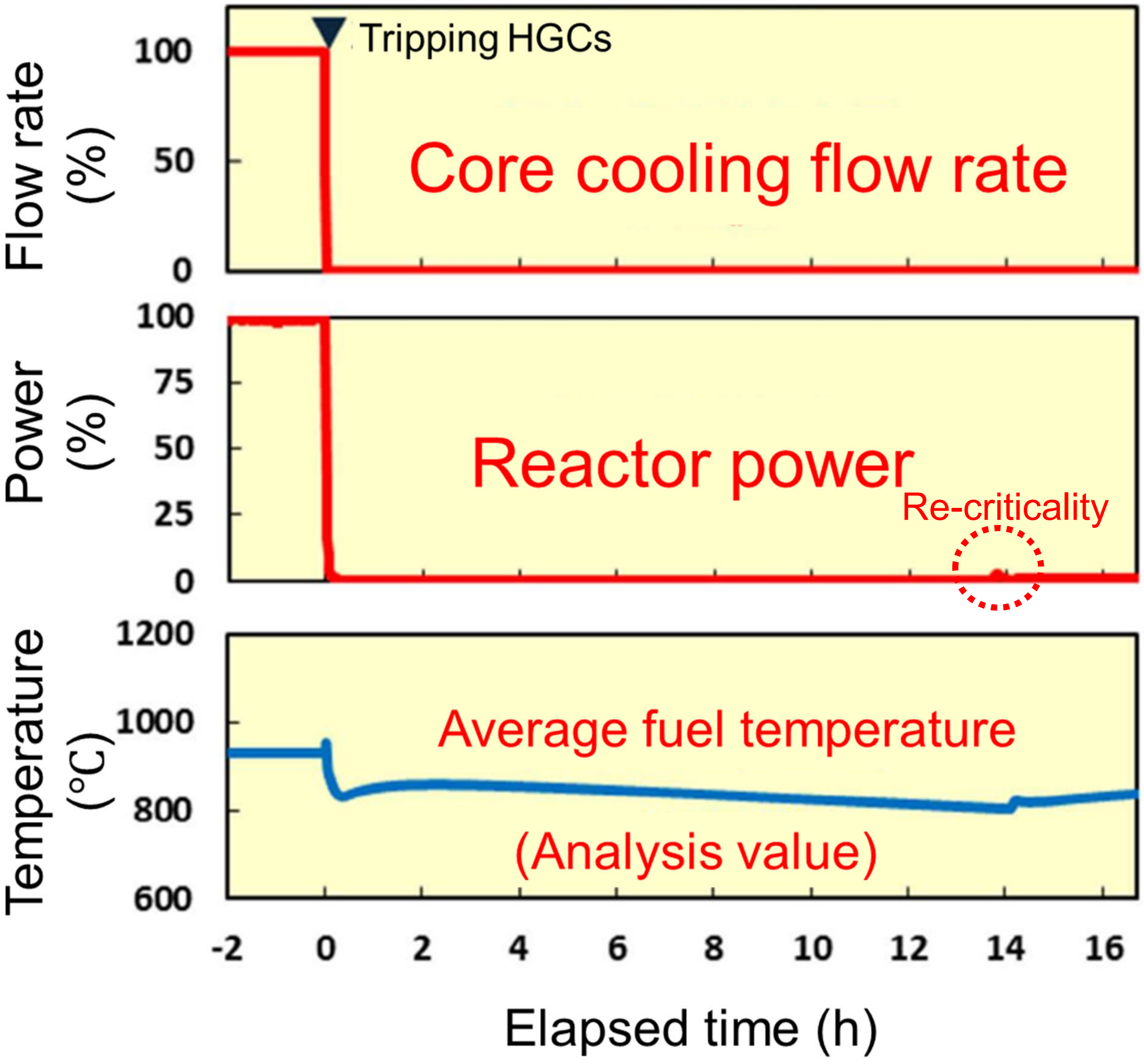
iii. Tripped All HGCs (primary coolant flow rate is lost)

iv. Tripped All VCS pumps [Run 3 only]

v. Monitored and collected test data

S. Nagasumi *et al.*, Nucl. Eng. Des. 446, 114542 (2026).

Test result (Run2)



- Coolant flow rate decreased soon after stopping HGCs.
- Reactor power also decreased due to the negative feedback effect.
- The reactor reached re-criticality about 14 h later. (The peak power is approximately 2.5%.)
- Re-criticality was caused by the increase of reactivity due to the temperature decrease of fuel and moderator, and decrease of Xe-135.
- After a sufficient time has elapsed, the reactor thermal power stabilizes at approximately 1%.
- Fuel temperature also decreased to approximately 800 ℃.

