Efforts and future prospects for restarting HTTR

～R&D of high-temperature gas reactor contributes to carbon neutrality strategy～

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Content

1. Overview of HTGRs and the role of HTTR
2. New safety design policy considering the HTGR inherent safety
3. Efforts to restart HTTR
4. Prospects towards practical use of the HTGRs

Overview of HTGRs

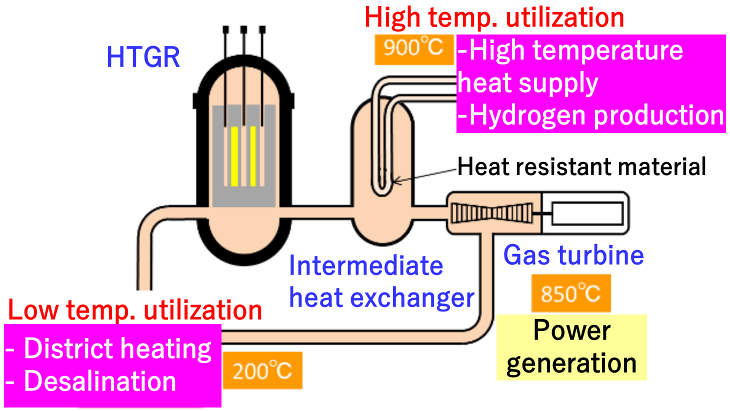
Innovative reactor for carbon neutrality with superior inherent safety and various heat utilizations

Promoting R&D as a national project in US, UK, Poland, Canada, and China, etc.

Various heat utilizations

- Supply 900 °C of heat

Hydrogen production, power generation, seawater desalination, etc.



Properties	HTGRs	LWRs
Outlet temp.	850°C~950°C	~300°C
Power generation efficiency	～50%	～35%
Coolant	Helium gas	Light water
Moderator	Graphite	Light water
Fuel type	Ceramic coated fuel particles	Zircaloy cladding tubes

