Performance and Aging Management Program of HANARO

Youngsan Choi, Sangjun Park, Jiye Jeong, Seunggyu Doo, Minwoo Lee, Minsu Kim*

HANARO Management Division, Korea Atomic Energy Research Institute
898-111 Daeduk-Daero., Yuseong-Gu, Daejeon
**Corresponding author:yschoe@kaeri.re.kr*

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1. Introduction

Unlike nuclear power plants (NPPs), regulations governing the lifetime management and extension of research reactors (RRs) remain ambiguous. In the United States, the U.S. Nuclear Regulatory Commission (USNRC) provides guidelines for operating permits and periodic license renewals for RRs. In contrast, some other countries, including France, the Netherlands, and Japan, apply NPP regulations to RRs.

In Korea, the necessity of conducting periodic safety reviews (PSRs) for RRs has been recognized. Consequently, a PSR for HANARO was first submitted in 2018 and must be renewed every 10 years, in accordance with domestic NPP regulations. In response, a comprehensive and systematic aging management system has been developed in 2024, incorporating a Preventive Maintenance Template (PMT) and an Aging Management Program (AMP) to enhance the reliability and safety of the Systems, Structures, and Components (SSCs) of HANARO.

2. Development of PMT and AMP

2.1 Maintenance Program of HANARO

The HANARO maintenance program consists of both corrective and preventive maintenance for critical components such as motors, pumps, and valves. Currently, preventive maintenance is primarily based on time-based procedures, including Periodic Inspection (PI), Surveillance Inspection (SI), and In-Service Inspection (ISI). However, essential activities such as condition-based maintenance, fault detection testing, and in-service testing have not been sufficiently implemented. Additionally, there is no established system for monitoring and managing the degradation of SSCs throughout HANARO's operational lifetime.

As HANARO ages, the likelihood of SSC failures and resulting operational restrictions increases. To mitigate these risks, a more structured and systematic management system is required to ensure the continued stability and safety of HANARO. To enhance the effectiveness of preventive maintenance, the adoption of the Preventive Maintenance Template (PMT), currently utilized in Korean NPPs, has been decided. In addition, an Aging Management Program (AMP) will be implemented in compliance with the Korean Nuclear Safety Act for PSR requirements.

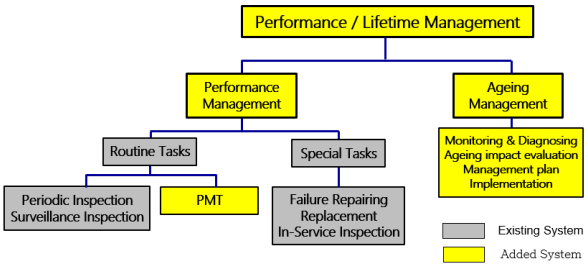

Fig. 1. Management program of HANARO

2.2 PMT Development

The Preventive Maintenance Template (PMT) was developed by the Electric Power Research Institute (EPRI) to provide standardized guidance for plant engineering and maintenance personnel, improving the efficiency of existing preventive maintenance programs [1]. In Korea, PMT is widely applied in NPPs as a structured maintenance framework. It defines preventive maintenance tasks and their frequency for various components based on operational conditions, thereby enhancing component reliability at an individual level.

The PMT for HANARO was developed with reference to EPRI's Preventive Maintenance Basis Database (PMBD) and the preventive maintenance template utilized by Korea Hydro & Nuclear Power (KHNP).

2.2.1 Classification of SSCs and FID

Approximately 2,000 SSCs in HANARO's maintenance system were categorized into 80 functional groups, including 33 related to machinery/processes, 16 to electrical systems, and 31 to instrumentation/control (I&C). A Functional Importance Determination (FID) was conducted to assess preventive maintenance significance, classifying SSCs into Critical, Minor, or No-Impact categories concerning reactor safety. Additionally, SSCs were further grouped into High or Low categories based on operational frequency and environmental conditions (e.g., temperature, pressure, radiation). The process followed the EPRI PMDB and Korean NPP maintenance guidelines.

2.2.2 PMT

Fig-2 presents a sample PMT for a plate-type heat exchanger, summarizing the following components:
- Name and Classification Code of a SSCs
- Types of maintenance tasks and their cycles:
  - •Condition monitoring task
  - •Time directed task
  - •Failure finding task
- Additional notes (e.g., "Run-to-failure" for items categorized under the 'No-Impact' group)

Typically, preventive maintenance is not required for SSCs with no significant impact on reactor safety, but all SSCs in HANARO are included in the PMT for consistency.