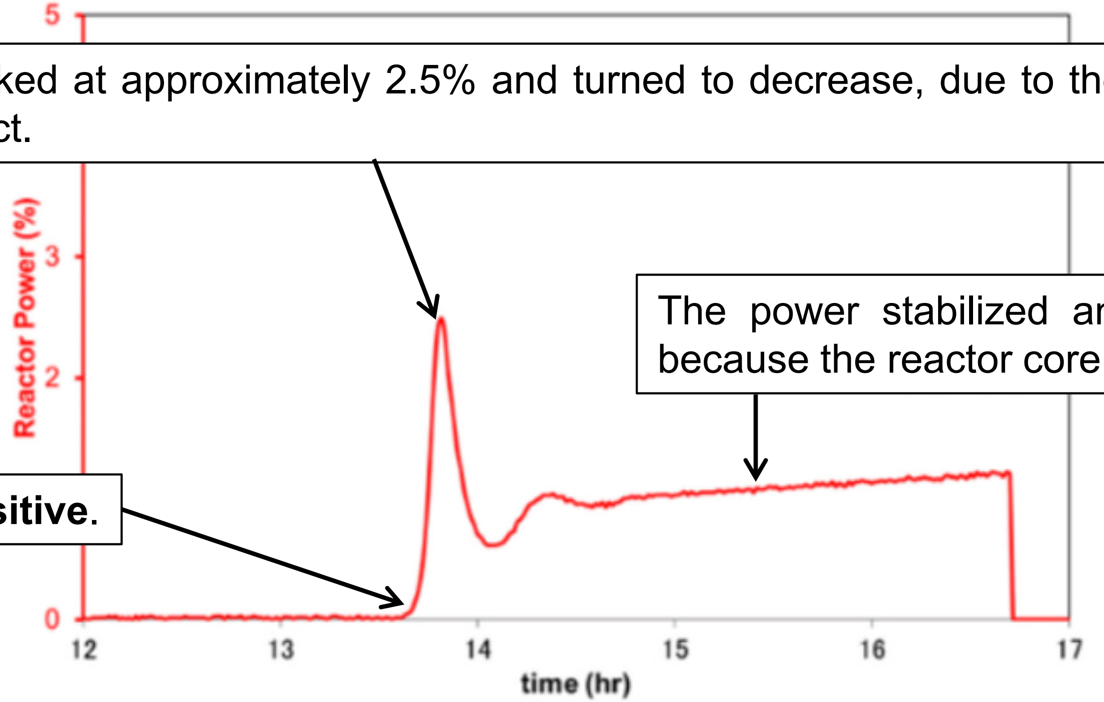
It was confirmed that the reactor power naturally decreased and reached to stable state without activating the reactor shutdown systems.

Department of HTTR, JAEA-Review 2025-32 (2025).

Reactor power around the re-criticality

The total reactivity depends on following three factors.

- **Fuel reactivity**
  When the fuel temperature rises, the reactivity decreases due to the Doppler effect.
- **Moderator reactivity**
  When the moderator temperature rises, the reactivity decreases due to neutron spectrum hardening.
- **Xenon reactivity**
  When Xenon concentration decreases due to the radioactive decay, the reactivity increases.



The reactor power peaked at approximately 2.5% and turned to decrease, due to the negative reactivity feedback effect.

The power stabilized and continued to rise slightly because the reactor core temperature still decreased.

