CURRENT STATUS OF THE SPENT FUEL MANAGEMENT IN HANARO

MUN LEE*, C.S LEE, H.W. KIM, K.H. LIM, G.H AHN, I.C. LIM
HANARO Management Division, Korea Atomic Energy Research Institute
1045, Daeduk-daero, Yusung-gu, Taejeon – KOREA
mlee@kaeri.re.kr

ABSTRACT

The nuclear research reactors TRIGA Mark II and III which had been operated in the 1960s and 1970s in Korea were shut down permanently by a decommissioning program in 1996. The total spent fuel from their operation was 299 rods (0.05 MTU), which was shipped back to the US DOE by the "Take-Back" program in 1998. Currently, HANARO is the sole multi-purpose research reactor in Korea. The total number of spent fuel from HANARO since 1995, initial criticality, was 324 assemblies, which is being stored in the spent fuel storage pool inside the HANARO reactor building. The form of spent fuel storage is wet storage as At-reactor pool where the water chemistry has been well controlled. The capacity of the spent fuel storage rack was originally planned for 20 years of full power operation, but the rack will be used for tighter storage lattice as part of the life extension. Therefore, the spent fuel storage capacity will be enlarged up to 65 %, and then, the spent fuel increased in accordance with reactor operation will be accepted. The two options for the spent fuel management at HANARO are as below: one is to return the spent fuel from HANARO to the country of origin. The other is to use pyro-processing technology. These options should be conducted in the frame work of national policy. A national policy for spent fuel management will be prepared in such a way as to sustain nuclear energy, to protect public health, and to minimize the environmental burden to the next generation through the treatment of the spent fuel in an appropriate manner.

1. Introduction

The nuclear research reactors TRIGA Mark II and III which had been operated in the 1960s and 1970s in Korea were shut down permanently by the decommissioning program in 1996. The total number of spent fuel from their operation was 299 rods, which were shipped back to the DOE, U.S.A. by the "Take-Back" program in 1998. Currently, HANARO is the sole multi-purpose research reactor in Korea, which is 30 MW_{th} open-tank-in-pool type reactor using enriched LEU of 19.75 w/o. The two types of HANARO driver fuels, 18-element fuel assembly and 36-element one, in the dispersed U_3Si form and Al clad are loaded in the core. The core geometry is as shown in Figure 1. The inner core which consists of 20 hexagonal fuel channels, 8 circular ones and 3 irradiation sites, CT, IR -1 and IR-2, can be used for irradiation tests. The CT and IR-2 hole are used to carry out the irradiation tests of instrumented fuel capsules, and the IR-1 hole is used to load the In-pile section of fuel test loop. The outer core has 4 circular fuel channels and 4 irradiation test sites which are mainly used to carry out isotope production and irradiation test.

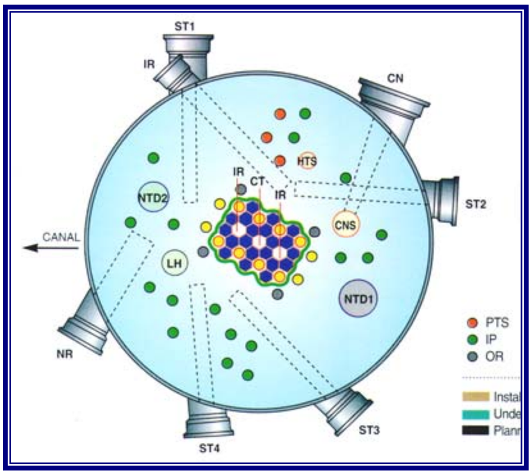

Figure 1. HANARO core geometry

This paper is divided into 3 parts: Part 1 presents the general information of spent fuel such as the total amount of spent fuel, discharged fuel burn-up, and country of origin etc., and also describes water treatment of the spent fuel storage pool. Part 2 demonstrates enlarging of the storage capacity of the spent fuel and its process schematically. Finally, in Part 3 two options for the HANARO spent fuel management will be discussed.

2. Status of the Spent Fuel from HANARO operation

The total amount of the spent fuel by reactor operation is 45 (9 cycles * 5 spent fuel/cycle) annually. The total number of the spent fuel until 2008 was 324 assemblies, with 310 of them stored at the spent fuel storage pool. When nuclear fuels are loaded in the core, 36-element fuel assembly is burned for about 196 days and 18-element fuel assembly for about 168 days during reactor operation [1]. It was estimated that an average burn-up rate of the discharged fuel went up to 55 % in the beginning. But the rate was less than estimated as shown in Table 1. During the early stage of operation, there was a FIV (Flow Induced Vibration) problem in nuclear fuel and this caused less burn-up of fuel. To solve the problems, the fresh fuel design was changed [2]. The origins of the fuel enrichment were form the USA and Russia. The number of fuel from US-origin was 235 assemblies and the fuel from Russian-origin was 75.

Table 1. Characteristics of the HANARO spent fuel in 2008.

