

Commissioning of Fuel Test Loop in HANARO



Sep. 28, 2009

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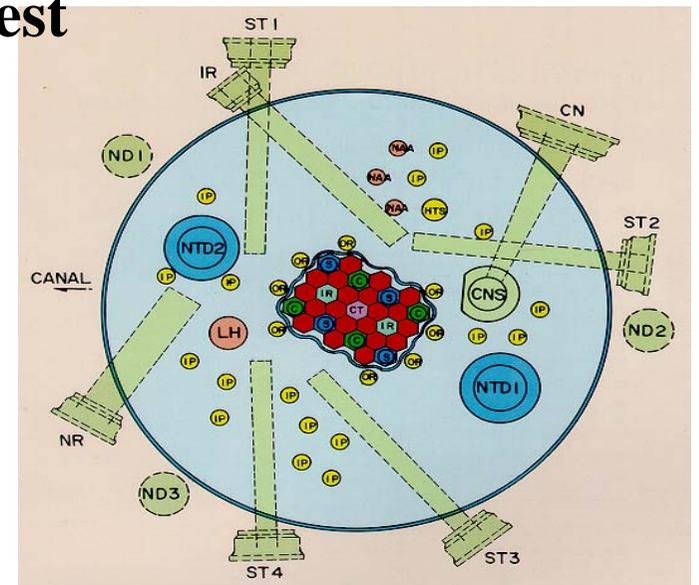
- Introduction of HANARO**
- Characteristics of HANARO Fuel Test Loop**
- Commissioning of Fuel Test Loop**

❖ HANARO : High-flux Advanced Neutron Application Reactor

- ❑ Type : Open-Tank-In-Pool
- ❑ Max. Thermal Power : 30 MWth
- ❑ Coolant : Light Water
- ❑ Reflector : Heavy Water
- ❑ Reactor Building : Confinement
- ❑ Thermal Neutron Flux : 2.1×10^{14} n/cm²·sec
- ❑ Fast Neutron Flux : 4×10^{14} n/cm²·sec
- ❑ 7 Horizontal Ports & 36 Vertical Holes

HANARO Utilization

- ❑ Neutron Beam Utilization
- ❑ Neutron Activation Analysis (NAA)
- ❑ Neutron Transmutation Doping of Silicon (NTD)
- ❑ Development and Commercial Supply of RI
- ❑ Cold Neutron Facility and Utilization
- ❑ Nuclear Fuels and Materials Irradiation Test
 - Capsule
 - **Fuel Test Loop**



Fuel Test Loop

- ❑ Simulates the NPP's **steady-state operating condition**
 - **PWR, CANDU**
- ❑ Irradiation Hole : IR1
- ❑ Thermal Neutron Flux : 1.2×10^{14} n/cm²·sec
- ❑ Fast Neutron Flux : 1.6×10^{14} n/cm²·sec
- ❑ Accommodate up to 3 pins of test fuel

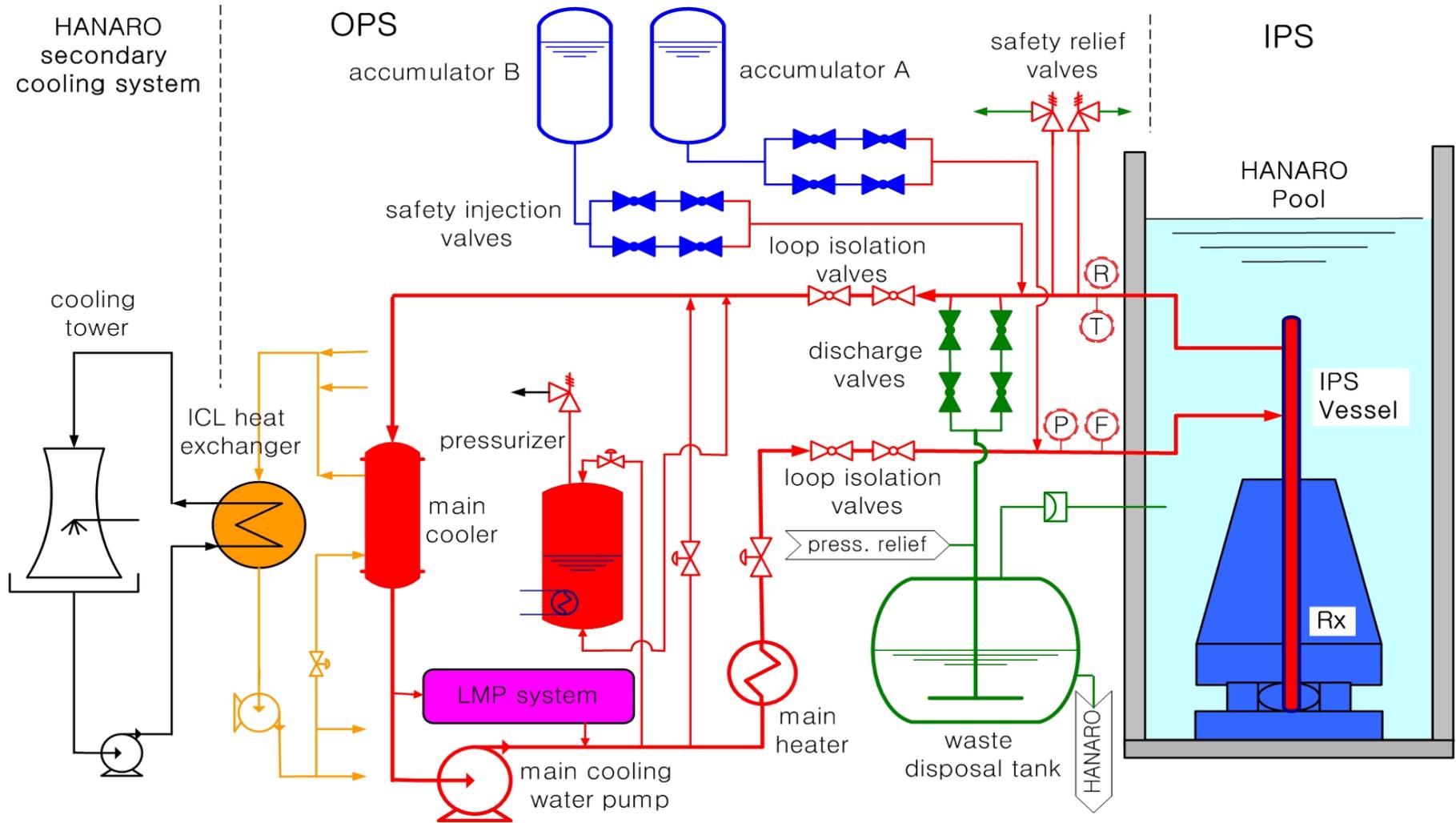
□ FTL design, manufacturing, installation ['01. 12. - '07. 3.]

