Safety Evaluation of VHTR Cogeneration System

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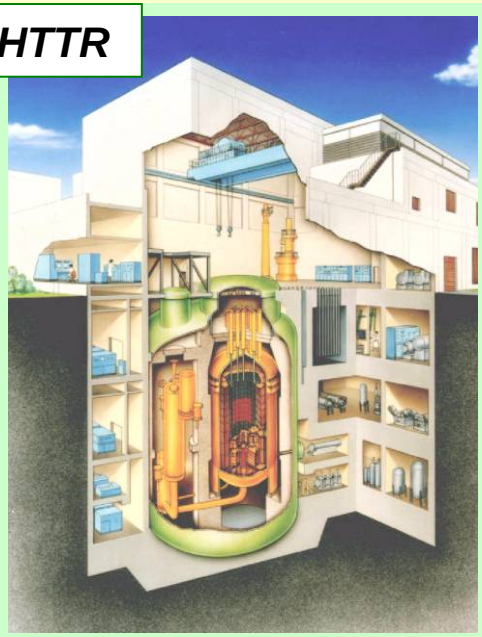
JAEA R&D for the VHTR system

HTTR



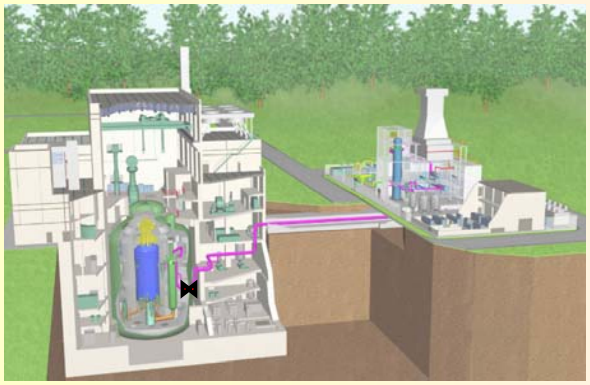
High temperature operation (950℃) : 2004

IS Process

Continuous hydrogen production 30NL/h 175hr : 2005

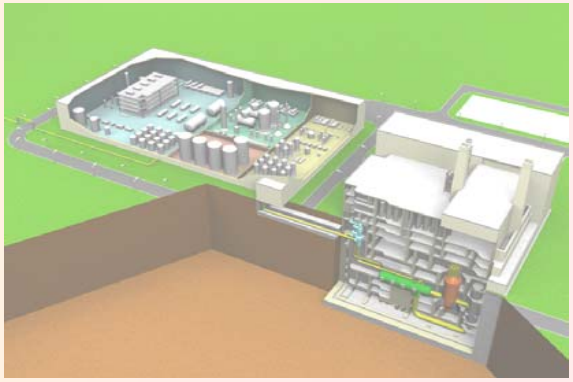
2010 ***2030***

HTTR-IS system



- ***World's first demonstration of hydrogen production utilizing heat from nuclear power***
- ***Hydrogen production rate : 800～1000 Nm^3/h***

Commercial VHTR system



- ***Hydrogen production for commercial use***
- ***Economically competitive (20.5 JPY / Nm^3 *)***

** T. Nishihara et al., Proc. of 15th International Conference on Nuclear Engineering, ICONE15-10157 (2007).*

Japanese Design of VHTR Cogeneration system

GTHTR300C *(170MWth for H_2 plant)*

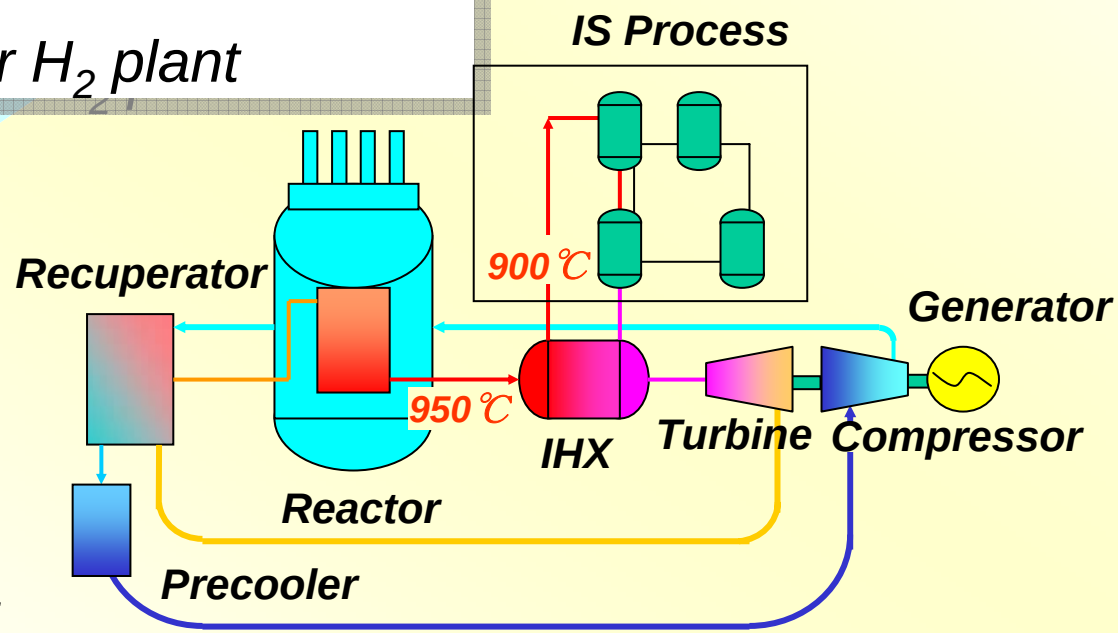
*for **C**ogeneration of electricity and hydrogen*

- *Electricity generation : 202MWe*
- *Hydrogen production rate : 2.6MNm^3/h*

GTHTR300C *(370MWth for H_2 plant)*

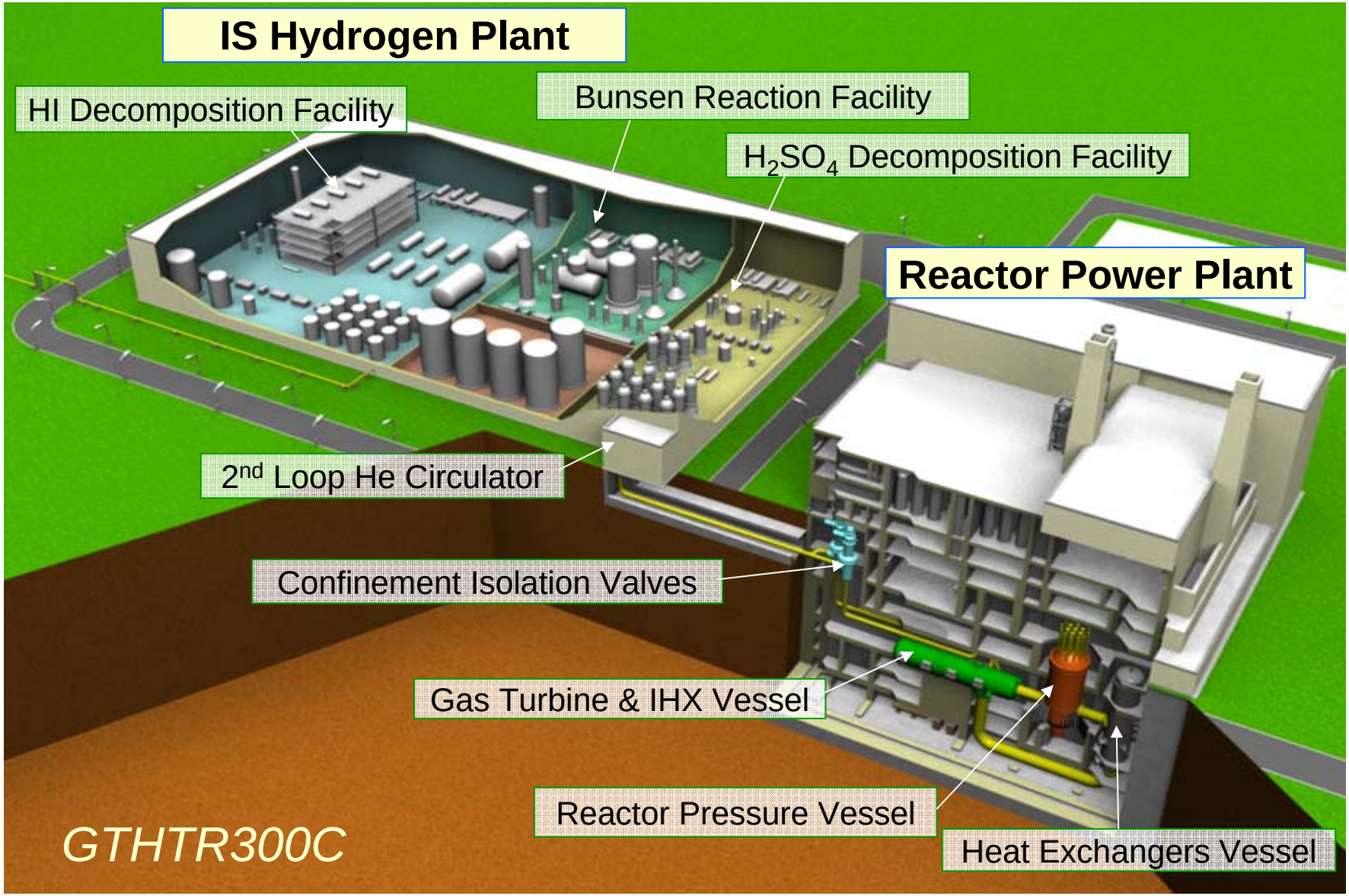
*for **H**ydrogen production only*

- *Hydrogen production rate : 5.6MNm^3/h*
- *Electricity generation for H_2 plant*