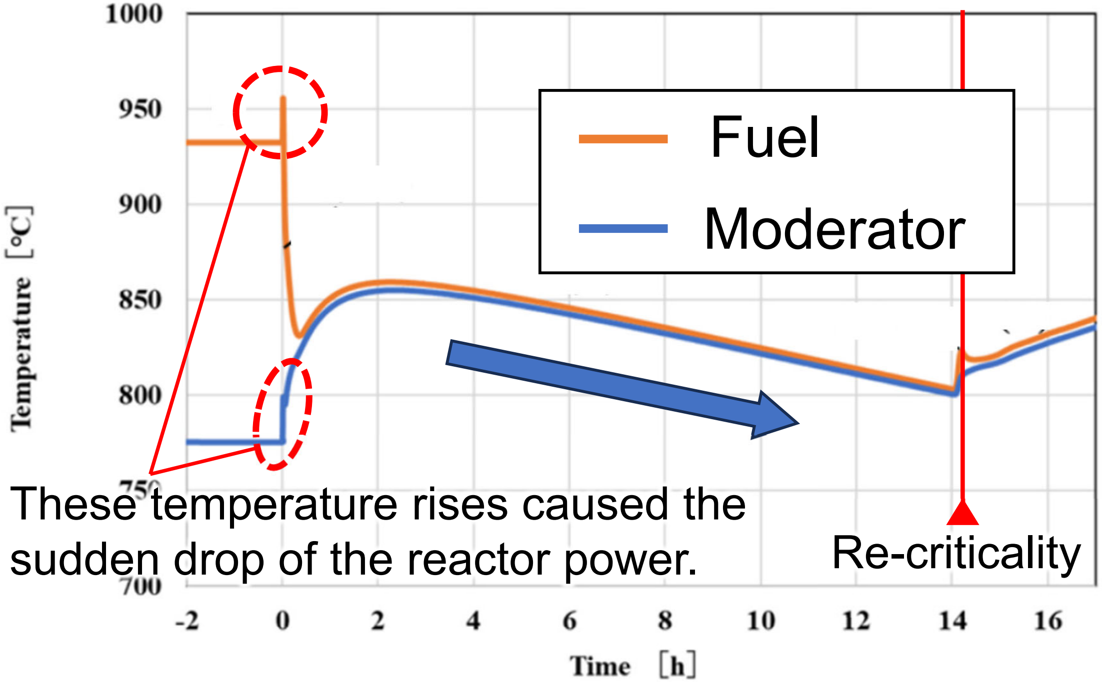
Total reactivity became **positive**.

Although the reactor power temporarily increased due to the re-criticality, the reactor remained in a low power state.

S. Nagasumi *et al.*, Nucl. Eng. Des. 446, 114542 (2026).

Temperature and Reactivity changes

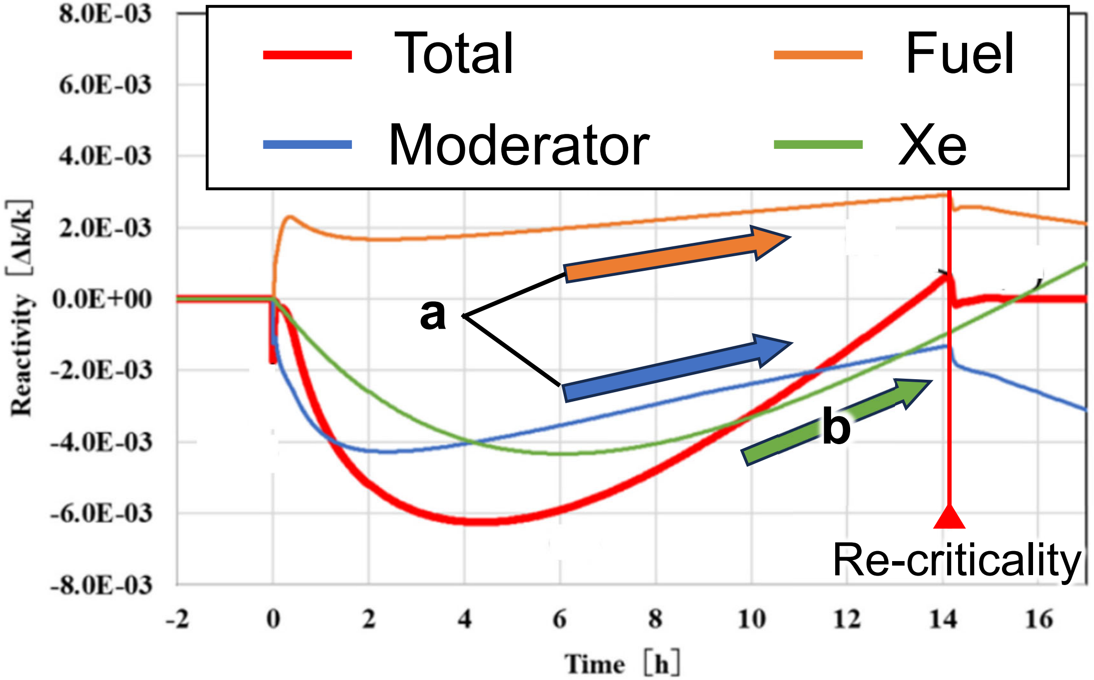
- Temperature change



These temperature rises caused the sudden drop of the reactor power.