Superior inherent safety

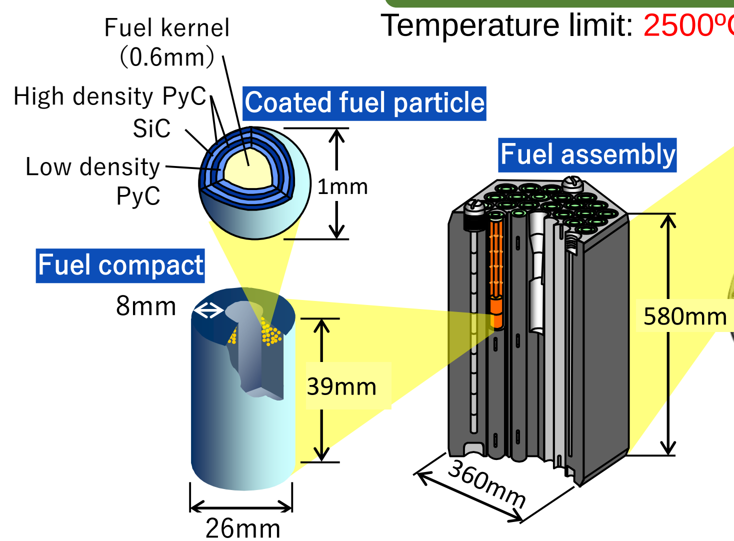
- Inherent safety features

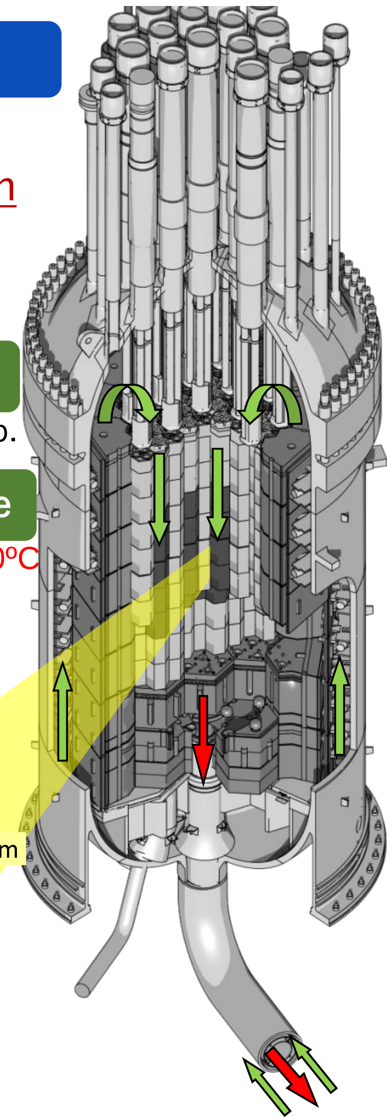
Designed to prevent core meltdown

Ceramic fuel coating
Retain radioactive material at 1600ºC

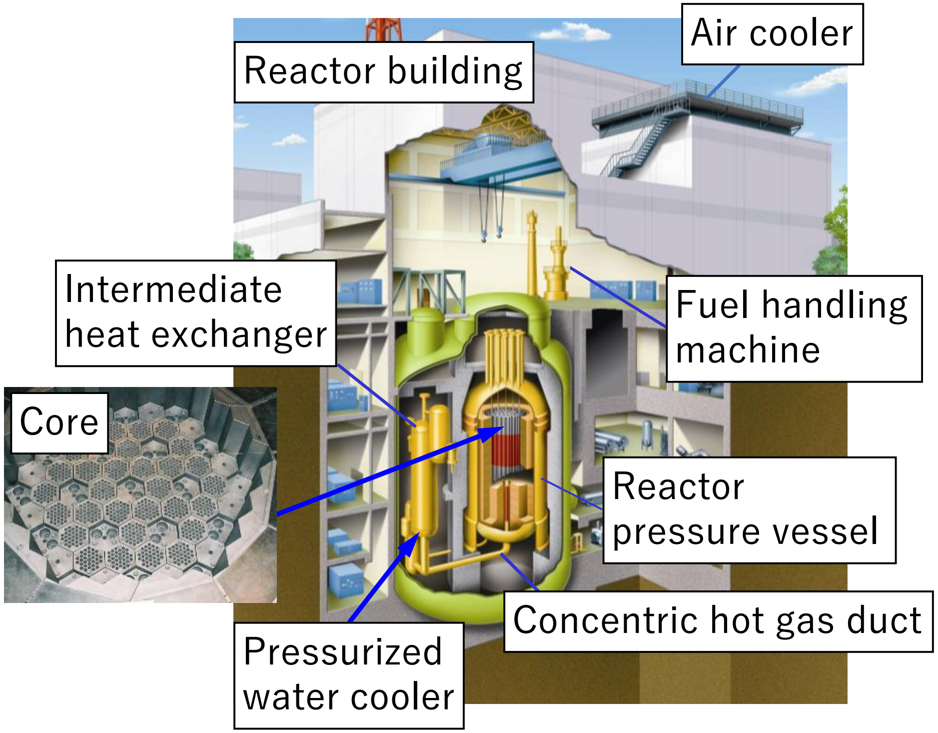
Helium coolant
Stable at high temp.

Graphite structure
Temperature limit: 2500ºC





Outline and role of the HTTR



Reactor thermal power	30MWt
Outlet temperature	850～950°C
Primary coolant	Helium
Moderator	Graphite
First criticality Achieved 950°C *(world's highest)*	1998 2004
Safety demonstration test 950°C/50 days operations	2010

HTTR restarted on 7/30/2021

Role of HTTR

①Establish basic technology for HTGRs by accumulating operation and test data

②Contribute to establishment of HTGR safety policy through safety demonstration tests

③Develop hydrogen production technology contributes to carbon neutrality

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Construction of a new safety design policy considering the inherent safety of HTGRs (1/2)