- Design : '01. 12. ~ '06. 7.
- Manufacturing : '04. 5. ~ '06. 6.
- Permission of FTL installation : '06. 7.
- Installation : '06. 7. ~ '07. 3.

□ Commissioning ['07. 4. ~ '09. 9.]

□ Irradiation test of PWR fuels ['09. 10. ~]

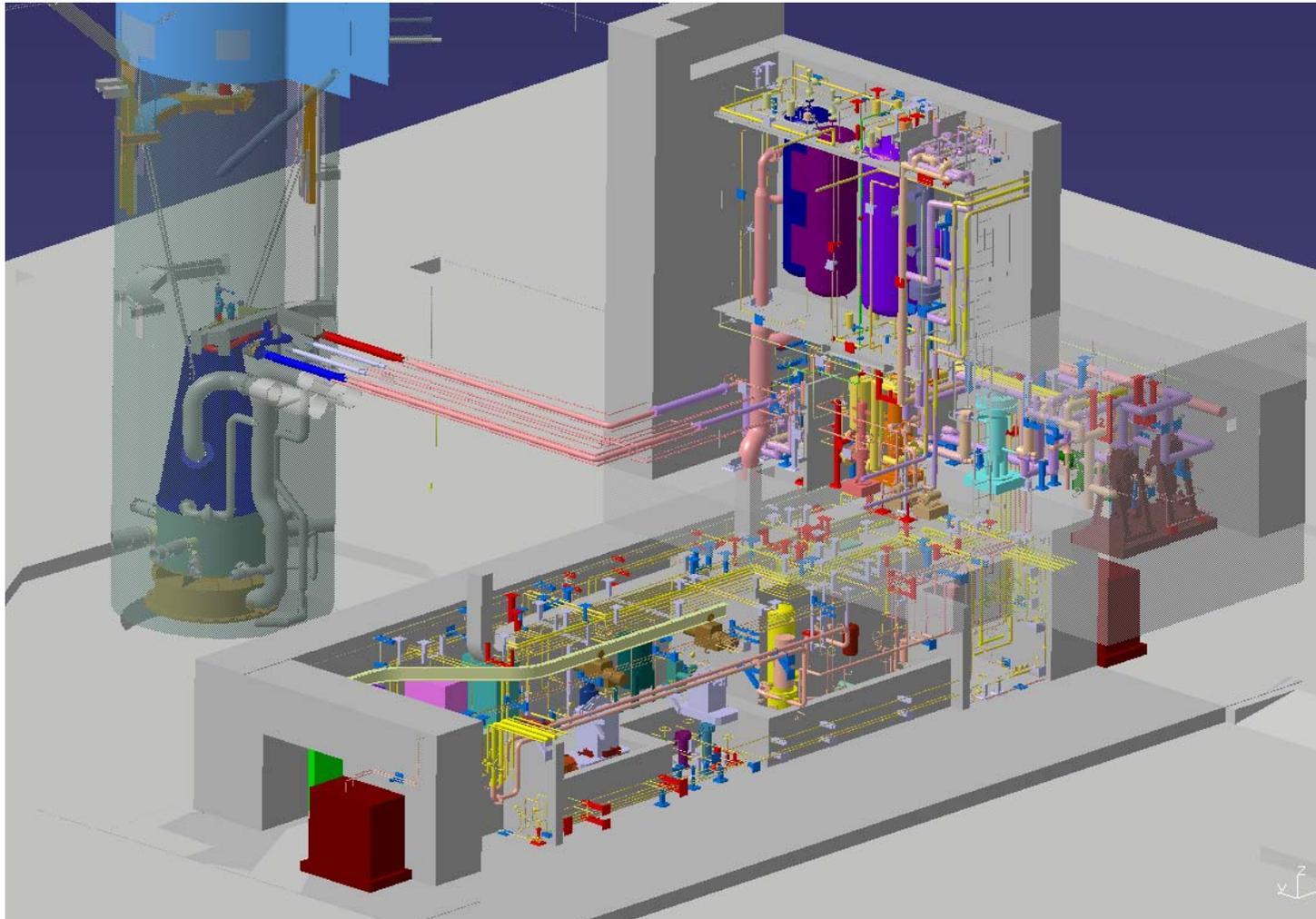
Schematic Diagram of FTL



Process Systems

Process Systems	Functions
Main Cooling Water System	Controls and regulates the system pressure, temperature and flow rates of coolant
Emergency Cooling Water System	Inject the emergency cooling water directly from accumulator to the MCW system if Line Break Accidents occur
Penetration Cooling Water System	Circulates the HANARO pool water to cool down the concrete penetration parts
Letdown, Make-up, Purification System	Controls the volume, purification and chemical quality of the MCW system
Waste Storage and Transfer System	Dispose the waste water which is ejected from safety valves, pressure relief valves and system water of loop
Intermediate Cooling Water System	Transfer the fissile and pump heat to the HANARO secondary cooling system
Sampling System	Monitors the water quality periodically
IPS Inter-space Gas Filling and Monitoring System	Fills neon gas to the pressure vessel gap and fills air gas to the in-pool pipe gap to insulate them from the pool water

Installation



- **Room #1 :**
Installation of Safety Related Components
- **Room #2 :**
Installation of Non-Safety Related Components
- **FTL Control Room :**
Installation of Control Related Components

Main Design Parameters

Parameters	PWR test mode	CANDU test mode
Design Pressure, MPa	17.5	17.5
Design Temperature, °C	350	350
Operating Pressure, MPa	15.6	10.1
Operating Temperature (IPS Inlet), °C	300.3	276.7
Operating Temperature (IPS outlet), °C	312.0	290.0
Operating Flow, kg/s	1.65	1.63