Re-criticality

- Reactivity change



Re-criticality

Fuel & Moderator temperature decreases due to the following mechanism;

1. The heat is conducted from the core region to the outer part.
2. The heat is removed through natural convection and radiation from RPV surface.

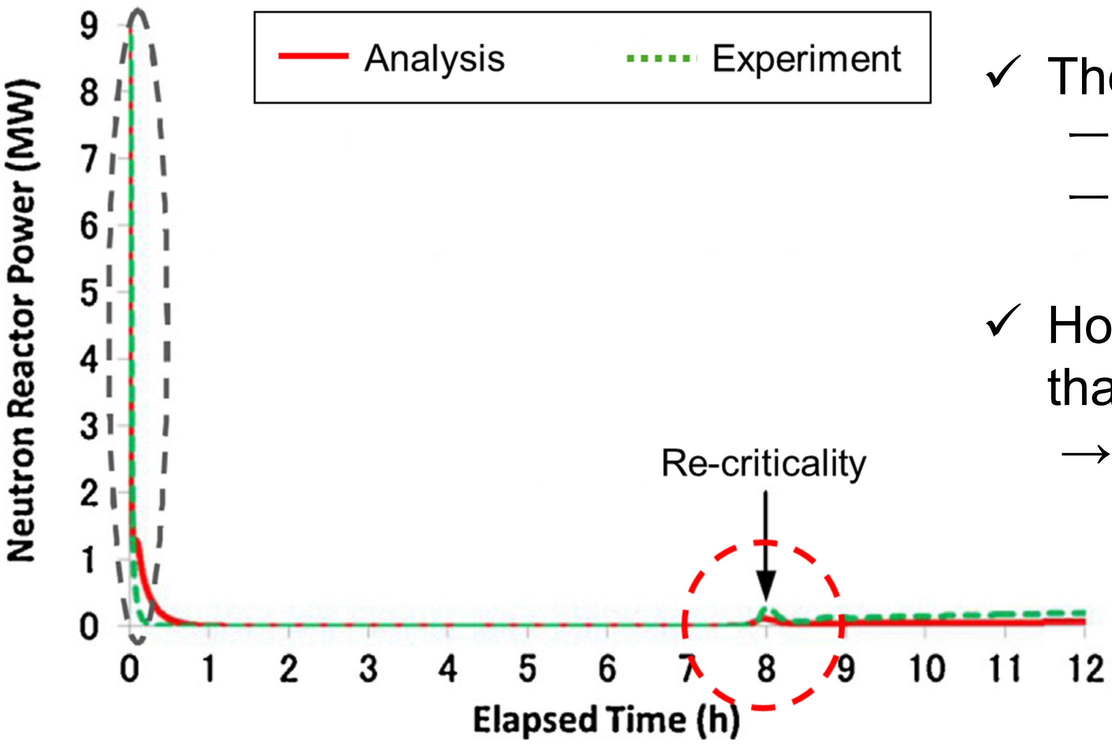
Each reactivity increases due to;

a → the decrease in the temperature.
b → the decrease in Xe concentration.
↓
Half-life of Xe-135: **9.14 h**

S. Nagasumi *et al.*, Nucl. Eng. Des. 446, 114542 (2026).

Test results of Run1 & Run3

- **Run 1** (Initial reactor power: 30%, VCS: Active)



Reactor power in Run 1

- ✓ The reactor power has a similar trend to Run 2.
  - ―It decreases soon after stopping HGCs.
  - ―It has a peak of the re-criticality.
- ✓ However, Run 1 reached the re-criticality sooner than Run 2.
  → In Run 2, Xenon override was larger than Run 1 due to the large initial reactor power.

- **Run 3** (Initial reactor power: 30%, VCS: **Inactive**)
  - ✓ The behavior in the reactor was almost same trend to that of Run 1.
  - ✓ The shielding concrete temperature around the RPV increased by 3 ℃.
    ―The heat transfer behavior during the VCS shutdown was observed.