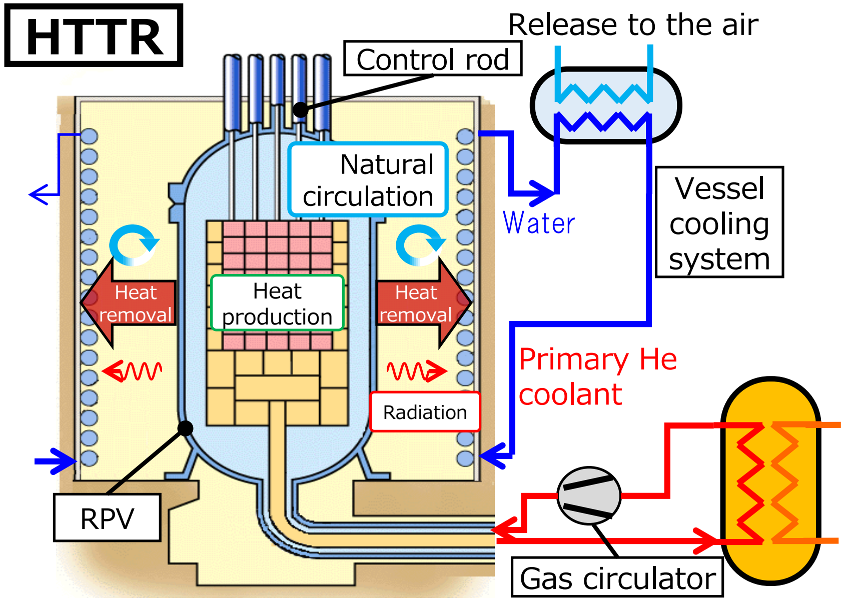
Task

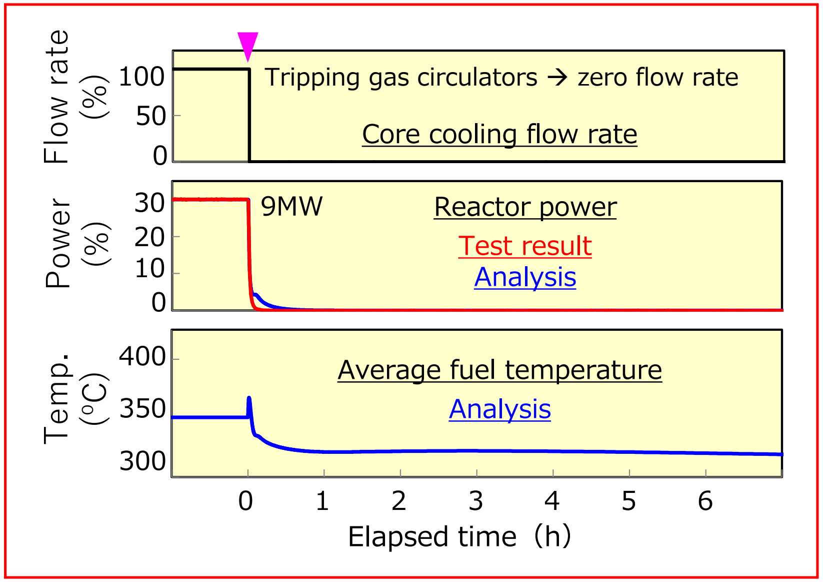
HTTR was designed based on LWR safety design policy without considering the inherent safety of HTGRs. For practical use, new safety design policy should be established by taking into account the inherent safety of the HTGRs.

Demonstration of inherent safety feature

Test conditions
- Tripping all gas circulators to reduce primary coolant flow rate to zero (No core cooling)
- No scram operation of reactor (No core reactivity control)

Test results
- Reactor is naturally shut down and kept stable (inherent shutdown feature)
- Residual heat is naturally removed from RPV by heat circulation and radiation





