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

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1. Introduction

Nuclear power plants (NPPs) use ion exchange resin (spent resin) in order to purify liquid radioactive wastes generated in the course of plant operation. The used ion exchange resin is currently stored in a spent resin storage tank and will be treated according to the nuclear decommissioning plan. Spent resin generated from a heavy water reactor, especially, includes a variety of radionuclides and the concentration of ^{14}C, a long half-life nuclide, is high. Therefore, it must be treated through cave disposal as an intermediate level radioactive waste (ILW) according to Korea's radioactive waste classification system. However, the total amount of ^{14}C in the spent resin from Wolsong #1 ~ 4 is around ten times larger than the upper limit amount of ^{14}C (1.66×10^{14} Bq) for a cave disposal site as specified in the safety analysis report (SAR) of Korea Radioactive Waste Agency (KORAD). Therefore, to reduce the treatment volume and cost, separation of resin with a high content of radionuclides and removal of ^{14}C from spent resin are necessary.

2. Methods and Results

In this study, spent resin mixture samples were collected from spent resin storage tank #2 of Wolsong #1, characteristics of the spent resin mixture samples were analyzed and also the spent resin storage tank was analyzed. Then, based on the analysis results, a resin separation system was developed.

2.1 Spent Resin Mixture Sampling

Spent resin mixture samples were collected from spent resin storage tank #2 of Wolsong #1. As a result of sampling, the composition of spent resin mixtures was found to vary according to their positions in the storage tank. While samples collected from the manhole, as in [Fig. 1], were comprised of contained zeolite, active carbon and spent resin, those from other positions were mostly spent resin.

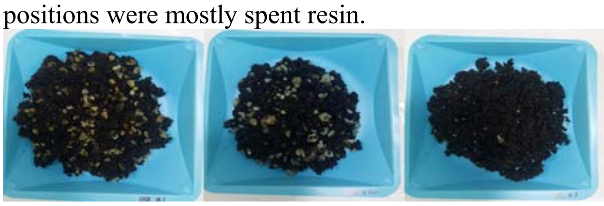

Fig. 1. Wolsong #1 Spent Resin Mixture Samples

2.2 Spent Resin Mixture Analysis

Based on the data of particle sizes from the purchase specifications of zeolite, active carbon and resin used in Wolsong #1, meshes of various sizes were selected and, using the meshes, a multi-level separation test was conducted. In the separation test, most active carbon and zeolite particles could not pass through the 850μm sieve. As for resin, it passed through 850μm and was distributed over several levels according to the particle size. However, only a small amount (friable resin) passed through a 300μm sieve. With this result, meshes of appropriate sizes were selected and, when using mesh 20 (0.85mm) and mesh 50 (0.30mm), resin, active carbon and zeolite could be separated effectively from the mixture.

Table 1. Analysis of Wolsong #1 Spent Resin Mixture Characteristics

Classification	Particle Size (Spec.)	Particle Size (Mesh Test)
Resin	0.3mm~1.18mm	Average : Less than 0.50mm
Active Carbon	1.0mm~3.35mm	Average : 0.71mm or larger
Zeolite	1/8" Pellets 4×8 Beads	Average : 0.71mm or larger

2.3 Analysis of Spent Resin Mixture Storage Tank

Spent resin storage tank #2 of Wolsong #1, which was selected as a target of spent resin mixture sampling, has a storage capacity of 200m^3. Currently, it stores spent resin by 145m^3, which is approximately 72.5% of the total capacity. As a particular feature of this storage tank, spent resin generated from the portable decontamination wastewater unit is injected with pure water into a manhole at the top of the storage tank and, therefore, the storage cross-section of the tank is sloped with the side of the manhole elevated from the side of inspection port. The spent resin storage tank is in the shape of a rectangular parallelepiped of which the height from the floor to the internal ceiling is 4.65m and the area of the floor surface is approximately 55.7m^2 (7.7726m×7.164m). In addition, inside the storage tank, pure water injected in the course of additional waste resin insertion from the waste resin transportation system or portable decontamination wastewater unit exists in the form of stored wastewater.

As in the drawings in [Fig. 2], spent resin generated in each unit is injected and stored through resin inlet at the top of the storage tank. For the treatment of spent resin as a result of nuclear decommissioning or when the storage tank becomes saturated in the future, the treatment must be carried out by connecting the spent resin treatment device currently in development to resin outlet, a 4-inch SUS pipeline marked with a cloud shape at the bottom. Currently, resin outlet pipeline is protruding to the outside at the bottom of the storage tank in a controlled zone and is fixed in position with 4-inch ball valves and blind flanges.

As a result of a field inspection and the storage tank analysis, the area around resin outlet pipeline to which the resin separation system in development can be connected was found to be very confined. This needs to be taken into consideration in the separation system layout and location selection.

