

CURRENT STATUS OF HANARO OPERATION AND CHALLENGING ISSUES



June 21, 2023

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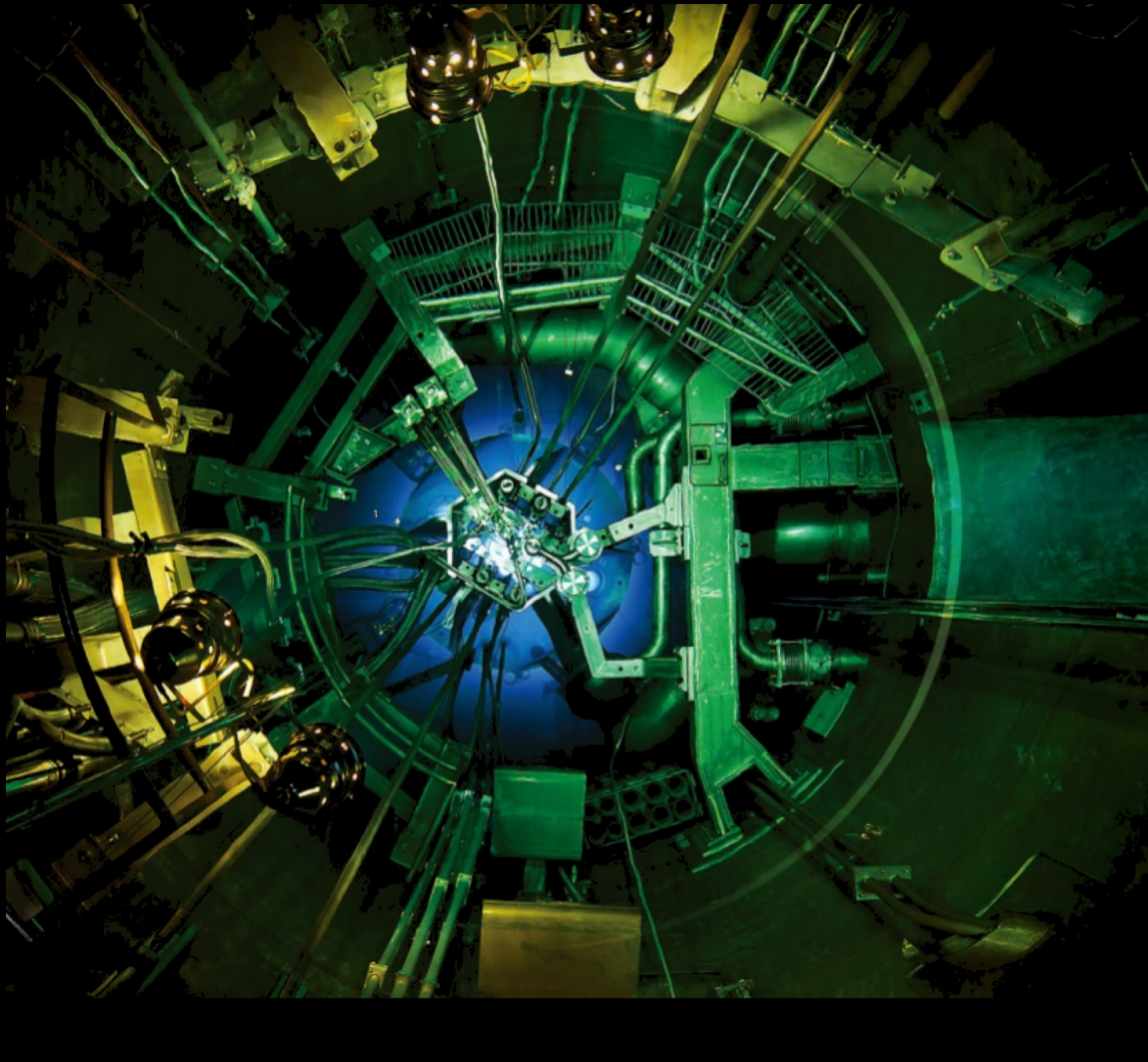
HANARO Management Division



