CURRENT STATUS OF HANARO OPERATION AND CHALLENGING ISSUES

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Jinwon Shin
HANARO Management Division

Korea Atomic Energy Research Institute

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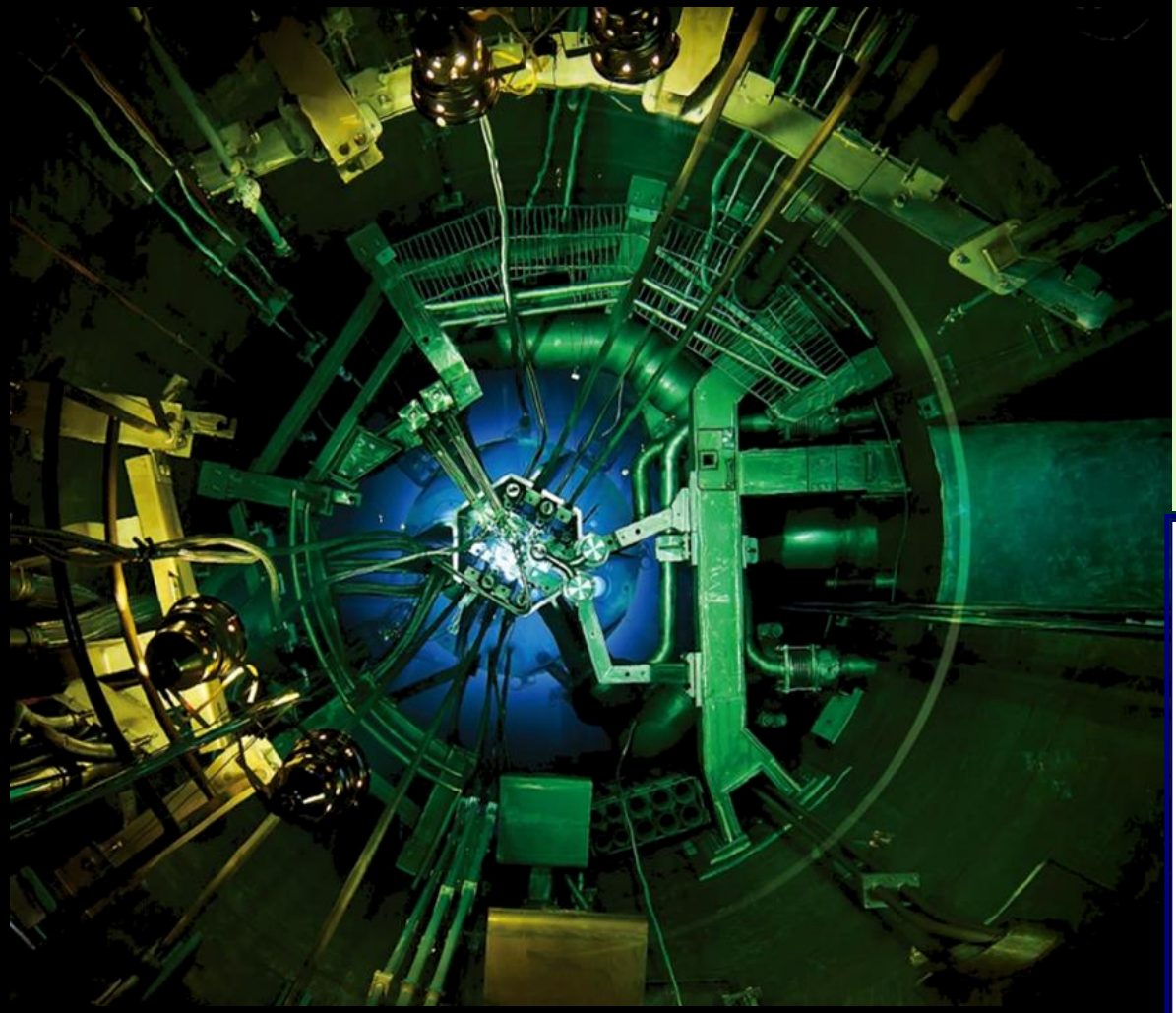
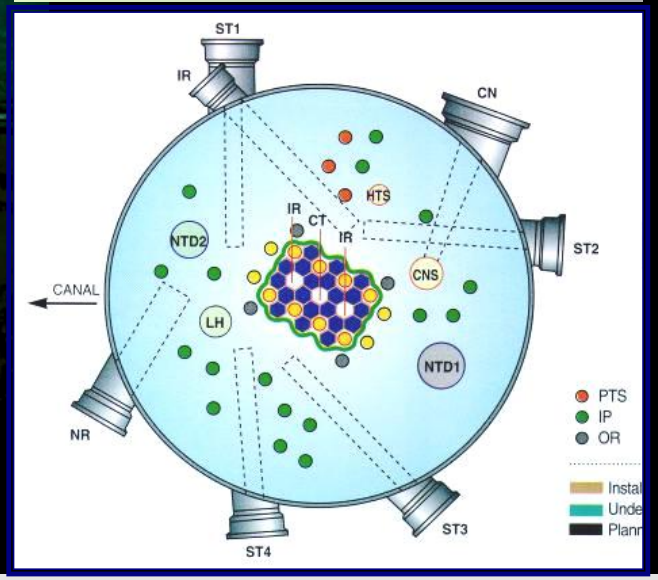
HANARO Overview