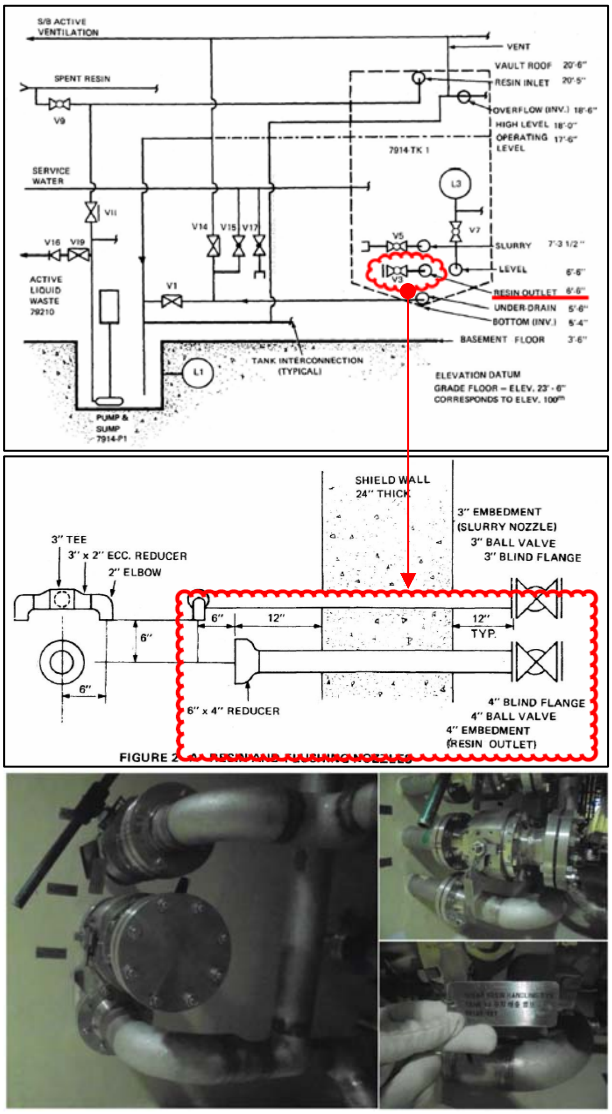

Fig. 2. Wolsong #1 Spent Resin Storage Tank Drawings and Resin Outlet

2.4 Resin Separation Simulation

Separation tests were conducted by collecting resin, active carbon and zeolite used in Wolsong #1. In the site, a simulation system for lab test in the concept of spent resin treatment through a resin separation unit connection to a resin outlet at the bottom of the spent resin storage tank was configured and separation tests were carried out under two conditions, which were horizontal and vertical structures.

As a result of a separation test using the horizontal spent resin mixture separation system in [Fig. 3], the separation rates were found to vary according to the pump capacity at the back. In addition, it was observed that a considerable amount of resin from the storage tank was deposited in the zeolite + active carbon separation level. To supplement this, nitrogen gas (N_2 Gas) was injected for artificial bubbling, and thus flow formation. Even so, the amount of resin flowing into the back was very small. When the resin separation level at the back was checked, substances other than resin were not observed. This once again verified that the mesh selection for mixture separation was very accurate.

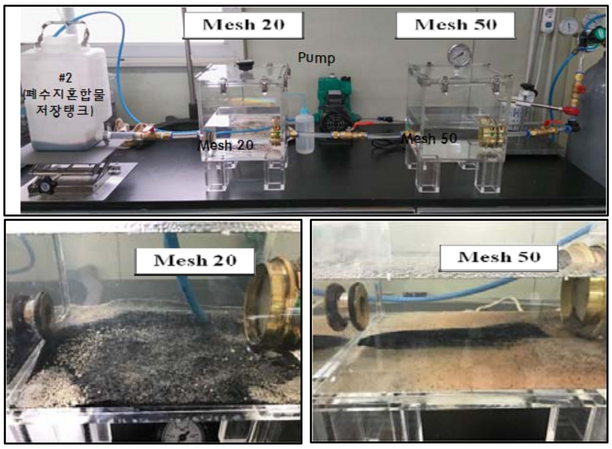

Fig. 3. Spent Resin Mixture Separation System for Simulation (Horizontal Structure)

Compared to the horizontal spent resin mixture separation system in [Fig. 3], the vertical spent resin mixture separation system in [Fig. 4] took a shorter amount of separation time and the separation rate was considerably improved. However, for additional improvement, a method to ensure even spray of water and mixture supplied from the storage tank to the mesh in zeolite + active carbon separation level, the top level, needs to be developed. This will contribute to further reducing separation time and increasing separation rate.