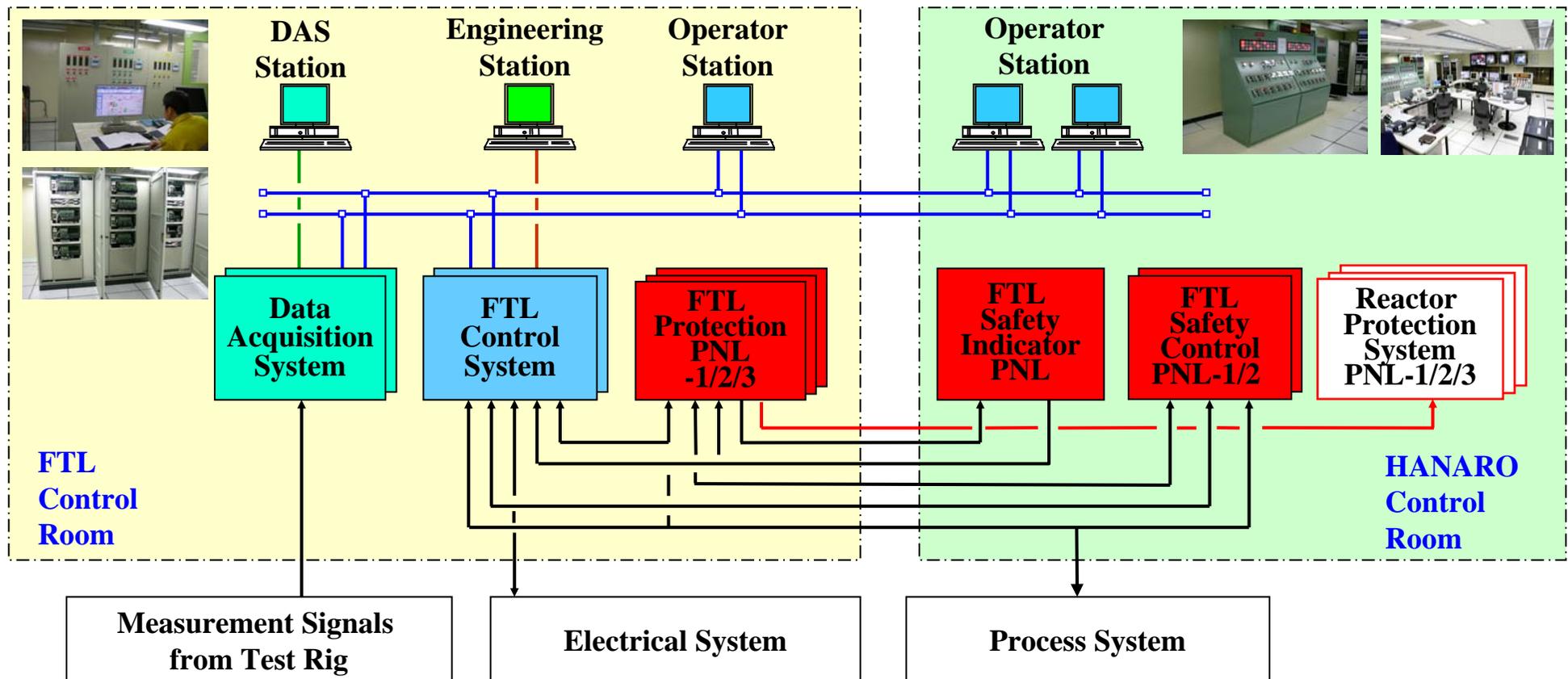
I&C System

□ Safety Related Control System

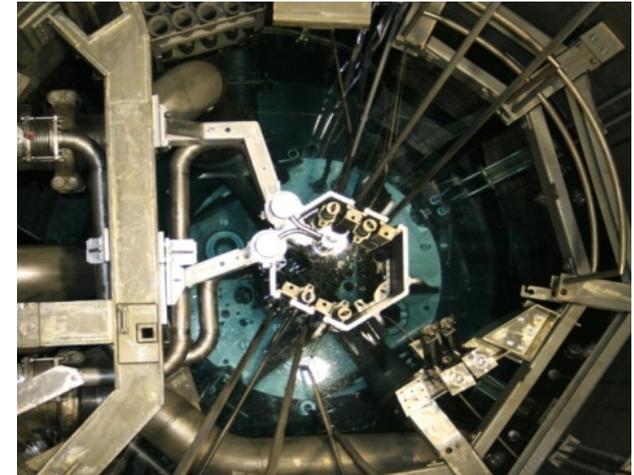
- FTL Safety Control & Monitoring, Reactor Trip

□ Non-Safety Related Control System

