Reuse of Ion Exchange Resins for Reduction of Spent Radioactive Resins – 17125

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ABSTRACT

A process is proposed to reuse ion exchange resins. The process consists of ion exchange beds for the ion exchange and regeneration, regeneration solution (regenerant) make-up tanks, an evaporator for concentration of spent regenerant, a dryer for the drying of concentrate, a pulverizer for grinding dried salt and a mixer for polymer solidification of the salt. A spent resins storage tank and a spent regenerant storage tank are also involved in the process. The role of each component in the process for reuse of the resins is explained. In addition, the effect of the reuse of ion exchange resins by regeneration was estimated in view of the reduction of spent resins. As the number of regenerations increases, the volume of spent resins is obviously inversely proportional to the number of regenerations. Although a polymer waste form is generated instead of spent resins when the ion exchange resins are reused, its volume is only about one-fifth of that of spent resins.

INTRODUCTION

Ion exchange resins, which are used in a primary cooling system and radioactive waste treatment system of a nuclear reactor, are usually discarded in Korea as spent radioactive resins (spent resins) without reuse through regeneration after reaching an ion exchange capacity limit. Although much effort to treat spent resins has been made, effective treatment technology has not been developed thus far. Therefore, the volume of spent resins is increasing every year [1, 2, 3]. Although a portion of spent resins has been recently treated through polymer solidification, most of the spent resins are still stored without any treatment [4].

In general, ion exchange resins are reused in other industries through regeneration. Even in a secondary cooling water system and make-up water supply system of nuclear power plants, ion exchange resins are reused using regeneration [5]. If ion exchange resins to be used for the removal of radionuclides can be reused through regeneration, the amount of spent resins produced will definitely decrease. The major reason why ion exchange resins are not reused, in spite of this fact, is the secondary waste, i.e., regeneration wastewater, produced during regeneration process [2]. The regeneration wastewater, which is the solution used for the regeneration of ion exchange resins, contains radionuclides and must be properly treated and finally converted into a waste form. Unfortunately, an effective technology for the regeneration wastewater treatment has not been developed yet, and the reuse of ion exchange resins has also not been adopted in Korea.

However, according to the recent advances of a drying system for wastewater and a solidification system for the dried powder from the drying system [6, 7], the reuse of ion exchange resins is reconsidered in the present paper for the reduction of spent resins.

PROCESS FOR REUSE OF IONEXCHANGE RESINS

To reuse ion exchange resins, a process was designed by the Korea Atomic Energy Research Institute and the Korea Nuclear Engineering Co [8]. A process flow diagram is shown in Fig. 1. Ion exchange treatment of a primary coolant or radioactive wastewater is basically performed by three ion exchange beds consisting of a cation bed, an anion bed, and a mixed bed. Influent (primary coolant or radioactive wastewater), which is injected into the cation bed after filtration, passes through the cation bed, the anion bed, and the mixed bed in series. Most of the cations and anions (including radioactive cation and anion) in the influent are removed in the cation and anion beds. Small amounts of cations and anions that are not removed in the cation and anion beds are finally removed in the mixed bed.

