IMPLEMENTATION OF IN-SERVICE INSPECTION PROGRAM FOR HANARO

J.S. WU, Y.C. PARK , Y.G. CHO and B.J. JUN

Reactor System Management Department
HANARO Center, Korea Atomic Energy Research Institute
P.O.Box 105, Yusong Taejon, KOREA

1. Introduction

HANARO, a 30 MW multi-purpose research reactor in Korea has been successfully in operation for 6 years since its initial criticality in February 1995. It is mainly used for the research areas including nuclear fuel and material irradiation tests, radioisotope production, neutron beam application, neutron activation analysis and neutron transmutation doping. HANARO was designed to perform for at least 20 years under full power operating condition. It is expected that the actual reactor lifetime will be much more than the design lifetime, due to a safety reassessment based on realistic data, preventive maintenance and appropriate in-service inspections (ISI).
Since ageing may affect the overall safety of the reactor facility, it is needed to detect and evaluate the effects on aged components and systems related to safety. During the lifetime of the reactor, structures, systems and components are subjected to environmental conditions of stress, temperature and irradiation that may lead to changes in the material properties and could result in unexpected failures. Evidence of ageing problems appears progressively. A rigorous inspection and visual examination based on a periodic ISI program should be established. It is desirable that the ageing surveillance activities is scheduled as early as possible and continued throughout the operating life of the reactor. An inspection plan for safety related structures, systems and components subjected to the ageing conditions is requested by the regulatory body to assess the safety status of reactor facility. A long-term ISI program for HANARO has been established for safety-related systems and components in the context of the overall reactor ageing management. The objective of this paper is to describe the ISI program and the result of the visual inspection as the first ISI.

2. Description of Safety Related Systems and Components

The major target of the ISI program is the reactor structure assembly and safety related piping. The reactor structure of HANARO is composed of a stainless steel plenum and grid plate, a zircaloy reflector vessel, an aluminum chimney, and the zircaloy flow tubes. The reflector vessel is a toroidal tank whose central channel encloses the array of flow tubes. It is also penetrated vertically by many irradiation and experimental sites and horizontally by 7 beam tubes. The chimney is a hexagonal duct extending above the core with two large inclined pipes for primary cooling system (PCS) outlets on its sides. There are 23 hexagonal and 8 cylindrical flow tubes, which are secured to the grid plate. The beam tubes are connected between the reflector vessel and pool liner by expansion joints. Three neutron detector housings are located at side of reflector vessel. On each cylindrical flow tube, a tubular hafnium neutron-absorber rod slides up and down. There are four shutoff rods (SOR) and four control absorber rods (CAR) identical to each other and located at 8 cylindrical flow tubes. A shroud tube extends above the cylindrical flow tube to guide the absorber rod. It also shields the absorber rod from the PCS flow exiting the core through the outlet nozzles. Each absorber is suspended from an offset, track guided carriage via a perforated support tube, which has a hollow swivel joint at each end. The track is mounted inside the chimney wall. The SOR is actuated by a directly linked hydraulic cylinder on the chimney, while CAR is actuated by an electric stepping motor at the pool top.

Figure 1 shows a side view of in-pool structure and components including the reactor, shutoff units, control absorber units, neutron detector housings (NDH) and beam tubes.