K. Takamatsu *et al.*, Nucl. Eng. Des. 271, 379-387 (2014).

Safety demonstration test Commemorative Ceremony

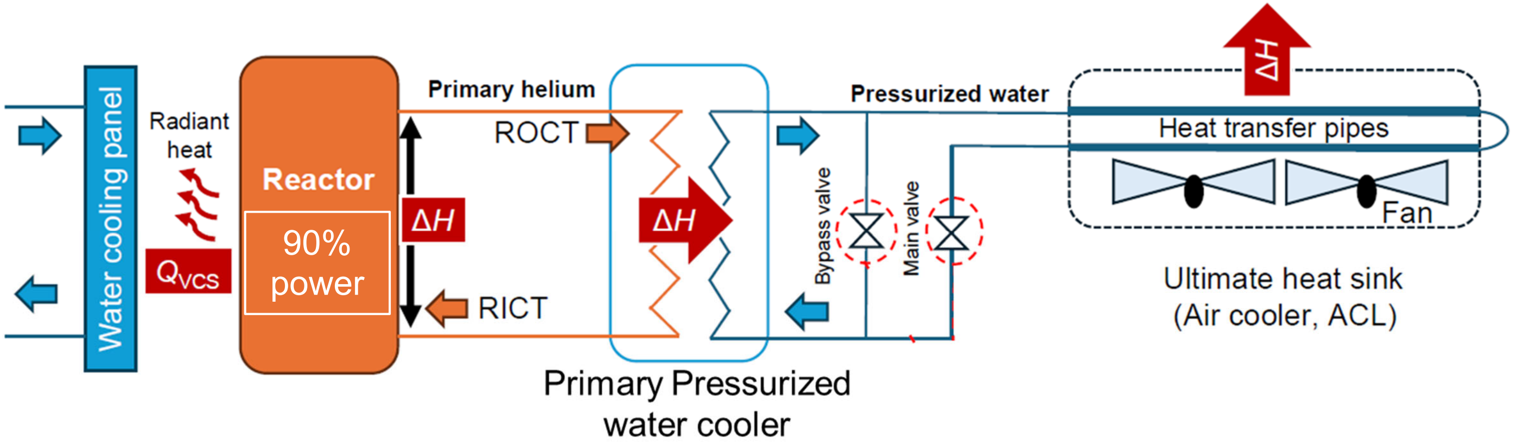
Safety Demonstration Test Commemorative Ceremony