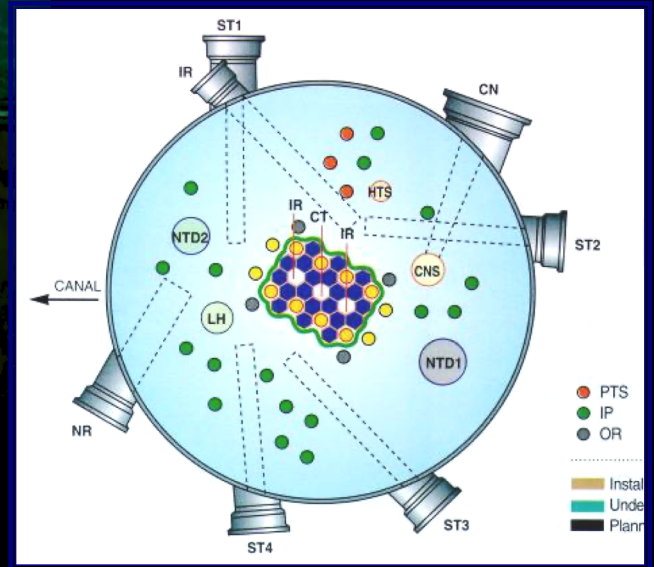
Korea Atomic Energy
Research Institute

- HANARO Overview
- Operation
- Inspection and Maintenance
- In-Service Inspection
- Ageing Management Program
- Preventive Maintenance Program
- Recent Refurbishment of Facilities
- Regulatory Issues on Research Reactors in Korea
- Summary

HANARO Overview



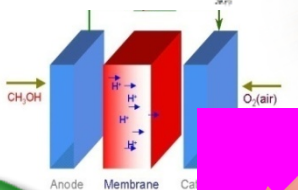
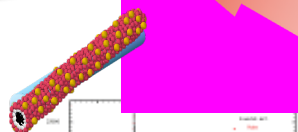
- | | |
|-----------------------------------------------------|--------------------------------------------|
| ● Type | <i>Open-tank-in-pool</i> |
| ● Power | <i>30 MW_{th}</i> |
| ● Coolant | <i>Light Water</i> |
| ● Reflector | <i>Heavy water</i> |
| ● Fuel Materials | <i>U₃Si, 19.75%</i> |
| ● Absorber | <i>Hafnium</i> |
| ● Reactor Building | <i>Confinement</i> |
| ● Max Thermal Flux | <i>5x10¹⁴ n/cm²s</i> |
| ● Typical flux at port nose | <i>2x10¹⁴ n/cm²s</i> |
| ● 7 horizontal ports & 36 vertical holes | |
| ● Vertical hole for cold neutron source | |



HANARO Utilization

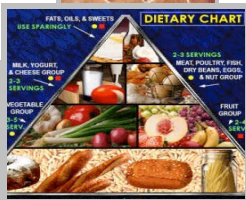
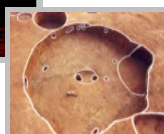
Neutron Beam Research

