Side Event of 63rd IAEA GC organized by JAEA, 18th September 2019, Vienna Austria

Role of HTGR in Japan and Japan's HTGR Technology

18th September 2019

Kazuhiko Kunitomi

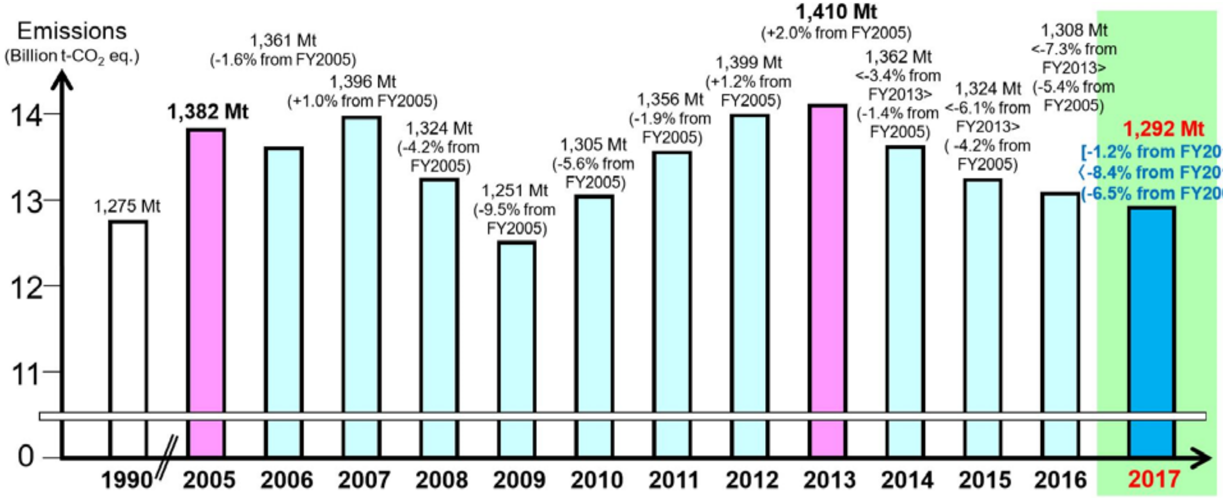
Sector of Fast Reactor and Advanced Reactor Research and Development
Japan Atomic Energy Agency (JAEA)

Role of HTGR in Japan
-Greenhouse gas emissions & reduction goals-

Plan for global warming countermeasures (Cabinet decision on May 13, 2016)

- Mid-term target: 26.0% reduction by FY2030 compared to FY2013
- Long-term goal: 80% reduction by 2050

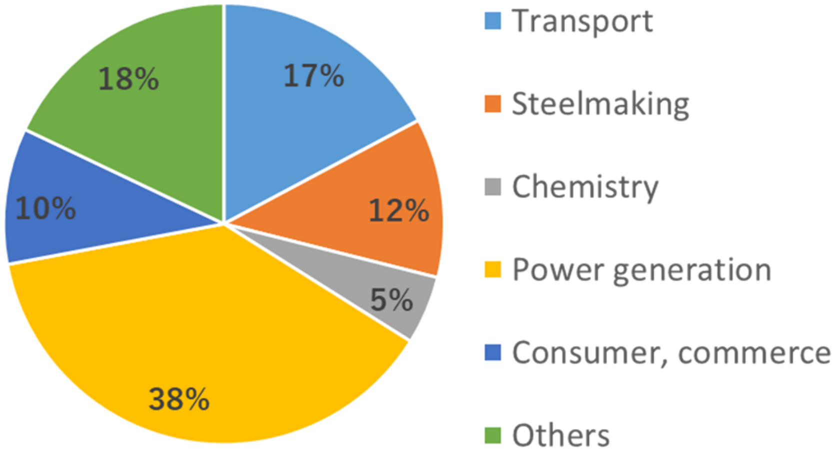
GHG emission in Japan (Final report of FY2017)



Ref. : Website of Ministry of Environment, Japan

- The emission reduction in FY2017 : 8.4% compared to FY2013
- To achieve the goal,
  - ✓Reduction by additional 18% by 2030
  - ✓Reduction by additional 72% by 2050

Breakdown of GHG emission (2016)