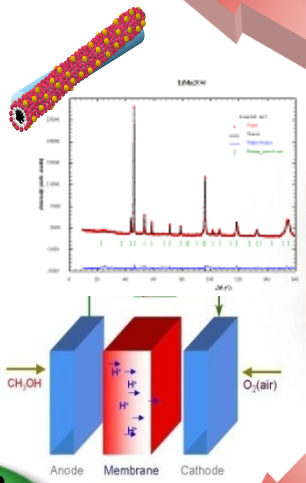
- *Type* — *Open-tank-in-pool*
- *Power* — *30 MW_{th}*
- *Coolant* — *Light Water*
- *Reflector* — *Heavy water*
- *Fuel Materials* — *U_3Si, 19.75%*
- *Absorber* — *Hafnium*
- *Reactor Building* — *Confinement*
- *Max Thermal Flux* — *$5x10^{14}$ n/cm^2s*
- *Typical flux at port nose* — *$2x10^{14}$ n/cm^2s*
- *7 horizontal ports & 36 vertical holes*
- *Vertical hole for cold neutron source*



HANARO Utilization

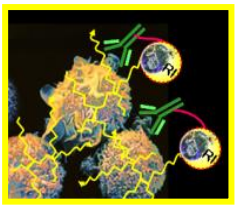
Neutron Beam Research

Nano structure
Li battery
Fuel cell
Hydrogen storage



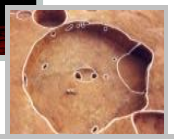
RI Production

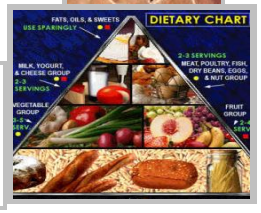
Cancer therapy
Target therapy
NDT
Hydrology



