R&D On Nuclear Hydrogen Production using HTGR at JAERI

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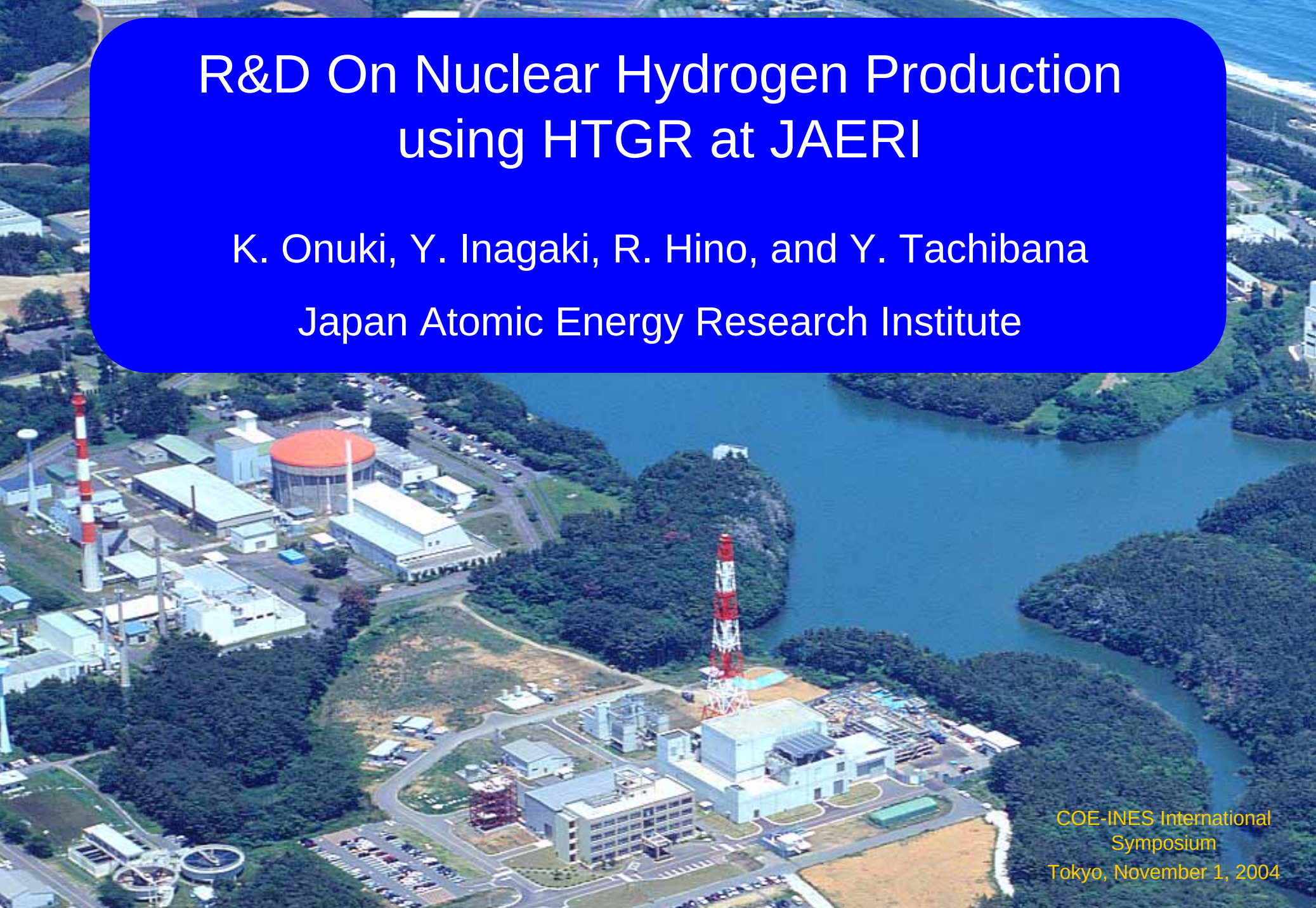


COE-INES International Symposium
Tokyo, November 1, 2004

Toward the Hydrogen Energy Society

Current Society depends on fossil energy

- Exhaustion of fossil energy
- Effects on global environment; acid rain, global warming, etc.

