CURRENT STATUS OF HANARO OPERATION AND CHALLENGING ISSUES

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The HANARO has been endeavoring to become a world-class research reactor and utilization facility operator since its first criticality in 1995. Through the safe and efficient operation of HANARO and its utilization facilities, it provides a platform for neutron utilization and contributes to the creation of outcomes through support for neutron users. After the Fukushima accident in 2011, we actively responded to the safety controversy of domestic nuclear facilities and established a long-term strategic plan to improve the performance of the facility and establish a sustainable operating system. As part of measures to protect control room operators, the seismic design and improvement of the control room was completed in 2013, and the seismic reinforcement of the reactor building was completed in 2017. The first Periodic Safety Review (PSR) project for HANARO commenced in 2015 after operating for 20 years. The PSR report of HANARO was submitted to the Nuclear Safety and Security Commission (NSSC) of the Korean government by the end of 2018. Despite a series of efforts, HANARO has not been able to recover its operating rate before the seismic retrofitting work. Due to the strengthening of regulation on research reactors started from 2018, all unplanned shutdowns of HANARO were required to be reported to the NSSC and approved for restart. It operated only 92 days with three unplanned shutdowns in 2022. In this paper, the status of operation and challenging issues for HANARO will be described.

1. Introduction

The HANARO (High-flux Advanced Neutron Application Reactor) is a 30 MW multi-purpose research reactor that produces a high neutron flux for scientific and technological purposes. Since its first criticality in 1995, HANARO has played an important role as a national facility in the area of neutron science, production of radioisotopes, material testing for power reactor application, neutron transmutation doping, neutron activation analyses, and neutron radiography. It has also served as a regional facility for neutron science since the installation of a CNS (Cold Neutron Source) in 2010.

The operation and utilization of HANARO had been steadily increasing until safety enhancement measures were implemented after the Fukushima Daiichi nuclear accident. As a result of the seismic margin assessment for the reactor building, it was found that some of the outer walls of the reactor building did not meet the seismic design criteria [1]. Seismic reinforcement of the reactor building was carried out from 2015 to 2017 under the order of the Korean government's Nuclear Safety and Security Commission (NSSC). In addition, the first Periodic Safety Review (PSR) of HANARO was started in 2015 and the report was submitted to the regulatory body in Dec. 2018 [2].

Since then, stable operation has been challenging due to the strengthening of regulations on research reactors for unplanned shutdowns caused by failure of non-safety system components. In order to improve reliability and availability of HANARO, a task force team was formed to examine the organization, manpower, assets, operating system, maintenance method, and aging management program. Based on the TFT's recommendations, we developed comprehensive measures and action plans to optimize the operating system and promote utilization. In 2020, test operations focused on stabilizing CNS system were

conducted, and normal operations resumed in 2021. Through various efforts to overcome the difficult situation, it was able to operate for 92 days in 2022, but it is still less than 50% of the previous annual operating days. This paper covers HANARO operation, maintenance, ageing management, refurbishment, and regulatory issues on research reactors in Korea.

2. HANARO Operation

HANARO's operating cycle is four weeks of operation followed by two weeks of maintenance. It typically operates six to seven cycles per year, with about 1.5 months of shutdown in summer during which various inspections, maintenances, and facility improvement works are carried out. The annual operation record (Figure 1) shows more than 200 days of operation in 2011, followed by a declining trend, and no operation from 2015 to 2017 during the shutdown period for seismic reinforcement of the reactor building. Since then, the normal operation of HANARO has been interrupted or delayed several times for various reasons, including investigation into the cause of unexpected shutdowns, the need to take measures to prevent recurrence of the shutdown, and complicated steps to be taken to obtain approval for re-operation from the regulatory body. After finishing improvement of outdated or obsolete equipments, including the replacement of the electric power distribution system in August 2020, and completing the test operation focused on CNS system in October, HANARO returned to normal operation with 73 and 92 operating days in 2021 and 2022, respectively [3].