Role of HTGR

- HTGR producing hydrogen for nuclear steel making and fuel cell vehicle
- HTGR producing steam for conventional industries
- HTGR for absorbing renewable power variation

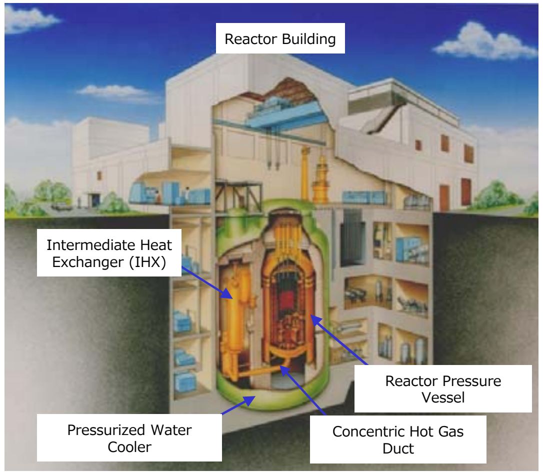
Use of HTGR for not only power generation but also for the other fields

History and status of HTTR

Specification

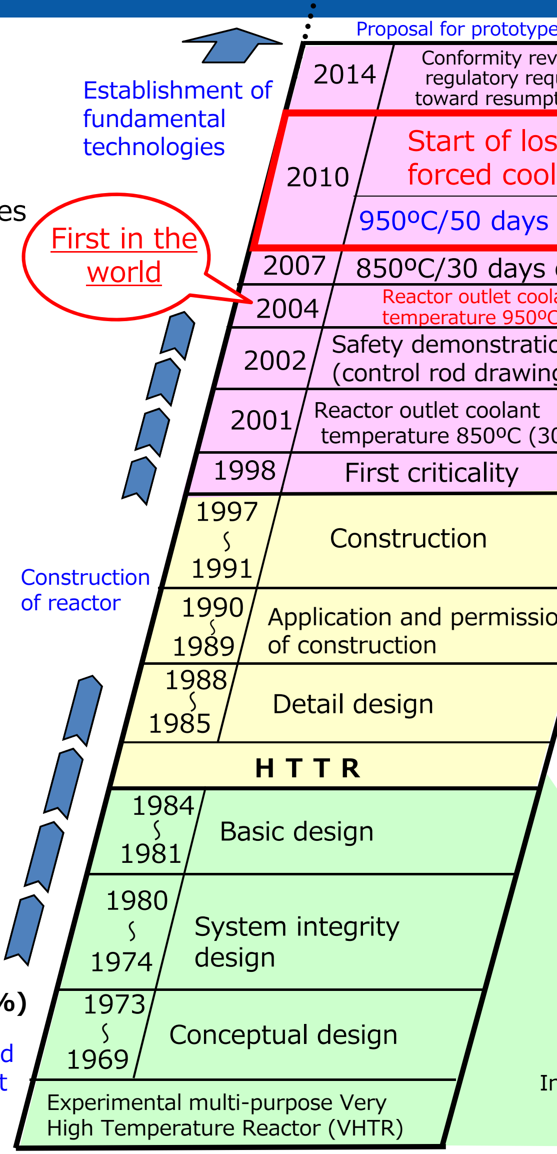
Purpose

☐ Establishment of HTGR technologies
☐ Establishment of heat application technologies



Specification of HTTR

- **Reactor thermal power ··30MW**
- **Reactor coolant ·············· Helium gas**
- **Reactor inlet/outlet coolant temperature ·········· 395ºC / 850ºC, 950ºC**
- **Reactor material ······ Graphite**
- **Fuel ·············· UO_2 coated particle fuel**
- **Uranium enrichment ··· 3% ~10% (average 6%)**