Nano structure
Li battery
Fuel cell
Hydrogen storage



Neutron Activation Analysis

Environmental research
Soil analysis
Food analysis
Purity measure



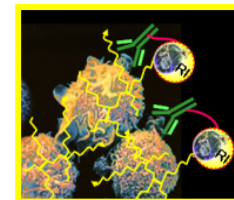
Semiconductor Production

Hybrid car
Express train
Windmill
Solar system



RI Production

Cancer therapy
Target therapy
NDT
Hydrology

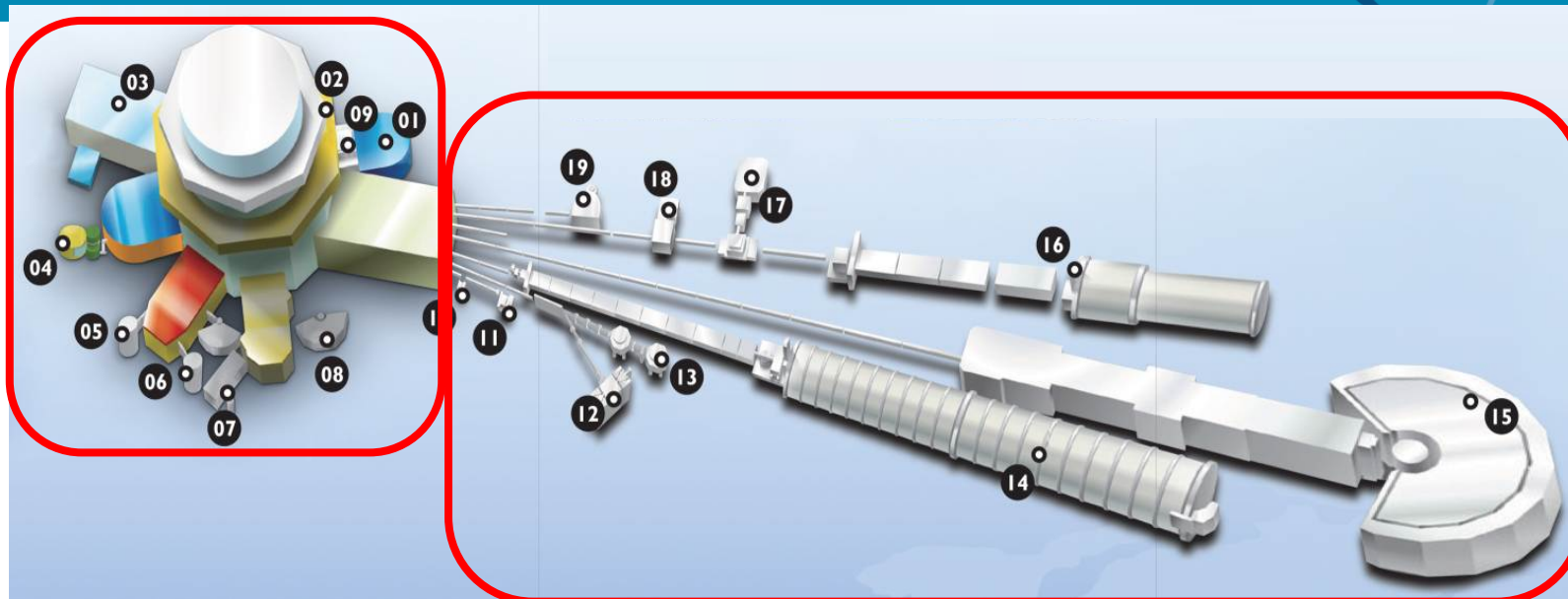


Irradiation Effect Research

Power reactor
Cosmic radiation
Super conductor



Neutron beam instruments layout



02 Ex-core Neutron irradiation Facility

09 Thermal Neutron Prompt Gamma Activation Analysis

01 Residual Stress Instrument

08 High Resolution Powder Diffractometer

07 Four Circle neutron Diffractometer

N/A High Intensity Powder Diffractometer

06 Bio-Diffractometer

05 Bio-diffractometer with neutron image plate Camera

04 Thermal neutron Triple-Axis Spectrometer

03 Neutron Radiography Facility

10 Guide Test Station

11 Vertical type REFlectometer

12-13 Cold Neutron Activation Station

14 40m Small Angle Neutron Scattering instrument

15 Disk-Chopper Time-of-Flight spectrometer

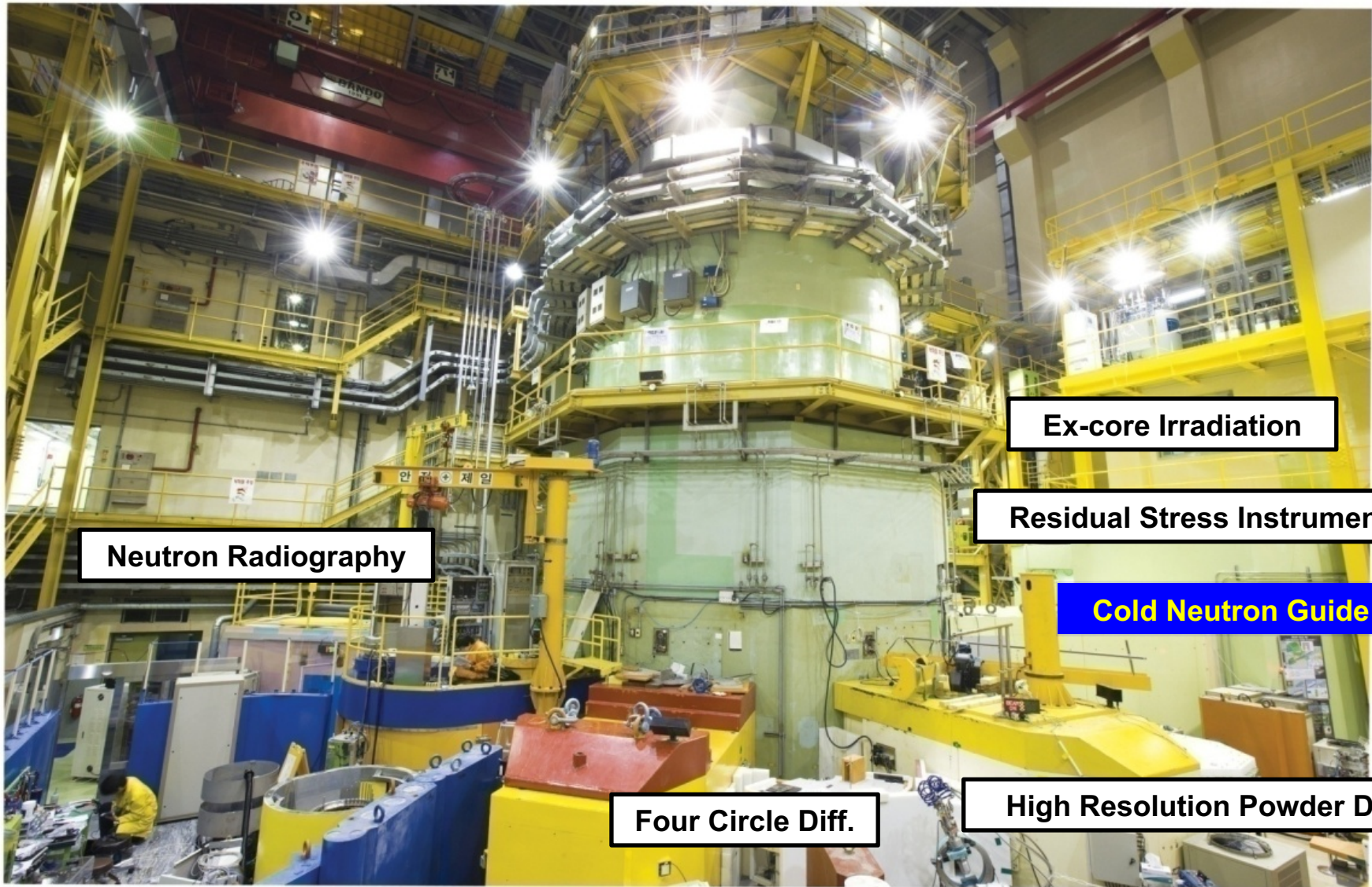
18 KIST Ultra-Small Angle Neutron Scattering instrument