Type of Fuel	Number of elements	Average Burn-up (%U-235)	Weight of Uranium (g)	Weight of U-235(g)	Origin	
					US	Russia
18-element	110	46.90	138,384	27,345	102	8
36-element	200	45.20	438,272	86,582	133	67

In Korea, the most commonly used form of spent fuel storage including HANARO is the At-reactor pool or basin. Most research reactor spent fuel stored in the spent fuel storage pool where the water chemistry has been well controlled should not be allowed to degrade the aluminum clad in 30 years [3]. The water quality management of the spent fuel storage pool is important to prevent the corrosion of fuel cladding and the structure material of the storage facility. The four main parameters leading to corrosion of the aluminum cladding are conductivity of the water, dissolved aggressive ions, galvanic coupling and settled solids [4]. The spent fuel storage pool cooling & purification system in HANARO is always operating for water quality management. The spent fuel storage pool water has been monitored by measuring the electrical conductivity, pH, Cl^- and F^- ions periodically. The conductivity has been managed within 1 μ S/cm, which is an operation target of HANARO. The annual average electrical conductivity of the spent fuel pool is as shown in Figure 2. The inlet and outlet electrical conductivity of the spent fuel purification system has been well controlled to 0.31 μ S/cm, 0.15 μ S/cm, on average respectively. The chemical treatment for Be, Cd and Fe is kept less than 0.4 ppb, 10 ppb, and 1 ppb respectively [5]. The temperature of the storage pool has been maintained at the annual average between 22 ~ 25℃ for the last ten years. Between 2004 and 2008, the average radiation level on the surface of the spent fuel pool was 0.26μ Sv/hr. It was background level where the average radiation level of the reactor hall was 0.2 ~ 0.7 μ Sv/hr in general.

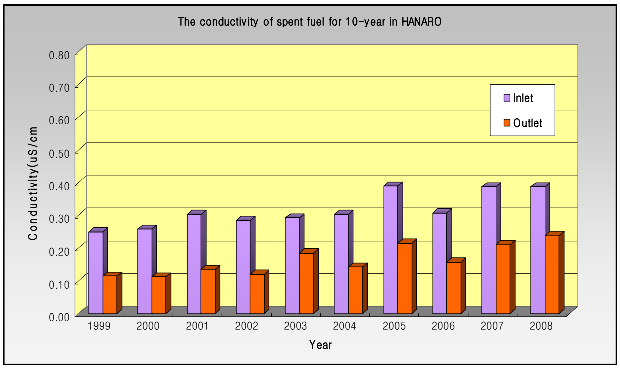

Figure 2. Status of the SF pool conductivity for

In contrast, if the water quality of the spent fuel pool is allowed to degrade the aluminum clad, the fuel will be seriously corroded. In case of the HANARO spent fuel pool, the water chemistry has been well controlled. Therefore, the corrosion of aluminium clad where the water chemistry has been well controlled in HANARO is not a concern at this time.

3. Enlargement of the Spent Fuel Pool Storage Capacity

The irradiated fuel from the HANARO core is being transferred and temporarily stored at the service pool region for visual inspection. The inspected fuel is moved and stored in the spent fuel storage rack which is connected with the service pool. The spent fuel storage pool is a heavy concrete structure lined with a stainless steel plate and the depth is 13m. Figure 3 shows the spent fuel storage racks and module of HANARO. There are three units of fixed spent fuel storage racks placed at the storage compartment. The pool has enough capacity for temporarily storing TRIGA fuels as well as spent fuel generated from normal operation for 20 years. The total capacity of the spent fuel storage is 432 18 elements assemblies and 600 36 elements assemblies at the present. The spent fuel from HANARO until 2008 was 324 assemblies which occupied one-third of the total capacity of the racks. When assuming to spend an annual 45 assemblies, after use, the spent fuel storage capacity is expected to be reached by 2023. HANARO has a plan to extend the operation lifetime and the storage capacity of spent fuel will be extended as below:

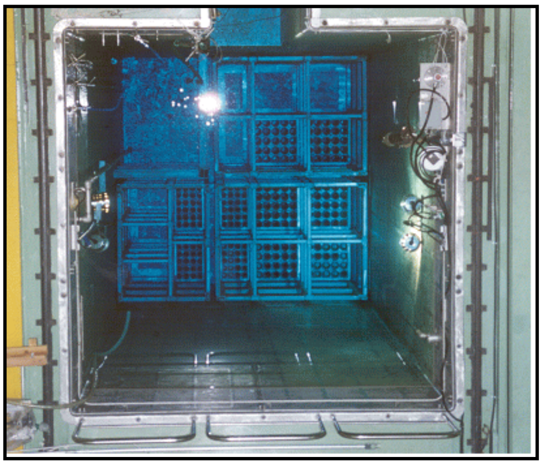

Figure 3. Top view of the SF pool

- Although the spent fuel storage rack for TRIGA II & III had been occupied at the beginning, their fuels were already taken back to the country of origin. Therefore, the fuel storage rack has room as much as the TRIGA fuel which were taken out from the storage rack.
- And enlargement of the spent fuel storage capacity was chosen to alter the design of the storage module into making the pitch more tightly between the fuel bundles.
- The enlargement of the spent fuel storage should satisfy the safety requirements such as nuclear criticality, shielding, mechanical integrities, and the cooling and purification ability at the spent fuel storage.