Proposal for prototype commercial system

Establishment of fundamental technologies

First in the world

Construction of reactor

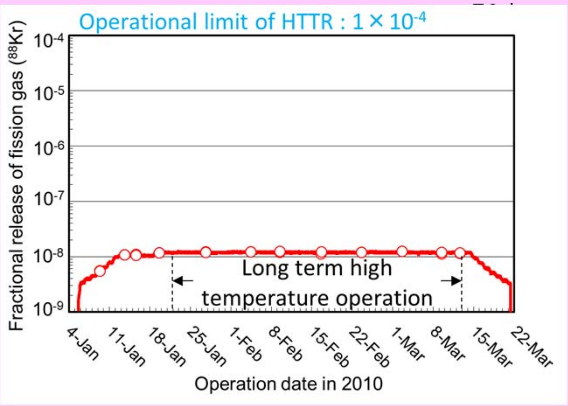
Research and development and design

2014	Conformity review on the new regulatory requirements start toward resumption of operation
2010	Start of loss of forced cooling test 950ºC/50 days operation
2007	850ºC/30 days operation
2004	Reactor outlet coolant temperature 950ºC
2002	Safety demonstration test (control rod drawing test)
2001	Reactor outlet coolant temperature 850ºC (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 (VHTR)	

Long term high temperature operation

<Integrity of fuel coating>

950oC,



➢ R/B of ^{88}Kr : 4 orders of magnitude less than the operational limit

Research and development

Fuels·Materials

In-pile helium loop (OGL-1)

Reactor physics

Very High Temperature Reactor Critical assembly (VHTRC)

Thermal hydraulics

Helium Engineering Demonstration Loop (HENDEL)

HTGR technologies developed in HTTR Project

Japan`s HTGR technologies are front runner in the world.

- Experiences of HTTR design, construction, operation
  (MHI, Toshiba/IHI, Hitachi, Fuji Electric, KHI, etc.)

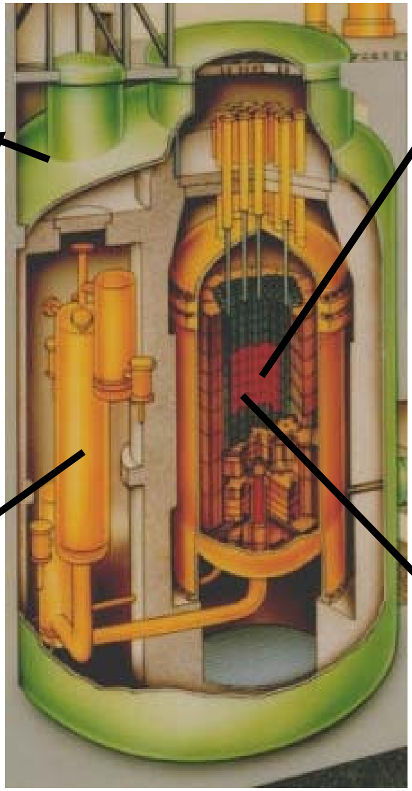
A lot of technical data of HTTR has been accumulated.
Optimum design of commercial HTGR may be conducted using Japan`s technologies alone.

- High temperature resistant metal, Hastelloy XR (Mitsubishi Material)

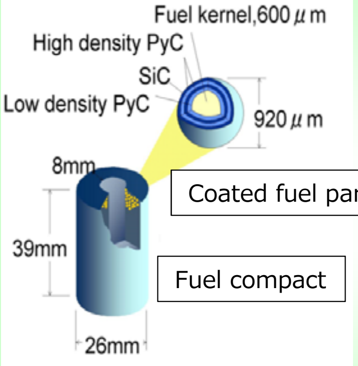

Intermediate heat exchanger (IHX)

Hastelloy XR is applicable at 950°C as nuclear structural material.

IHX（Toshiba/IHI) can deliver hot helium gas at 950°C to outside of the reactor pressure vessel.



- Fuel (Nuclear Fuel Industry)

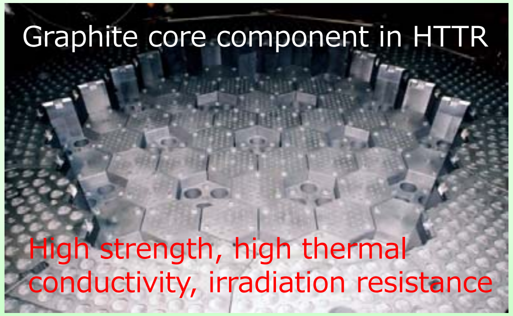


Ceramics coating layer retains fission products inside the coated fuel particle at extreme low leak level.