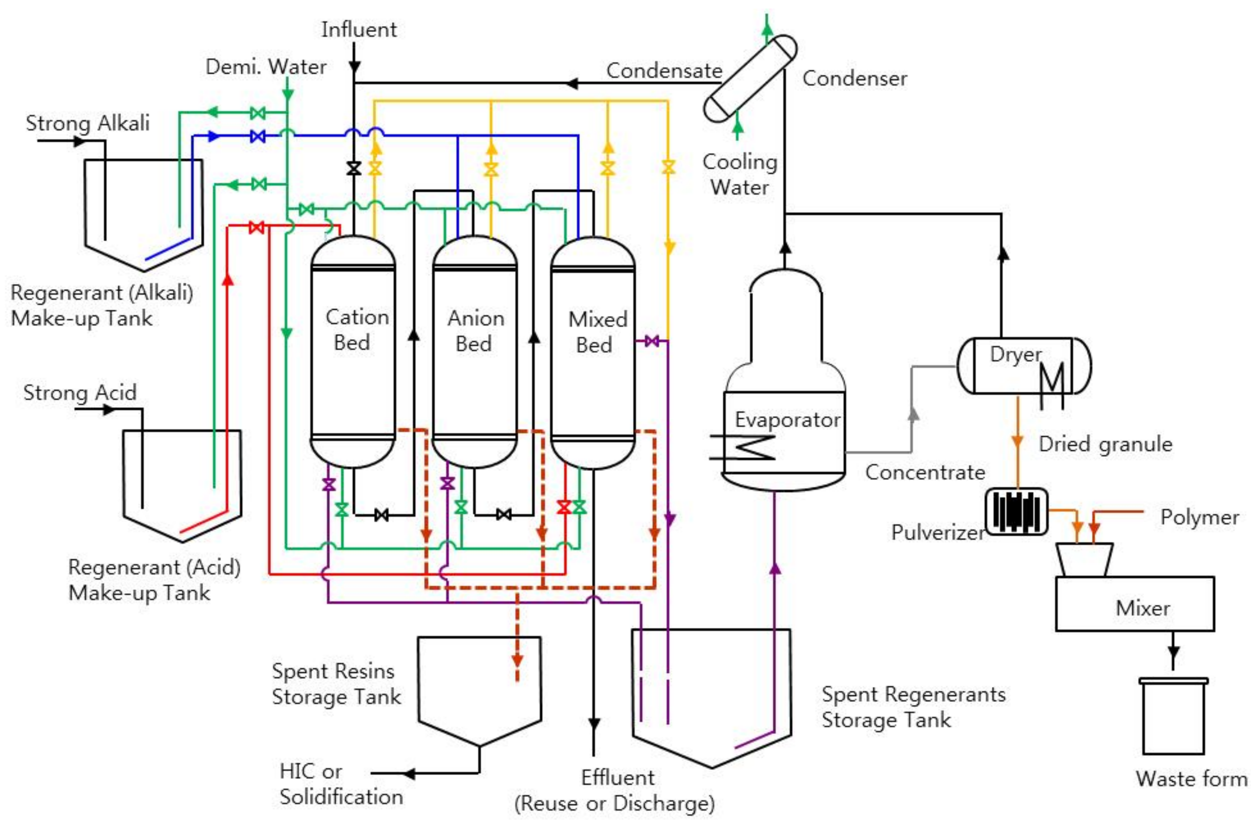

Fig. 1 Process flow diagram for reuse of ion exchange resins

When the beds cannot remove any more ions, the ion exchange resins in each bed are regenerated using an appropriate solution (regenerant). The regenerant for a cation bed is made in a make-up tank using a strong acid solution, and the regenerant for an anion bed in another make-up tank is made using a strong alkali solution. For regeneration of a mixed bed, two regenerants used in the cation and anion beds are simultaneously utilized. Prior to regeneration, the beds are respectively backwashed to remove suspended solids by using demineralized water. After backwashing, the cation exchange resins and anion exchange resins in the mixed bed are separated into two layers based on the difference in density (the upper layer is the anion exchange resins and the lower layer is the cation exchange resins). Then, regenerants are respectively injected into the beds. In the case of a mixed bed, the regenerant for the anion exchange resins is injected into the top of the bed, and the regenerant for the cation exchange resins is injected into the bottom of the bed. Spent regenerants from the beds flow into a spent regenerant storage tank. When the injection of the regenerants is finished, the beds are rinsed with demineralized water to remove the residual regenerant between the resins. After rinsing, the cation exchange resins and anion exchange resins in the mixed beds are re-mixed with clean compressed air and the bed is refilled with demineralized water.

Spent regenerant in a storage tank is concentrated to the appropriate level using an evaporator. The vapor from the evaporator is condensed through the condenser and the condensate is injected into the ion exchange bed. Concentrate from the evaporator is moved to the dryer and dried out into a solid matter. This solid matter consist, mainly, of the salt from the regenerants and a small amount of the materials that exist in the suspended solids in the beds. Because its form is made up of irregular granules, it is ground to a power of a certain size using a pulverizer.

Finally, the powder from the pulverizer is solidified using an epoxy polymer. The powder and polymer are mixed in a mixer, and the mixture flows into the drum. The mixture is hardened and solidified into a solid waste form after a certain period of time.

The spent resins that can no longer be regenerated owing to the surpassing of their life time are discharged to the spent resins storage tank. They are then transferred to a HIC (High Integrity Container) or solidified with a polymer for disposal.