Neutron Activation Analysis

Environmental research
Soil analysis
Food analysis
Purity measure



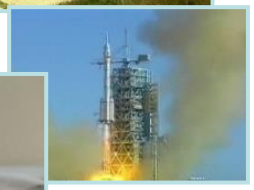


Semiconductor Production

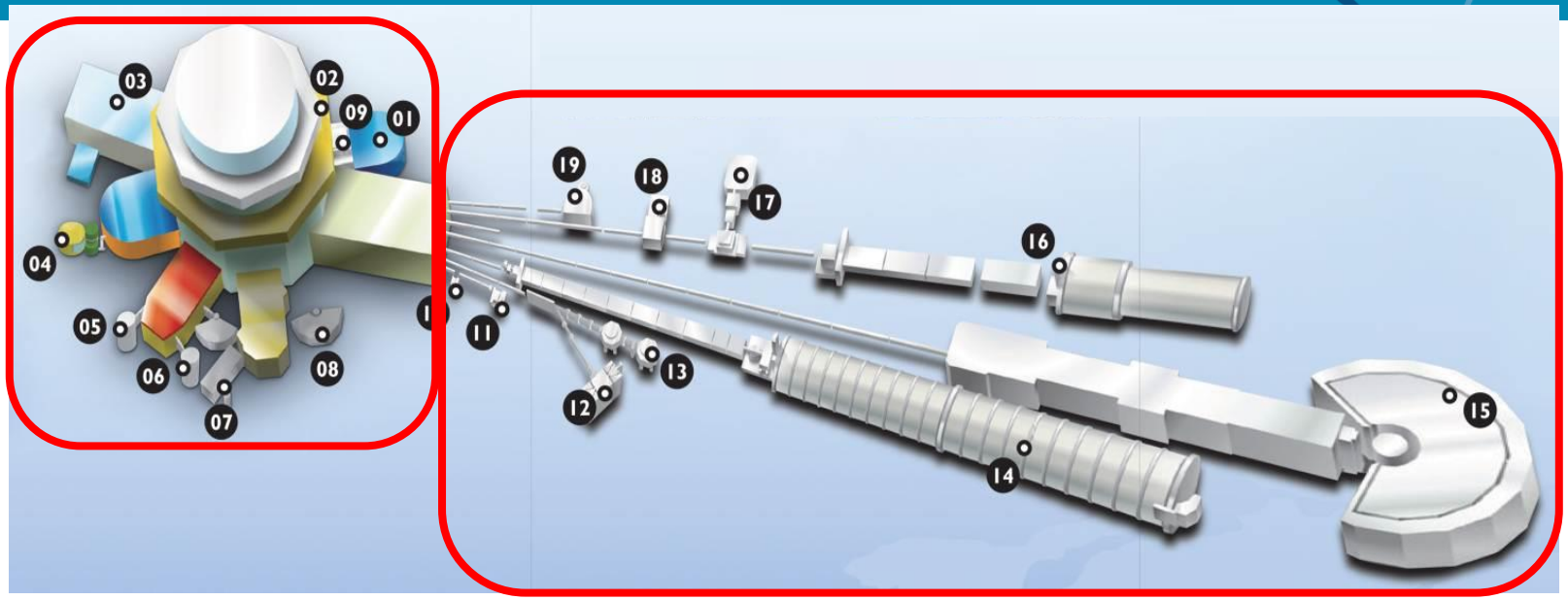
Hybrid car
Express train
Windmill
Solar system