Ceramics coating is stable for long-term.
(3 times higher burnup than LWR)

- Graphite, IG-110 (Toyo Tanso)

World highest quality graphite
(isotropic, high density) →Adoption by HTR-PM


Graphite core component in HTTR

High strength, high thermal conductivity, irradiation resistance

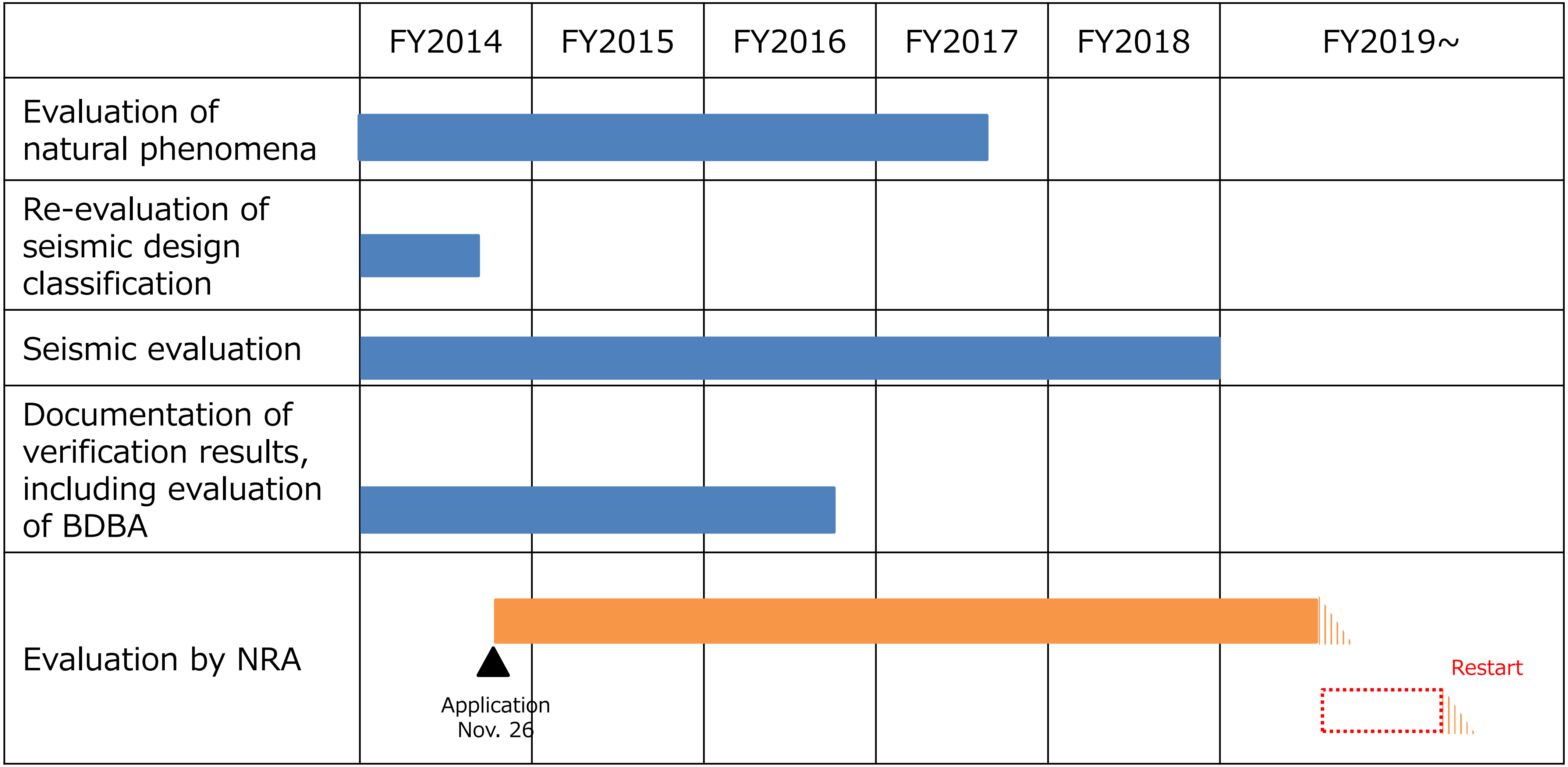
Status of regulatory review on HTTR

Major discussion item		Regulatory review condition	Regulatory review results	Additional countermeasures
Earthquake	Design seismic ground motion	Raised from 350gal to 973gal	No large-scale reinforcement due to the degradation of the SSCs.	Not required
	Re-evaluation of seismic design classification	Some of safety systems, components and structures (SSCs) were classified from S to B based on results of safety demonstration tests. ➢ Core heat removal: S class to B class ➢ Reactor internal structure: S class to B class.		
Tsunami evaluation		Assumption of tsunami height for evaluation : 17.8m from sea level	Tsunami does not reach the site because siting location is 36.5 meters high from the sea level.	Not required
Evaluation of integrity of SSCs against natural phenomena such as tornado, volcano, etc.		● Design basis tornado wind speed: 100 m/s ● Thickness of descent pyroclastic material by volcano: 50 cm	● All SSCs needed to be protected are installed inside the reactor building ● Fire proof belt necessary around reactor building.	Fire proof belt was required.