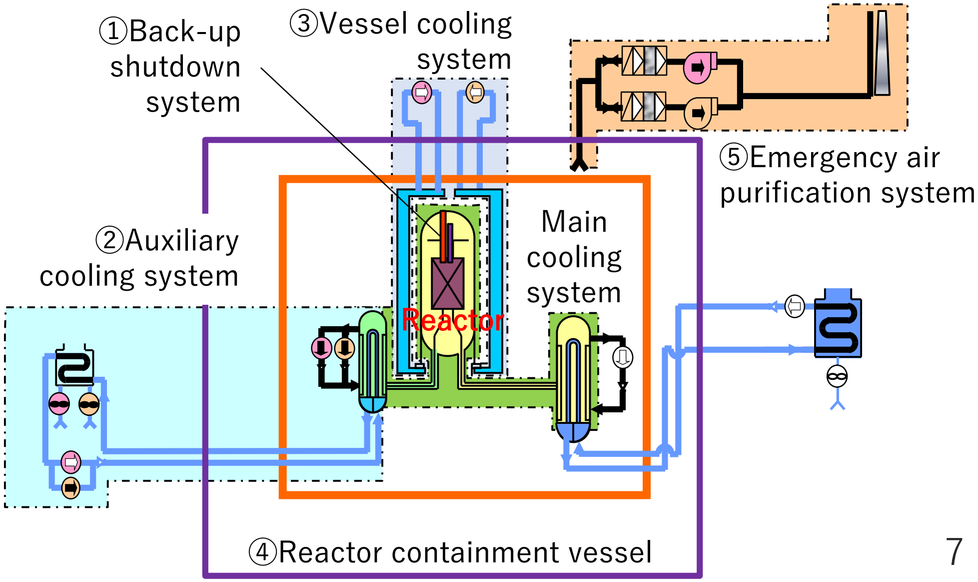
Construction of a new safety design policy considering the inherent safety of HTGRs (2/2)

Result

- Established new safety design policy considering inherent safety of HTGRs; obtained permission to change the reactor installation
- Relax design requirements. Not require large-scale reinforcement, such as secure power supply, which is essential for LWRs

Safety functions	Safety policy at HTTR construction	HTTR's new safety design policy
Shutdown	Main：Control rods system＊ Reserve：Back-up shutdown system＊	Main：Control rods system＊ Reserve：Inherent shutdown characteristic, ① back-up shutdown system＊
Cooling	Auxiliary cooling system＊ Vessel cooling system＊	Natural heat removal from the core, ②Auxiliary cooling system＊, ③Vessel cooling system＊
Confinement	Reactor containment vessel ＊ Emergency air purification system＊	Confinement by coated fuel particles, ④Reactor containment vessel＊, ⑤Emergency air purification system＊

＊Safety systems



Optimized ①～⑤ safety systems (class 1⇒class 2)

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Efforts to restart the HTTR

Activities for restarting

Established the team to examine issues for restarting in the department of HTTR

- Examined impact of long-term shutdown
- Investigated aging-deteriorations

→ Confirmed equipment soundness in operation without nuclear heat

- Classify items to be confirmed in operations

→ Confirmed at each stage of output rise

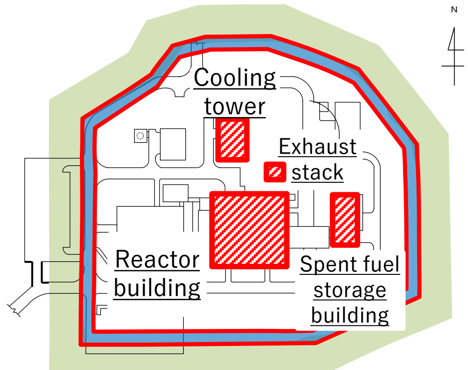
Safety measures construction

External fire measures

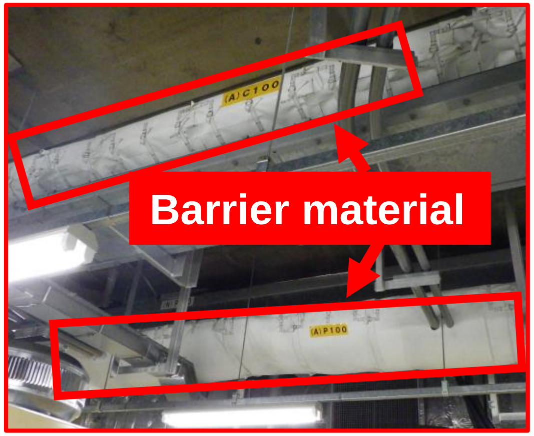
- Established a new firebreak surrounding HTTR to prevent the spread of external fire