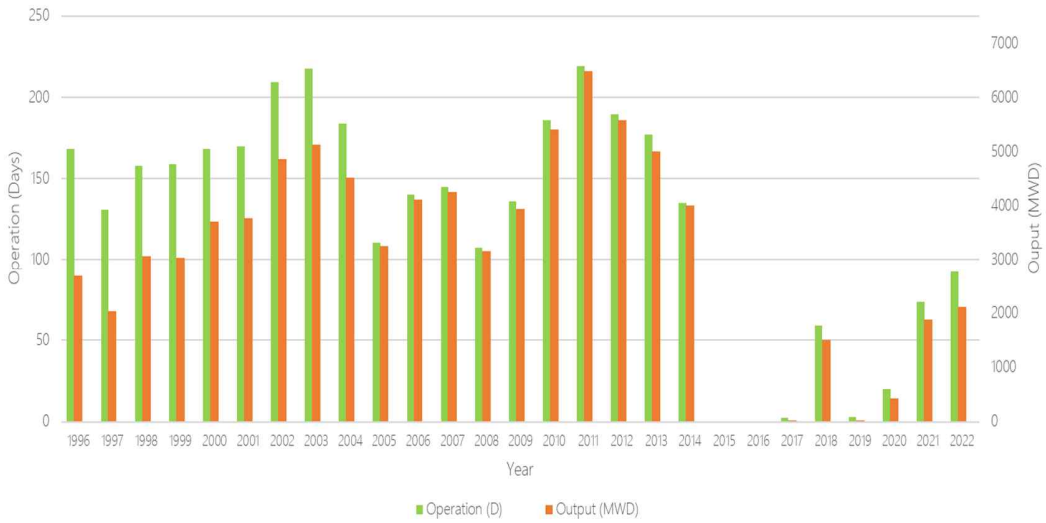

Figure 1: Annual operation records of HANARO

Figure 2 shows how many users have worked with the neutron scattering and imaging instruments since 1998 [4]. The number peaked in 2013 to 682 users (HANARO was operated on 177 days in that year) and recorded 324 in 2022 (HANARO was operated on 92 days). The number of publications (SCI, SCIE) by year are summarized in Figure 3 [4]. The number peaked to 62 in 2014, continued to decrease as a result of long shutdowns for reinforcement of the reactor building and several trips of HANARO (from 2014 to 2020), and rebounded to 15 in 2022.

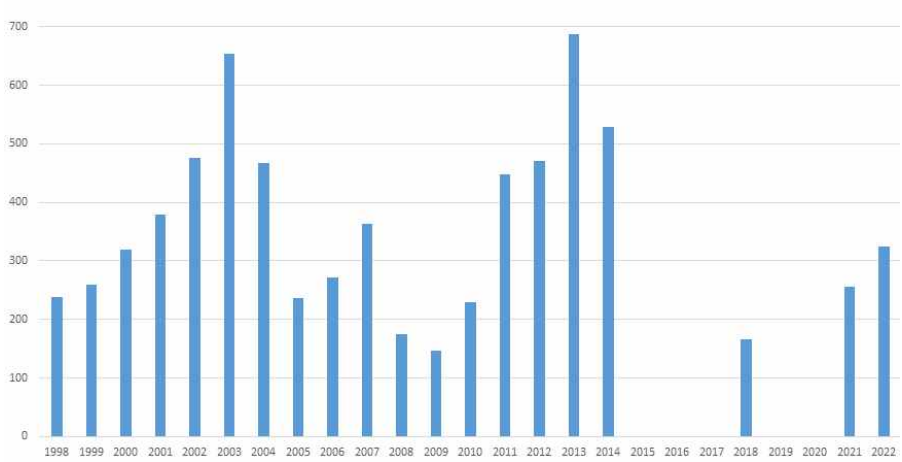

Figure 2: Number of neutron beam users by year

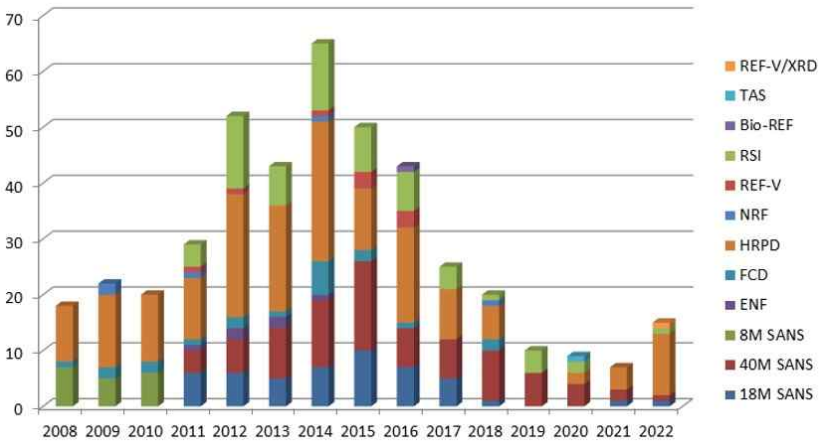

Figure 3: Number of SCI publication by year

3. Maintenance, Inspection, and Aging Management

As key activities of maintenance, three kinds of system inspection, which consist of Surveillance Inspection (SI), Periodic Inspection (PI) and In-Service Inspection (ISI) are performed to maintain the system, structures and components (SSCs) of the reactor in a safe condition. The SI is for the safety grade components and should be accompanied by a quality assurance procedure, while the PI is for non-safety grade and not necessarily mandatory. The ISI is carried out for the ASME Sec. III components such as reactor structures, reactivity control units, and safety related piping systems. According to the results of inspections, corrective and preventive maintenances have been fulfilled in appropriate ways.

