Development of Treatment Equipment for Spent Resin Mixture in Heavy Water Reactors (HWR)

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1. Introduction

To purify the liquid radioactive waste generated in the process of operating the Nuclear Power Plants (NPPs) are using the ion exchange resin. This spent resin is currently stored in the spent resin storage tanks in the NPPs as the treatment method has not been determined. The treatment method of the stored spent resins will be determined and the spent resins will be disposed according to the NPP decommissioning plan. The spent resin from Heavy Water Reactor (HWR) NPPs contains various radionuclides, and particularly a high concentration of C-14, a long half-life nuclide.

According to the domestic radioactive waste classification system, the currently stored HWR spent resin mixture is classified as Intermediate-Level Waste (ILW), and must be disposed of in rock caverns. However, the total activity of C-14 in the spent resin from Wolsung NPPs Units 1 through 4 is about 10 times as much as the total C-14 limit (1.66×10^{14} Bq) of rock-cavern disposal facilities specified in the Safety Analysis Report (SAR) of Korea Radioactive Waste Agency (KORAD). Accordingly, to reduce disposal quantities and disposal costs, it is necessary to separate the resins containing highly-concentrated radionuclides from the spent resin mixture, and remove C-14 from the separated spent resin.

2. Methods and Results

The purpose of this study is to develop a HWR spent resin mixture treatment system based on the results of collecting spent resin mixture samples from the spent resin storage tank #2 in Wolsung NPPs Unit 1, and analyzing the properties and the spent resin storage tank.

2.1 Spent resin mixture disposal scenario

As about 20% of the spent resin mixture of HWR NPPs is the active carbon and zeolite mixture and 80% of it is the mixed (anion and cation) resin, a disposal scenario was developed to reduce disposal quantities and disposal costs.

To dispose of the spent resin mixture of HWR NPPs, the spent resins must be separated from active carbon and zeolite, and the validity of deregulation must be reviewed, and to dispose of the spent resin corresponding to the ILW as Low-Level Waste (LLW) or Very-Low-Level Waste (VLLW), C-14, a highly-concentrated long half-life radionuclide, must be removed. The removed C-14 must be collected in a chemically stable form, and the disposal volume must be reduced and disposal safety must be ensured. Also, the validity of recovering and recycling the radioisotope C-14, an expensive resource, generated in the treatment process from the spent resin rather than disposing of it will be reviewed.

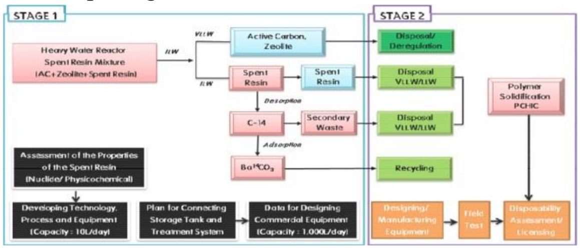

Fig. 1. HWR spent resin mixture disposal scenario.

2.2 Sampling the spent resin mixture and analyzing properties

Samples of the spent resin mixtures were collected from the spent resin storage tank #2 in Wolsung NPPs Unit 1. According to the results of sampling, the composition of the spent resin mixtures varied depending on their location in the storage tank. As illustrated in Fig. 2, zeolite, active carbon and spent resin were mixed in the sample collected from the manhole, whereas most of the samples consisted of spent resin at other locations.

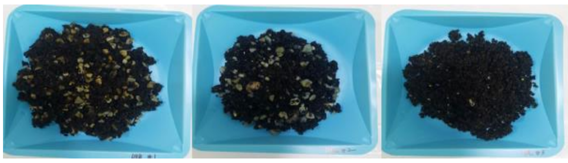
Fig. 2. Spent resin mixture samples from Wolsung NPPs Unit 1.

Table 1. Analysis of the properties of the spent resin from Wolsung NPPs Unit 1

Classification	Particle size (Spec.)	Particle size (Mesh experiment)
Resin	0.3mm~1.18mm	Less than 0.50mm on average
Active carbon	1.0mm~3.35mm	0.71mmor more on average
Zeolite	1/8" Pellets 4×8 Beads	0.71mmor more on average

Based on the particle size data in the purchase specifications of the zeolite, active carbon and resin from Wolsung NPPs Unit 1, meshes of various sizes were selected, and a multi-level separation experiment was conducted. In the separation experiment, most active carbon and zeolite did not pass the 850μm sieve. All resin passed the 850μm sieve, and resin was distributed on several layers depending on particle size, but it was confirmed that only a small quantity (friability resin) passed the 300μm sieve.