17 Bio-REFlectometer

16 18m Small Angle Neutron Scattering instrument

19 Cold neutron Triple-Axis Spectrometer

Instruments in the Reactor Hall



Neutron Radiography

Ex-core Irradiation

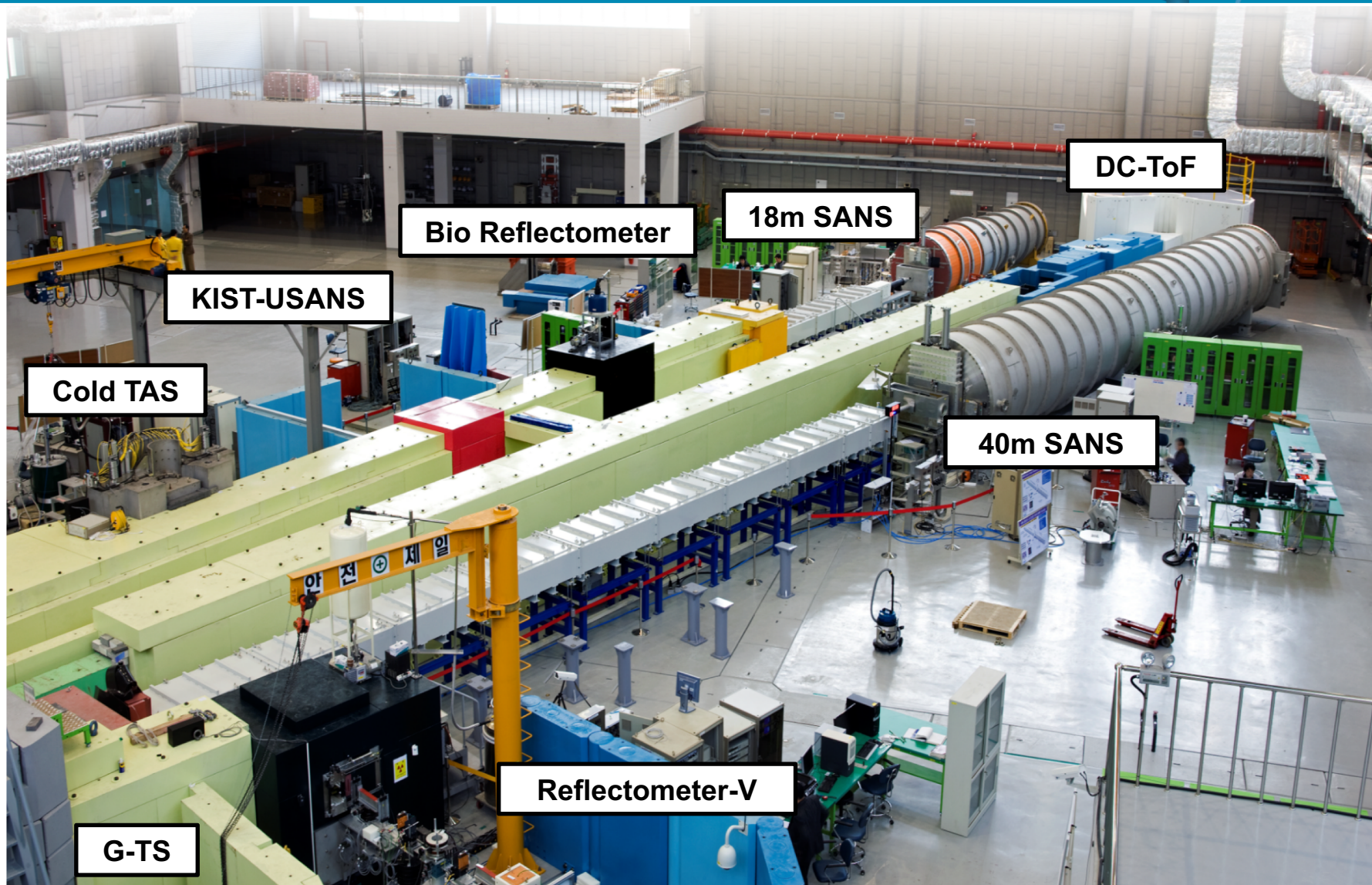
Residual Stress Instrument

Cold Neutron Guide

Four Circle Diff.