Activities on Hydrogen in Japan

"Basic Plan for Energy Supply and Demand"
based on "Basic Law on Energy Policy Making"
(Decided upon by the Cabinet on 6 October, 2003)

Effort for Hydrogen Energy Utilization (**Chapter 2, section 6.3**)

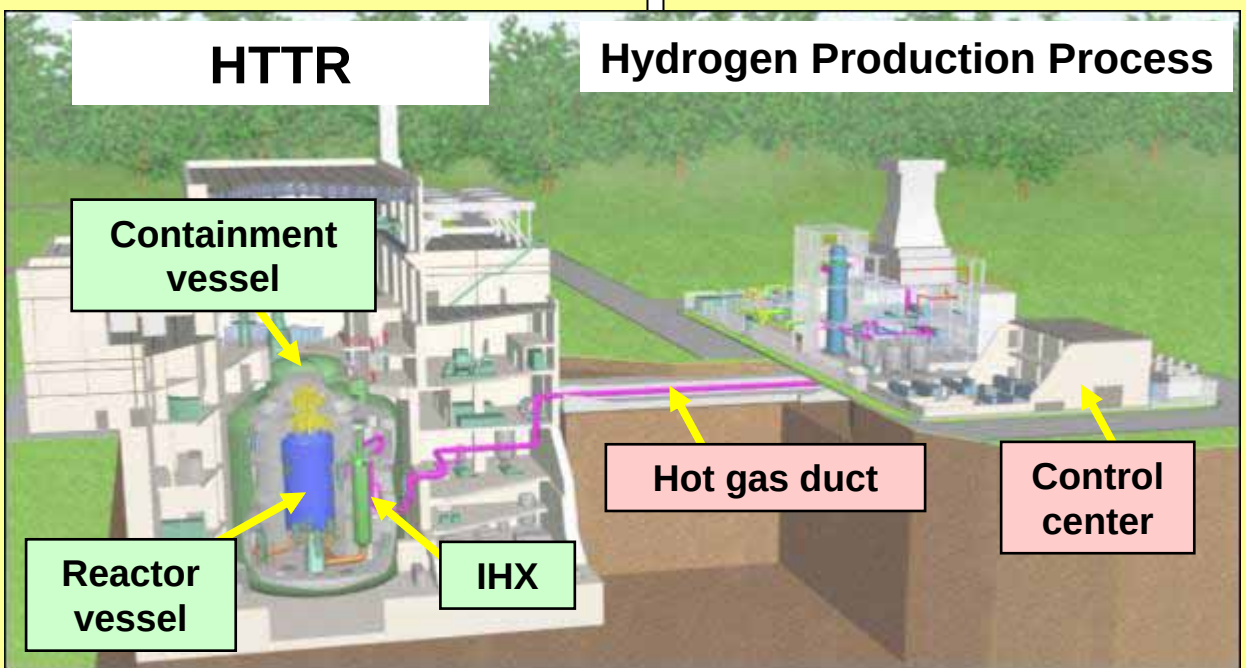
- Hydrogen is a clean energy carrier without CO_2 emission.
- Commercialization of hydrogen production system using nuclear, solar and biomass, not fossil fuels, is desired.

Overview of R&D at JAERI

Objective: **Establishment of HTGR technology**

Establishment of heat utilization technology

Reactor Technology



System Integration Technology

Hydrogen Production Technology

Bench-scale apparatus of IS Process

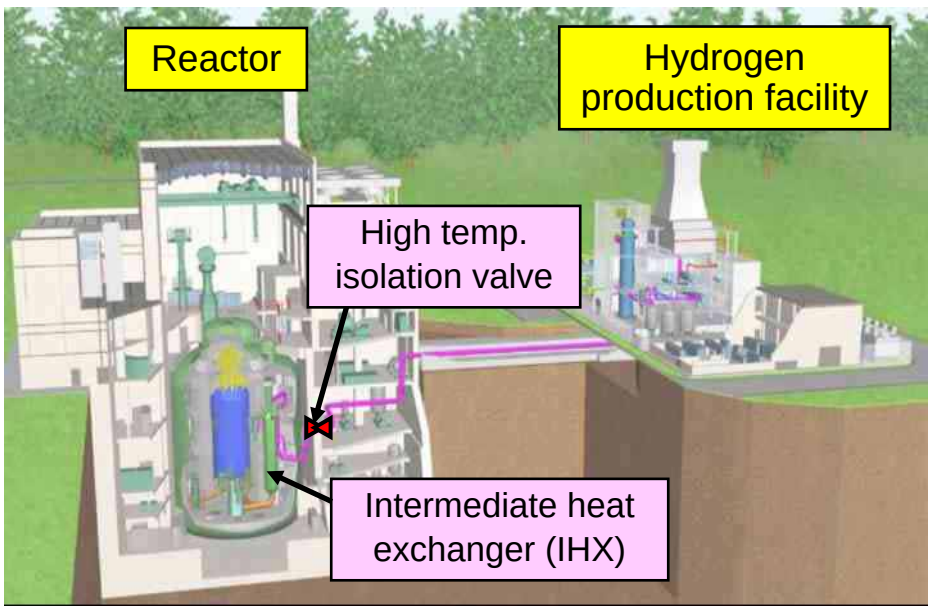
System Integration Technology

Objective

- Development of technology for safe and economical connection between reactor and hydrogen production facility