Fire		Burnable materials in and around the reactor building was additionally evaluated.	● Amount of burnable materials in the reactor building is limited. ● Cables necessary to be protected against fire	Cable protection against fire was required.
Reliability of power supply		Emergency power supply failure was evaluated.	Decay heat is removable from the core without electricity.	Only portable power generator for monitoring during accident is required.
Beyond design basis accident (BDBA)		Postulated BDBAs ➢ DBA + failure of reactor scram ➢ DBA + failure of heat removal from the core ➢ DBA + failure of containment vessel ➢ Intentional aircraft crash	● No core melt occurs in all BDBAs. ● Intentional aircraft crash does not damage SSCs in the reactor building.	

New regulation standard was issued on 18 December, 2013, according to which application was submitted to NRA on 26

HTTR is expected to restart without significant additional reinforcement due to its own high-level inherent safety features

Target schedule towards HTTR restart

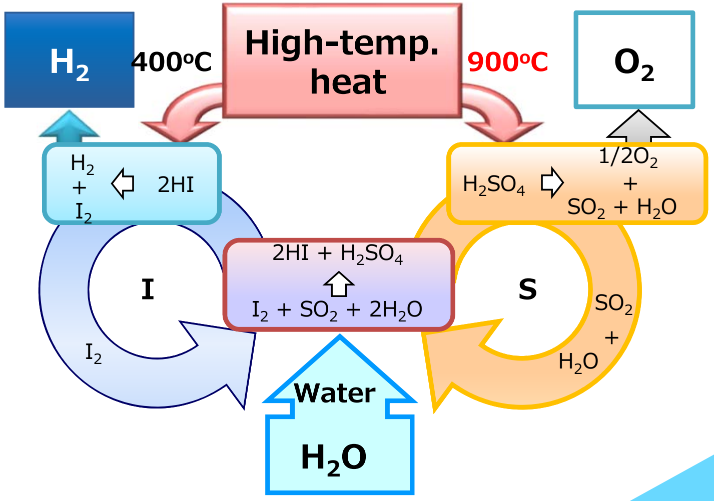


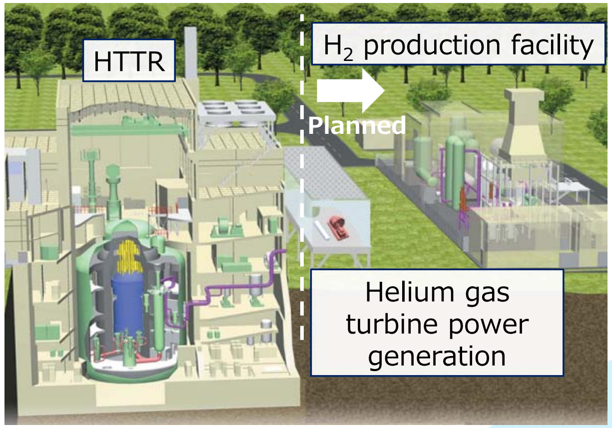
	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019~
Evaluation of natural phenomena	■	■	■	■		
Re-evaluation of seismic design classification	■					
Seismic evaluation	■	■	■	■	■	
Documentation of verification results, including evaluation of BDBA	■	■	■			
Evaluation by NRA	▲ ■ Application Nov. 26	■	■	■	■	■ Restart