Irradiation Effect Research

Power reactor
Cosmic radiation
Super conductor

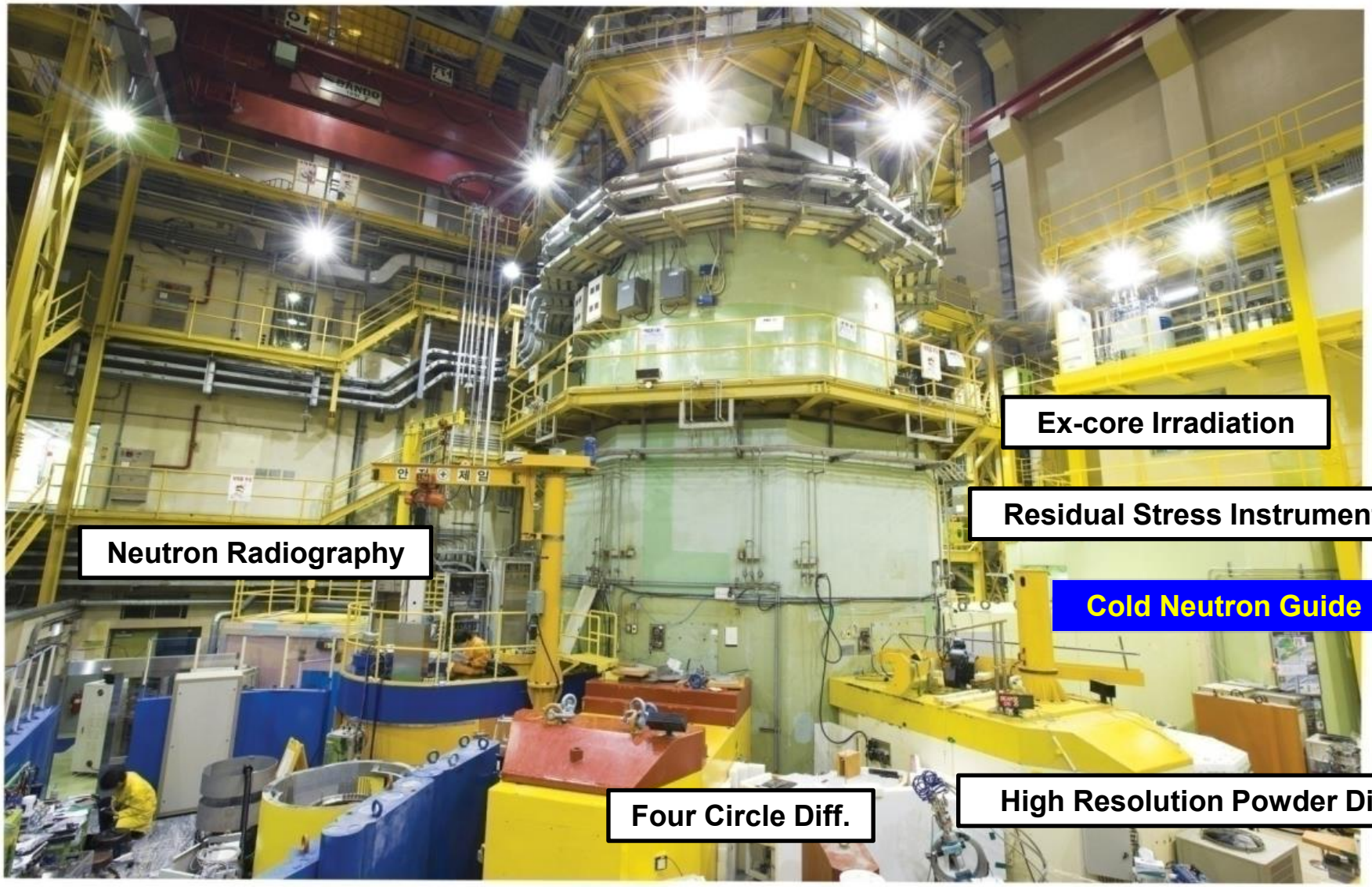


Neutron beam instruments layout

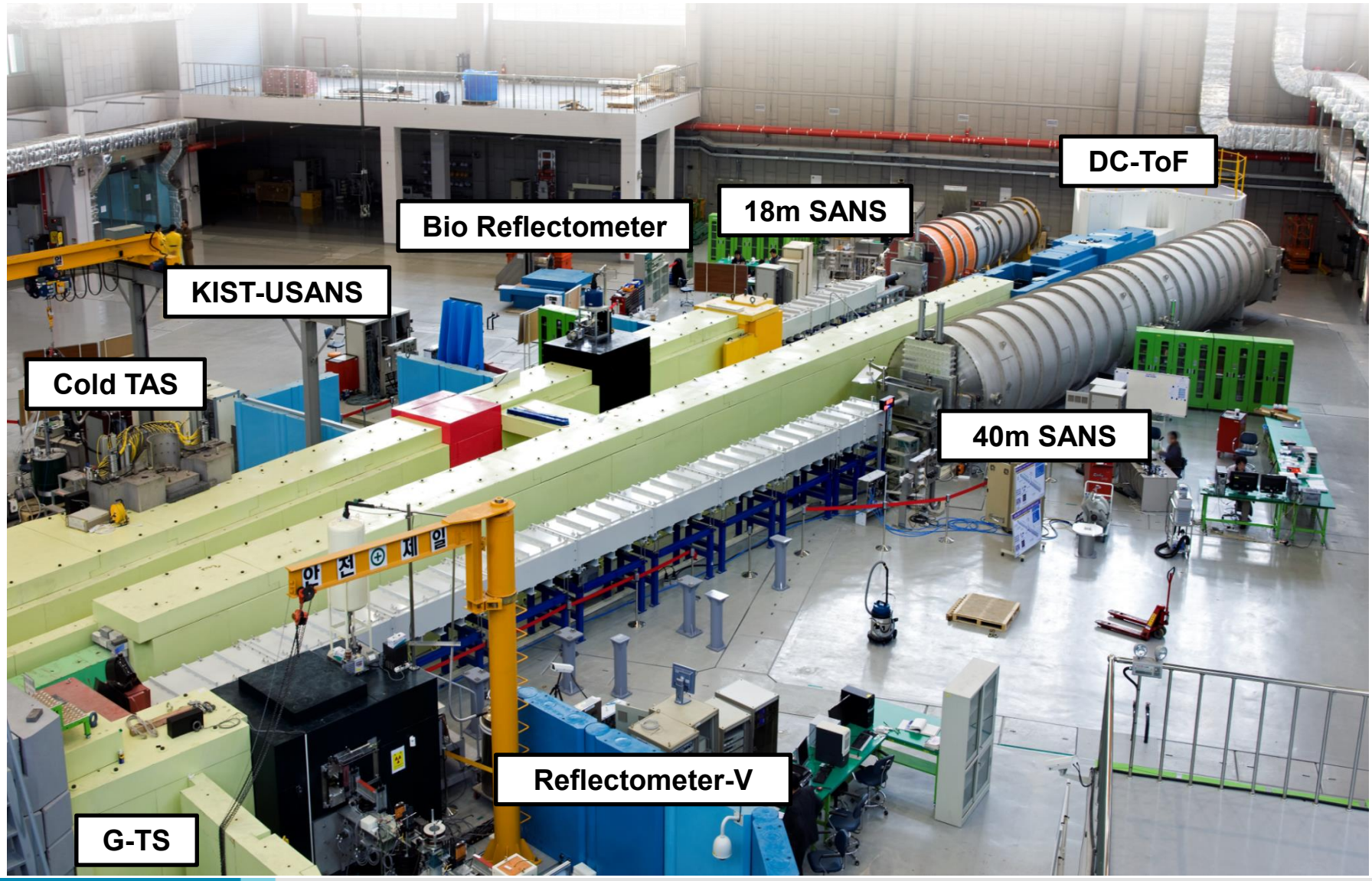


02 Ex-core Neutron irradiation Facility	10 Guide Test Station
09 Thermal Neutron Prompt Gamma Activation Analysis	11 Vertical type REFlectometer
01 Residual Stress Instrument	12-13 Cold Neutron Activation Station
08 High Resolution Powder Diffractometer	14 40m Small Angle Neutron Scattering instrument
07 Four Circle neutron Diffractometer	15 Disk-Chopper Time-of-Flight spectrometer