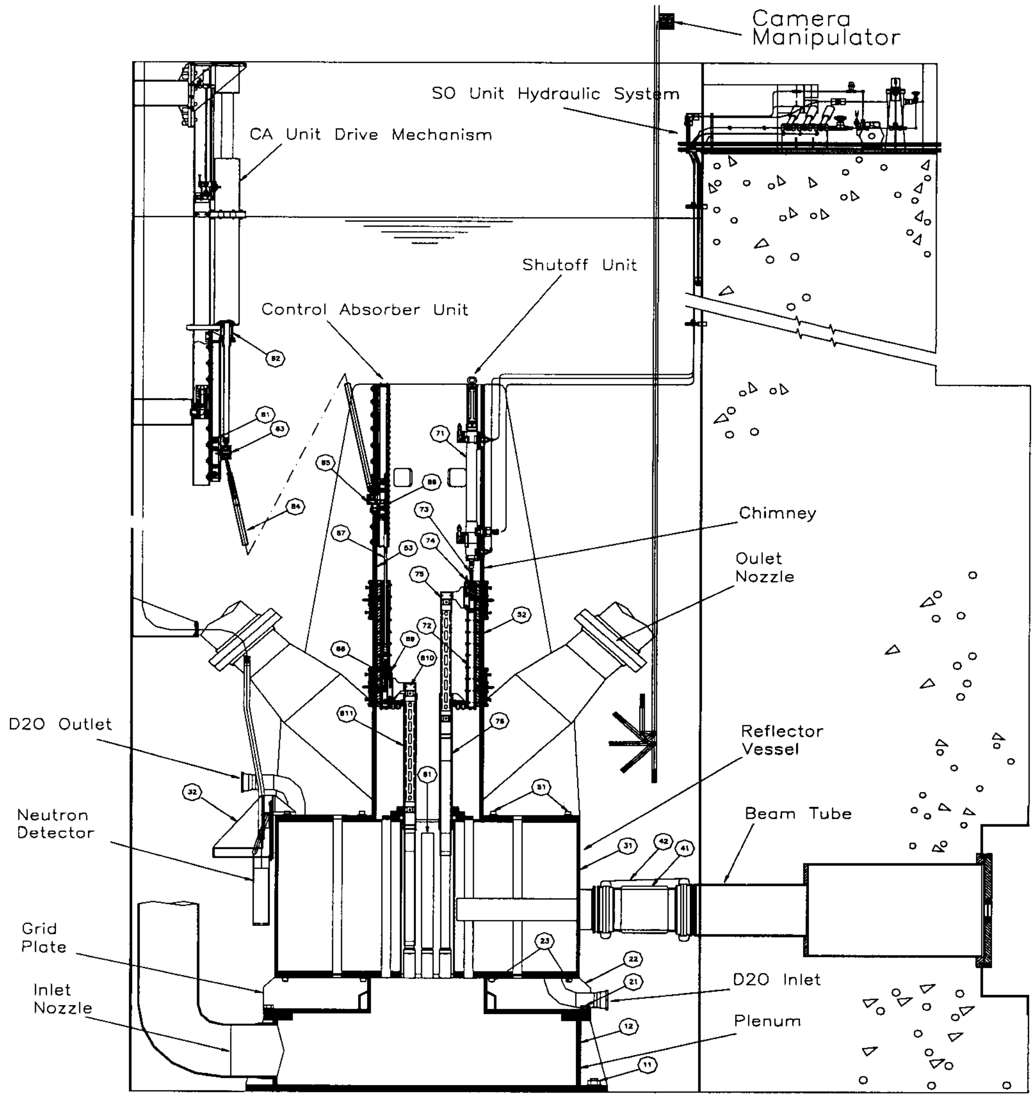

Figure 1 Side view of in-pool structure

The process systems classified into safety class (SC)-3 boundary in HANARO are primary cooling system (PCS), primary purification system (PPS) and emergency water supply system (EWSS). The PCS consists of two parallel circuits with a pump and a plate type heat exchanger of 50% capacity each. About 1% of total primary flow is continuously purified by PPS. For the provision of loss of coolant accident, the emergency water is reserved in EWSS tank at pool top. All piping and equipment classified into safety grade are installed in the reactor concrete island enclosed with 1.2m heavy concrete walls.

3. Long-Term ISI Program

The reactor status can be improved if the ISI program is well established in addition to the regular maintenance and periodic testing. The purpose of ISI is to assess the status of structures, systems and components related to safety in terms of ageing effects. Several mechanical structures and components in HANARO are classified into ASME Section III components that require ISI during reactor operation.

Reactor and reactivity control units (RCU) [1]
The ISI programs for the in-pool structures include the visual inspection, dimensional inspection, and wear evaluation for corresponding components. The visual inspection means to check the surface condition of components for corrosion, erosion, wear, crack, and fastening status of wire-locking on large bolts. Table 1 shows the items of the periodic ISI for the components in reactor assembly and RCU (Shutoff units and Control absorber units).