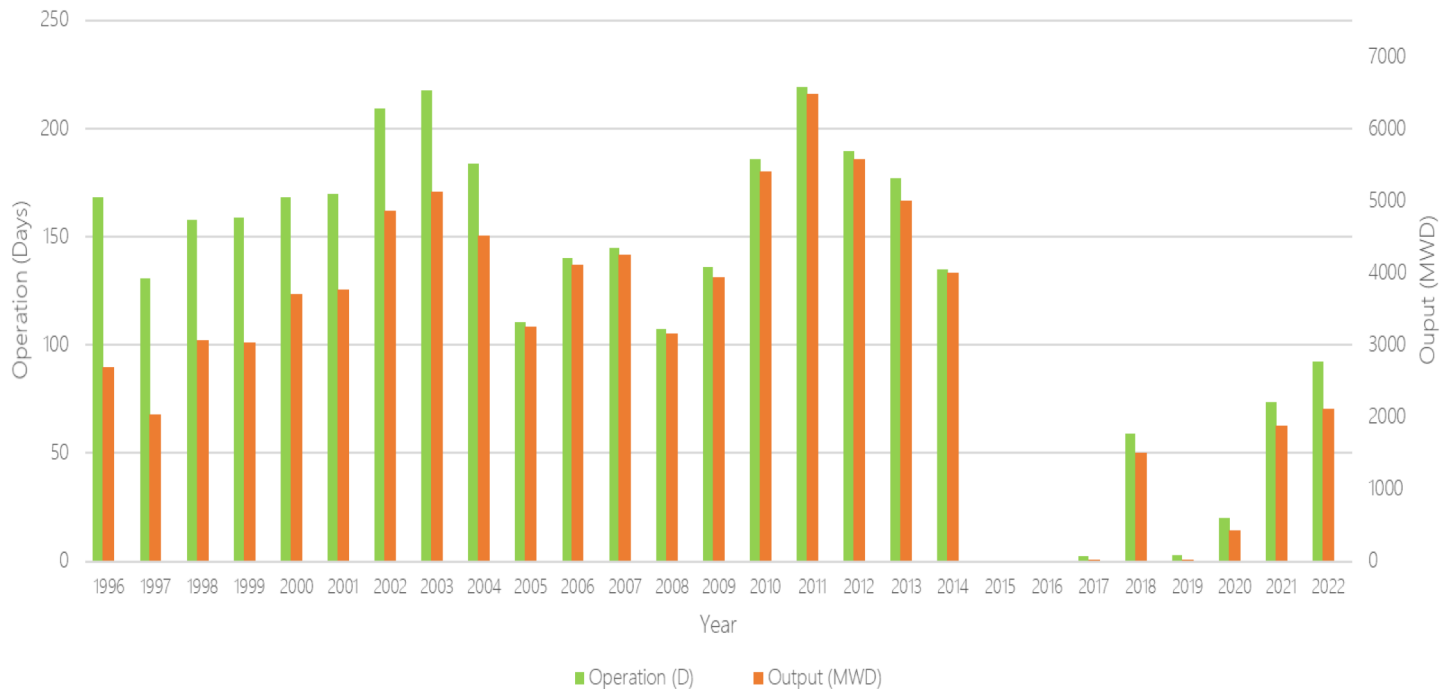
High Resolution Powder Diff.

Instruments in the Neutron Guide Hall

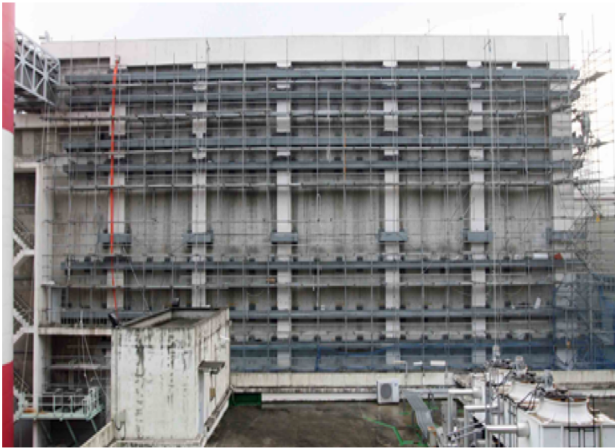


HANARO Operation

- Operation cycle: 4 weeks operation + 2 weeks maintenance
 - 6~7 periods operation per year was possible until July 2014.
- It recorded **219 days of operation in 2011** and has been on a declining trend with no operations from 2015 to 2017 for long shutdowns.