N/A High Intensity Powder Diffractometer	18 KIST Ultra-Small Angle Neutron Scattering instrument
06 Bio-Diffractometer	17 Bio-REFlectometer
05 Bio-diffractometer with neutron image plate Camera	16 18m Small Angle Neutron Scattering instrument
04 Thermal neutron Triple-Axis Spectrometer	19 Cold neutron Triple-Axis Spectrometer
03 Neutron Radiography Facility	

Instruments in the Reactor Hall



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.

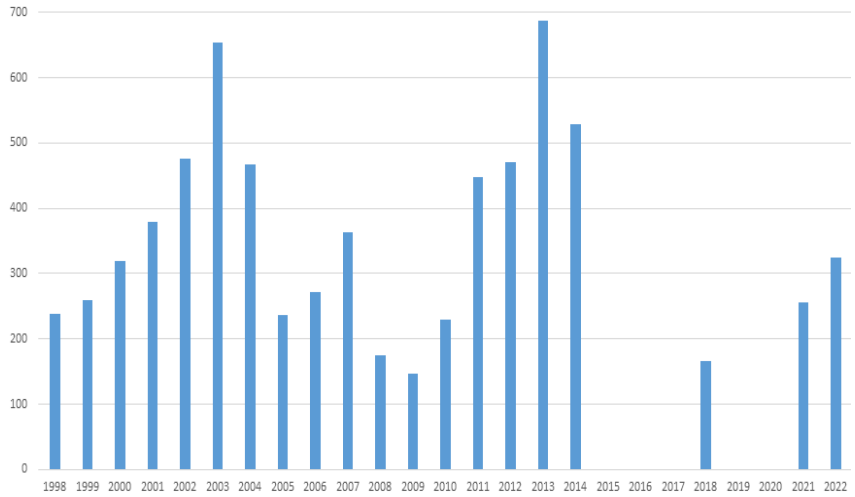
HANARO Operation(Cont'd)