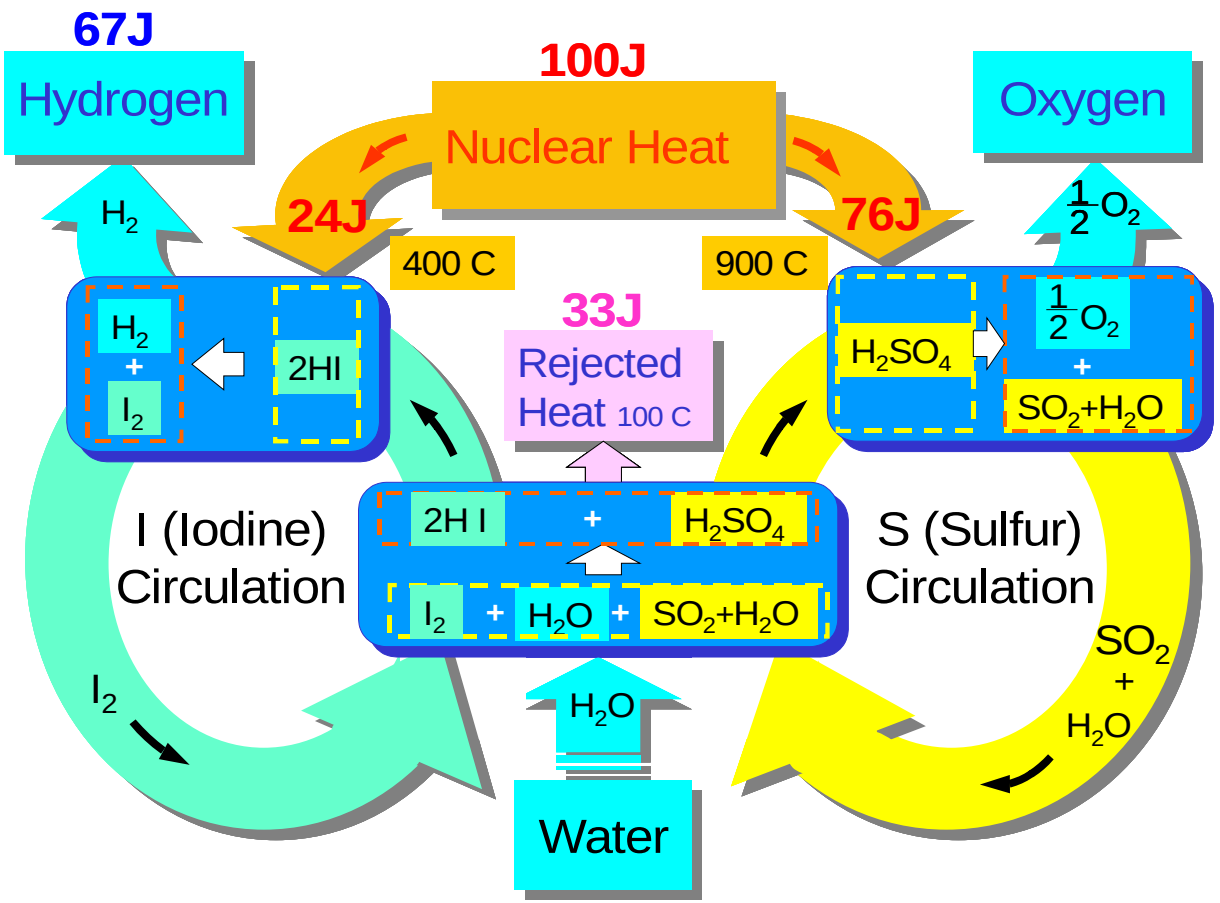
R&D Items

- Safety technology against explosion
  - Design for protection and mitigation against combustible gas release: underway
  - Estimation of damage on nuclear plant by blast waves from explosion: underway
- Safety technology against radioactive materials release
  - Development of high temp. isolation valve: underway
  - Estimation of tritium permeation passing through IHX: finished
- Control technology
  - Prevention of thermal disturbance from hydrogen production facility to reactor by steam generator : finished
- Plant simulation code
  - Verification by simulation test: underway



[This study is entrusted from MEXT of Japan.]

Hydrogen Production Technology



IS Process

- ***Hydrogen from water and nuclear heat (CO_2 free)***
- ***Thermochemical cycle***
- ***Iodine- and Sulfur-compounds are used as recycling materials***

R&D on IS Process

Completion of Hydrogen Production (June 2004)

Continuous hydrogen production was successfully achieved at the hydrogen production rate of 32 NL/h for 1 week.