X. Yan et al., Proc. of 3rd information exchange meeting on nuclear production of hydrogen (2005).

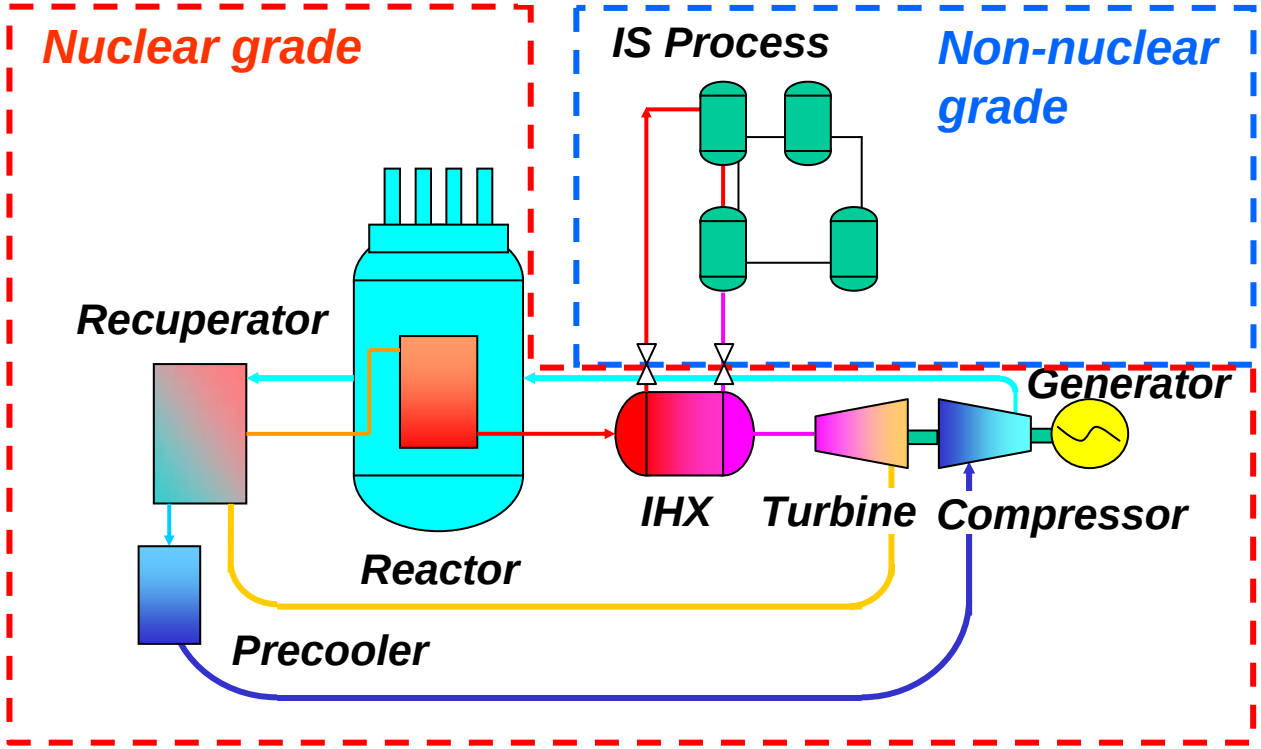
Plant Layout of GTHTR300C



Basic Philosophy of GHTHR300C Design

Why Non-nuclear grade IS process ?

- Open the door to non-nuclear industries
  - IS process will be managed by oil and gas companies
- Reducing the construction costs of the IS process
  - Apply the chemical plant design standard to the IS process



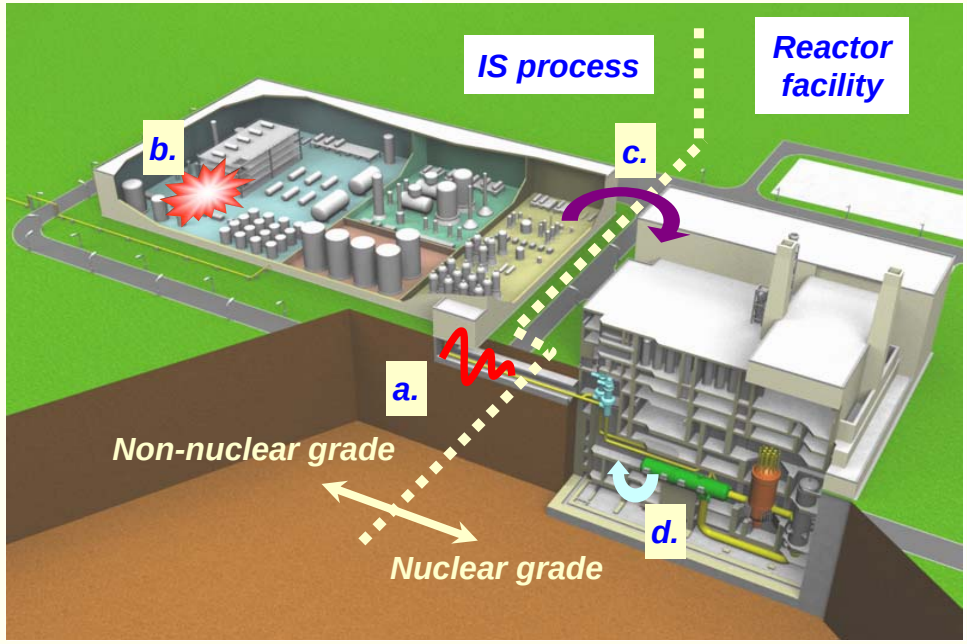
Non-nuclear Design for IS process

Safety philosophy for non-nuclear grade IS process*

- Exempt the IS process from Prevention system 3 (PS-3)
- Identify the abnormal events initiated in IS process as external events

*K. Ohashi, et. Al., J. Atom. Energ. Soc. Jpn., Vol.6, No.1 (2007)

R&D for non-nuclear grade IS process



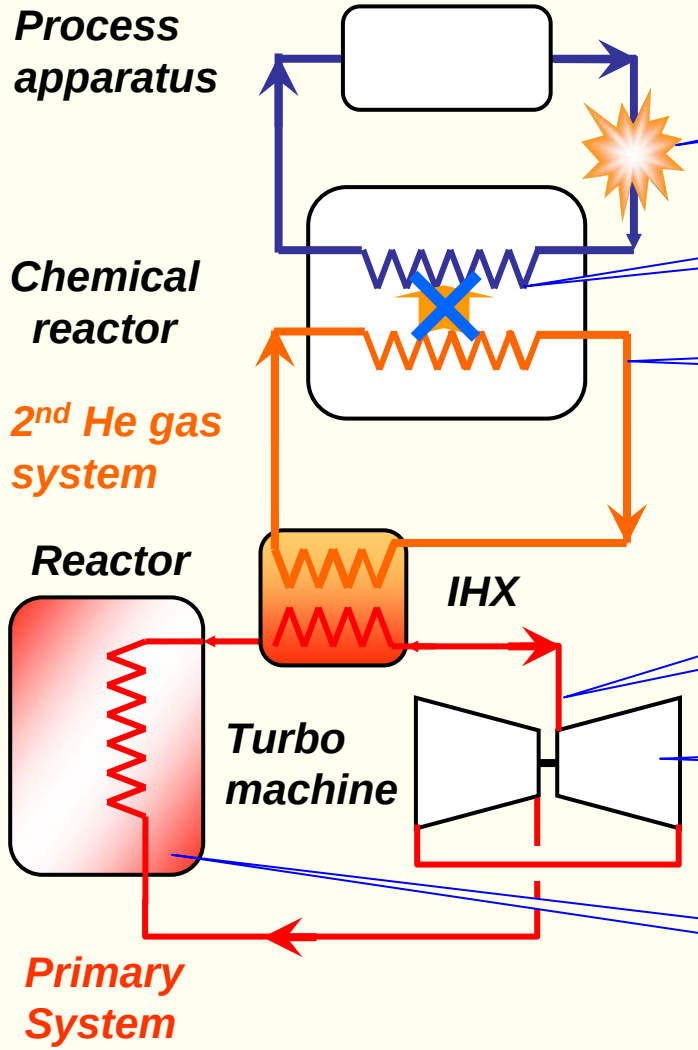
a. Establishment of IS process thermal load disturbance absorption method