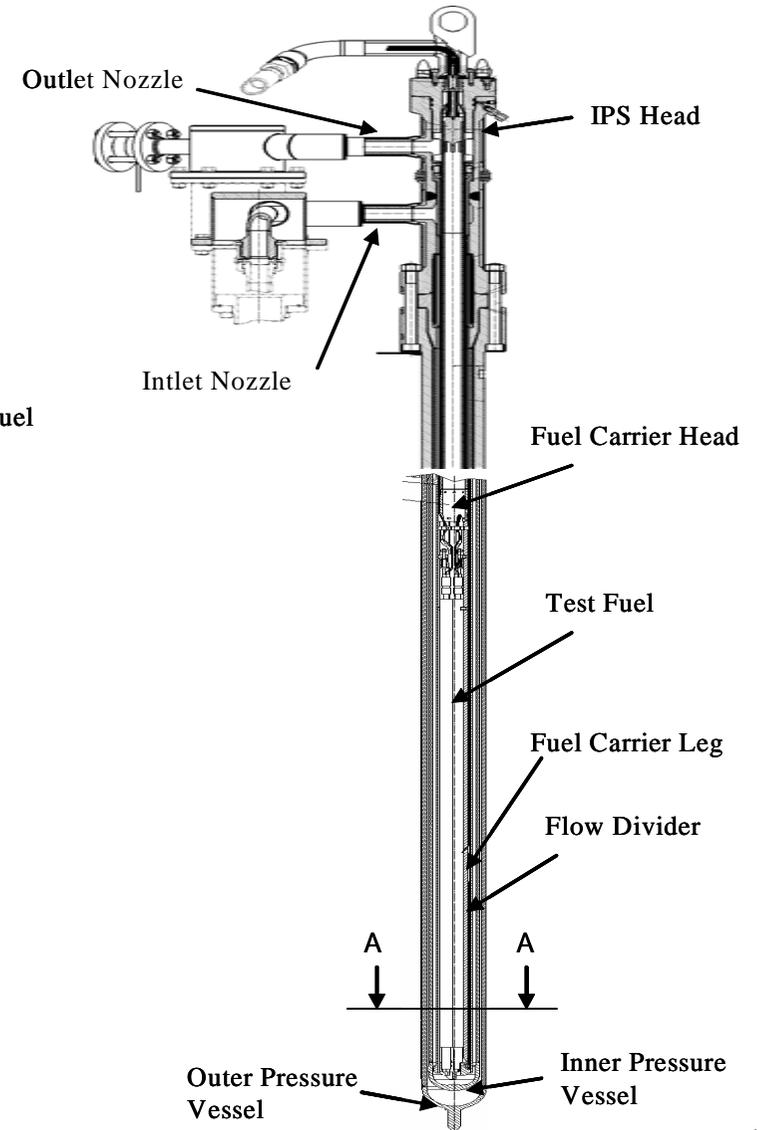
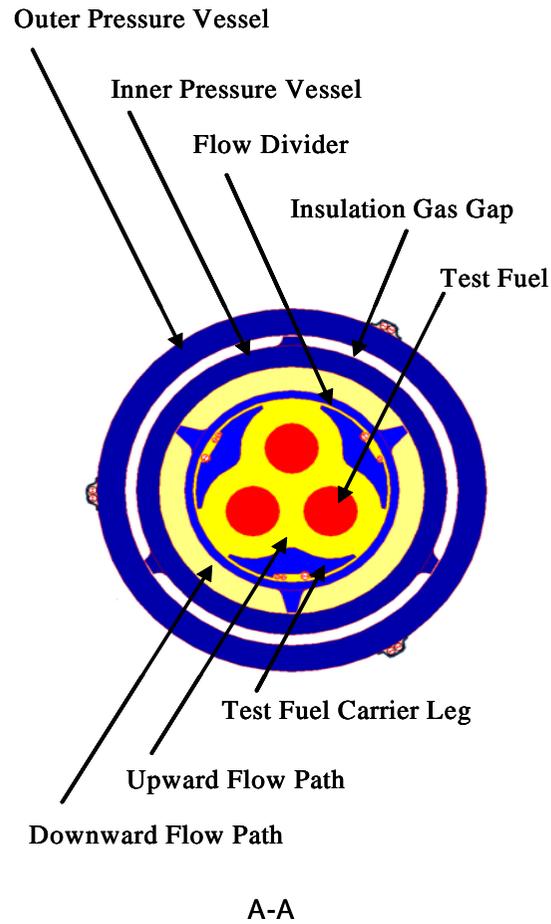
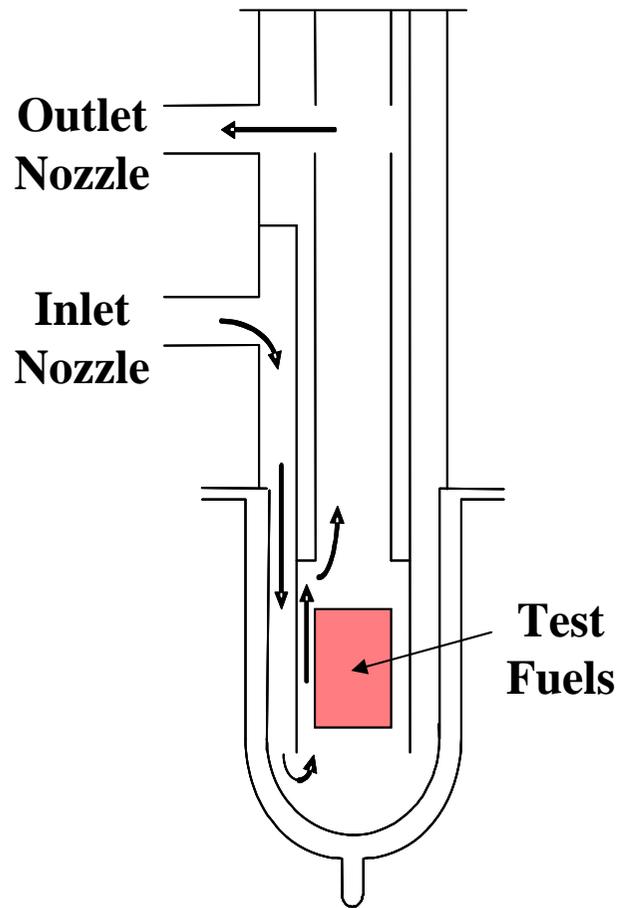
- Process Automatic Control, Experimental Data Acquisition