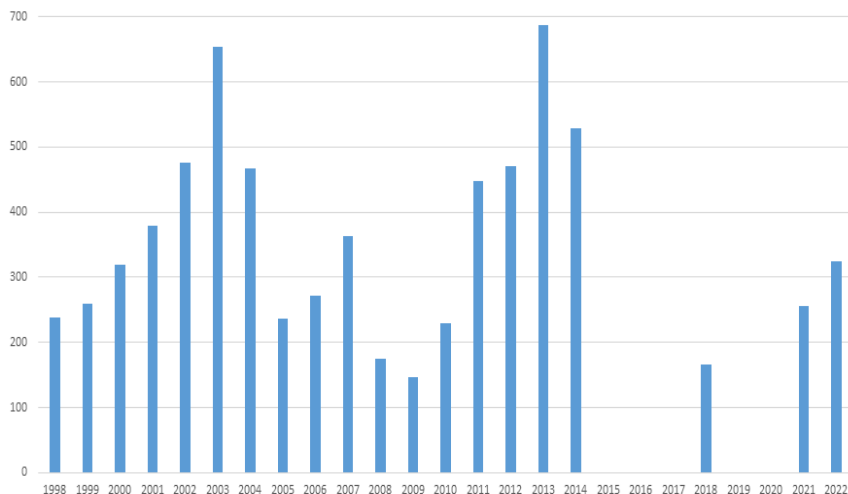


- 2015.2 ~ 2017.12 **Seismic reinforcement** of reactor building

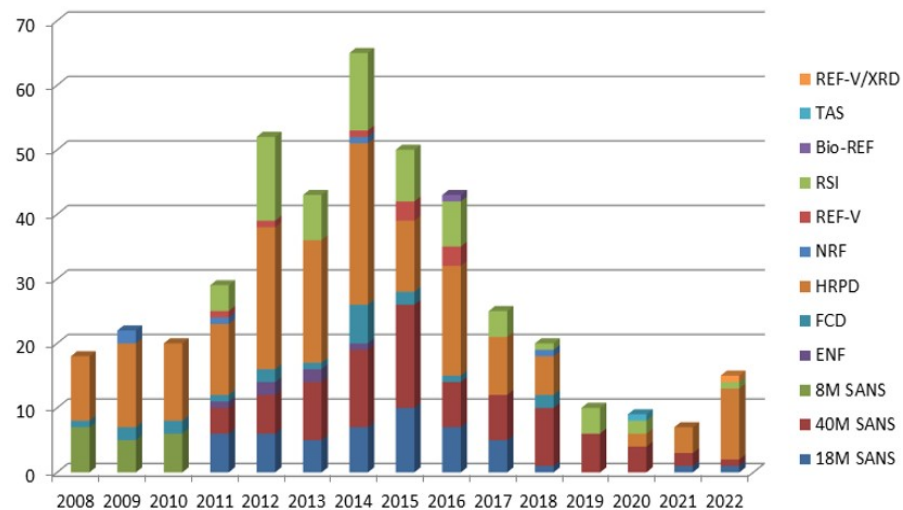


- 2018.7 **Amendment of Nuclear Safety Act** for research reactors in Korea
- 2018.12 ~ 2019.10 **Special safety inspection** for HANARO and utilization facilities by the government

- The number of neutron beam users peaked to 682 users in 2013
- The number of SCI publications peaked to 62 in 2014, continued to decrease as a result of long shutdowns and rebounded to 15 in 2022.



Number of neutron beam users by year



Number of SCI publication by year

Types of Inspection

- Surveillance Inspection (SI)
 - Requirement of SAR and Tech. Spec.
- Periodic Inspection (PI)
- In-service Inspection (ISI)
 - Requirement of Nuclear Safety Act

Inspection periods

- Daily, weekly, monthly, quarterly, semi-yearly, yearly, and long-term period(18 months, 3 years,...)
- 442 inspections per year

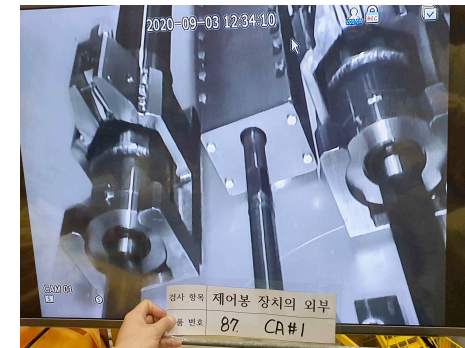
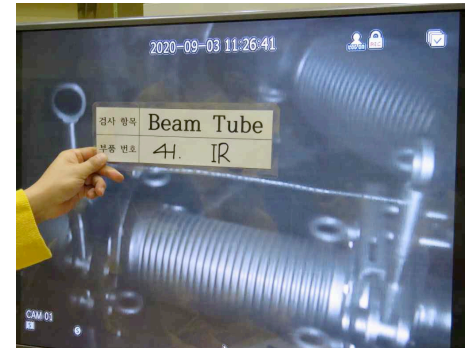
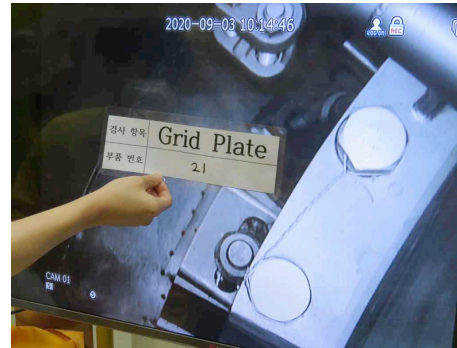
Maintenance team and qualified companies perform inspections.