b. Countermeasure for H_2 explosion

c. Countermeasure for toxic gas inflow to reactor control room

d. Reduction of tritium releasing to environment & mixing to product H_2

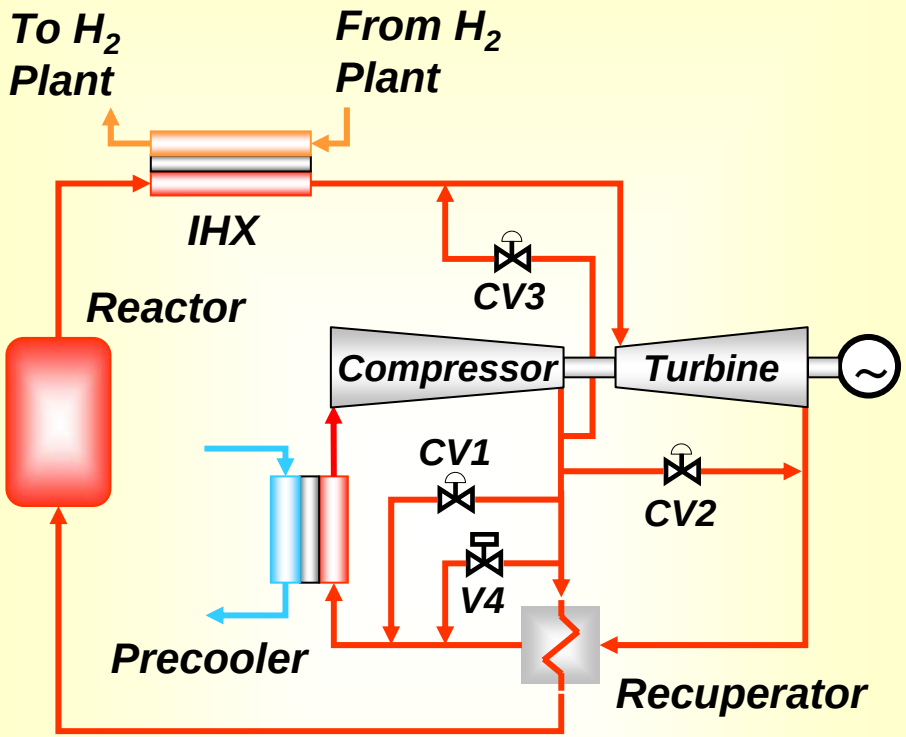
Loss of IS process Thermal Load



- Process apparatus failure
  e.g. Pump trip, Leakage
- Loss of chemical reaction
- Outlet temperature increase
- Turbine inlet temperature increase
- Turbine trip
- Reactor scram