Internal fire measures

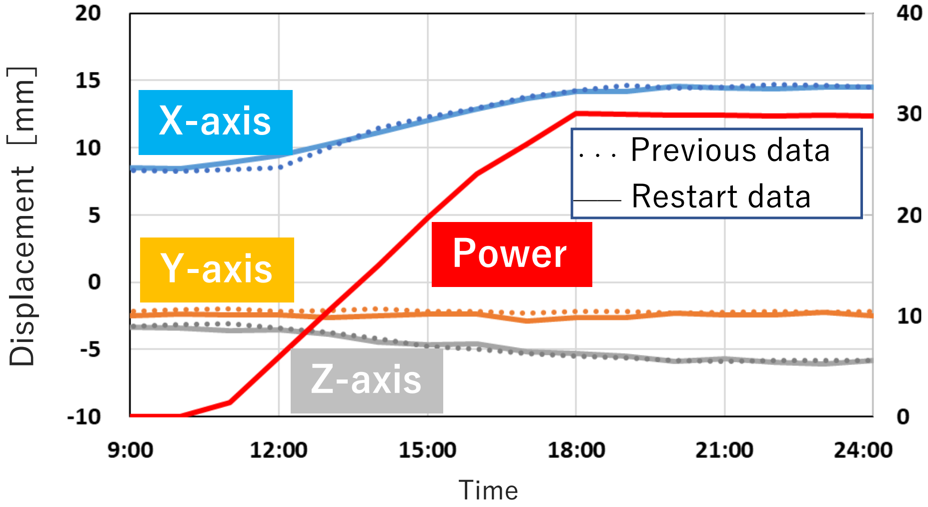
- Installed fire-resistant and heat-shielding barrier to protect cables



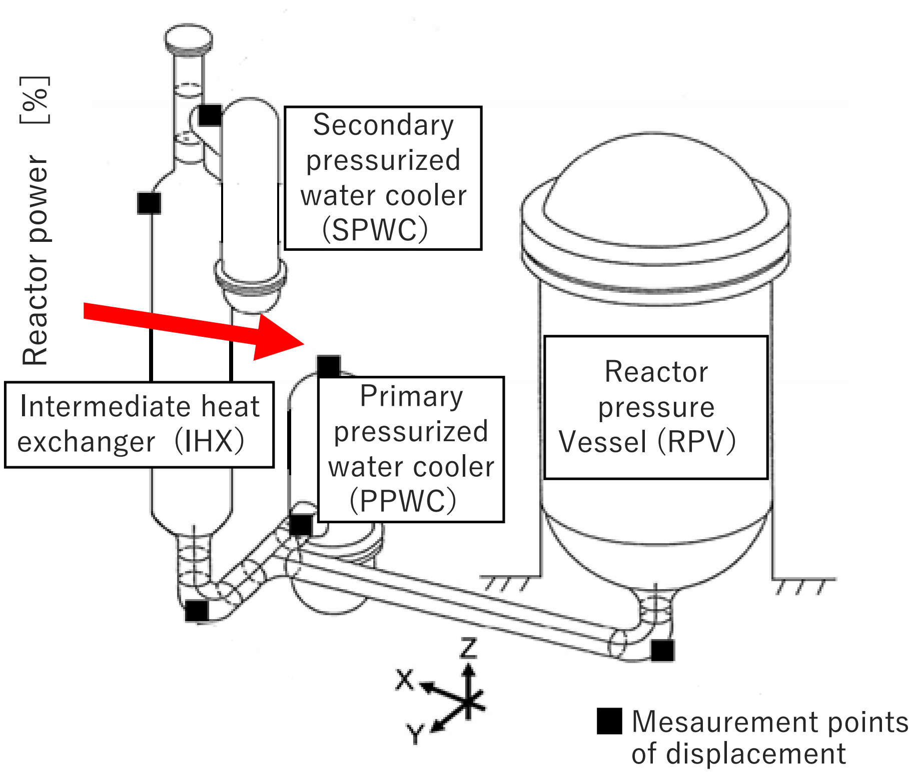
: Fire protection road (wide9.5m)
: Firebreak zone (wide 20m)
: Protective equipment



Restart of HTTR



Thermal displacement of primary pressurized water cooler (power from 0 – 30%)