Maintenance works are done depending on the result of inspections(Corrective or preventive maintenance).

Component	Inspection item	Method
Piping	<ul style="list-style-type: none"> - Primary Cooling System - Emergency Water Supply System 	VT-1, VT-2, VT-3
Heat Exchanger	<ul style="list-style-type: none"> - Primary Cooling Heat Exchanger support 	VT-3
Pump	<ul style="list-style-type: none"> - Primary Cooling Pump support - Primary Cooling Pump Flywheel 	VT-3, UT
Reactor Structure Assembly	<ul style="list-style-type: none"> - Reactor structure, reactivity control unit and beam tubes 	VT-3
	<ul style="list-style-type: none"> - Inner shell of reflector tank 	Measurement (vertical straightness)
	<ul style="list-style-type: none"> - Flow tube - Shroud tube - Control absorber rod - Shut off rod 	Measurement (diameter)

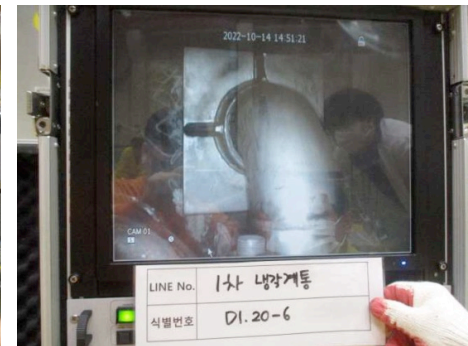
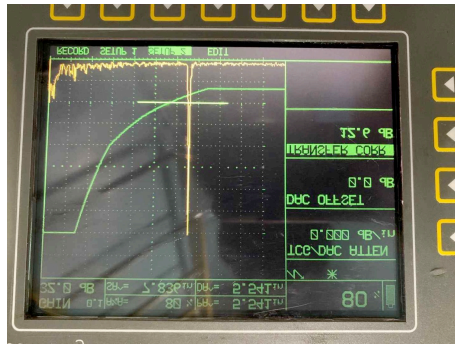
■ Reactor structure assembly and in-pool components

- Reactor structure, reactivity control unit and beam tubes(VT-3)



■ Safety related pump, heat exchanger and pipe

- Support for primary cooling pump, heat exchanger, and pipe(VT-1, VT-3)
- Primary cooling and emergency water supply system(VT-2)
- Fly wheel(UT)



■ Ageing management matrix(in use)

- Categorization of structure, system and components
- Input of ageing information of SSCs
- Prioritization
 - *Consideration of safety, operability, life expectancy, and performance*
- Planning maintenance and refurbishment

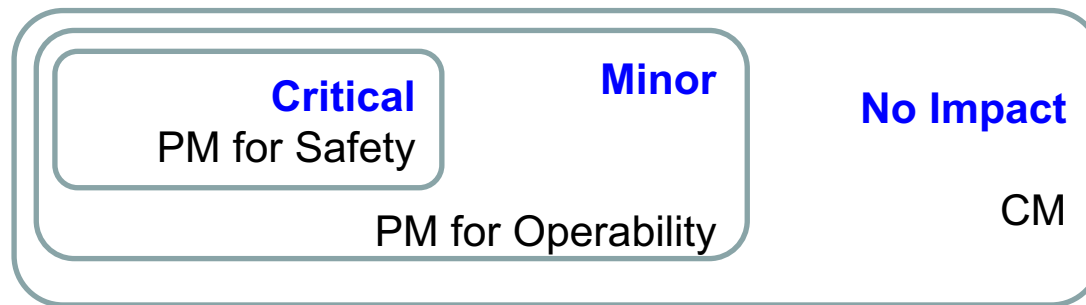
■ Ageing management program(in development)

- A systematic and comprehensive ageing management program will have been established until 2023.
- Principles of HANARO AMP development
 - *To maintain the SSCs with no reduction in performance or safety margins;*
 - *To prevent failures of critical SSCs*
 - *To understand ageing mechanisms*

Preventive Maintenance Program

■ FID(Functional Importance Determination)

- Process used to assign a value of importance to a given component based on nuclear safety and operability.