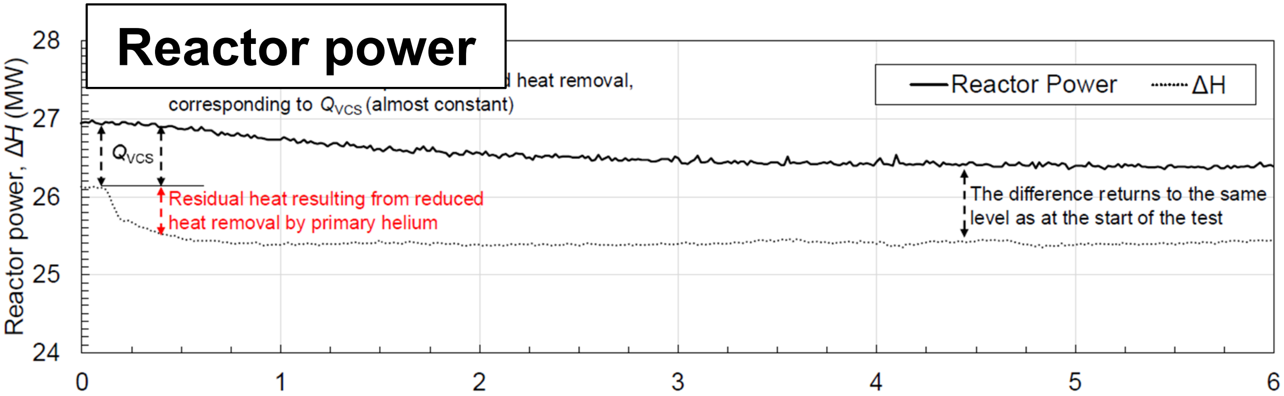
March 27, 2024

4. Thermal load fluctuation test

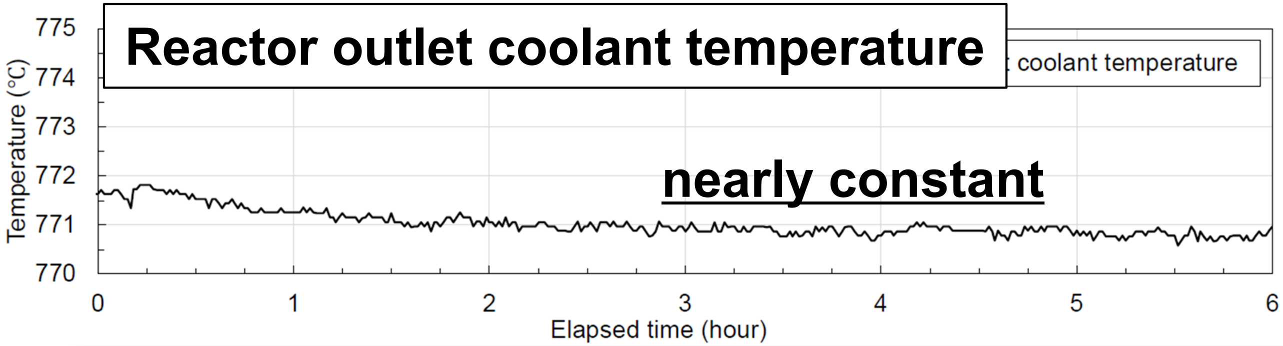
➢ Test conditions

- Reactor power: 90%.
- Reactor inlet coolant temperature (RICT) was intentionally raised by 11 ℃.




Reactor power

- The reactor power decreased by 2% and settled in a steady state without active controls such as the control rods insertion.


Reactor outlet coolant temperature

- The reactor outlet coolant temperature did not increase due to the heat storage capability of the core graphite blocks.

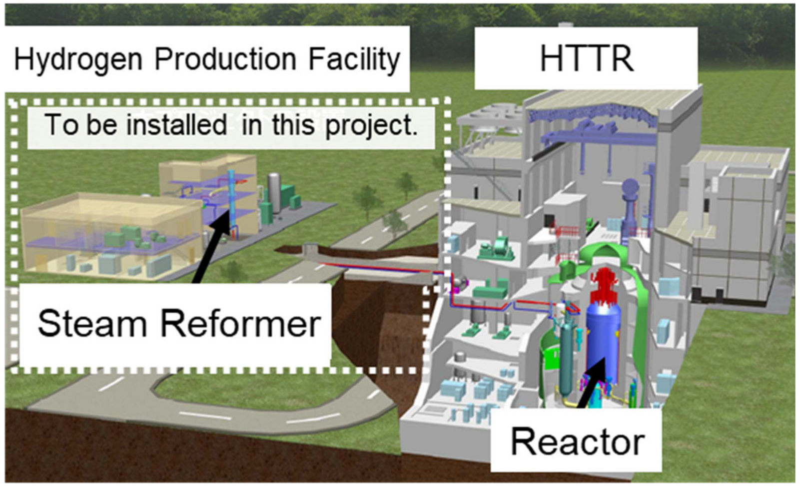
This result suggests that a reactor scram can be avoided even in the presence of disturbances.