Facility Pictures



In-Pile test Section



Commissioning

- ❑ **Stage 1 : Performance test for each process systems
at room temperature**

- ❑ **Stage 2 : Performance test with mock-up fuels
at high temperature**

- ❑ **Stage 3 : Performance test with test fuels
at high temperature**

Performance test for each process systems

Stage 1	Performance tests
Function tests for electric and control devices	<ul style="list-style-type: none"> - Transmitters (press., diff. press.) - Switches (pressure, level) - RTDs - Detectors (dissolved oxygen, hydrogen, conductivity)
Performance tests for electric and control systems	<ul style="list-style-type: none"> - Electric system - Computer control system - Data acquisition system - Safety related control system
Performance tests for process systems	<ul style="list-style-type: none"> - Main cooling water (MCW) system - Emergency cooling water system - Penetration cooling water system - Letdown, makeup, and purification system - Intermediate cooling water system - Waste storage and transfer system - Sampling system - Radiation monitoring system - IPS inter-space gas filling and monitoring system - Miscellaneous systems

Performance test with mock-up fuels

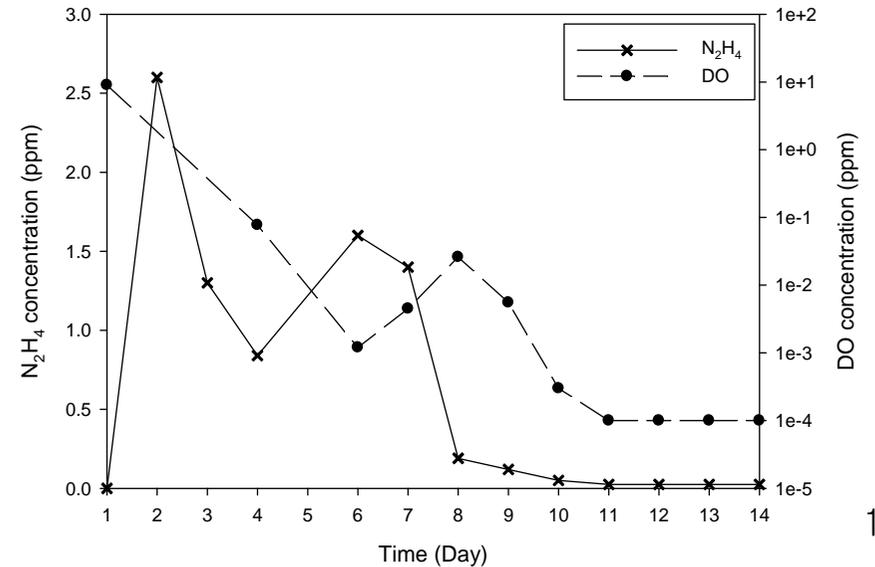
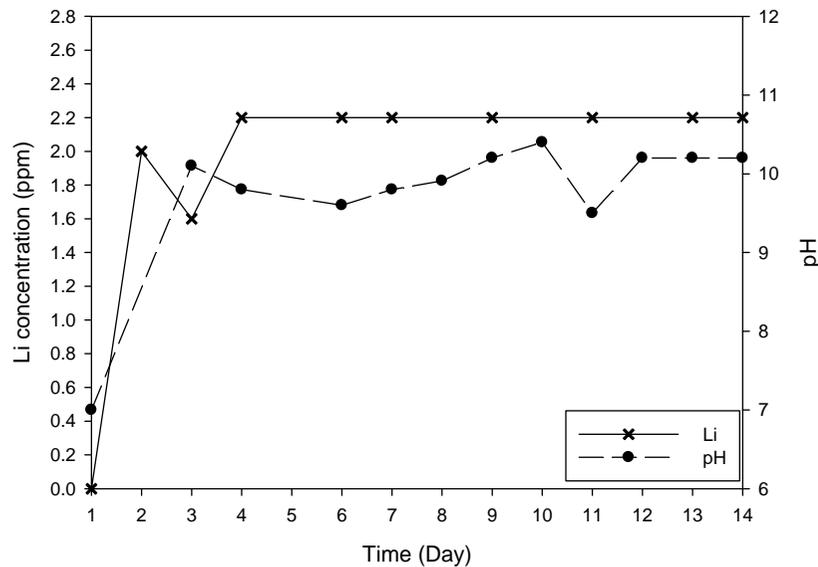
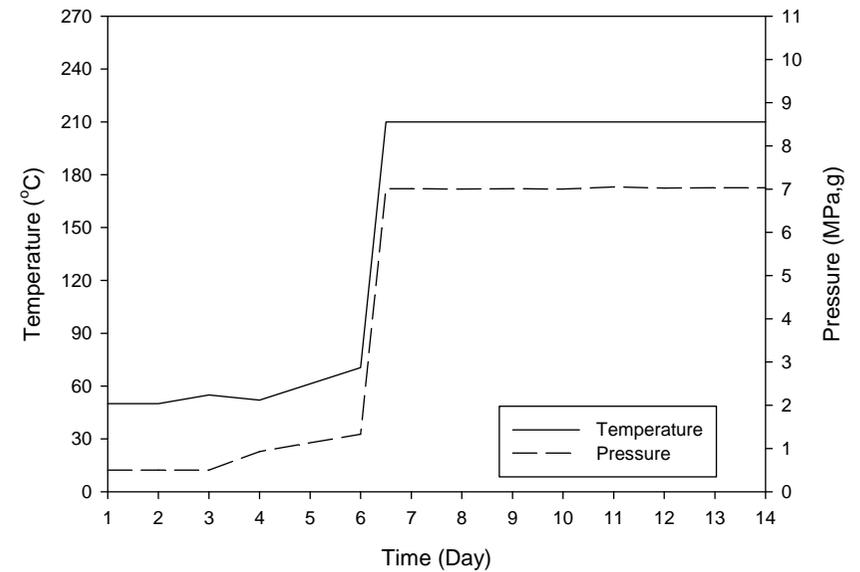
Stage 2	Performance tests
<p>Integral system performance test with mock-up fuels under high temperature condition</p>	<ul style="list-style-type: none"> - Performance test for main heater - Performance, heat loss, and level control tests for pressurizer - Heat loss test for pressurizer - Flow measurement test for main cooling system - Vibration and thermal expansion test for MCW system - Water chemistry analysis test for MCW system - Emergency cooling water injection test - Nuclear heat measurement test - Neutron flux measurement test

Operation Mode

Parameter	LSD	CSB1	CSB2	HSB	HOP
MCW Temp. (°C)	$T < 50$	$T < 50$	$50 \leq T < 90$	$90 \leq T < 300$	$270 \leq T$
MCW pump	Off	On	On	On	On
Main heater	Off	Off	On	On	Auto
Pressurizer heater	Off	On	On	On	On
Reactor power (MW)	0	0	0	0	30