Table 1. Periodic ISI for the components related to reactor and RCU

Component	Inspection item	period
Reactor structure & Beam tube	Visual inspection - reactor structure - beam tube	5 years
	Measurement of vertical straightness - inner shell of reflector tank	10 years
	Measurement of diameter - fuel flow tube	10 years
Reactivity control units (RCU)	Visual inspection - control absorber rod - shutoff rod	5 years
	Wear inspection - carriage - track	10 years
	Measurement of diameter - shroud tube - control absorber rod - shut off rod	10 years
Neutron detector housing (NDH)	Torque test - bolt of NDH	5 years

The typical items of visual inspection for reactor structure and beam tube are as followings:
- Wire locking of fastening bolts at inlet plenum, grid plate, chimney, and expansion joint clamp of beam tubes
- Outer surface of pleum, reflector vessel, grid plate, chimney, and beam tube assemblies in pool

The plan for wear evaluation for the RCU is periodic visual inspection of the upper track and carriage on the CAR drive assembly which can be easily removed from the reactor pool for dismantling. The period will be every 10 years or when the drop cycles of CAR or SOR reach the design verified numbers. Each assembly of carriage and track, which serves the most frequent movement among the shutoff units and control absorber units, will be removed from the reactor for inspection.
Regarding dimensional changes due to the irradiation effect on the components which are related to RCU movement, periodic inspections are required to check the functionality of the flow tubes, shrouds and absorber rods for the designated functions of RCU. The plan for dimensional inspection includes the measurement of the diameter of absorber rods, cylindrical flow tubes, and guide shrouds of RCU. Various special tools such as dial gauges, calipers, and replacement tools are being developed for the remote measurement of these dimensions.
Besides the existing ISI scope, the periodic inspections for the fastening status of the flow tubes and bolts, and the performance testing of RCU are being performed as per independent procedures. It has been monitored through commissioning and periodic tests. No considerable deterioration in the performance of RCU has been reported. Nevertheless, as an additional plan regarding the evaluation of structural integrity and drop performance of the CAR, measuring the acceleration amplitudes during the CAR drop will check the damping performance of the CAR drive assembly. Structural integrity will be evaluated based on the measurement results. The neutron absorber of a RCU is a cylindrical hafnium pipe connected to a stainless steel pipe. Since it is driven from the

core top, the connection part is always placed above the core where the neutron flux is very low. Therefore, concern about the degradation of its mechanical properties due to irradiation can be relaxed.

Another concern is the endurance of a whole reactivity control unit regarding the lifetime for drop cycles of absorber rods. Its lifetime was determined as proposed in the design stage for an endurance-verified number of drops. According to operating experience, unfortunately, the RCU are expected to exceed the verified number of drops much sooner than the end of the reactor life[3]. For lifetime extension, therefore, each spare assembly for SOR and CAR used for endurance testing will be qualified for additional drops in the test facility. Verification of structural integrity for the increased drop cycles means a validation of longer life of the RCU being used in the reactor. The test facility has a half core configuration with full-scale dimensions for multi-purpose testing of components or equipment before they are used in the reactor.

Through a preliminary review, it was found that the inner shell of the reflector vessel surrounding the core is the most critical part from the viewpoint of neutron irradiation. It serves as a boundary separating the heavy water reflector from the core region, and should maintain the necessary clearance from the adjacent core components of flow tubes and absorber rods. According to creep and growth analysis the inner shell is supposed to be deformed inward, at the middle of the wide side of the shell, due to the combined effect of neutron irradiation and stress. The safety analysis report shows that its safety margin is large enough but reconfirmation is needed. As a possible way of evaluating the ageing effect, a reassessment of the irradiation creep and growth combined with a physical follow-up for the dimensional change in its vertical straightness is considered as the first priority. The first measurement of the inner shell to find the vertical straightness will be done in 2001 as one of the ISI.