Table 2. The changed storage capacity of the SF pool

Contents	36-element Storage Module		18-element Storage Module	
Fuel Storage Module	Previous Lattice	TRIGA Lattice	Previous Lattice	TRIGA Lattice
Storage Capacity of the Fuel Bundle per Module	36 (6×6)	20 (5×4)	35 (7×5)	30 (6×5)
Number of Modules	24(8×3 layer)	6(2×3 layer)	18(6×3 layer)	3(1×3 layer)
Storage Capacity	864	120	630	90
Sub Total	984		720	
Enlarged Capacity(times)	1.64 (=984/600)		1.67 (=720/432)	

As a result, the capacity of the spent fuel storage pool after renovation is expected to be 720 18-element assemblies and 984 36-element assemblies [6]. When the capacity is enlarged, the spent fuel that can be generated until 2040 can be accommodated easily. Then the spent fuel storage capacity will be enlarged to 65 % by changing the geometry.

4. Options for Final Disposal

The management program of the spent fuel from both HANARO and domestic nuclear power plants should be conducted in the frame work of national policy. A national policy of spent fuel management will be prepared in a way to contribute to sustaining nuclear energy, protecting public health, and minimizing the environmental burden to the next generation through the treatment of the spent fuel in an appropriate manner [7]. In the case of HANARO, There are two options for the management program of the spent fuel:

- Option 1 is to return the spent fuel from HANARO to the origin country by the take-back program [8]. Even through the spent fuel acceptance program of the US DOE is now extended to May 2016, it is anticipated that HANARO will be operated continually by 2040 through the life extension.
- Option 2 is to store the interim storage and to use pyro-processing technology. The technology that is highly proliferation-resistant is being planned. Moreover, the sodium-cooled fast reactor which is linked with pyro-processing reduces the volume and toxicity of the high-level radio-active waste drastically. Designing and constructing mock-up equipment are planned to be completed by 2011, and they will be verified with engineering-scale by 2016. The pilot facility will be completed by 2025 and the volume of the spent fuel from both HANARO and the power plants will be reduced.

For conducting these options, there should be dialog about granting authorization, financial problems as well as research and technical aspects.

5. Remarks

Domestically there is neither interim storage facility nor ultimate disposal for spent nuclear fuel. So it is time to discuss the management program for the interim storage facility and the ultimate disposal of spent fuel. However, the government in 2003, in the process of site selection for low level radioactive waste without sufficient convergence of opinions, was in disagreement with local residents and have experienced many conflicts between stakeholders. To prevent the same mistake, the government needs to discuss with stakeholders in advance. Fortunately, ‘a social acceptance committee’ that represents the public and stakeholders, for the sake of managing the program will be organized soon.

For the pyro-processing of the spent fuel in Korea, a pact signed on a nuclear cooperation agreement in 1973 should be renegotiated between Korea and the U.S. Korea has voluntarily refrained from reprocessing nuclear materials since 1974. However, spent fuel has piled up and concerns are rising that the capacity of the spent fuel storage facilities will be reached or close to the limit as part of the nuclear site around 2016. Positive results for a revision of this nuclear cooperation agreement are expected between Korea and the U.S. because South Korea is one of the largest nuclear power users in the world.

In conclusion, the spent fuel management program is one of South Korea’s national policies that require long-term strategies.

References

[1] H.W. Kim et all, “Production of the HANARO spent fuel, analysis of the average burn-up, and a plan for enlarging the spent fuel storage rack”, 2007 HANARO Symposium, 2007.

[2] M. Lee et all, “Status of the damaged fuel assemblies in HANARO”, Korean Nuclear Society, Oct. 2007.

[3] Iain G. Ritchie, “Growing dimensions spent fuel management at research reactors”, IAEA bulletin, IAEA, 2008

[4] L.V. RAMANATHAN et all, “Corrosion of spent aluminum-clad research reactor fuel – Synergism in the role of storage basin water parameters”, IAEA Tecdoc, 2008

[5] Chemistry Analysis Team, “Analysis report for spent fuel pool water in HANARO”, KAERI, 2008

[6] S.Y. Oh, “A plan for enlarging the spent fuel storage rack” Internal Memo in HANARO, HAN-RR-CR-354-05-048, 2005.

[7] ARKHANGELSKY, N.V et all, “Management and storage of spent fuel at research and test reactors, IAEATECDOC-900 (1996)

[8] C.E. Messick et all, “THE UNITED STATES FOREIGN RESEARCH REACTOR SPENT NUCLEAR FUEL ACCECPTANCE PROGRAM”, RERTR, 2008