Measures to improve operational reliability of HANARO

Minsu Kim, Wonho In, Cheongwon Kim, Byunggun Park, Jinwon Shin, Myongseop Kim

HANARO Management Division, KAERI

Daedeok-daero 989beon-gil, 34057 – Korea

Introduction

• Repeated unplanned shutdowns at HANARO have raised public concern and caused inconvenience for users

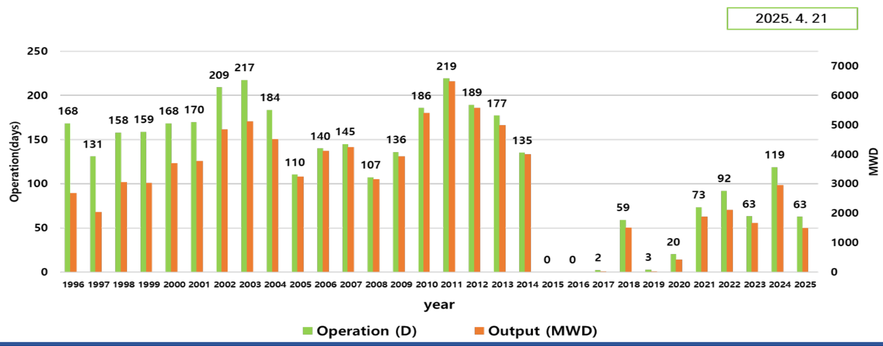
• Total of six unplanned shutdown occurred between 2021 and 2024.

• Unplanned shutdowns led to delays in medical radioisotope and power semiconductor production

→ Need for diagnosis of causes and implementation of fundamental corrective actions.

→ Comprehensive inspection of technical management, QA, organizational structure, budgeting, and safety culture is required.

• Goal: Ensure safe and reliable operation of HANARO through root cause analysis and long-term improvements.



Methods and Results

♦ Plan

• Form a Task Force Team (TFT) led by facility operation and safety management heads.

• Establish improvement measures and detailed implementation plans.

• Conduct regular monitoring to track progress and effectiveness.

♦ Unplanned Shutdowns and Response Status

• From the start of operation in 1996 to 2014, HANARO maintained stable operation. However, after a long-term shutdown due to seismic reinforcement of the reactor building from 2015 to 2017, the operation rate declined, and the frequency and duration of unplanned shutdowns have increased significantly since 2018.

[Table 1. Unplanned Shutdowns Since 2018]

No	Date	Reactor trip due to	Cause	RPS	RRS		Manual shutdown	
					HANARO	Experimental	HANARO	Experimental
1	'18.7.30	compressed air system	HANARO		■			
2	'18.12.10	rising hydrogen pressure of CNS	Experimental					■
3	'19.12.6	abnormal hydrogen pressure of CNS	Experimental (human error)			■		
4	'21.7.1	abnormal hydrogen pressure of CNS	Experimental			■		
5	'22.4.25	abnormal hydrogen pressure of CNS	Experimental			■		
6	'22.7.29	primary cooling pump stop	External power	■				
7	'22.11.15	rising CNS coolant temperature	Experimental					■
8	'23.2.1	control rod stepping motor	HANARO		■			
9	'23.5.14	helium compressor abnormal of CNS	Experimental			■		
Total		Scram	–	1	2	4	0	2
					6		2	

[Table 2. Measures to Prevent Unplanned Shutdowns Since 2018]