T. Hasegawa *et al.*, “Reactor Response during Thermal Load Fluctuation Test Using HTTR” ICAPP 2025.

Heat Application Test plan in HTTR

➢ Objective

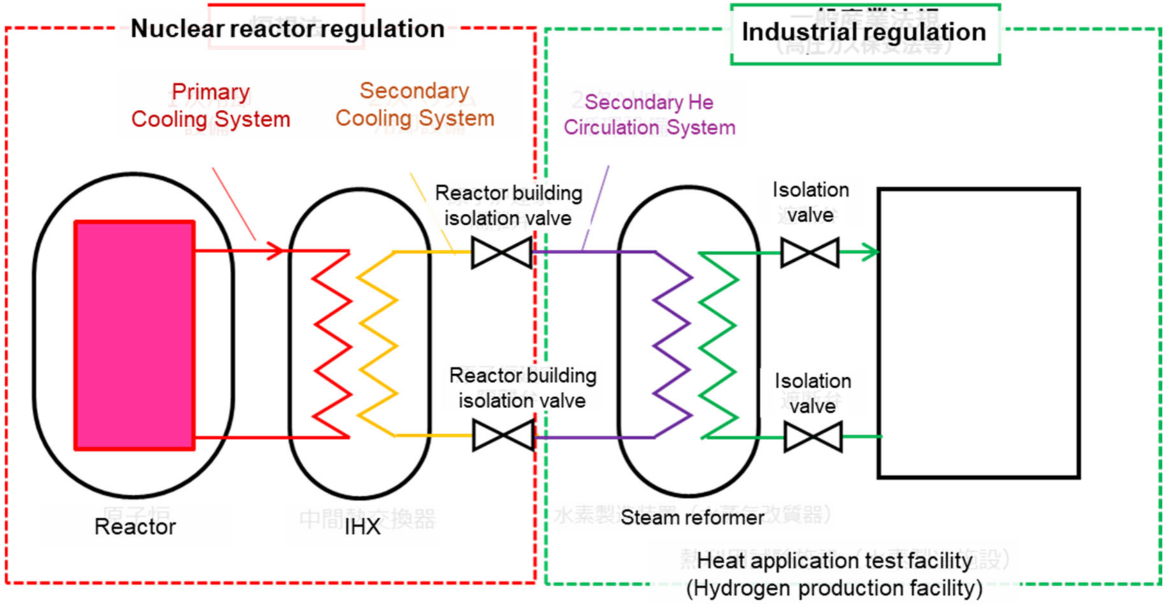
- Establish a safety design for coupling HTGR and H_2 plant through the licensing by the Japanese Nuclear Regulation Authority.
- Demonstrate the performance of components required for coupling between HTGR and H_2 plant.
    - ✓ High temperature isolation valve
    - ✓ Hot gas duct, etc.



Test image

➢ Tasks

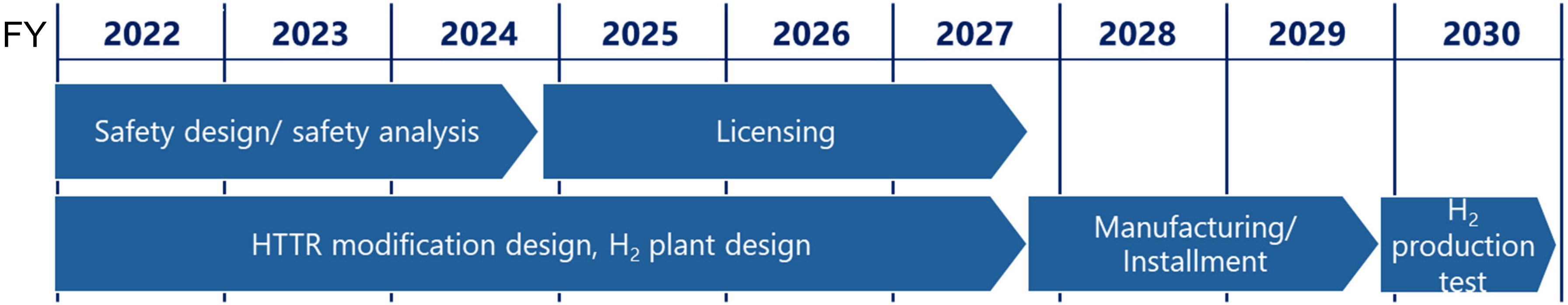
- Construct a steam methane reforming H_2 plant and connect to the HTTR.
- Conduct a continuous H_2 production test and plant dynamic tests.