REGENERANT

Ion exchange resins generally used in a nuclear facility are gel-type strong acid cation resins for cation exchange and a gel type strong base anion resins for anion exchange. Resins in a mixed bed are a mixture of these resins. Strong acid cation resins can be regenerated with a regenerant using hydrochloric acid, nitric acid, or sulfuric acid. The strong base anion resins can be regenerated using sodium hydroxide. The acid or alkali concentration of the regenerant is within the range of 0.5 to 3 N. When two spent regenerants (for cation resins and anion resins) are mixed in the storage tank after regeneration, they are changed into salt (e.g., sodium chloride, sodium nitrate, or sodium sulfate) solution. The amount of salt in the solution depends on the kind of acid used. As shown in Fig. 2, the amount of salt in the solution increases in the order of hydrochloric acid, sulfuric acid, and nitric acid. Hydrochloric acid is slightly more preferable as a regenerant for cation resins in view of the waste amount.

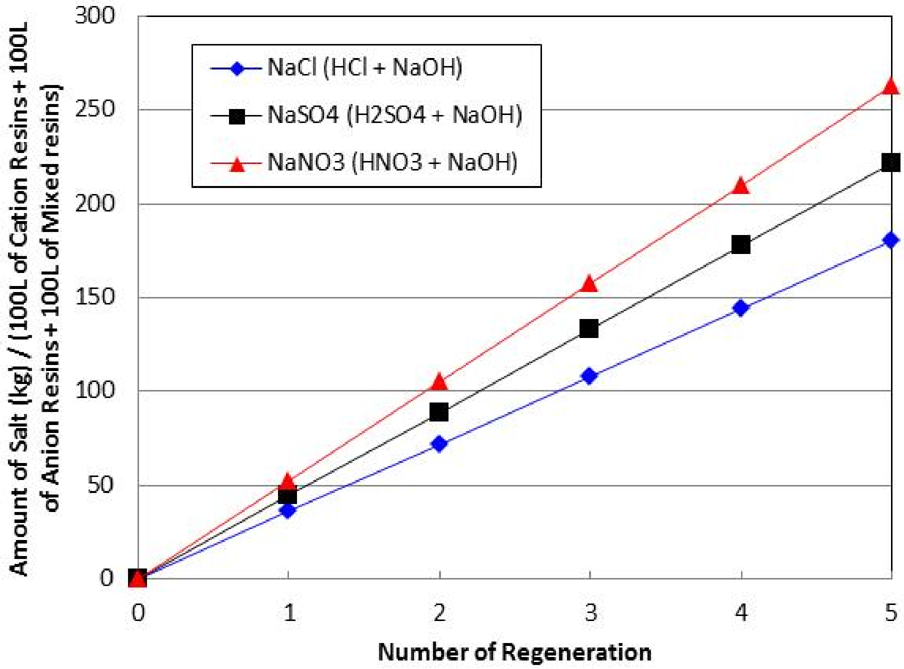

Fig. 2 Amount of salt through regeneration

ESTIMATION OF REDUCTION OF SPENT RESINS BY REUSE OF ION EXCHANGE RESINS

The final waste volume is estimated on the basis of a 100L cation bed, 100L anion bed, and 100L mixed bed. In addition, the regenerants are hydrochloric acid and sodium hydroxide. The salt loading in waste form is 40wt/wt%. If ion exchange resins are used without regeneration, the resins are changed into fresh resins when they reach the exchange limit and must be discarded as spent resins. On the other hand, if the ion exchange resins are reused through regeneration, the resins are not changed into fresh resins until the exchange capability of the resins can no longer be recovered through regeneration. (Although the media capacity decreases slowly owing to the degradation as regeneration increases, this effect was not considered at this stage. Only through our experience in preparing the make-up water used in the primary coolant of a reactor, could the resins be regenerated around seven times without severe degradation.) Therefore, when ion exchange resins are reused through regeneration, the volume of spent resins is constant regardless of the number of regenerations, but when ion exchange resins are used without regeneration, the volume of spent resins increases in direct proportion to the number of changes in the ion exchange resins. The volume of spent resins when the resins are reused with and without regeneration is shown in Fig. 3. If the ion exchange resins are reused once through regeneration and discarded as spent resins, the volume of spent resins is reduced in half as compared with the use of ion exchange resins without regeneration. In addition, if the ion exchange resins are reused twice, the volume of spent resins is reduced to a third as compared with the use of ion exchange resins without regeneration. However, in the case of regeneration, spent salt is generated as compared to no regeneration of resins. This salt is finally solidified into a polymer waste form. The volume of the polymer waste form increases directly in proportion to the number of regenerations. However, the volume of the polymer waste form of salt is only about one-fifth of that of spent resins, and the total waste volume (spent resins + polymer waste form of salt) through regeneration is smaller than the volume of spent resins from no regeneration. In addition, as the number of regenerations increases, the difference between the waste volume through regeneration and that by no generation increases. If the ion exchange resins are reused once through regeneration, the total waste volumes reaches about 60 % of the volume of spent resins when ion exchange resins are used without regeneration. However, if the ion exchange resins are reused five times through regeneration, the total waste volume is about 30 % of the volume of spent resins when the ion exchange resins are used without regeneration.