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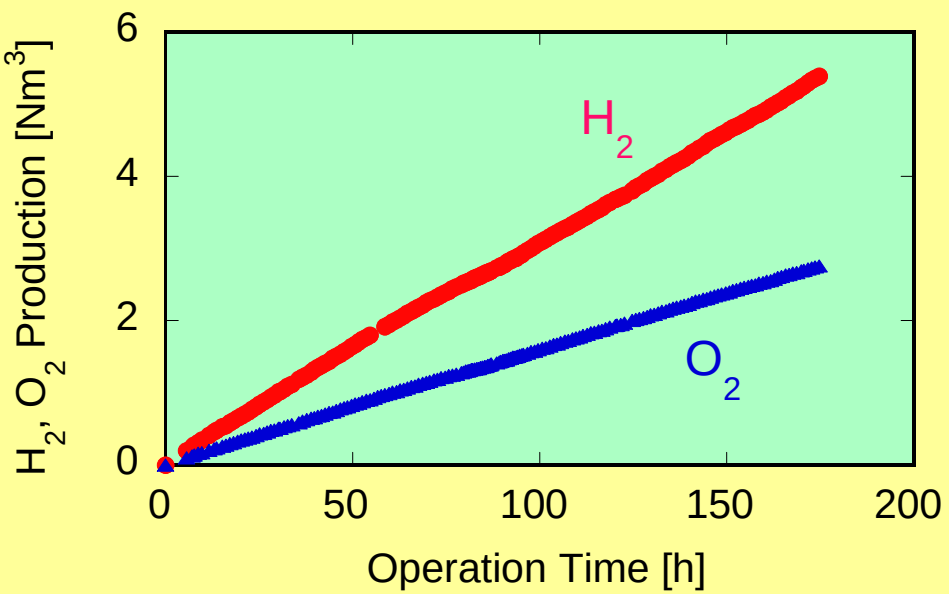


Commercialization

HTTR Test (10MW, ～1000m³/h)

Pilot Test (0.4MW, ～30m³/h)

He heating, Industrial materials, High pressure

Bench-scale Test
(1999-2004)

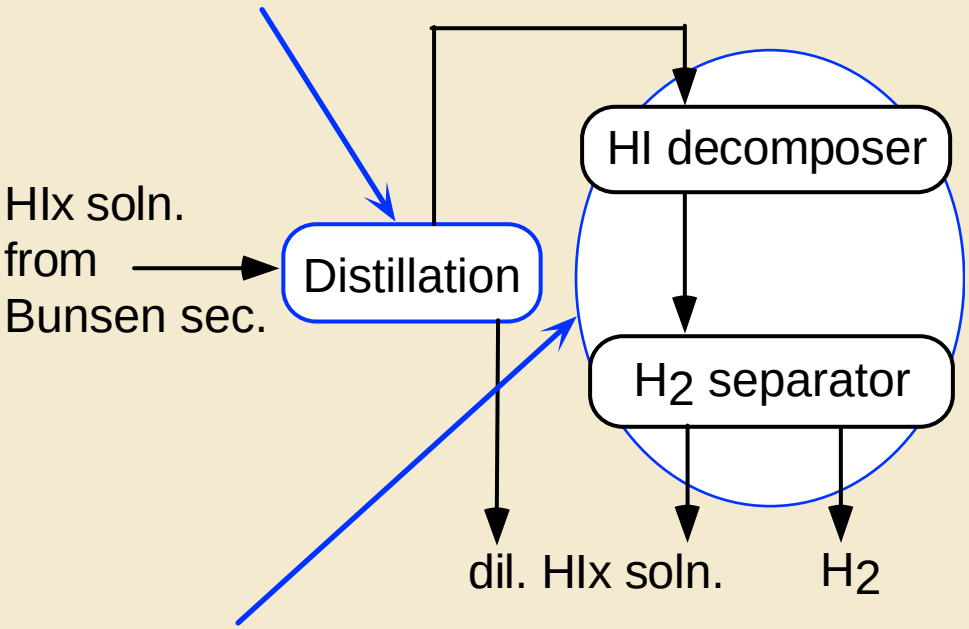
Lab-scale Test

Verification of Theory (1997)

For efficient H_2 production,

<Problems>

/ large thermal burden for the distillation of azeotropic hydriodic acid (HI/H_2O: 1/5)



/ excess HI circulation due to low equilibrium conversion of HI (ca. 20%)

<Approach>

(1) Extractive distillation (GA)

Destroy the azeotrope with H_3PO_4

(2) Reactive distillation (RWTH Aachen)

Shift the azeotropic composition at elevated pressure (e.g. 20bar).