- 2015.2 ~ 2017.12 Seismic reinforcement of reactor building

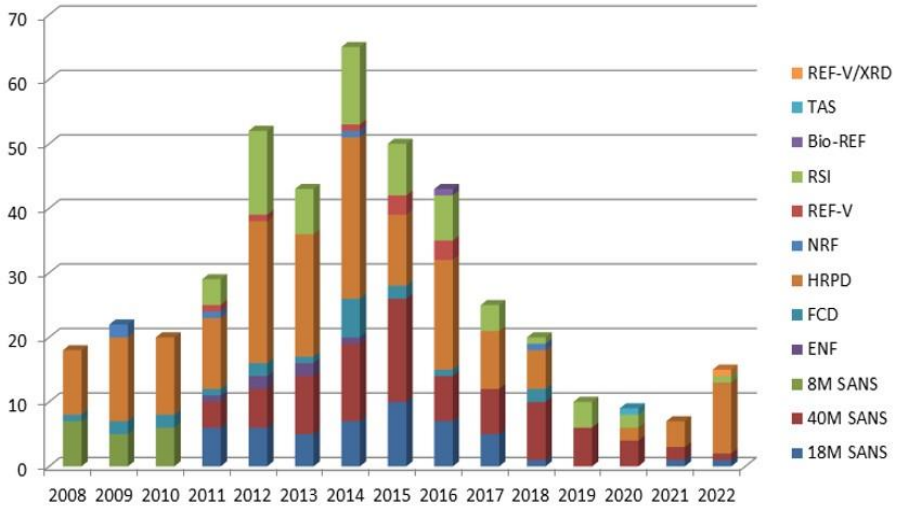
- 2018.7 Amendment of Nuclear Safety Act for research reactors in Korea
- 2018.12 ~ 2019.10 Special safety inspection for HANARO and utilization facilities by the government

HANARO Operation(Cont'd)

- 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

HANARO Inspection and Maintenance

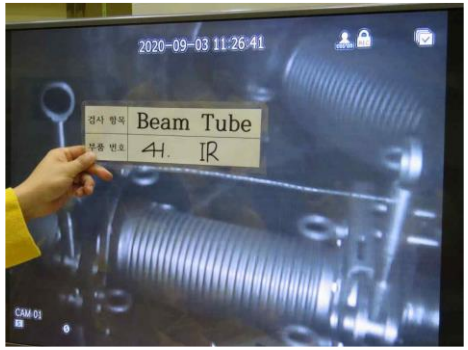
- Types of Inspection
  - Surveillance Inspection (SI)
    - Requirement of SAR and Tech. Spec.
  - Periodic Inspection (PI)
  - In-service Inspection (ISI)
    - Requirement of Nuclear Safety Act
- Inspection periods
  - Daily, weekly, monthly, quarterly, semi-yearly, yearly, and long-term period(18 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).

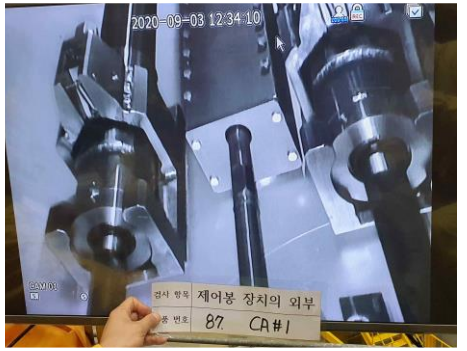
HANARO In-Service Inspection

Component	Inspection item	Method
Piping	- Primary Cooling System - Emergency Water Supply System	VT-1, VT-2, VT-3
Heat Exchanger	- Primary Cooling Heat Exchanger support	VT-3
Pump	- Primary Cooling Pump support - Primary Cooling Pump Flywheel	VT-3, UT
Reactor Structure Assembly	- Reactor structure, reactivity control unit and beam tubes	VT-3
	- Inner shell of reflector tank	Measurement (vertical straightness)
	- Flow tube - Shroud tube - Control absorber rod - Shut off rod	Measurement (diameter)

HANARO In-Service Inspection(Cont'd)

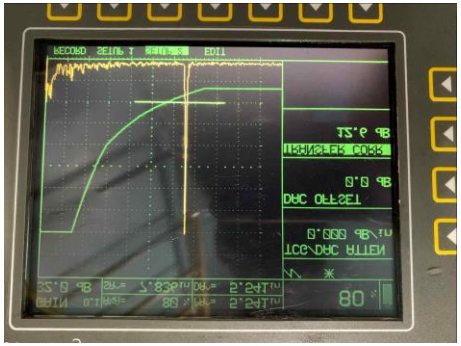
- **Reactor structure assembly and in-pool components**
  - Reactor structure, reactivity control unit and beam tubes(VT-3)