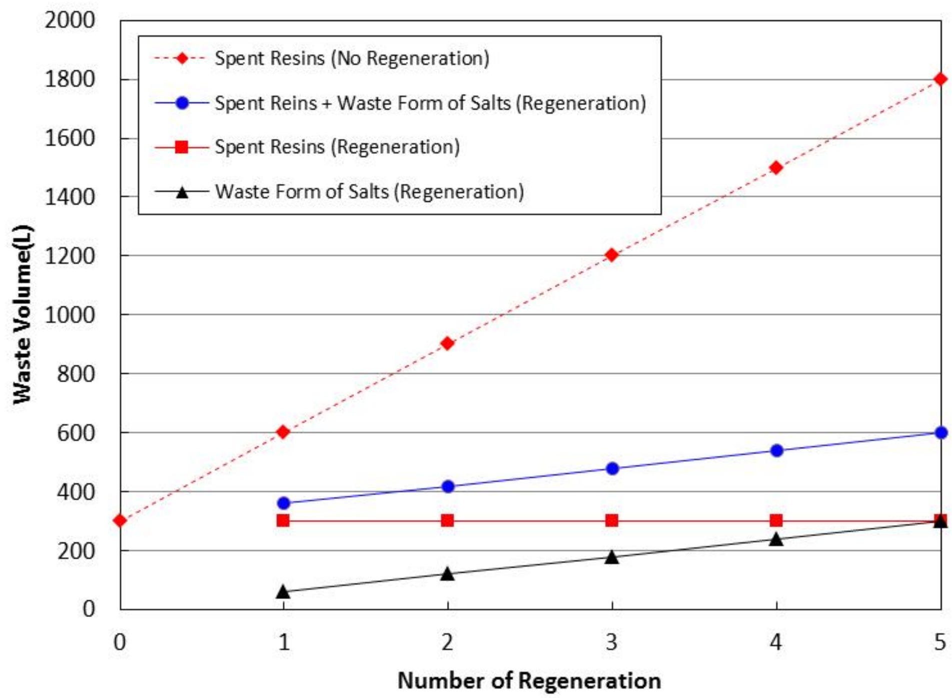

Fig. 3 Waste volumes through regeneration of ion exchange resins and with no regeneration of ion exchange resins

Basis : 100L of cation bed, 100L of anion bed, 100L of mixed bed

40 wt/wt% of salt (NaCl) in polymer waste form

SUMMARY

Ion exchange resins are used in the primary cooling system and radioactive waste treatment system of a nuclear reactor. When their exchange capacity reaches a certain limit, they are usually discarded as spent resins without reuse through regeneration owing to a difficulty in spent regenerant treatment. However,

according to the recent advances in technology for spent regenerant treatment, the reuse of ion exchange resins is now feasible.

To reuse ion exchange resins, a process was proposed in the present paper. The process consists of ion exchange beds for regeneration, regeneration make-up tanks, an evaporator, a dryer, and a mixer for polymer solidification. In addition, a spent resins storage tank and a spent regenerant storage tank are also involved in the process. When the ion exchange beds are regenerated, spent regenerant is generated from the beds. Spent regenerant is concentrated by the evaporator and dried out by the dryer. The product in the form of granule from the dryer is ground in the form of powder of a certain size using a pulverizer. The powder is mixed with polymer and finally solidified.

An estimation was performed for the final waste volume when the process for the reuse of ion exchange resins is applied, and compared with that when the ion exchange resins were used without regeneration. As the number of regenerations increases, the volume of spent resins is, clearly, inversely proportional to the number of regenerations. Although a polymer waste form is generated instead of spent resins when the ion exchange resins are reused, its volume is only about one-fifth of that of spent resins.

Therefore, it is expected that the process for the reuse of ion exchange resins will contribute significantly to a reduction of spent ion resins. This process has not been demonstrated yet in Korea, but demonstration will be conducted as soon as possible.

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