HTGR-H_2 system technology development

IS process

- Thermal decomposition of water requires heat above 4000ºC .
- IS process decomposes water with heat of ca. 900ºC using chemical reactions of iodine (I) and sulfur (S).
  - ・I and S circulate in the process. ⇒ No harmful waste
  - ・HTGR heat is used. ⇒ No CO_2 emission





- To successfully license and operate the world's first HTGR gas turbine power generation and hydrogen production plant
- To establish safety design criteria for coupling chemical plant such as hydrogen production plant to nuclear reactor
- To complete the system technology required for construction of the first demonstration plant

2045～

Commercial use

Technology transfer to private sectors

～2035

HTTR-GT/H_2 test

- Establishment of safety design standard for integrating heat application systems with reactor

Present

Industrial material component test

- Integrity of components / operation stability
- Plant operation control system

HI decomposer
Ni-base alloy
(<500ºC)

Bunsen reactor
Fluoro-plastic lined steel
(<100ºC)

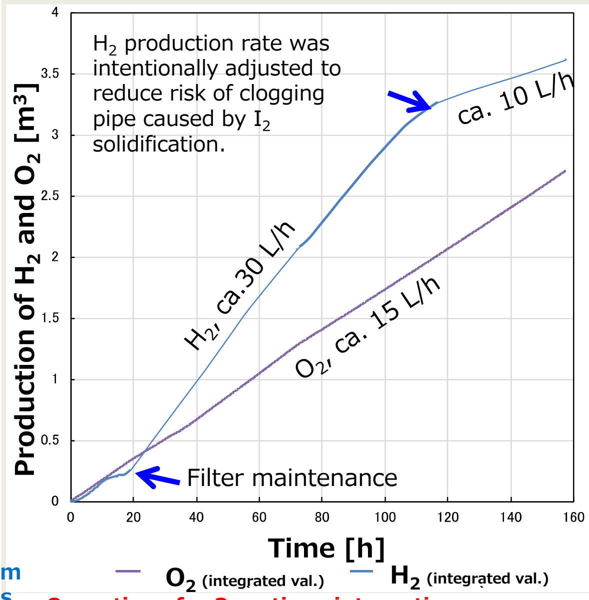
H_2SO_4 decomposer
Ceramic (SiC)
(<900ºC)

Corrosion-resistant lining vessel (fluoro-plastic, glass)

Development of key components in the IS process environment (corrosion resistance, heat resistance)

H_2 production test facility ($0.1 m^3/h$)

- Verification of integrity of total components and stability of hydrogen production
- Development of strength evaluation methodology for ceramic components
- Plant operation control system
  Plant maintenance techniques
- Membrane technologies to improve thermal efficiency



Operations for 3 sections integration was successfully carried out (30 L/h for 150 h).

R&D towards commercialization of GT and hydrogen HTGR

2020 2030 2040 2050

Target schedule (Private sector)**

- Design of demonstration reactor (GT, SR)
- Construction of demonstration reactor (GT, SR)
- Design of demonstration reactor (GT, IS)
- Construction of commercial reactor (GT, SR)
- Construction of demonstration reactor (GT, IS)

International collaboration

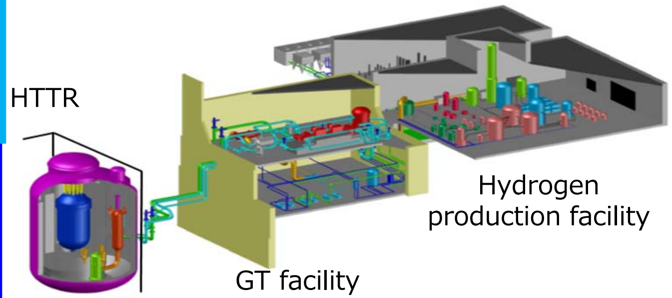
Research reactor

Demonstration reactor

- Technology of Steam generator, Steam system connecting technology
- High burnup fuel, High performance core,
- System with inherent safety
- Establishment of safety standard for steam connecting technology

HTTR-GT/H_2 test

- Design of GT, fuel, and IS facility, core, heat flow and seismic design, support of safety evaluation
- Provision of HTTR-GT/H2 test data and technical knowledge
- Training of operator



