Design Factor Analysis of the Treatment Equipment for the Spent Resin Mixture From Pressurized Heavy Water Reactor

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1. Introduction

The annual average amount of spent resin mixtures, generated in domestic PHWR (Pressurized Heavy Water Reactor) nuclear power plants, is 124,560 L. They are stored in 200 m^3 concrete storage tanks located inside the nuclear power plants.

PHWR spent resin has high specific radioactivity of C-14, and as the total radioactivity is about 10 times higher than the total amount limit (3.04×10^{14} Bq) of the underground repository, it is absolutely necessary to remove C-14 in the spent resin for permanent disposal of spent resin mixtures.

This study separated spent resin from the spent resin mixture, deposited C-14, collected it in $Ca(OH)_2$ or $Ba(OH)_2$, and analyzed the factors that must be considered when designing a commercial device for treating PHWR spent resin mixtures based on the on-site verification experiment conducted to review the validity of recycling.

2. Body

PHWR spent resin mixture treatment equipment consists of 4 stages, i.e. the spent resin mixture transfer process, the resin separation process, the C-14 desorption process, and the C-14 adsorption process, and the authors analyzed the factors necessary for designing the device in consideration of the characteristics of each process.

2.1 Treatment capacity

The total capacity of the spent resin storage tanks of Wolsong Nuclear Power Plants 1 and 2 is 1,786 ㎥. Assuming that spent resin is stored at up to 80% of the total capacity in consideration of safety, the total amount of spent resin mixtures to be treated is 1,428,800 L, and assuming that all stored spent resin mixtures are treated in the next 3 years after permanent shutdown according to the NPP decommissioning plan, the daily treatment capacity was calculated as 1000 L/day. Based on this, the treatment capacity of each process was calculated as shown in Table 1.

Table 1. Treatment capacity of each process

Classification		Design capacity	Treatment capacity
Transfer	SUMP HOPPER	850 L	600 L
Separation	1st separation tank A, B	1000 L	600 L
	Zeolite+activated carbon recovery tank	2390 L	1910 L
	RESIN BUFFER TANK	2390 L	1910 L
	RESIN DAILY TANK	1550 L	850 L
	2nd separation tank	300 L	150 L
	Constant SCALE HOPPER	150 L	130 L
	Constant FEEDER	30 L/min	30 L/min
Desorption	MW REACTOR A, B	380 L	125 L
Adsorption	C-14 adsorption tower A	12 L	6 L
	C-14 adsorption tower B	9 L	3 L

2.2 Treatment time

The pretreatment process for treating spent resin mixtures, i.e. the 'concrete storage tank→SUMP HOPPER→1st separation tank A, B→RESIN BUFFER TANK→RESIN DAILY TANK' process, is operated automatically by the level sensor attached to each tank, and it is constantly operated separately from back-end processes.

The separated spent resin treatment process has a closed circulatory structure consisting of 'feeding spent resin→C-14 desorption→removing moisture→C-14 adsorption→discharging spent resin after reaction,' and the treatment time for all processes is 2 hr/Batch. The spent resin treatment process is operated 4 batches a day, and 8 hours of operation treats 800 L of spent resin.

2.3 Removing spent resin mixtures

Stored spent resin is stored in liquid waste in the form of a mixture of zeolite, activated carbon and spent resin. Depending on their location, part of mixtures, which have been stored for a long time, may be hardened. So there must be a way to crush them before removal. Propeller-type equipment with a digging function will be used to crush the hardened parts, and transfer them to the Sump Tank through the Resin Outlet.

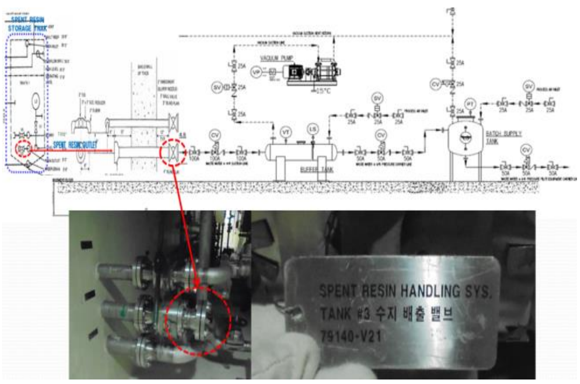

Fig. 1. Spent resin mixture removal process.