Carry out the decomposition in the distillation column.

(3) Membrane separation (JAERI)

Pre-concentrate the HIx soln. by electrodialysis.

Enhance the one-pass conversion by membrane reactor.

JAERI's approach for efficient H_2 production

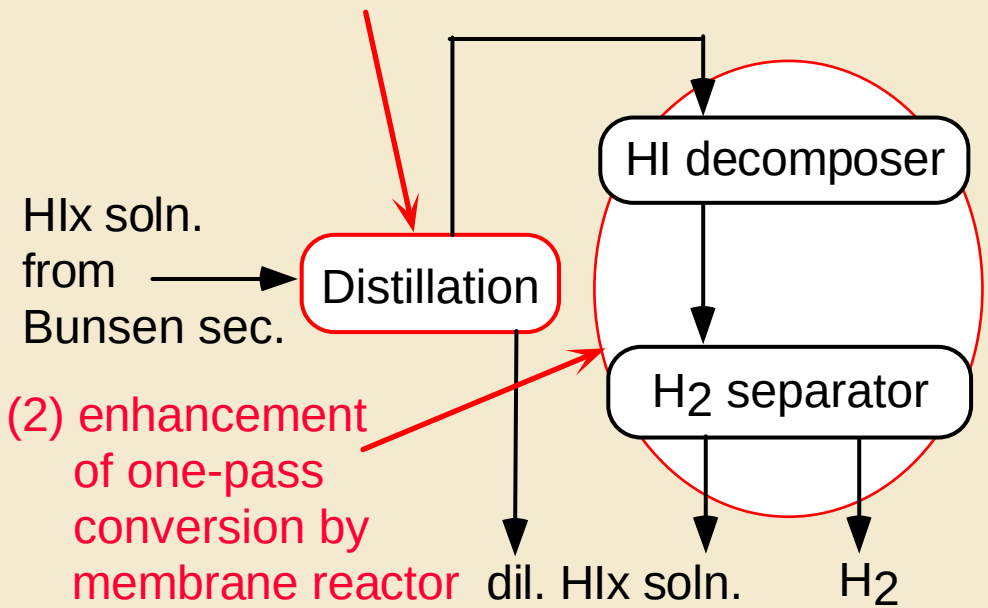
<Problems>

/ large thermal burden for the distillation of azeotropic hydriodic acid (HI/H_2O: 1/5)

/ excess HI circulation due to low equilibrium conversion of HI (ca. 20%)

<Measures>

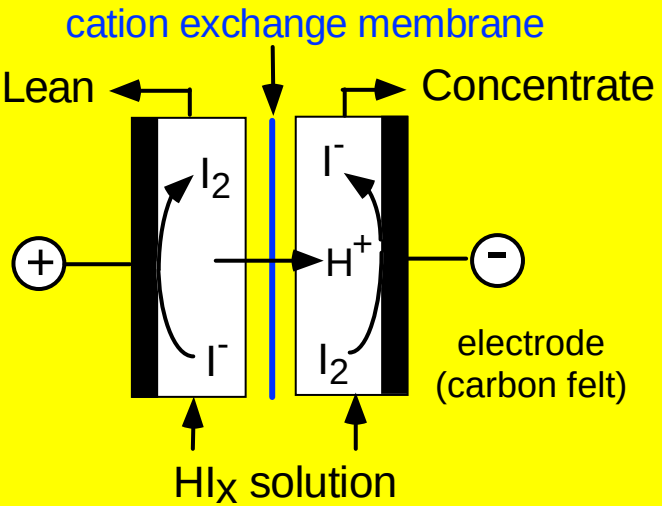
(1) preconcentration to overazeotropic composition



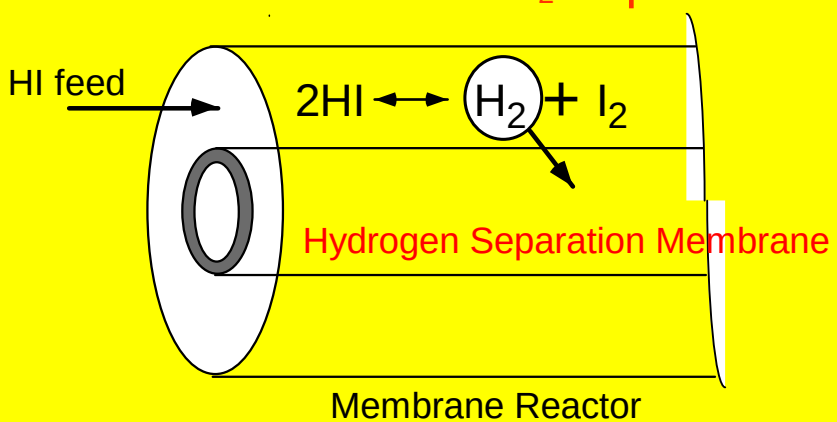
(2) enhancement of one-pass conversion by membrane reactor