개정 번호	0	예방정비기준 (PM Template)								대분류				Heat Exchanger
개정 일자										설비유형				HEPT
기능적중요도결정(FID)														
중요도		Critical				Minor				RTF				판형 열교환기 Plate Type
운전빈도		High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	
운전환경		Severe		Mild		Severe		Mild		Severe		Mild		
예방정비 직무		CHS	CLS	CHM	CLM	MHS	MLS	MHM	MLM	RHS	RLS	RHM	RLM	직무 및 주기 선정기준
상태감시 직무(Condition Monitoring Task)														
성능감시		3M		3M									AR	해외정보, 정비경험
현장점검		1M		1M									AR	Note 2, 3, 해외정보
비파괴검사		AR		AR									AR	정비경험
주기정비 직무(Time Directed Task)														
청소 및 교체		2/20Y		2/20Y									AR	Note 6, 7, 해외정보
NR : Not Required, AR : As Required, Y : Year, M : Month, D : Day, R : Random, W : Wearout, UW : Unconditional Wearout														
비 고 : 1. Run To Failure (RTF) 부품은 고장발견 시 제품을 수리할 수 있음 2. 하나로 운영 기술지침서 3. 하나로 SAR 17장														

Fig. 2. A sample of PMT

Subsequently, the PMT provide guidelines for actual preventive maintenance as follows :
- Identification of performance degradation mechanisms and their causes
- Detection and mitigation tasks with assigned time intervals
- Additional considerations for preventive maintenance measures

2.3 AMP Development

The AMP aims to understand the behavior and impact of aging mechanisms on SSCs, detect and assess aging effects, and establish preventive and corrective measures to mitigate potential risks. The AMP facilitates informed decision-making for the safe and sustainable operation of the reactor. As part of the Periodic Safety Review (PSR), establishing an AMP for SSCs that are critical to reactor safety is a legal requirement.

2.3.1 Selecting of SSCs to apply AMP

The Nuclear Safety and Security Commission's (NSSC) notifications specify the SSCs for which an AMP must be established. These include 39 items for Pressurized Water Reactors (PWRs) and 38 items for Heavy Water Reactors (HWRs). The same regulations applied to NPPs are also extended to RRs.
Based on these regulatory categories, an evaluation process referencing the IAEA Safety Guide SSG-10 was conducted to identify the applicable SSCs for HANARO. As a result, a total of 17 items were designated as AMP targets.

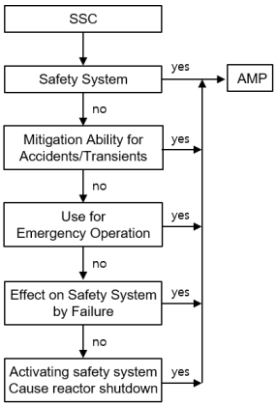

Fig. 3 Procedure for slecting SSCs to apply AMP

- ISI of safety-grade system
- ISI of safety-grade support
- One-time inspection
- Reflector tank monitoring
- Water chemistry
- Structure in the reactor pool
- Lifting equipment
- Fuel oil chemistry
- Leakage test of reactor building
- Structures
- Nuclear grade paining
- Fire protection equipment
- Fire water system
- Electric cable and non-metallic Connections (Non-EQ)
- Metallic connection of Instrument circuit cable (Non-EQ)
- Metallic connection of
- Electric cable (Non-EQ)
- Heavy water management

Fig. 4. AMP targets

2.3.2 Developing AMP

Each AMP was developed based on international standards, including the IAEA Safety Guide SSG-10, NUREG-1800, and NUREG-1801. These documents provide critical guidelines for aging management, covering key aspects such as monitoring and inspection parameters, degradation trend analysis, acceptance criteria, corrective actions, verification processes, and operational experiences. Practical aging management tasks should be conducted following the relevant operational procedures to ensure long-term reactor integrity.

3. Conclusions

This study presents the development of a comprehensive performance and lifetime management program for HANARO. The PMT standardizes and optimizes maintenance tasks by systematically analyzing failure modes and aging mechanisms of SSCs. Its implementation ensures that maintenance procedures are executed efficiently, minimizing unexpected failures and enhancing overall reactor stability. By establishing a structured framework, the PMT contributes to extending the service life of critical components while improving operational efficiency.
The AMP plays a crucial role in preserving the structural and functional integrity of SSCs by proactively identifying and mitigating aging-related degradation. Through systematic monitoring and corrective measures, it supports the sustainable operation of HANARO and helps prevent potential failures that could compromise reactor safety. Regular assessments and iterative improvements will ensure the program remains effective in addressing emerging risks and regulatory requirements.

By integrating these two management programs, HANARO can achieve a higher level of reliability and safety. The combination of preventive maintenance and aging management strategies ensures continuous operational excellence while aligning with international best practices. This approach will contribute to the long-term sustainability and stability of HANARO, reinforcing its role as a reliable research reactor.

REFERENCES

[1] "Nuclear Maintenance Applications Center: Preventive Maintenance Program Guideline", Technical Report, 2011, EPR