Operation for Passivation

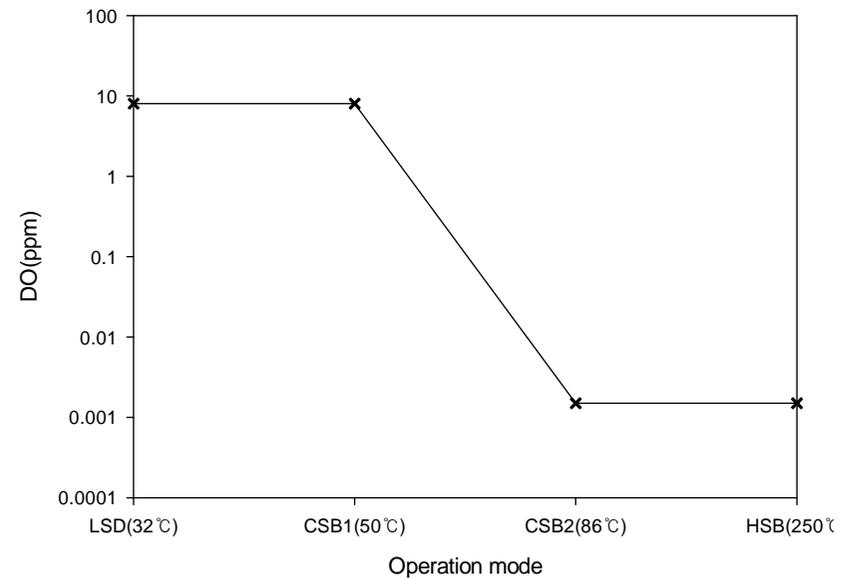
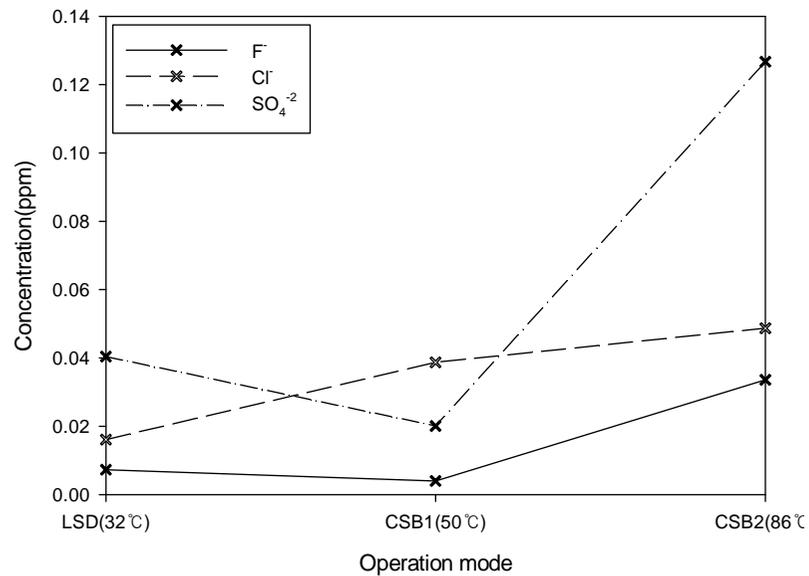
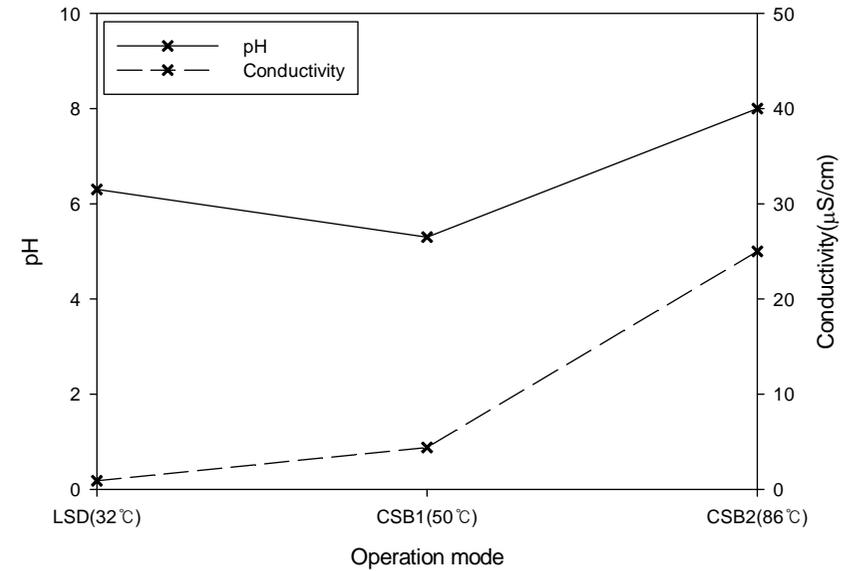
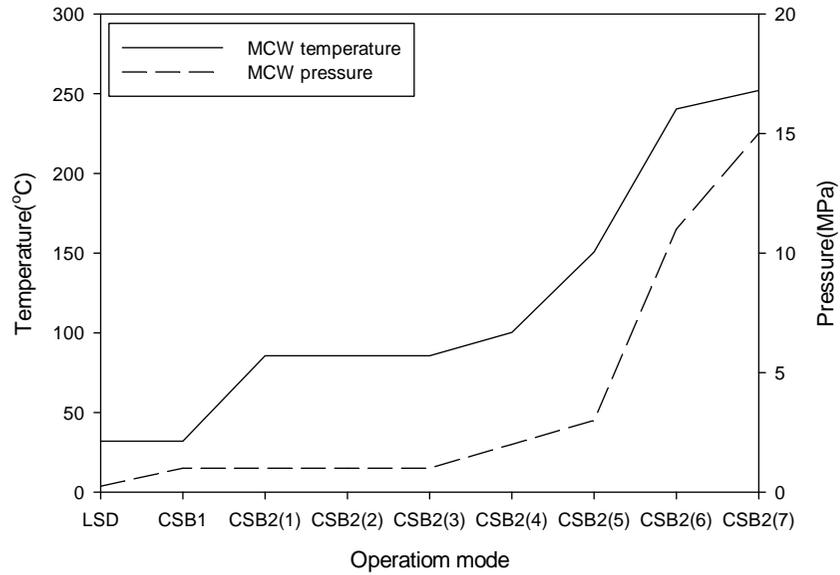
Items		Limit criterion
Li (after $\text{Li}^7\text{OH}\cdot\text{H}_2\text{O}$ is added)		1.0 ~ 2.2 ppm
pH	at coolant temp. < 177 °C	3.8 ~ 10.4
	at coolant temp. ≥ 177 °C	9.0 ~ 10.4
N_2H_4	at coolant temp. ≤ 177 °C	≤ 1 ppm
DO (at coolant temp. ≥ 121.5 °C)		≤ 0.1 ppm
Operation (at coolant temp ≥ 177 °C)		7 ~ 10 days