For the ageing management, HANARO is using a so-called Ageing Matrix, which includes categorization of SSCs, ageing information, and prioritization in consideration of safety, operability, life expectancy, and performance. A systematic and comprehensive ageing management program including performance and lifetime management is being built to continue reliable operation under the strengthened regulations, and is expected to be

completed in 2023. The principle of development for HANARO ageing management program is that maintaining the SSCs with no reduction in performance or safety margins, preventing failures of critical SSCs, and understanding ageing mechanisms.

4. Refurbishment of SSCs

Upgrade or refurbishment of the instrumentation, control and monitoring systems have been carried out to overcome obsolescence problem for long-term sustainable operation with assured availability and reliability. Recently, several major systems for the reactor control and monitoring have been refurbished according to HANARO ageing management planning Figure 4). These included:

- HANARO Control Computer System (2015)
- Pool Radiation Monitoring System (2018)
- Seismic Monitoring System (2020)
- Electric Power Distribution System (2020)
- CNS Control Computer System (2022)

(a) HANARO control computer (b) Pool Radiation Monitoring System (c) Electric Power Distribution System (d) CNS control computer system

Figure 4: Refurbishment of I&C and monitoring systems

There have also been cases of replacing systems that could have disrupted reactor operations due to aging. Heat exchangers between primary and secondary coolant was leaking due to aging of gaskets. So the entire plates with gaskets of heat exchangers were replaced with new ones in 2022 (Figure 5). The cooling fan equipment used for CNS's helium compressor and refrigerator was aging and cooling efficiency was reduced, which could cause it overloaded during hot and humid summer. Therefore, it was replaced with a new product with improved cooling performance in 2022 (Figure 5).

(a) HANARO Heat Exchanger (b) CNS Cooling Fan

Figure 5: Refurbishment of Heat Exchangers and Cooling Fan Equipment

5. Regulatory Issues

According to the NSSC Notice 2018-3, "*Regulations for Reporting and Disclosure of Incidents and Malfunctions at Nuclear Utilization Facilities*", which was revised in 2018, all unplanned shutdowns of research reactors in Korea must be reported to the NSSC and approved for restart, a process that took several months from reporting to approval. Between December 2017 and December 2022, there were eight unplanned reactor trips, including five automatic and three manual shutdowns. In 2022, with a target of 170 days of operation, only 92 days were operational, three unplanned shutdowns were issued, and the average time to restart was 78 days.

Unplanned reactor shutdowns in HANARO have occurred every year since 1995, when the facility first started operation, but most of them were automatic trips by the reactor regulation system (RRS) unrelated to reactor safety, and manual shutdowns were performed by operators when necessary to change the experimental plan or for pre-emptive safety measures. Prior to the amendment to the Notice, except for shutdowns caused by the reactor protection system (RPS), the HANARO reactor manager was able to restart the reactor after identifying the cause of shutdowns and taking appropriate measures. It is worth noting that in most research reactors of other countries, the facility director or administrator may authorize restarting the reactor if the cause of the unplanned shutdowns was identified and corrected, except for the violation of reactor safety limits or limiting conditions of operation (LCO).

For the smooth operation of HANARO and its utilization facilities, it is necessary to ease the regulatory procedures for reporting shutdown cases and approval for re-operation considering the characteristics of research reactors, which are subject to the same regulations as nuclear power plants. Recently, HANARO management division in KAERI have prepared a proposal to exclude reactor shutdowns caused by reactor regulation systems that do not affect reactor safety from reporting and approval, which has been submitted to the NSSC and is under review.

6. Conclusions

Since the Fukushima Daiichi Accident, various safety enhancement measures and strengthened regulations on national nuclear facilities have caused significant disruptions to the operation of HANARO. Regulations have changed to require that even research reactors report unplanned shutdowns in any case and get approval for re-operation from the government. In response, various measures have been developed and implemented to

minimize unplanned shutdowns by refurbishing systems, components and structures. These efforts have resulted in a recent increase in operation and utilization rates, but they have not yet recovered to their previous levels. We have requested regulatory changes for research reactors, which are currently under review by the regulatory body. Once regulations are in place that take into account their own characteristics of research reactors, we expect that HANARO will be able to operate as smoothly as before.

References

[1] J.W. Shin and et al., “Safety Reassessments and Actions Taken in HANARO since Fukushima Daiichi Accident”, IGORR 2017, Sydney, Australia, 3-7 Dec. 2017.

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[3] Annual Report of HANARO & Utilization Facility Management, KAERI, 2022.

[4] Update on the Utilization of HANARO Neutron Scattering and Imaging Instruments in 2022, KAERI.