Present study focuses on

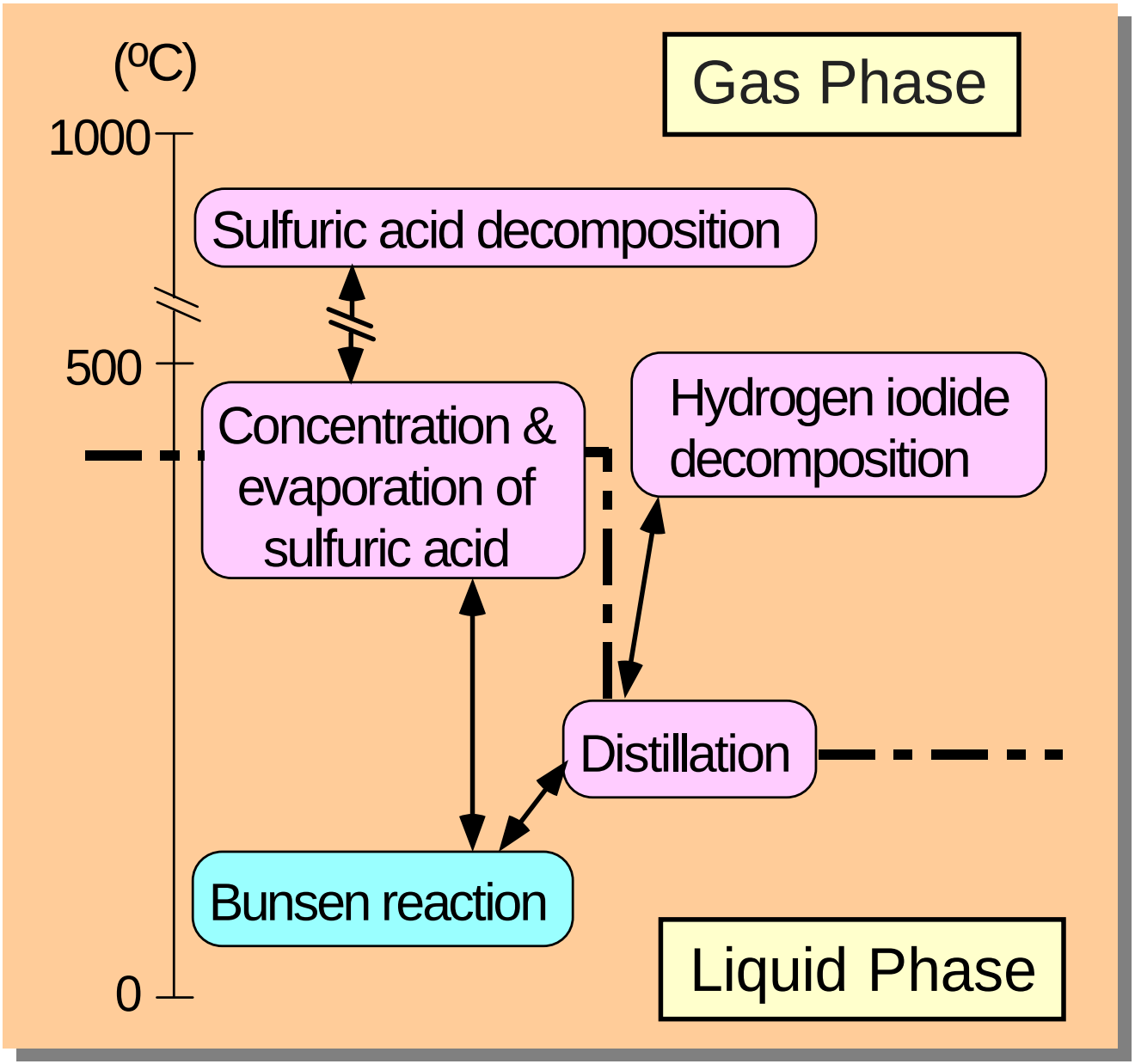
(1) Electro-electrodialysis



(2) Silica membrane for H_2 separation



Corrosion Environments in IS Process



Sulfur Environments

Sulfuric Acid

50 - 96wt% Sulfuric acid
90 - 500ºC, 0.1 - 2 MPa
minor component: Iodine

Gaseous SO_3, SO_2 , O_2

500 - 900ºC, 2 MPa

Iodine Environments

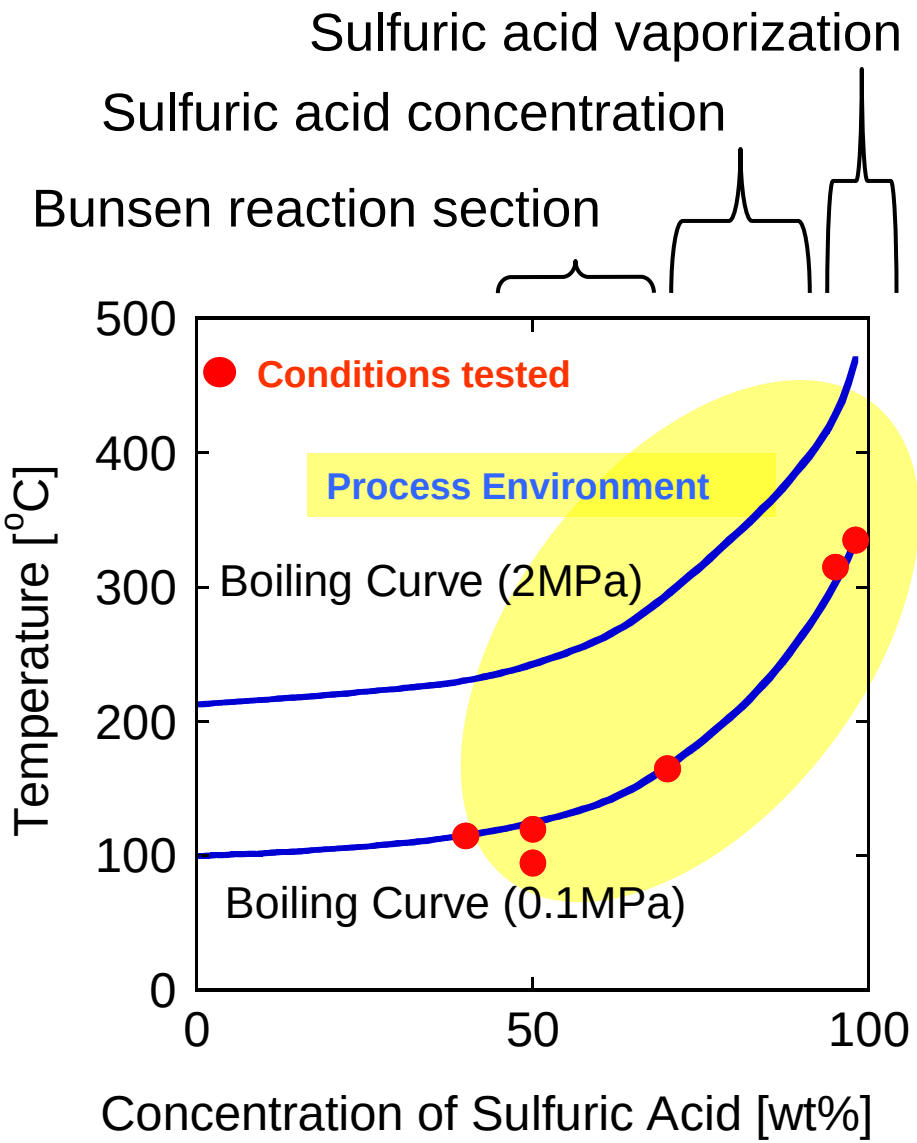
HIx Solution

$HI–I_2–H_2O$,
90 - 200ºC, 0.1 - 1 MPa

Gaseous HI, I_2, H_2, H_2O

200 - 500ºC, 1 MPa

Previous Corrosion Study in Sulfuric Acid at JAERI



Candidate materials for sulfuric acid service in IS process screened by the corrosion study carried out under atomospheric pressure condition

- For Bunsen reaction section
  Ta, Zr, SiC, Si_3N_4, SiO_2, PFA

- For sulfuric acid concentration
  Ta, Zr, Fe-Si, SiSiC, SiC, Si_3N_4

- For sulfuric acid vaporization
  Fe-Si, SiSiC, SiC, Si_3N_4

Corrosion Test under Pressurized Condition

Autoclave

Quartz ampoule with test piece and sulfuric acid

Test Results in Sulfuric Acid

Corrosion rates in 95wt% sulfuric acid*1)

Material	Corrosion rate [g/m^2 h]	
	100hr test	1000hr test
SiC	- 0.10	- 0.002
Si-SiC	0.0	- 0.006
Si_3N_4	0.0	- 0.007
Fe-Si (as-prepared)	1.1	0.13
Fe-Si (annealed)*2)	- 0.12	0.065
SX (pre-oxidized) *3)	- 0.28	0.96 *4)