Water Chemistry Control

Items	Limit criterion
F⁻	≤ 0.15 ppm
Cl⁻	≤ 0.15 ppm
SO₄⁻²	≤ 0.15 ppm
DO (at coolant temp ≥ 121.5°C)	≤ 0.1 ppm
pH	5.5 ~ 8.0
Conductivity	≤ 50 μS/cm

Experimental Results

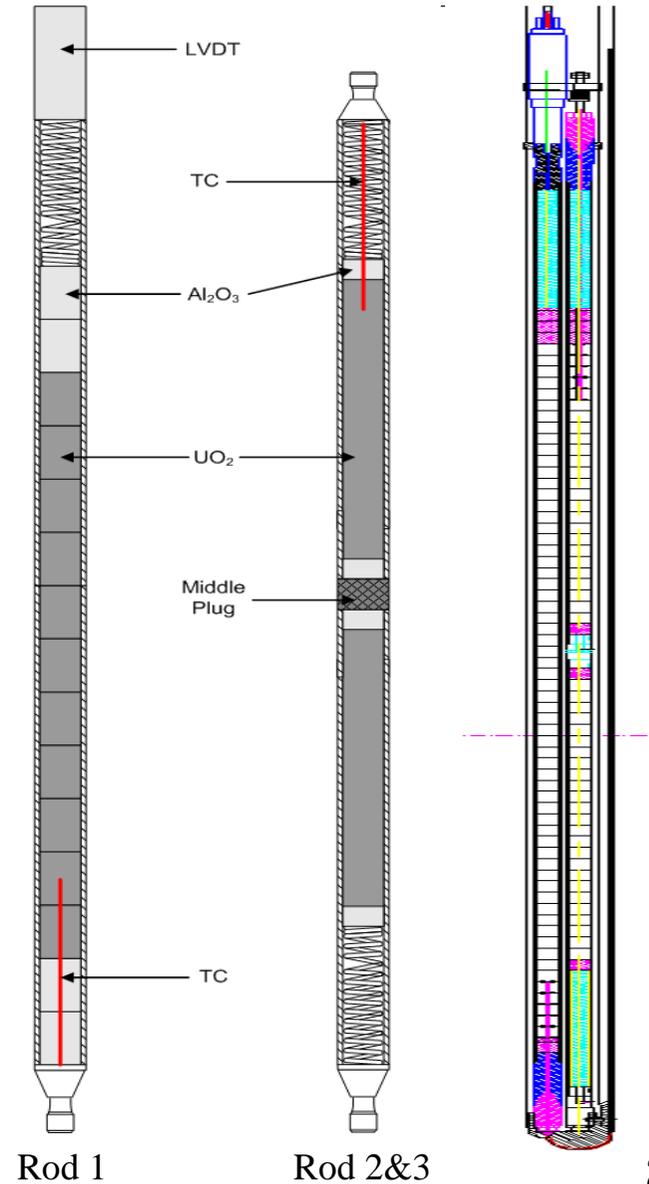


Performance test with test fuels

Stage 3	Performance tests
<p>Integral system performance test with test fuels under high temperature condition</p>	<ul style="list-style-type: none"> - Reactor power increasing test - Flow measurement test for main cooling system - Water chemistry analysis test for MCW system - Neutron flux measurement test - Background Radiation measurement test

In-pile Instrumentation

		Parameters (Instrument)
Rod 1		Fission Gas Pressure (LVDT) Centerline Temp. (C-Type T/C)
Rod 2	Upper fuel	Centerline Temp. (C-Type T/C)
	Lower fuel	-
Rod 3	Upper fuel	Centerline Temp. (C-Type T/C)
	Lower fuel	-
IPS Assembly (Upper/Middle/Lower)		Neutron flux (SPND) Coolant Temp. (K-Type T/C)



Status of Commissioning

Stage	Operation/Test Conditions	Status
<p>Performance test for each process systems</p>	<ul style="list-style-type: none"> ➤ Reactor : Shutdown ➤ FTL : Room temperature ➤ IPS : By-pass 	<p>Completion</p>
<p>Integral system performance test with mock-up fuels</p>	<ul style="list-style-type: none"> ➤ Reactor : Shutdown/Operation ➤ FTL : High temperature/high pressure (FTL Operation mode) ➤ IPS : Mock-up fuels 	<p>Completion</p>
<p>Integral system performance test with test fuels</p>	<ul style="list-style-type: none"> ➤ Reactor : Operation ➤ FTL : Operation ➤ IPS : Test fuels 	<p>In-progress</p>

Conclusions

- ❑ HANARO FTL Simulates the **steady-state operating condition of PWR and CANDU reactors**
- ❑ Commissioning is performed with **3 stages**
- ❑ **Irradiation test for PWR fuels** will be performed after completion of the commissioning