Countermeasure for loss of the IS process thermal load is required

Operational Sequence for GTHTR300C

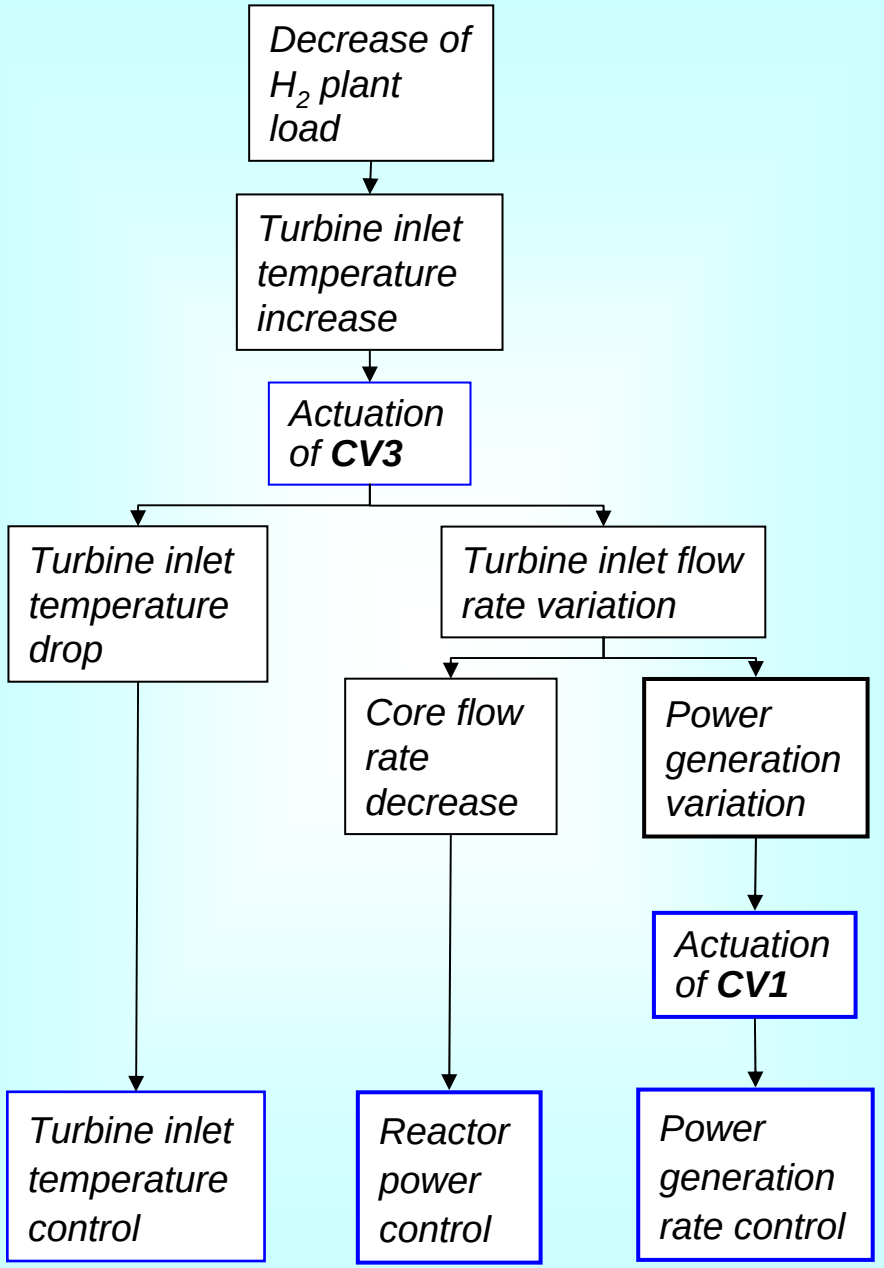


CV1 : Turbine bypass flow control valve

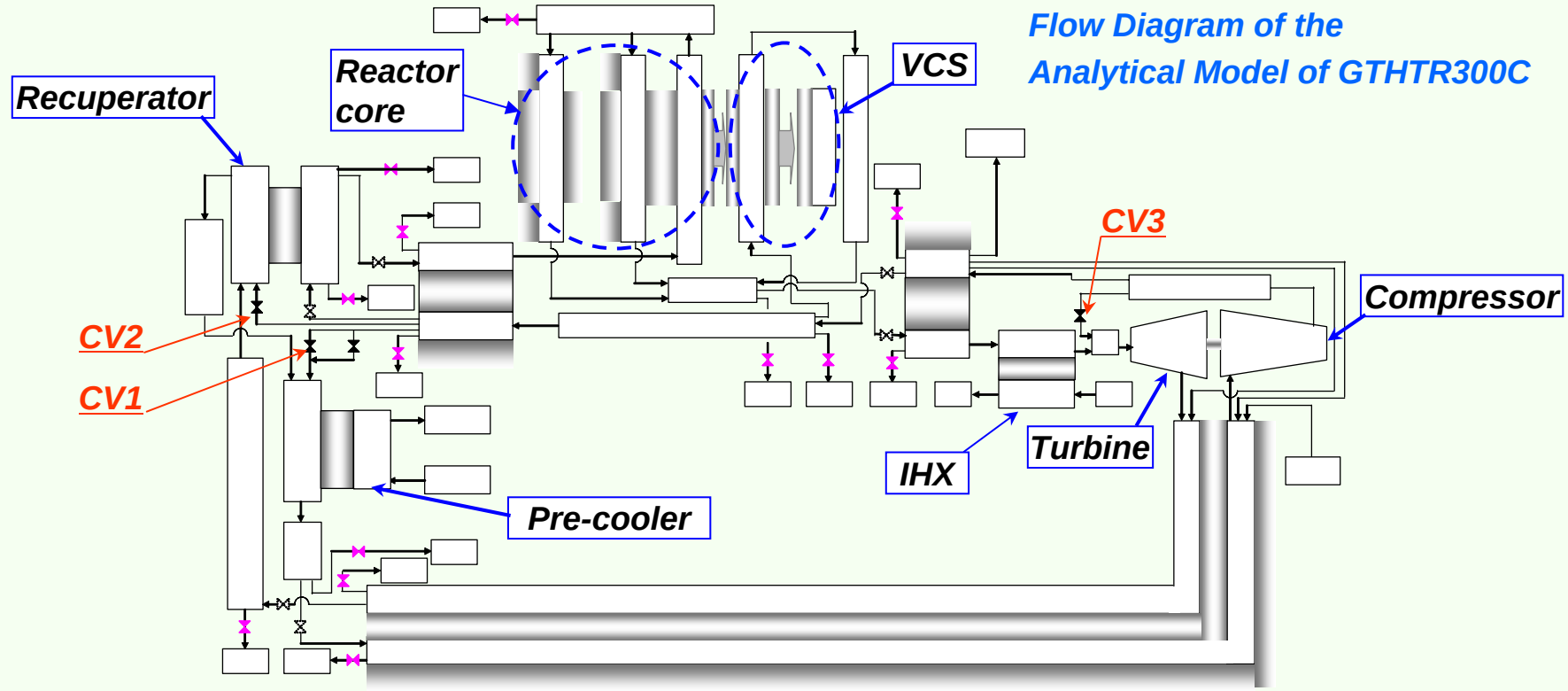
CV2 : Recuperator inlet temperature control valve

CV3 : Turbine inlet temperature control valve

V4 : Turbine bypass valve



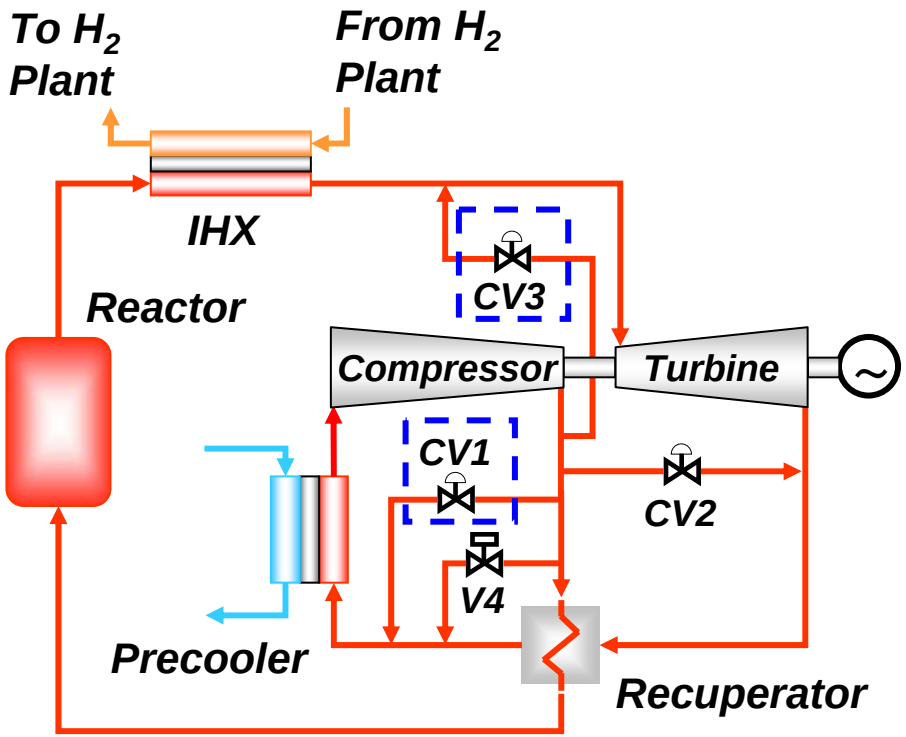
Dynamic Simulation Code for GTHTR300C



- *Thermal-hydraulic model*
  - *Non-condensable gas model*
  - *Field equations*
    Mass continuity, Momentum conservation, Energy conservation
  - *Heat transfer correlation equation*
    Experimental equation, Conventional equation
- *Component model*
  - *Gas Turbine*
  - *Compressor*
  - *Control system*
- *Reactor kinetics*
  - *Point nuclear kinetic equation*
  - *Reactor kinetics data*

Dynamic Calculation (1/2)

- Loss of thermal load of H_2 Plant (170MW) in GTHTR300C -



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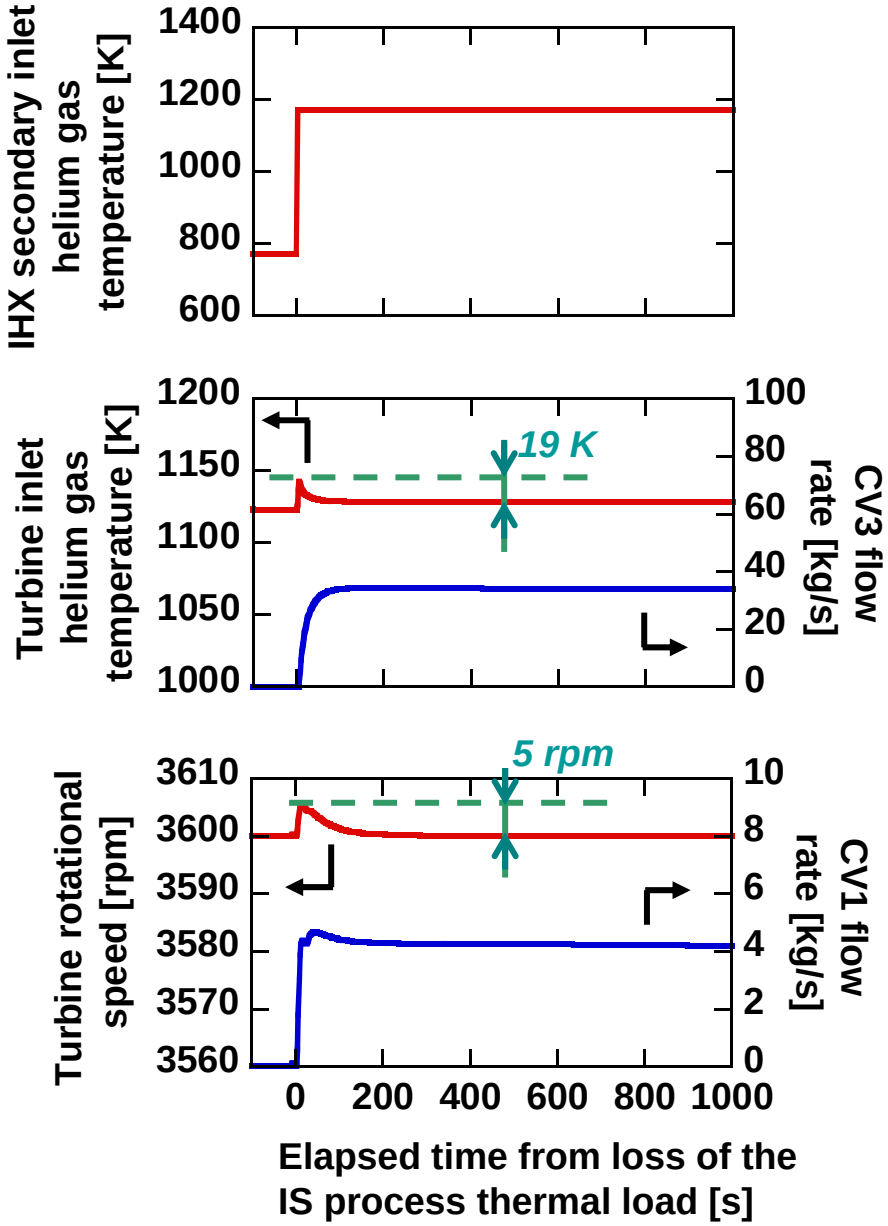
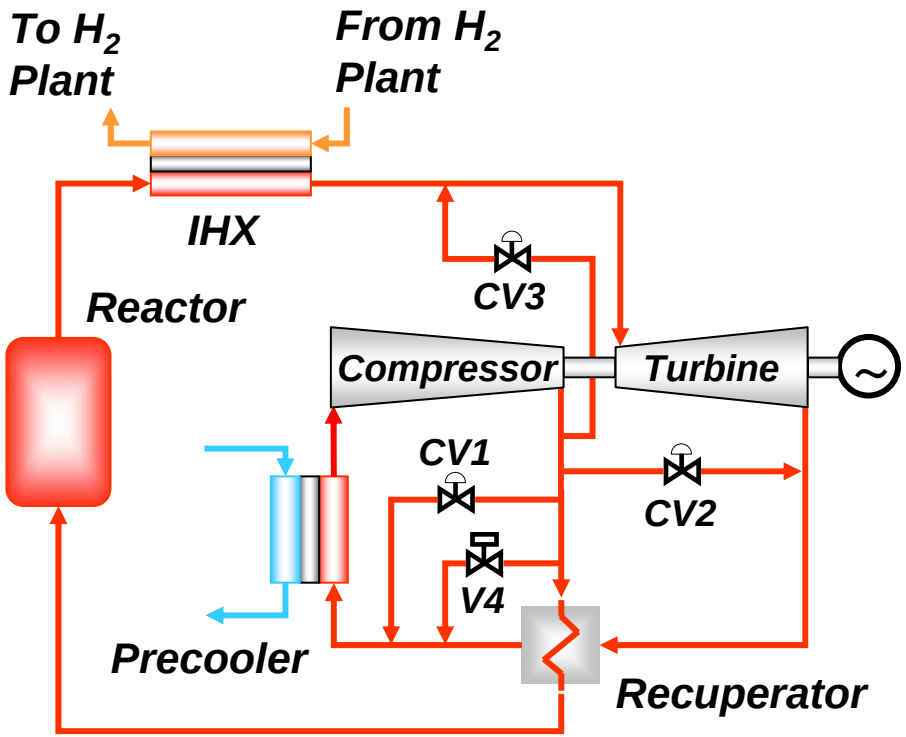