No	(Date)Title of incident	Cause (Classification)	Measure	Termination
1	('18.7.30) regulator of compressed air system	regulator fail (RRS)	regulator replacement	complete
			procedure for periodic leak testing and replacement of regulator	complete
2	('18.12.10) rising hydrogen pressure of CNS	CNS helium refrigerator automatic valve fail (manual stop)	disassembly and inspection of automatic valves related to helium refrigeration box	complete
			CNS helium refrigeration system inspection procedure revision	complete
			securing spare part	complete
			addition of alarm function related to hydrogen cooperation	complete
			conducting polymerization function test on all systems and experimental equipment prior to reactor cycle operation	complete
			introduction of automatic reactor shutdown function when hydrogen pressure persists	complete
			introduction of an aging management program	complete (2024)
3	('19.12.6) abnormal hydrogen pressure of CNS	CNS logic error (human error) (RRS)	complementing the software management process	complete
			applying software management processes to alert functions	complete
			conducting training to ensure software management operation quality	complete
			applying improved software management processes to CNS control computers	complete
4	('21.7.1) abnormal hydrogen pressure of CNS	CNS system fuse fail (RRS)	CNS control system fuses replacement	complete
			replacement of fuses related to measurement of RPS and RRS parameters	complete
			3year cycle of exchange of HANARO and CNS fuses	complete
5	('22.4.25) abnormal hydrogen pressure of CNS	CNS air supply solenoid valve fail (RRS)	CNS air supply equipment inspection and replacement	complete
			setting and reflecting in the procedure the calibration/replacement/maintenance cycle of moisture absorber, solenoid valves, and dew point meters	complete
			priority disassembly and maintenance of CNS and devices that can cause sudden shutdowns	complete
			establishing a preventive maintenance plan for each component in the entire system	complete (2024)
6	('22.7.29) primary cooling pump stop	primary cooling pump fail by external power (RPS)	replacement of all digital protection relays in the HANARO power system	complete
			procedure for performing fault current operation test after replacing digital protection relays	complete
7	('22.11.15) rising CNS coolant temperature	CNS cooling tower filter fail	CNS cooling tower filter specification change and replacement	complete
			strengthening the review of system impact when replacing equipment or devices that may cause a single stop	complete (2024)
8	('23.2.1) control rod stepping motor	stepping motor fail for control rod drive (RRS)	replacement, insulation/winding resistance measurement	complete
			control rod signal line integrity check(X-ray), control rod normal operation confirmation test	complete
			improved procedure for checking the integrity of power supply cables for new stepping motors	complete (2024)
			review of design improvement technology to improve the performance of the control rod drive device	ongoing
9	('23.5.14) helium compressor abnormal of CNS	helium compressor control system condenser failure(RRS)	helium compressor frequency converter cooling fan condenser replacement and inspection procedure revised(specifies periodic replacement)	complete
			helium compressor power condenser replacement	complete (2024)

♦ Cause Analysis

• Technical issues of the CNS facilities → Improvements are needed in CNS facilities and operation method. Etc.

• Inadequate preventive maintenance system → It is necessary to list the systems that cause stoppages and establish a robust preventive maintenance system.

• Management issues such as staffing and budgeting → Securing personnel and budget for safe operation and establishing a systematic technology management system are crucial management issues.

• Insufficient efforts in internal and external safety communication and promotion of safety culture → In order to create a safe operating environment, active communication efforts are needed not only within the organization but also with external related organizations and local residents.

♦ Key Measures and Implementation Plans

• Six key areas of improvement identified.

• Fourteen specific action items developed across these areas.

• Action items organized into six task groups and implemented via dedicated task cards.

• Measures address technical upgrades, maintenance protocols, staffing, budgeting, and safety communication.

Scope	Key Measures	Detailed Implementation Plans
Technical Management	1. Establish a preventive maintenance system and strengthen technical management	1. Improve CNS facilities 2. Promote aging management and preventive maintenance program
Quality Assurance	2. Strengthen configuration management for general-grade items that cause shutdowns	1. Completion of configuration data for general-grade items causing shutdowns 2. Establish procedures for system impact evaluation due to equipment replacement
Organization	3. Improve HANARO operational efficiency through reorganization	1. Establish a dedicated "HANARO Utilization Research Division" 2. Emphasize the importance and safe operation of HANARO in organizational management
Manpower	4. Renew workforce and enhance practical capabilities	1. Personnel reassignment and competency enhancement for detailed tasks 2. Strengthen qualification requirements and training for new test personnel 3. Improve technical support capabilities 4. Acquire advanced reactor operation technologies through active external communication
Budget	5. Secure a stable budget for facility operation and maintenance	1. Prioritize allocation of fixed costs for stable facility operation 2. Establish a roadmap for facility and equipment improvement
Safety Culture	6. Enhance safety culture and awareness	1. Declare executive commitment to safety-first management 2. Develop and implement communication enhancement programs

Completed case	Department head and researchers Group
3-1	3-2, 4-1, 5-1, 6-4
Maintenance Group(Procedure, ongoing)	Operating Group
1-2, 2-1, 2-2	4-2
Maintenance Group	Safety management Group and engineering technology support Group
1-1, 4-3, 5-2	4-4, 6-2

♦ Implementation Status

The implementation status of the 14 task cards is as follows:

1-1 Improvement of CNS facilities.