Results

- HTTR restarted on 7/30/2021
- Confirmed no effect of long-term shutdown by comparing to the past operation data; achieved safe and stable operation
- Resume accumulating technical data for the development of HTGR

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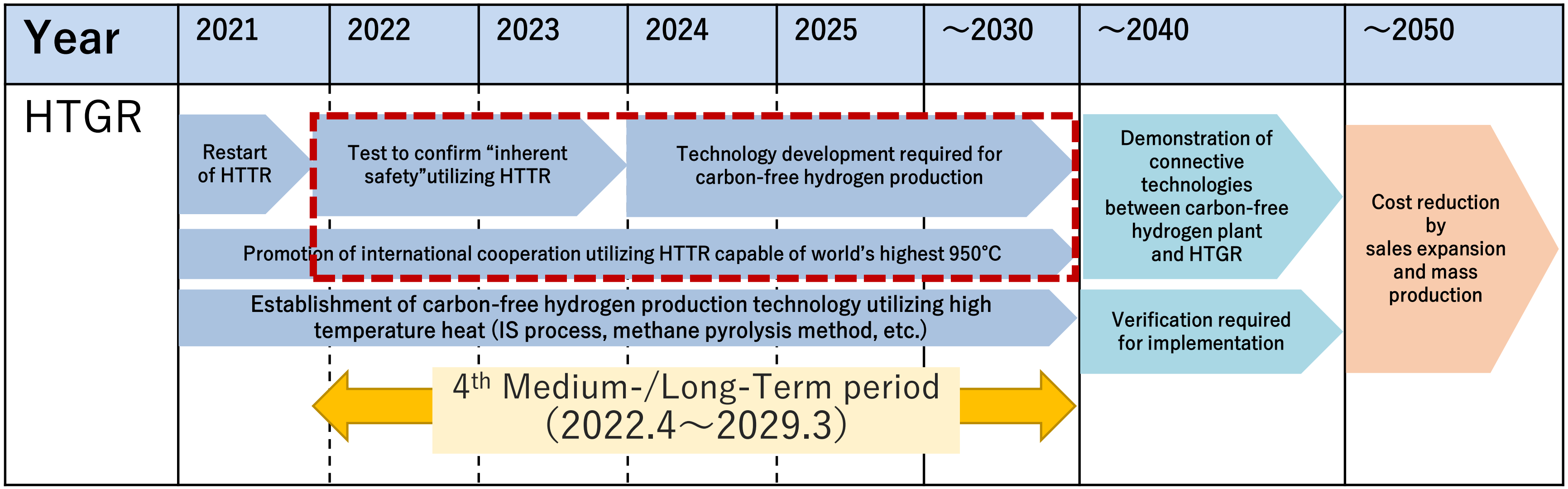
Position of HTTR in green growth strategy

"Roadmap" of Growth strategies for nuclear industry

Green Growth Strategy Through Achieving Carbon Neutrality in 2050 (from 2021.6.18)



・Confirm inherent safety with HTTR demonstration test, promote international cooperation
⇒ Joint Test by HTTR, LOFC* Project to demonstrate the safety of HTGRs

・Develop technology required for carbon-free hydrogen production
⇒ Demonstrate hydrogen production using nuclear heat by connecting the hydrogen production facility to HTTR

*LOFC: Loss of forced cooling test

Safety demonstration test

Overview

Joint Test by HTTR, LOFC Project

Japan US France Germany Korea Czech Republic Hungary

- Simulating station blackout
- Inactive control rods system
- Inactive all cooling functions (gas circulator + vessel cooling system)