Dynamic Calculation (2/2)

- Loss of Thermal Load of H_2 Plant (170MW) in GTHTR300C -



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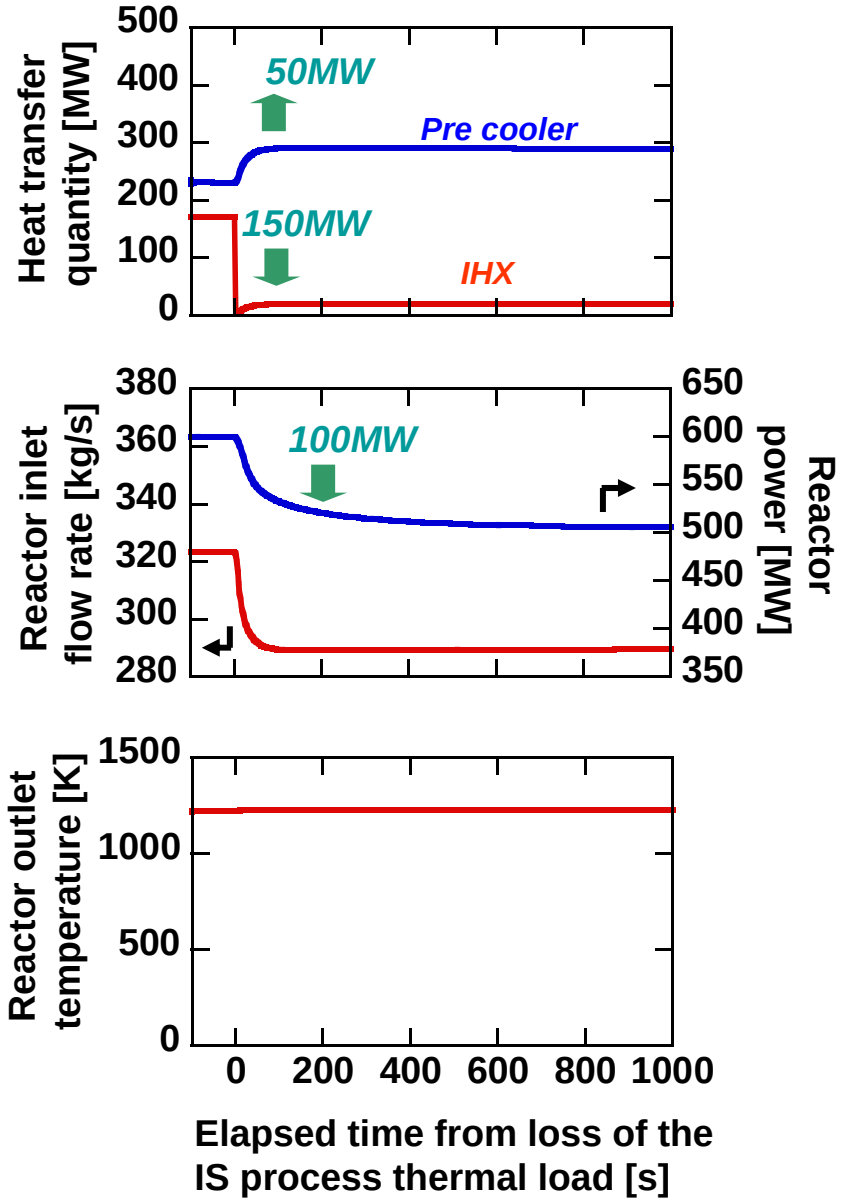

Concluding Remarks

- *JAEA started the R&D for the safety design of commercial VHTR systems GTHTR300C*
- *Dynamic simulation models of GTHTR300C was developed*
- *Loss of the H_2 plant thermal load can be absorbed by the operational sequence*

Thanks for your attention.

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Back ground information

Analytical model of IHX

IHX heat transfer correlation

(Shell side)

$$Nu = C_1 Re^{0.8} Pr^{0.4} \qquad (800<Re\leq 7000)$$

$$Nu = C_2 Re^{0.6} Pr^{0.3} \qquad (Re>7000)$$

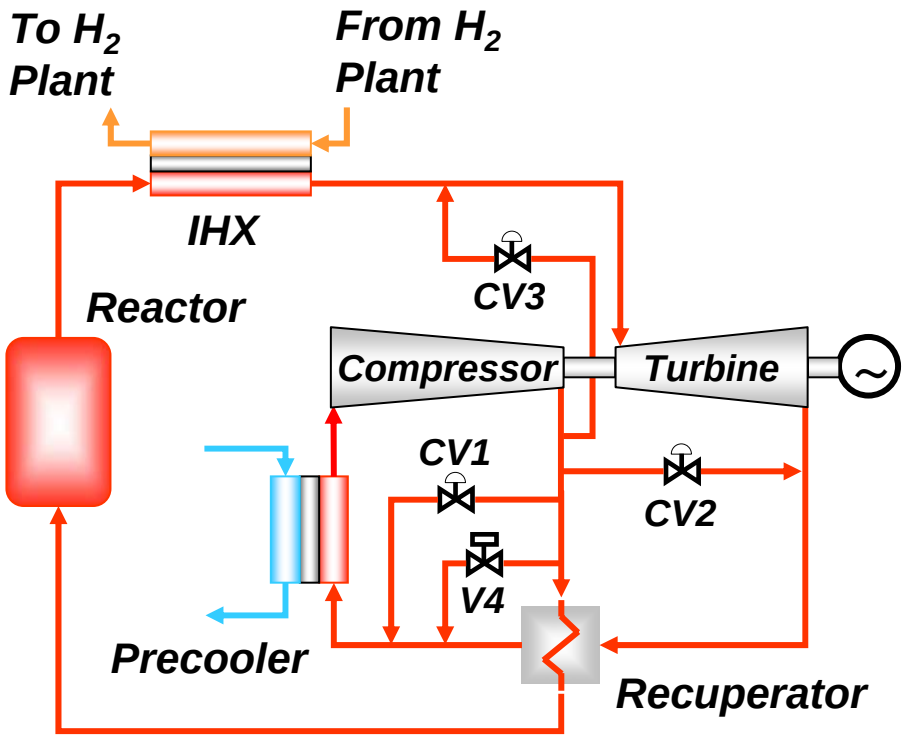
(Tube side)

$$Nu = 0.0223 Re^{(5/6)} di \frac{Pr}{Pr^{0.6} - 0.0057} \times \left(1 + \frac{0.0615}{(Re \cdot di^{2.5})^{(1/6)}}\right)$$

C_1, C_2 : Design Coefficient

Dynamic Calculation (3/4)