2.4 Separation of spent resin

The spent resin mixture, transferred to the SUMP TANK, will be transferred to the 1st separation tank, and passes through multi-stage mesh in the liquid stage, and it is separated into 'zeolite+activated carbon' and 'spent resin.' The separated 'zeolite+activated carbon' will be transferred to the recovery tank, and the spent resin will be transferred to the BUFFER TANK for storage.

2.5 C-14 desorption

1 kW Magnetrons (26) will be used to generate electromagnetic waves (2.45 GHz) in the cylindrical reactor, designed with optimization simulation that has a treatment capacity of 100L/Batch, and C-14 is desorbed in the form of $^{14}CO_2$ gas due to functional group pyrolysis.

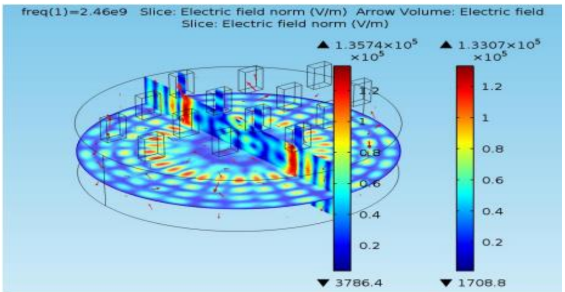

Fig. 2. Optimization simulation.

2.6 C-14 adsorption and recycling

$^{14}CO_2$, which passed the heat exchanger and had moisture removed, was designed as a lattice structure to maximize the reaction efficiency of the adsorbent and the surface area, and the CO_2 adsorbent (Ca or Ba series) will be loaded in each stage, and C-14 will be adsorbed.

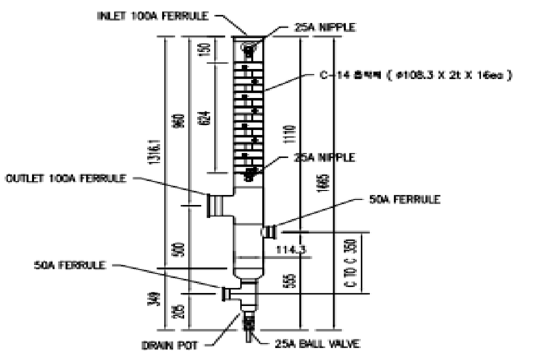

Fig. 3. lattice structure's adsorption tower.

C-14, recovered in the adsorbent, is an expensive resource. The authors are planning to find a method of concentrating and recycling it in the adsorption process so that it satisfies the commercial standard (50mCi/mmol) for manufacturing labeled compounds.

2.7 Disposal of wastes

The 'zeolite+activated carbon,' recovered in the spent resin mixture separation process and the 'post-treatment spent resin' will be stored in their respective storage tanks, and put in their respective containers using the automatic packing system, and treated according to plan.

2.8 Radiation protection

To minimize the influence of radiation on the workers operating the PHWR spent resin mixture treatment device, workers' exposure was minimized through modeling with the VISIPLAN code. and risk factors were verified.

2.9 PHWR spent resin mixture treatment process

Design factors of each key process were analyzed, and a device, capable of treating 1000 L of spent resin mixtures (zeolite+activated carbon+spent resin+stored liquid waste) per day, was designed. The design standard of each process is a capacity that can treat 800 L of pre-reaction spent resin (moisture content about 50%) in view of the component ratio (spent resin 80%) of spent resin mixtures.

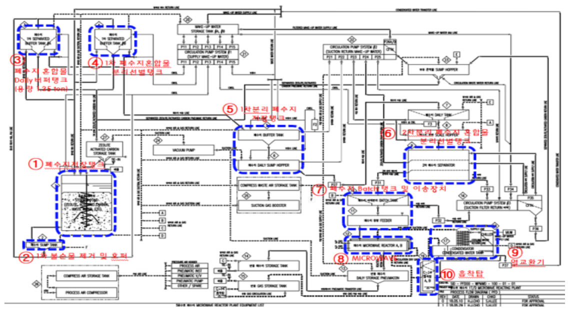
Fig. 4. PHWR spent resin mixture treatment process.

3. Conclusion

The 'PHWR spent resin mixture treatment commercialization equipment,' designed in this study, can be used to secure the safety of radioactive waste disposal. Also, it is believed that the disposal costs will be reduced as the volume of the wastes, generated by NPPs, is reduced, and economic gains will be generated through the recycling of expensive resources. But it is necessary to reflect the inadequacy of the current system and the regulatory agency licensing process.

ACKNOWLEDGEMENT

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