2.3 Development of the spent resin mixture separator

Based on the result of analyzing the properties of the spent resin, appropriate meshes were selected, and it was confirmed that if Mesh 20 (0.85mm) and Mesh 50 (0.30mm) are used to separate the mixture, the resin can be effectively separated from active carbon and zeolite.

In the same way as the spent resin mixture is treated in the field, the spent resin mixture separator was connected to the resin outlet at the bottom of the storage tank, and a simulation was conducted. The simulation was done horizontally and vertically.

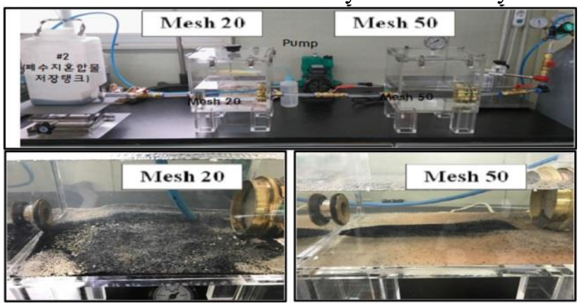

Fig. 3. Lab scale spent resin mixture separator (horizontal).

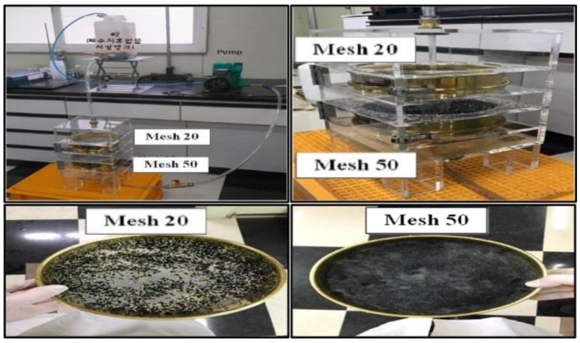

Fig. 4. Lab scale spent resin mixture separator (vertical).

The vertical structure separator in Fig. 4 had a shorter separation time than the horizontal structure in Fig. 3, and the vertical structure had a very high separation rate. Also, it was very easy to treat the separated waste at each level in the vertical structure separator. Based on these experimental results, the spent resin mixture separator was developed as shown in Fig. 5.

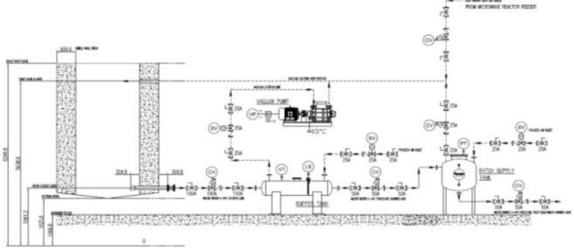
Fig. 5. Spent resin mixture separator.

2.4 Spent resin treatment system

To remove C-14 in the separated spent resin, this study used microwave. As the conventional C-14 removal technology uses the desorption solution, the cation and anion materials remain in the spent resin besides the spent resin. So there are residues and secondary waste after desorption. However, the heating and desorption method using can raise the temperature quickly, and as no materials are added in the desorption, there is no secondary waste, and the resin can be dried.

Table 2. Properties of the microwave

Classification	Microwave	Simple heating
Characteristics	- directly heating the molecules in the sample	Indirect heating (heat conduction)
Strengths	- quickly raising the temperature - uniform heating - selective heating - temperature control - high efficiency (80%) - easy to operate - No noise/heat/exhaust gas	General purpose
Weaknesses	- Limited applicability due to the chemical structure	Nonselective

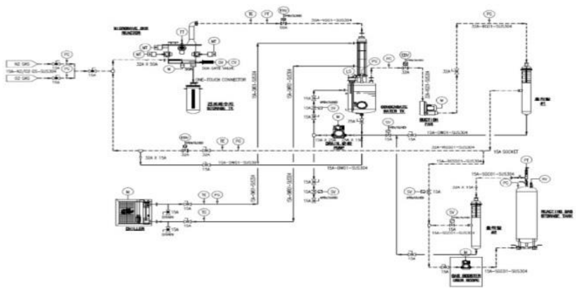
Fig. 6. Spent resin treatment system.

3. Conclusions

The purpose of this study is to come up with a scenario for disposing of the spent resin mixture from HWR NPPs, and develop the technology for securing disposal stability by optimizing and demonstrating the technology for removing C-14 in the spent resin of NPPs.

The technology for disposing of the spent resin of NPPs is expected to improve the stability of NPPs. Also, it is deemed possible to develop products that can reduce disposal costs by more than 50%, and flexibly establish NPPs operation and radioactive waste management policies.

REFERENCES

[1] Jianlong Wanga, Zhong Wan, Treatment and disposal of spent radioactive ion-exchange resins produced in the nuclear industry, Progress in Nuclear Energy, Volume 78, January 2015, Pages 47.