Boundary of regulations

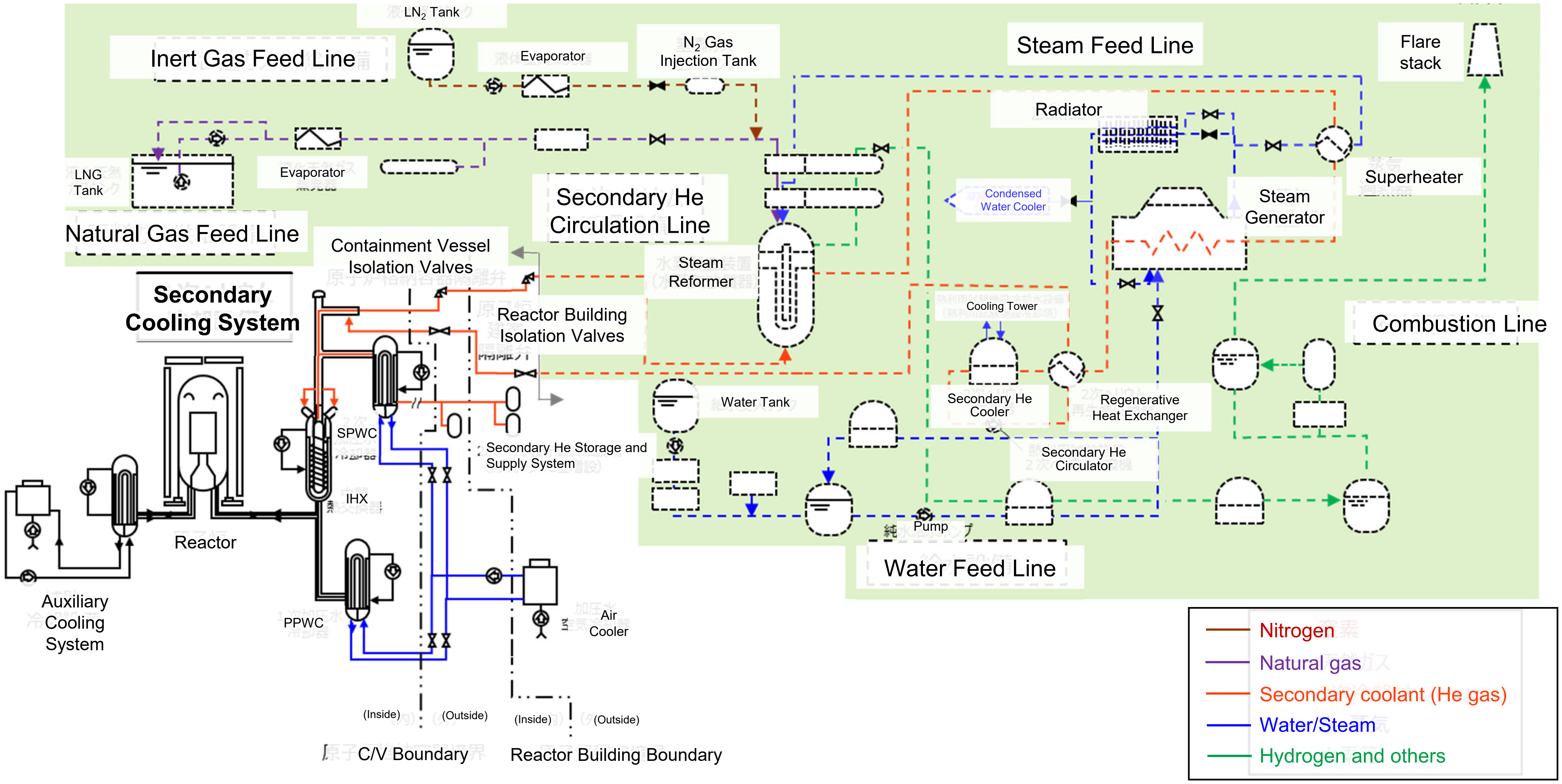
清水　厚志, 高温ガス炉試験研究炉「HTTR」の取り組み, 日本原子力学会　2026年春の年会 (2026).

➢ Project schedule (Plan)



Connect HTTR to the Heat Application Test Facility

- Secondary He piping of existing IHX will be modified and the piping will be extended to the outside of C/V and the reactor building.
- Hydrogen is produced by the Steam Generator using natural gas and steam.



*This chart can be changed due to upcoming detail design.

清水 厚志, 高温ガス炉試験研究炉「HTTR」の取り組み, 日本原子力学会 2026年春の年会 (2026).

Summary

- JAEA has established the technical basis for HTGRs through reactivity insertion test, high temperature continuous operation, LOFC tests, thermal load fluctuation test, etc. in HTTR.

- HTGRs have the inherent safety feature, which reduce reactor power naturally and transfer to a lower power state even if forced cooling and reactor shutdown functions are not operational.

- JAEA experimentally demonstrated the inherent safety features of HTGR through the safety demonstration tests in HTTR.
  → The first achievement in the world.

- Heat application test facility will be constructed near HTTR reactor building and hydrogen production demonstration will be started with using the heat from HTTR .