- Loss of Thermal Load of H_2 Plant (370MW) in GTHTR300C -



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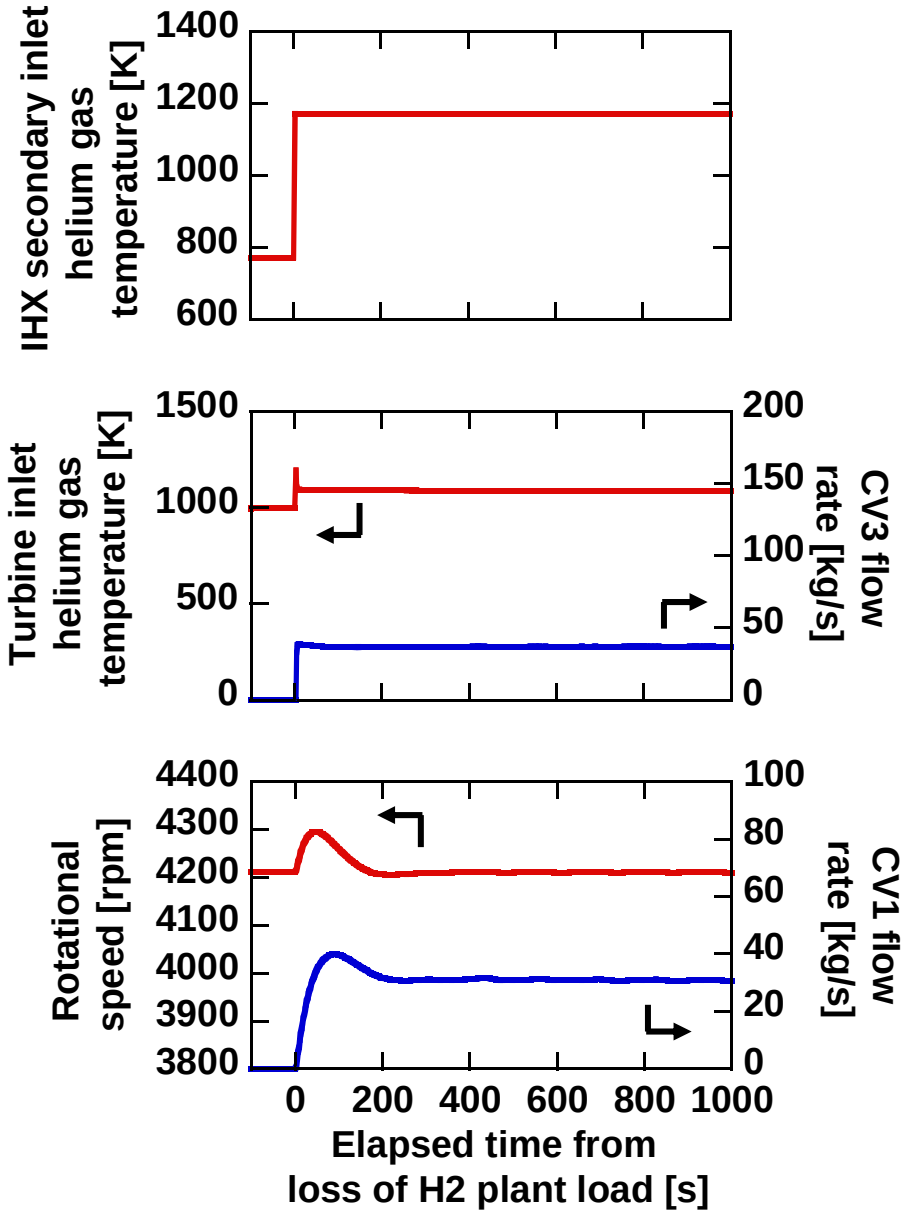
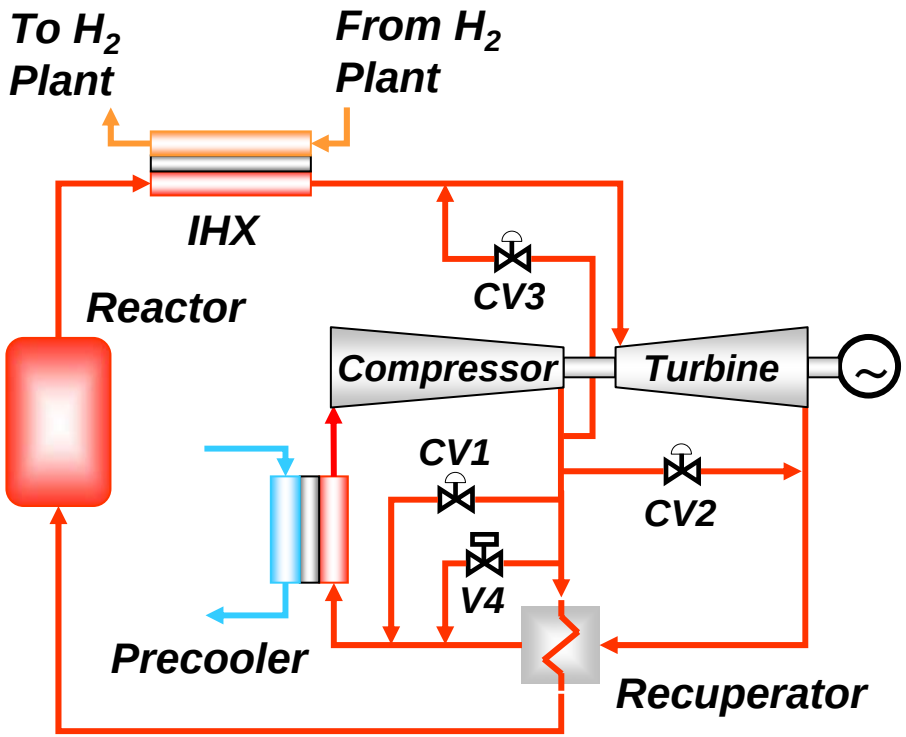


Dynamic Calculation (4/4)