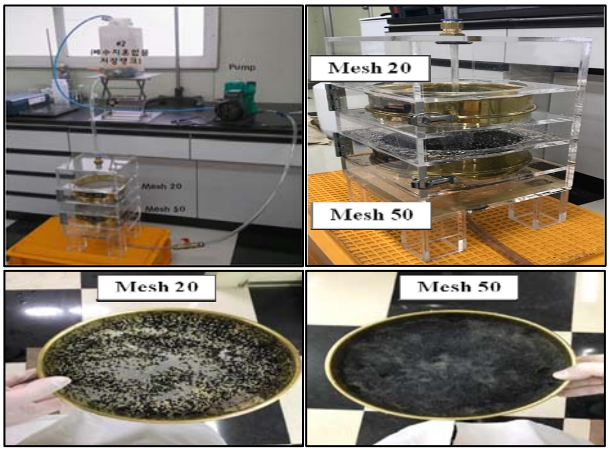

Fig. 4. Spent Resin Mixture Separation System for Simulation (Vertical Structure)

Table 2. Spent Resin Mixture Separation Rate according to Composition

Classification	Horizontal Structure	Vertical Structure
Separation Rate (%)	95.16	32.18
Supplementation	Separation rate of each separation level varies depending on the pump capacity. Separation is difficult as the mixture mostly sinks down to the bottom of the separation level.	The method of mixture supplied from the storage tank and water evenly sprayed all over the mesh for separation is supplemented.

2.5 Spent Resin Mixture Separation Process Design

Through an analysis of the characteristics of spent resin mixture and simulation tests, the optimal conditions for separation and efficient separation system configuration were found. Based on this, a resin separation process in [Fig. 5] was designed.

As mentioned earlier, the space of resin outlet pipeline in the storage tank is very confined. Therefore, lifting is minimized by forming a horizontal line from resin outlet pipeline to where the resin separation system is located and spent resin mixture is first moved to the primary storage (interface) and then supplied to the separation system using a pump at the back.

At the front part of zeolite + active carbon level, a sieve with a mesh size of 1cm×1cm is installed to remove other impurities (bolts and nuts) inside the storage tank. In addition, at the back part of resin separation level, a sieve with mesh 400 (0.038mm), which is 1/10 the size of the mesh for resin separation level, is installed to also collect friable resin and transport the resin to the resin storage tank.

Resin collected in the resin storage tank is transported to the post-processing unit using a transportation device in order to remove ^{14}C contained in the resin.

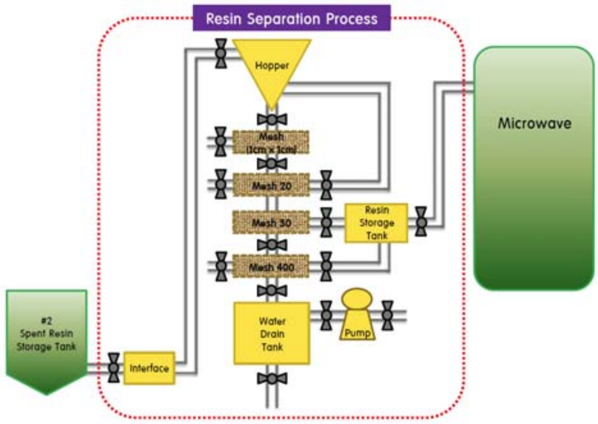

Fig. 5 Resin Separation Process

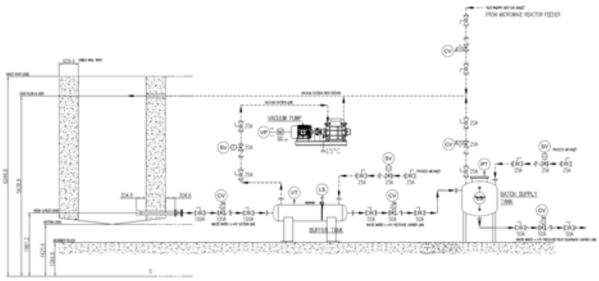

Fig. 6 Resin Separation Process Drawings

3. Conclusions

From the heavy water reactor spent resin mixtures currently in the storage tank, active carbon and zeolite mixtures can be separated and examined for feasibility of deregulation. As for the spent resin categorized as ILW, it will be possible to lower classification to below low level by removing radionuclides. In addition, the removed radionuclide ^{14}C can be recycled or collected/ treated into a chemically stable form so as to reduce the spent resin treatment volume. Therefore, this study is considered an important technological development to secure safety of spent resin treatment.

REFERENCES

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[2] IAEA Technical Report, Management of Waste Containing Tritium and Carbon-14, IAEA Tech. Report No. 421, IAEA, Vienna, 2004.