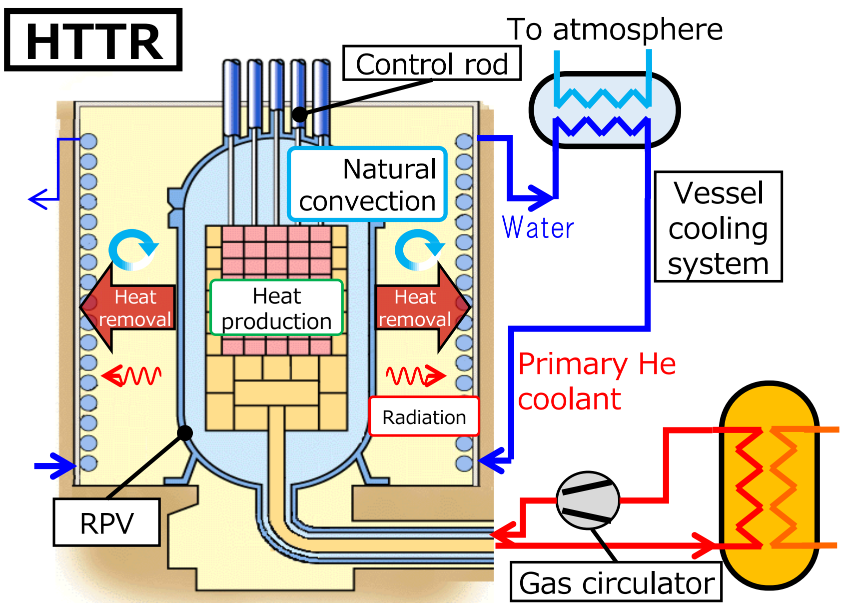
→Ensure the inherent safety of the reactor

Test plan

☑ Low power (30%(9MW)) **LOFC test (Run1)**
- Tripped gas circulators
- Inactive control rods system ・ ・ **Completed** (2010)

☐ High power (100%(30MW)) **LOFC test (Run2)**
- Tripped gas circulators
- Inactive control rods system

☐ Low power (30%(9MW)) **LOFC test (Run3)**
- Tripped gas circulators
- Inactive control rods system
- Inactive vessel cooling system



Expected results

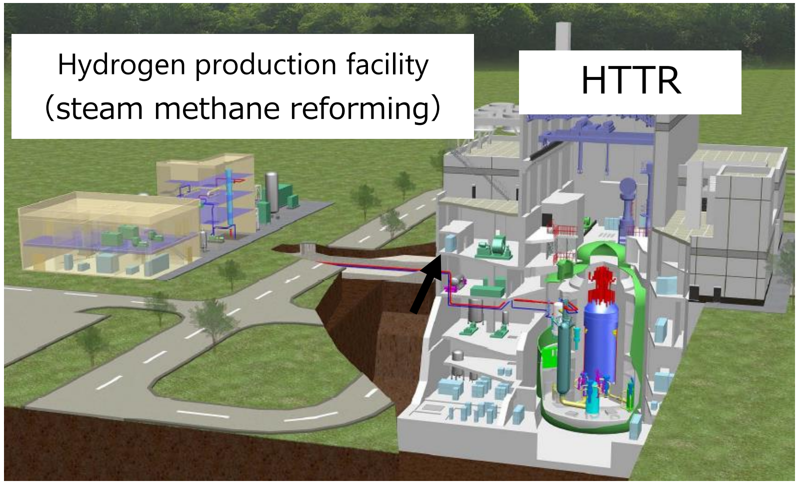
- Demonstrate inherent safety of the HTGR with actual facilities
- Accumulate data for the development of a practical HTGR

Connection of hydrogen production facility to HTTR

Purpose

Develop technology for carbon-free hydrogen production based on Green growth strategy by 2030

- Establish a safety design for connecting HTTR to Hydrogen production facility
- Confirm stable production performance and plant control by Hydrogen production test



Expected results

- Demonstrate performance of components required for coupling between HTGR and Hydrogen production facility design

FY	2022	2023	2024	2025	2026	2027	2028	2029	2030
Design, Construction, Operation	HTTR modification design				Modification	Commissioning	Hydrogen production test		
	Hydrogen production facility design			Manufacturing	Installment				
Safety evaluation permit compliance test plan	Safety evaluation method development			Test plan Evaluation method development					
		Safety evaluation			Examination plan review				

Development schedule

R&D of high-temperature gas reactor contributes to carbon neutrality strategy

- Establish the technical foundation by Joint Test by HTTR, LOFC Project to demonstrate the safety of HTGRs

- Demonstrate Japan’s HTGR technology through international collaboration

- Demonstrate hydrogen production using nuclear heat by connecting a hydrogen production facility to HTTR