- Loss of Thermal Load of H_2 Plant (370MW) in GTHTR300C -



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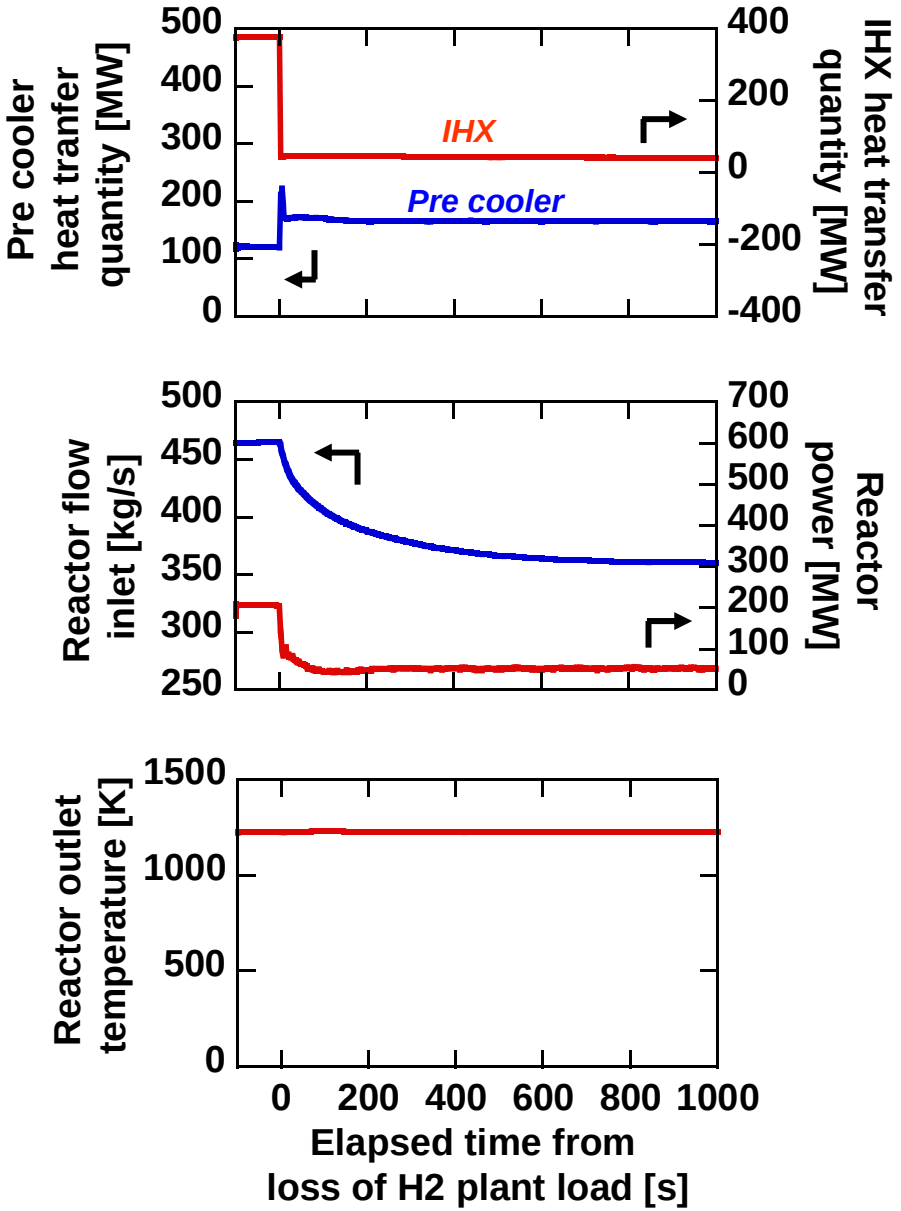
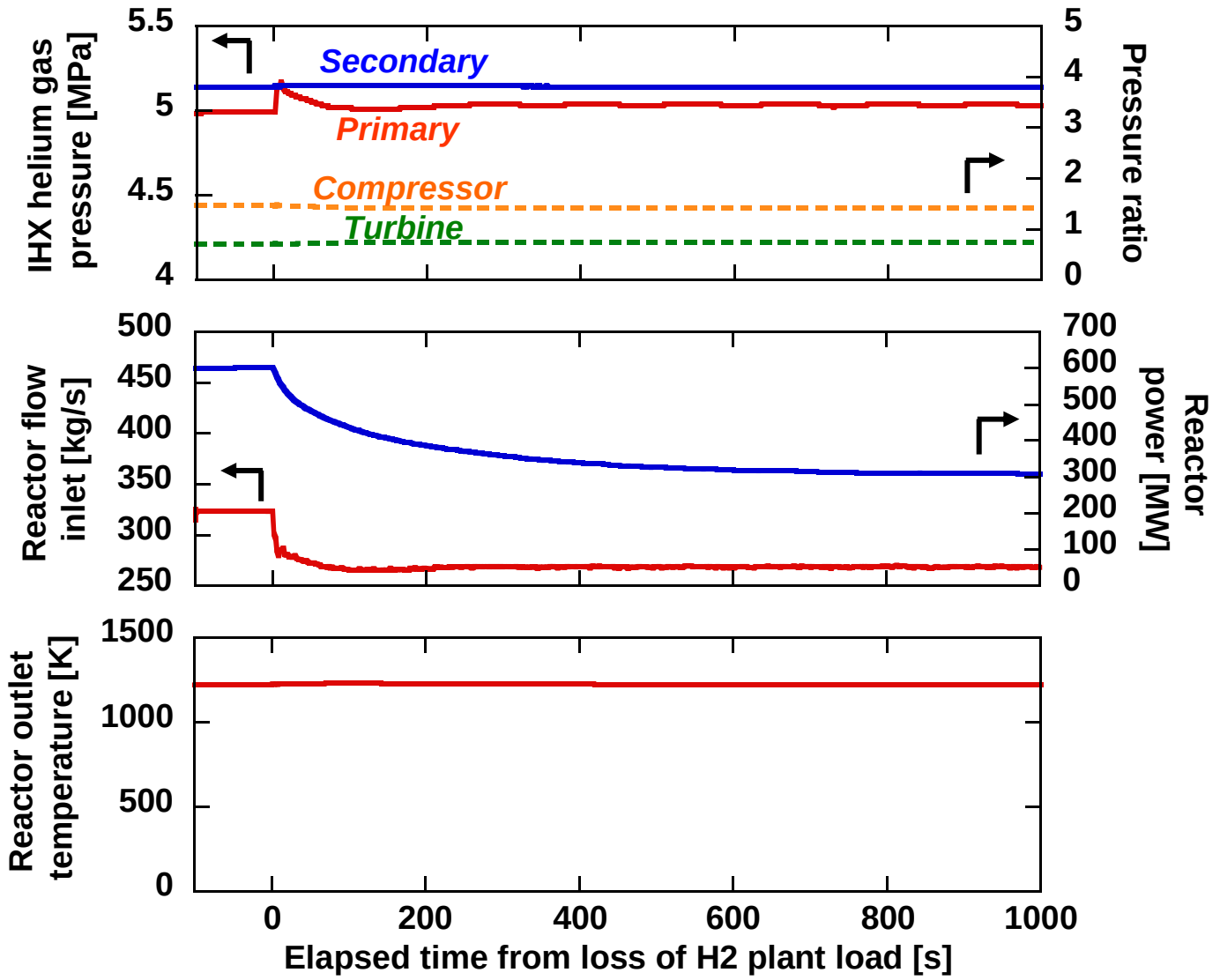


Dynamic calculation (4/4)

- Loss of thermal load of H_2 Plant (370MW) in GTHTR300C -



IHX pressure difference

MAX

: +0.16 MPa

Reactor inlet flow rate variation

: -59.7 kg/s

Reactor power variation

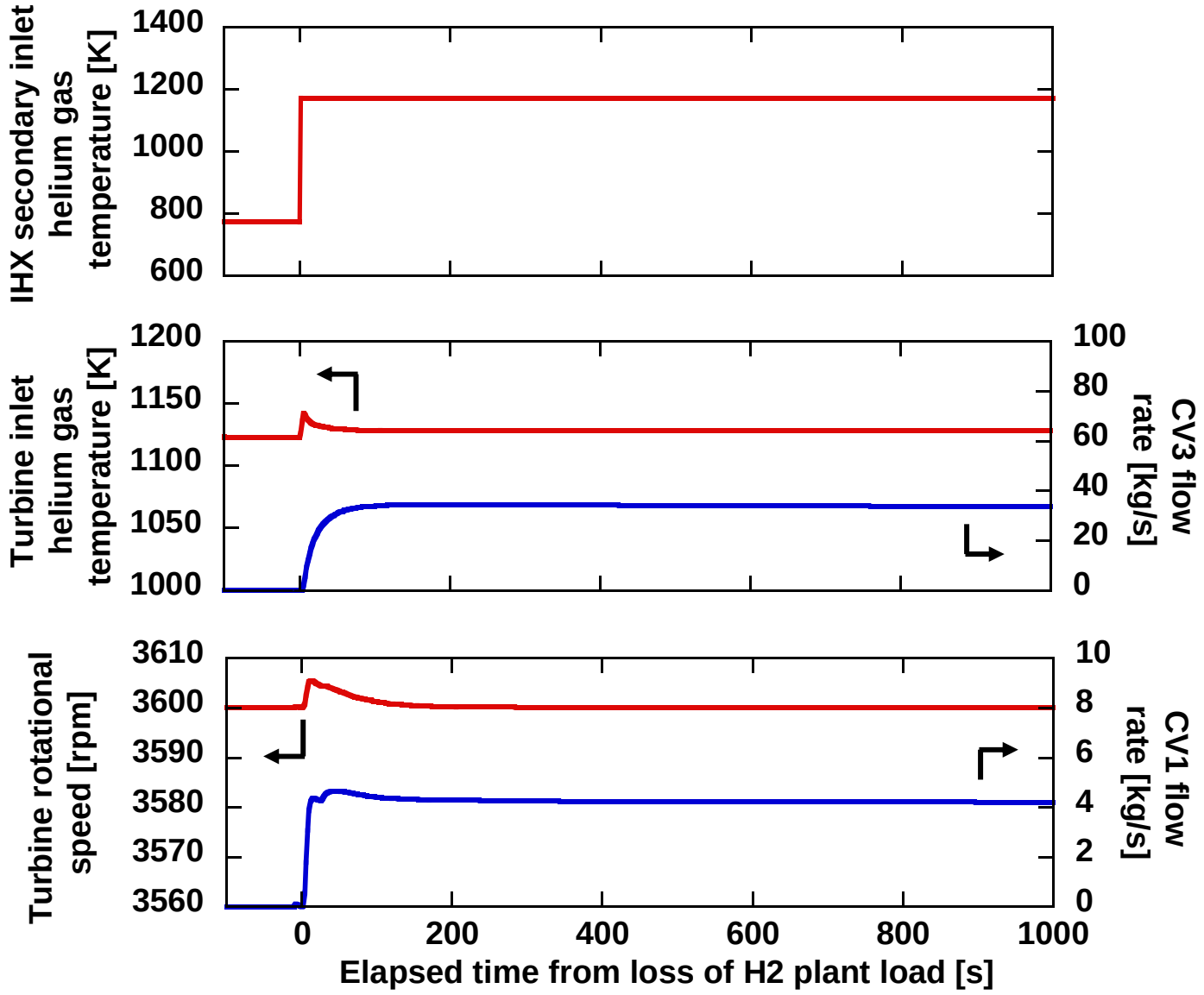
: -293 MW

Reactor outlet temperature

: Constant

Dynamic calculation (1/4)