- A strategy for redundancy of CNS systems and selection criteria for major facilities were established.
- A new project initiated for facility improvement.
- Technical exchanges on CNS upgrade status with Australia's OPAL reactor have been conducted.

1.2 Promote aging management and preventive maintenance programs.

- Documentation for PMT (Preventive Maintenance Template) and AMP (Aging Management Program) has been completed.

2-1 Completion of configuration data for general-grade items causing shutdowns.

- Registration of configuration management data for general-grade and quality class S equipment with shutdown potential.

2-2 Establishment of system impact evaluation procedures for equipment replacement.

- Completion of procedure for evaluating system impact when replacing quality S-class equipment in HANARO and related facilities (includes material/specification verification, technical impact assessment, inspection/test acceptance criteria, and O&M review).

3-1 Creation of a centralized HANARO Utilization Research Division.

- Integration of previously separated operations and utilization departments into the "HANARO Utilization Research Division" (includes securing safety through engineering support and nuclear fuel supply, and establishing clear authority/responsibility for reactor operation and utilization).

3-2 Emphasis on the importance and safe operation of HANARO in KAERI's policy.

- Inclusion of HANARO safety operation policy in KAERI's institutional operation plan and safety management responsibility report.

4-1 Personnel reassignment and competency enhancement for detailed tasks.

- Change of task leaders and establishment/implementation of leadership training programs.

4-2 Strengthening qualification requirements and training programs for new test staff.

- Enhanced qualification standards in the HANARO test personnel procedure.
- Development and implementation of external training programs.
- Seminars with original HANARO designers and retired experts conducted.

4-3 Improve technical support capabilities.

- Development and operation of HANARO technical advisory guidelines.
- Formation of emergency response technical support team.
- Preparation and publication of reactor operation and safety review reports.

4-4 Acquisition of advanced reactor operation technology through external collaboration.

- Participation in academic and technical nuclear forums.
- Workshops and conferences conducted via knowledge-sharing programs.
- Exchange with domestic power plant technology groups (e.g., KHNP).

5-1 Priority allocation of fixed costs to ensure stable facility operation.

- Strategy established to minimize utility cost volatility (electricity, gas).
- Annual fixed cost roadmap prepared (for minor maintenance, consumables, facility/equipment upgrades).
- Additional budget secured based on roadmap.

5-2 Development of a roadmap for facility and equipment upgrades.

- Assessment of facility status and maintenance history completed.
- Roadmap prepared to secure additional government funding through increased utilization.

6-1 Declaration of senior management's commitment to safety-first management.

- Strengthened safety education and seminars.
- Promotion of safety excellence awards.
- Introduction of "devil's advocate" system for safety issue raising.

6-2 Development and execution of a communication enhancement program.

- Development of communication enhancement program through improvement of ANSIM system.

Conclusions

❖ Conclusions

• Fourteen task cards were developed to address root causes of unplanned shutdowns.

• By the end of 2024, 8 tasks were completed, and the remaining are scheduled through 2025.

• Most tasks will be finalized by the end of 2025, excluding long-term facility upgrades.

• All measures have been submitted to and reviewed by the regulatory authority.

• As of 2025, HANARO has achieved its longest uninterrupted run since initial operation.

• Excluding a 4-month reactor building repair, 110 out of 174 planned operation days have already been completed in 2025.

• These achievements demonstrate measurable improvements in reliability, safety culture, and institutional support.

❖ References

[1] Joo, H. K. "Fundamental Measures for Improving HANARO Operational Reliability", Report to the Nuclear Safety and Security Commission. (2023)

[2] HANARO Management Division. "Task Cards for measures to improve operational reliability of HANARO", Internal document