PM: Preventive Maintenance
CM: Corrective Maintenance

■ PM(Preventive Maintenance) Templates

- Templates for PM according to functional importance, environmental conditions and duty cycles of components
- PM templates is being built with the standardization of the task list and resources for each type of component.

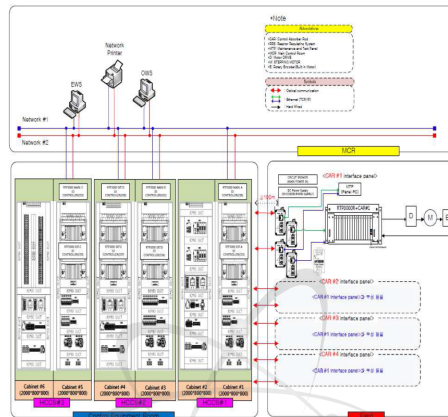
Rev	2		PM Template						Class1	Pump
Date	'10.11.05								Class2	PPHC
FID(Functional Importance)										
Importance	Critical				Minor				Horizontal Pump	
Op. Frequency	High	Low	High	Low	High	Low	High	Low		
Op. Environment	Severe		Mild		Severe		Mild			
PM Task	CHS	CLS	CHM	CLM	MHS	MLS	MHM	MLM		
Condition Monitoring Task	Frequency								Reference	
Vibration Analysis	1M	1M	1M	1M	3M	3M	3M	3M	EPRI, Industry Template	
Lubricant Analysis	3M	1F	3M	1F	1F	1F	1F	AR	EPRI, Industry Template	
Performance Monitoring	6M	6M	6M	6M	6M	6M	1F	1F	EPRI, Industry Template	
IR(Infra-Red) Analysis	6M	6M	6M	6M	12M	12M	12M	12M	EPRI, OE	
Operator Shift Log	1S	1S	1S	1S	1D	1D	1D	1D	EPRI	
Time Directed Task	Frequency								Reference	
Coupling check	2F	3F	2F	3F	AR	AR	AR	AR	OE, Industry Template	
Nozzle NDI	6F	AR	6F	AR	6F	AR	6F	AR	OE, Industry Template	
Partial overhaul	AR	AR	AR	AR	AR	AR	AR	AR	EPRI, Industry Template	
Failure Finding Task	Frequency								Reference	
Functional Test	AR	AR	AR	AR	AR	AR	AR	AR	EPRI, Industry Template	

Recent Refurbishment of Facilities

- 2015: Installation of additional emergency diesel generator
- 2017: Replacement of HANARO control computer system
- 2018: Replacement of pool radiation monitoring system
- 2020: Replacement of electric power distribution system



Additional emergency diesel generator



HANARO control computer system



Pool Radiation Monitoring System



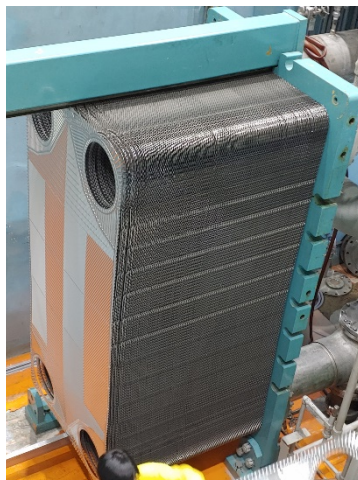
Electric Power Distribution System

Recent Refurbishment of Facilities(Cont'd)

- 2020: Replacement of seismic monitoring system
- 2022: Replacement of heat exchanger(2 sets)
- 2022: Replacement of cooling tower for CNS
- 2022: Replacement of CNS control computer system



Seismic Monitoring System



Heat Exchanger



Cooling tower for CNS



CNS control computer system

- Regulations for research reactors has been strengthened since July 2018
 - All unplanned shutdowns of research reactors should be reported and regulatory approval be obtained for restart.
(NSSC Notice 2018-3, “Regulations for Reporting and Disclosure of Incidents and Malfunctions at Nuclear Utilization Facilities”)
 - Only events caused by the reactor protection system used to be reported before the amendment.
 - Recently, it took several months to re-operate the reactor after unplanned shutdowns.

- Efforts to change the regulations for research reactors
 - KAERI is requesting the government for amending the Nuclear Safety Act in consideration of the characteristics of research reactors.
 - In user group, various efforts is being made to issue to related parties about the need of HANARO operation and amendment of regulations.

- Operation of HANARO has been dramatically reduced since the shutdown for seismic reinforcement of the reactor building and the amendment of nuclear safety act on research reactors in KOREA
- Corrective or preventive maintenance works are done depending on the result of surveillance or periodic inspections
- A systematic and comprehensive ageing management program is being developed replacing current ageing management matrix
- Preventive maintenance templates are being made to reduce unplanned shutdowns for reliability and availability
- Efforts are underway to change the regulations on research reactors.