ISI for Safety Related Piping [2]

Periodic examinations and tests are necessary to verify the integrity of safety related piping. The ISI for piping system was planned in accordance with the requirements of ASME Section III and ASME Section XI. The safety related piping is classified into examination category "D-B". The category "D-B" indicates that pressure retaining components and their integral attachments to the pipe bigger than 4 inches inclusive should be examined by visual inspections; VT-2 to check the leakage of pressure retaining components and VT-3 to check the mechanical or structural damage of pipe supports and restrains. The test requirements for safety related piping are shown in Table 2.

Table 2. Test/ Examination Requirements for safety related piping

Item No	Parts Examined	Test/Examination Requirements	Examination Method	Purpose
D2.10	Pressure retaining components	IWD-5000 Test by system pressure - Functional test - Hydrostatic test	Visual, VT-2	To check leakage
D2.20	Integral attachments (supports & restrains)	IWD-2500 Examination of welding joints between components and attachments	Visual, VT-3	To check mechanical or structural integrity including welding joints

The inspection schedule for safety related piping is summarized in Table 3. It includes the function test of emergency water supply system (EWSS), the hydrostatic test of primary cooling system (PCS) & primary purification system (PPS) and the visual inspection of several points for pipe supports and restraints. All items will be examined every 10 years in accordance with the ASME Section XI.

Table 3. ISI Schedule for Safety Related Piping

ID No.	Examination Points	Method	Inspection Schedule (year)									
			1	2	3	4	5	6	7	8	9	10
D2.10-1	EWSS	Functional test								x		
D2.10-2	PCS	Hydrostatic test								x		
D2.10-3	PPS	Hydrostatic test								x		
D2.20-1	14" suction pipe anchor	Visual test					x					
D2.20-2	14" suction pipe anchor	Visual test					x					
D2.20-3	16" discharge pipe anchor	Visual test					x					
D2.20-4	14" discharge pipe support	Visual test					x					
D2.20-5	14" discharge pipe support	Visual test										x
D2.20-6	6" bypass pipe anchor	Visual test										x
D2.20-7	6" bypass pipe support	Visual test										x

4. The First Visual Inspection of ISI

The ISI program for the in-pool components includes visual inspection, dimensional measurement, and wears evaluation for the components of the reactor structure, RCU and beam tubes. The visual inspection will be performed every 5 years for the surface of the reactor assembly, shutoff units, control absorber units, neutron detector housings, and beam tubes. Inspection points are outside of all components, inside of chimney and top of the core. The focus of inspection is to survey the evidences of corrosion, erosion, wear, and crack on surface and welding joint. It also includes checking the status of wire locking of the clamping bolts fastening on pool liner, plenum, grid plate, reflector vessel, chimney, and beam tubes. The top of reactor core was inspected to find any contact between flow channels and reactor inner shell. As the result of inspection, there was no defect of the surface of reactor components and all welding points. It was found that the locking conditions of the clamping bolts have been kept well. Design clearances are distinctly being maintained that means no deformation of flow tubes.

The process systems classified into SC-3 boundary in HANARO are PCS, PPS and EWSS.

Figure 2 indicates the visual inspection points of SC-3 piping.

Using the VT-3 procedure, the mechanical and structural status of the components and their supports, such as clearances, physical displacements, loose or missing parts, debris, corrosion, wear, erosion or the loss of integrity at bolted or welded connections was checked out. The four examination points are the anchor support (D2.20-1) for 16-inch pipe at common discharge, the anchor supports (D2.20-2 & D2.20-3) for 14-inch pipe at each discharge of primary pumps, and the under-support (D2.20-4) for 14-inch pipe. Qualified inspectors according to the LEVEL II requirements of ASME section V carried out a VT-3 visual examination for the PCS piping. It was verified that all components and welding joints are maintaining their mechanical and structural integrity without any remarkable defect.

For visual inspection in pool, the remotely operable underwater camera has been developed. The camera unit is composed of a color camera head with built-in lightings, manipulator, supplementary lighting and video recorder. The camera head was designed to a compact size to access in the inlet plenum through a small hole in the core. The manipulator was designed not only to adjust the angle of the camera head but also to adjust the length of handling shaft from 8 to 15 meters. The resolution of the camera was verified in the reactor pool using the visual gray card defined by a relevant code. It was possible, with the camera & manipulator assembly developed, to access in any direction by rotating of manipulator shaft and adjusting of head-angle up to +/-180 degrees, in addition to focus control.