JAEA

- HTTR-GT test
- Confirmation of fuel/material performance under commercial reactor condition
- Support of establishing design/ material standard
- Development of basic technologies for IS process

- HTTR-IS test
- Confirmation of fuel/material performance under commercial reactor condition

Review

- Establsihment of safety standards
- Reviewing heat utilization facility
- Accumulating technical knowledge
- Pre-reviewing demonstration reactor (GT, SR)

- Reviewing heat utilization facility
- Reviewing demonstration reactor (GT, SR)
- Pre-reviewing demonstration reactor (GT, IS)

- Reviewing demonstration reactor (GT, IS)

※GT : Gas Turbine, SR : Steam reformer, IS : IS process ** JAEA's draft plan

JAEA international collaboration on HTGR

Multilateral collaboration

OECD／NEA

Czech France Germany Hungary Korea USA

Joint Test by HTTR, LOFC Project (Contracted Research)

- Loss of forced cooling test (Completed)
  - All three primary helium gas circulators were tripped at the initial reactor power of 30%
- Loss of core cooling test (planned)
  - All three primary helium gas circulators are tripped at the initial reactor power of 100%
  - Vessel cooling system is simultaneous tripped at reactor power of 30%

NI2050

- Cooperation related to HTGR cogeneration

IAEA

China France Germany Indonesia Holland Kazakhstan

Korea Russia South Africa Switzerland Turkey Ukraine United Kingdom USA

Coordinated Research Project (CRP) under Technical Working Group on Gas Cooled Reactors (TWG-GCR)

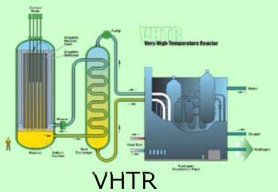
- Modular HTGR safety design

Generation IV International Forum (GIF)

Canada China France Korea Switzerland USA EU Australia

Very High Temperature Reactor (VHTR)

- Hydrogen Production System Project
- Fuel and Fuel Cycle Project
- Material Project
- Computational Methods Validation and Benchmarking Project



VHTR

EU

GEMINI+ Project

- Design and R&D of HTGR with heat application

HTTR

- **The only test and research reactor of HTGR in the world to supply heat of 950ºC**
- **International joint researches for needs of each country**

Bilateral collaboration

Poland

- Information exchange based on public information under “Action Plan for the Implementation of the Strategic Partnership between Japan and the Republic of Poland (2017-2020)” (National Centre for Nuclear Research: NCBJ)

United Kingdom

- Cooperation to U-Battery project (Commercial HTGR system) (URENCO, etc.)

USA

Civil Nuclear R&D Working Group (CNWG)

- Development of simulation algorithm, validation of analytical model, study of connecting test between HTTR and heat utilization system (Department of Energy: DOE, Idaho National Laboratory: INL)

Indonesia

(Badan Tenaga Nuklir Nasional: BATAN)

China

(Tsinghua University, Institute of Nuclear and New Energy Technology: INET)

Korea

(Korea Atomic Energy Institute: KAERI)

- Information exchange

Kazakhstan

- Design collaboration for pre-FS of HTGR (National Nuclear Center: NNC)
- High burn-up fuel research (Institute of Nuclear Physics: INP)
- Oxidation-resistant graphite research (Al-Farabi Kazakh National University: KazNU, INP)
- Safety research (Nuclear Technology Safety Center: NTSC)

Summary

- JAEA and Japanese industries have been developing HTGR, Gas Turbine and Hydrogen production technologies.

- HTTR is expected to restart without additional major reinforcements since high-level inherent safety features of HTTR were confirmed through safety review by NRA.

- Regarding the Iodine-Sulfur hydrogen production technology, 150-hour and 30 L/h continuous H_2 production was successfully completed in January 2019 using the hydrogen production test facility.

- HTGR fits for SMR since HTGR has high-level inherent safety and is superior in economy due to its high efficiency. HTGR is an attractive reactor not only for nuclear power generation system but also for such other systems as hydrogen production system, hybrid system with renewable energy, etc.

- JAEA and Japanese industries have established various advanced HTGR technologies necessary for commercial HTGR systems. We are ready to meet your interest and form partnership in application of Japan’s HTGR technologies to HTGR development in your countries.