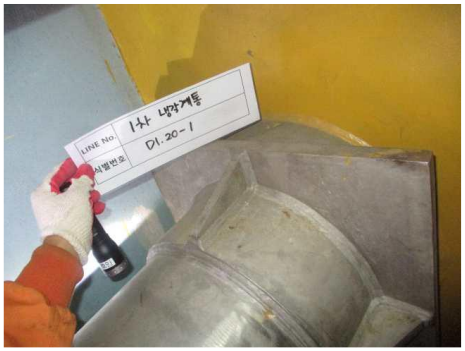




HANARO In-Service Inspection(Cont'd)

- **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)



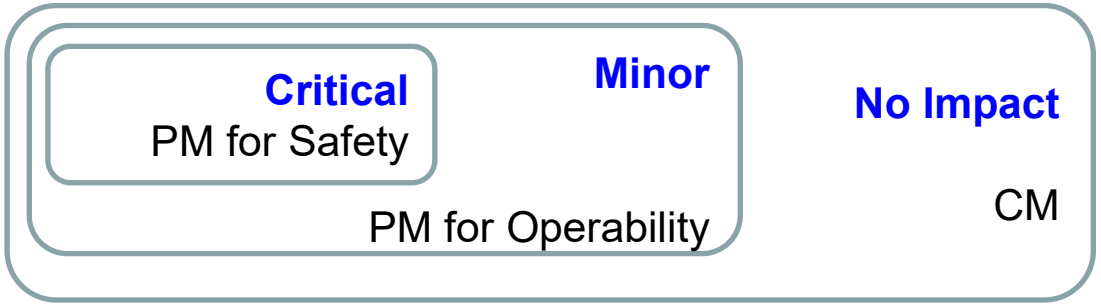
Ageing Management Program

- **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

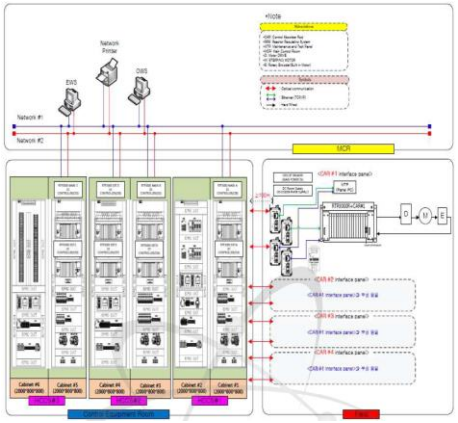
- Templates for PM according to functional importance, environmental conditions and duty cycles of components
- PM templates is being built with the standardization of the task list and resources for each type of component.

Rev	2	PM Template								Class1	Pump
Date	'10.11.05									Class2	PPHC
FID(Functional Importance)										Horizontal Pump	
Importance		Critical				Minor					
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 NDT		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											
Functional Test		AR	AR	AR	AR	AR	AR	AR	AR	EPRI, Industry Template	

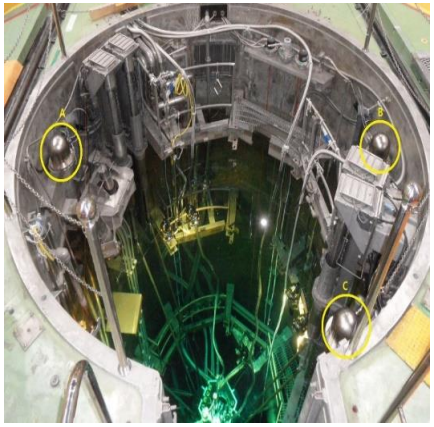
Recent Refurbishment of Facilities

- 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



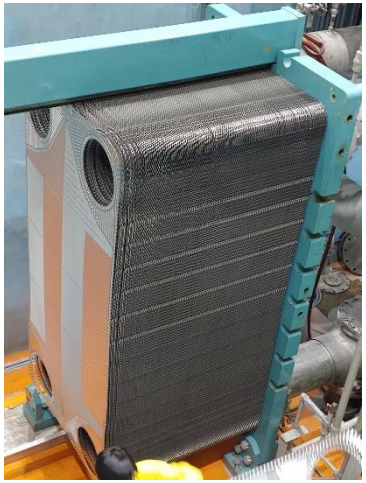
Pool Radiation Monitoring System

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

Regulatory Issues on RRs in Korea

- 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.

Summary

- 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.


Thank you