- Loss of thermal load of H_2 Plant (170MW) in GTHTR300C -



Thermal disturbance

IHX

2nd inlet

: **+400 K**

Turbine

Inlet

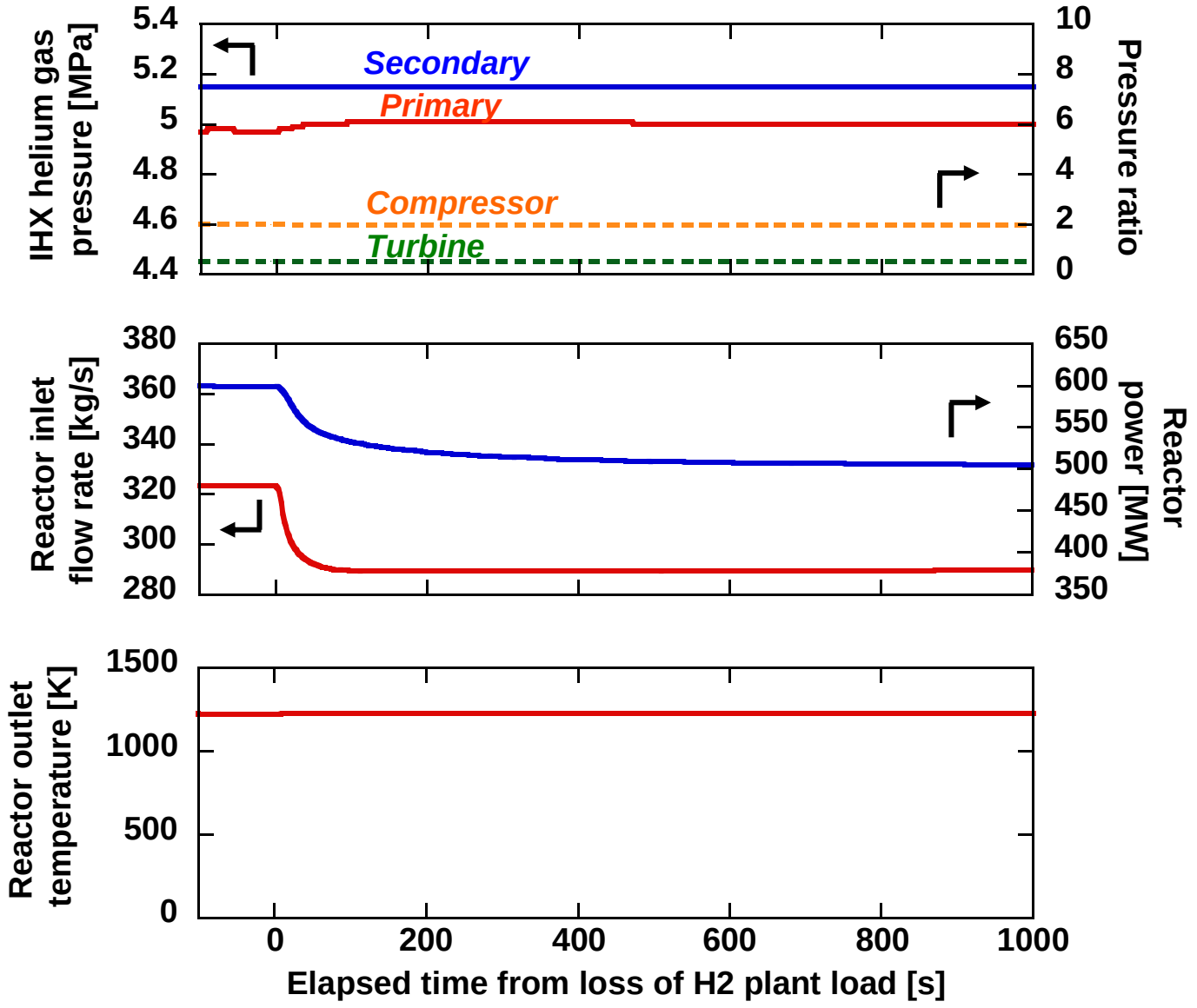
: **+19.7 K**

Turbine R.P.M. increase

: **+ 5 r.p.m.**

Dynamic calculation (2/4)

- Loss of thermal load of H_2 Plant (170MW) in GTHTR300C -



IHX pressure difference

MAX

: +0.19 MPa

Reactor inlet flow rate variation

: -34.0 kg/s

Reactor power variation

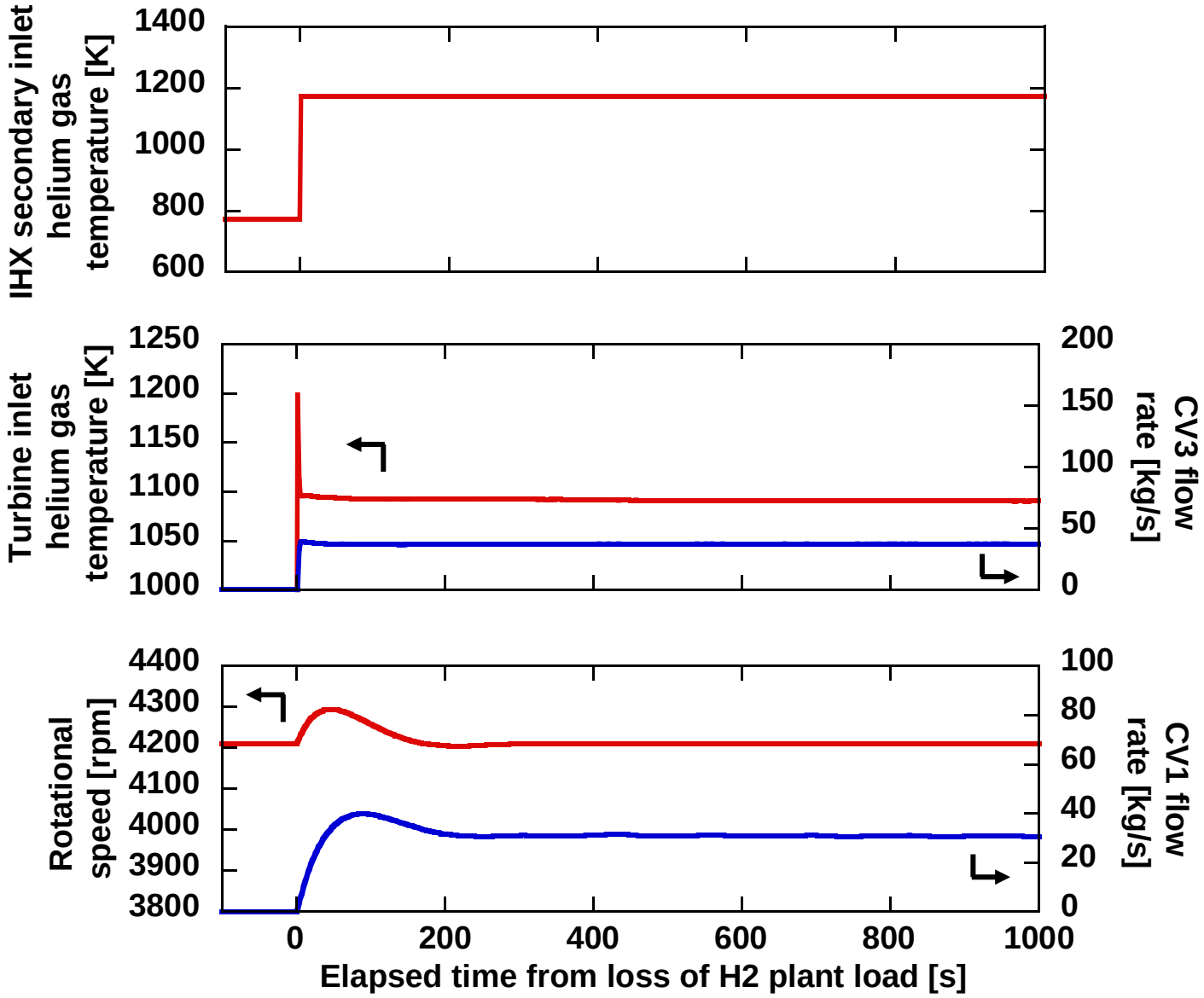
: -93.5 MW

Reactor outlet temperature

: Constant

Dynamic calculation (3/4)

- Loss of thermal load of H_2 Plant (370MW) in GTHTR300C -



Thermal disturbance

IHX

2nd inlet

: ***+400 K***

Turbine

Inlet

: ***+201 K***

Turbine R.P.M. increase

: ***+ 90 r.p.m.***