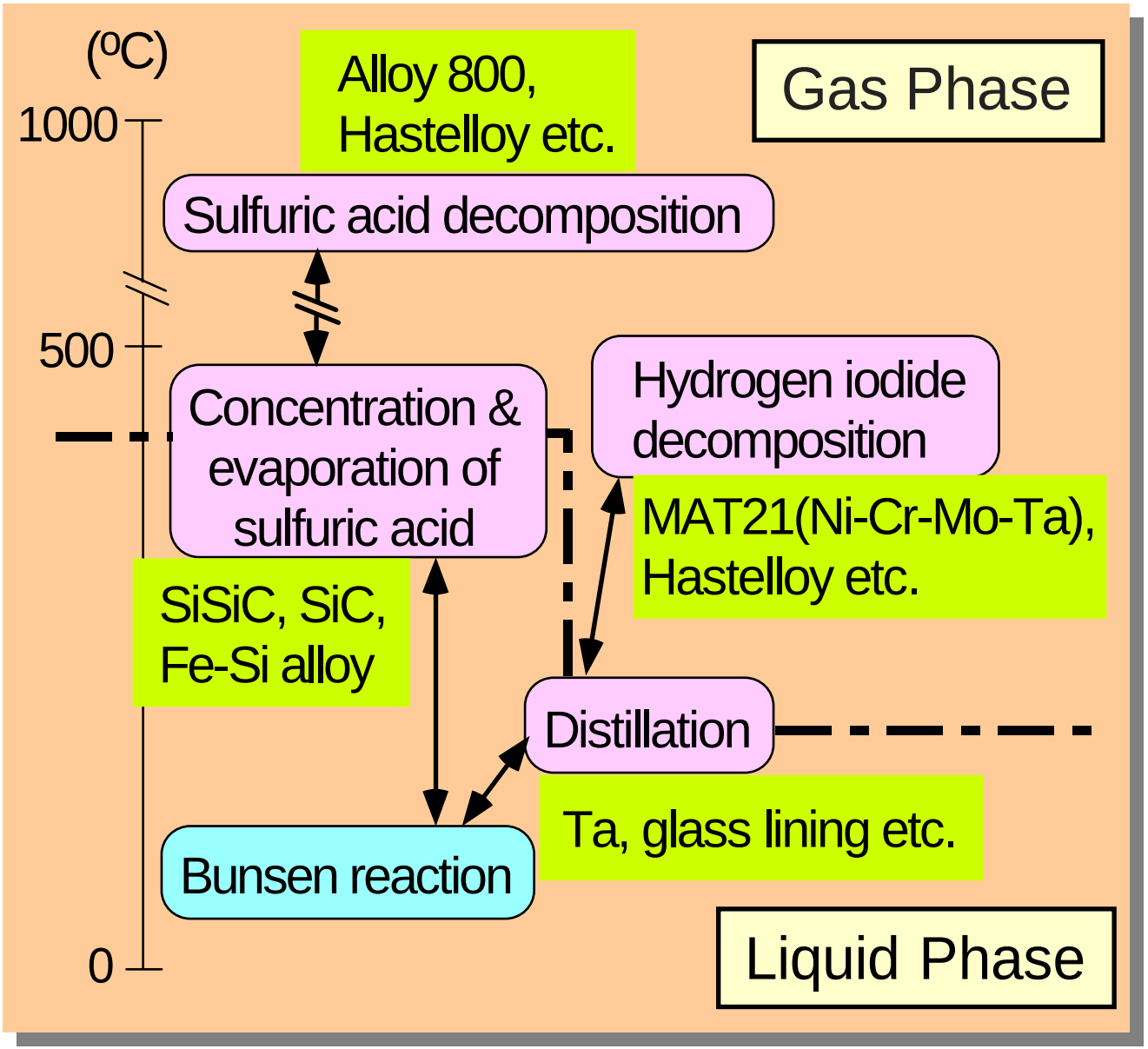
*1) test conditions: 733K(460^{o}C), 2MPa.

*2) annealed at 1373K(1100^{o}C) under vacuum for 100hr.

*3) oxidized in air at 1073K(800^{o}C) for 90hr.

*4) test piece size: 4x4x20mm. ampoule broken after 800hr.

Screening Results of Candidate Materials



Candidate materials has been screened by corrosion tests in the process condition.

R&D is required for the components used in the boiling sulfuric acid environments.

ex) hybridization of corrosion resistant material and pressure resistant material

R&D Plan of IS Process in JAERI