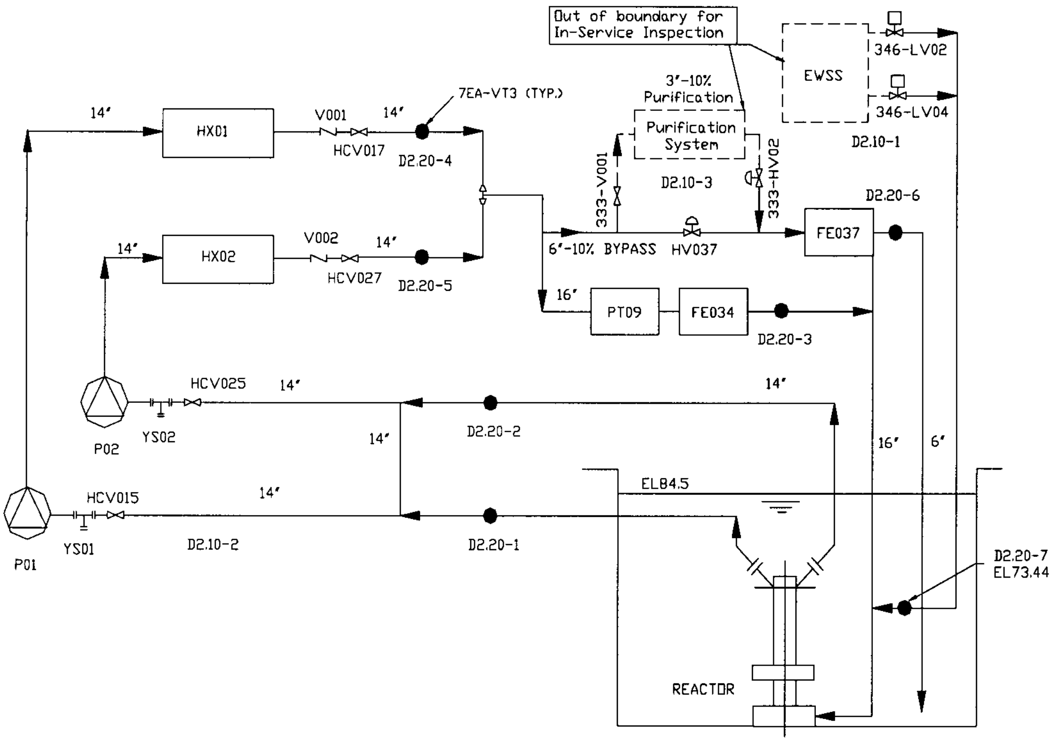

Figure 2. Visual inspection points of SC-3 boundary piping

5. Summary

The long-term ISI program for HANARO was prepared for the purpose of the safe operation and lifetime extension of reactor. As the first step of the ISI, a visual inspection for the reactor components and piping related to safety was carried out last year without any remarkable findings. The result will be reference data for future inspections every five years.

In the near future, the assessment of ageing effects on critical components such as the reactor inner shell and reactivity control units will be performed to acquire useful data for the monitoring of dimensional change due to neutron irradiation. The development of special tools and remote measurements of inner shell straightness will be a challenge this year. Also the tools to measure the amount of wear of flow tubes are being developed. Other various special tools have been developed or are being developed for ISI and ageing evaluation.

References

[1] Y.G. Cho, "ISI Plan for Reactor Components", HANTAP-05-OD-ROP-SI-56, HANARO Operation Procedure, KAERI, June 16, 1998

[2] Y.C. Park, "ISI Plan for Safety Related Piping", HANTAP-05-OD-ROP-SI-58, HANARO Operation Procedure, KAERI, July 25, 2000

[3] Y.G. Cho, J.S. Wu, J.S. Ryu & Y.C. Park, "Ageing Management & In-service Inspection of The Reactor Structure and Reactivity Control Units in HANARO", IAEA/RCA Regional Seminar on Ageing Management, December, 2000