SPRAY DRYING OF BEAD RESINS:

FEASIBILITY TESTS

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ABSTRACT

Rockwell International has developed a volume reduction system for low-level reactor wastes based on drying the wastes in a heated-air spray dryer. The drying of slurries of sodium sulfate, boric acid, and powdered ion exchange resins was demonstrated in previous tests. The drying of bead ion exchange resins can be especially difficult due to the relatively large size of bead resins (about 500 to 800 microns) and their natural affinity for water. This water becomes part of the pore structure of the resins and normally comprises 50 to 60 wt % of the resin weight.

A 76-cm-diameter spray dryer was used for feasibility tests of spray drying of cation and anion bead resins. These resins were fed to the dryer in the as-received form (similar to dewatered resins) and as slurries. A dry, free-flowing product was produced in all the tests. The volume of the spray-dried product was one-half to one-third the volume of the as-received material.

An economic analysis was made of the potential cost savings that can be achieved using the Rockwell spray dryer system. In-plant costs, transportation costs, and burial costs of spray-dried resins were compared to similar costs for disposal of dewatered resins. A typical utility producing 170 m^3 (6,000 ft^3) per year of dewatered resins can save \$600,000 to \$700,000 per year using this volume reduction system.

BACKGROUND

Ion exchange resins are used at nuclear power plants to purify many liquid streams. These resins ultimately reach an end to their useful lifetime and become a low-level radioactive waste. Current disposal regulations require that low-level wastes contain less than 1 vol % free-standing water in the disposal container. Typical methods for preparing bead or powdered ion exchange resins for burial are based on the need for removing the water from the resins. Water is currently removed by centrifuging the resins or pumping on the resins. The dewatered resins are then shipped to burial sites in high integrity containers (HICs), or are solidified in immobilization agents such as cement, asphalt, or polymer.

Ion exchange resins are used in a powdered form, mean diameter 50 to 60 μ, and in a bead form, mean diameter 500 to 800 μ. Water that has been absorbed by the resins becomes an integral part of the resin structure. Water in the resins can increase the resin volume, increase the weight for disposal, and hinder achievement of high waste loadings in some solidification matrices.

Rockwell International has developed a volume reduction system for low-level reactor wastes that is based on drying the wastes in a heated-air spray dryer. Demonstration tests with this system were reported at Waste Management 1983.[1] In this previous work, full-scale tests were run in which slurries of sodium sulfate, boric acid, and powdered ion exchange resin-filter aid mixtures were dried. These slurries were dried completely, including the powdered resin.

Drying of resins can lead to significant cost savings by reducing the volume and weight of waste that is shipped to disposal. Drying of the larger bead resins is more difficult than drying of the smaller powdered resins because the larger resins have more internal pore structure and slower heat transfer to the center of the particle.

In the work described in this paper, the drying of the more difficult bead resins is reported using the Rockwell spray dryer system. An economic analysis is also presented which indicates that large cost savings can be achieved with the Rockwell system.

RESIN WATER CONTENT

Dewatered ion exchange resins still contain about 50 to 70 wt % water. Most of this water is contained in the internal pore structure of the resins. The ASTM procedure for determining the quantity of water in ion exchange resins specifies that the resins be dried for an unspecified length of time at 110°C.[2]

Preliminary tests were conducted by convection-drying of small samples of bead resins in ovens where dry air at a predetermined temperature was constantly blown over the beakers containing the bead resin samples. Ecodyne Gravex anion (GR-1) and cation (GR-2) bead resins were used for these studies. Initial tests indicated that these resins continued to lose weight even after 20 hours at 110°C. Essentially constant weight loss was found for both the anion and cation bead resins upon heating at 125°C for time periods of 20 to 100 hours. The anion resins, as received from Ecodyne, contained 65 wt % water. The as-received cation resins contained 35 wt % water. These values were used in later spray drying tests as being equal to the internally bound water content.

A schematic diagram of the Rockwell spray dryer volume reduction system is shown in Fig. 1. Resin waste is fed from a feed tank to the top of a heated-air spray dryer. There it is contacted with hot air inside the well-mixed zone of the spray dryer. The direct contact of the hot air and the resins accomplishes rapid drying of the resins. The dried resins become a free-flowing powder which is entrained in the

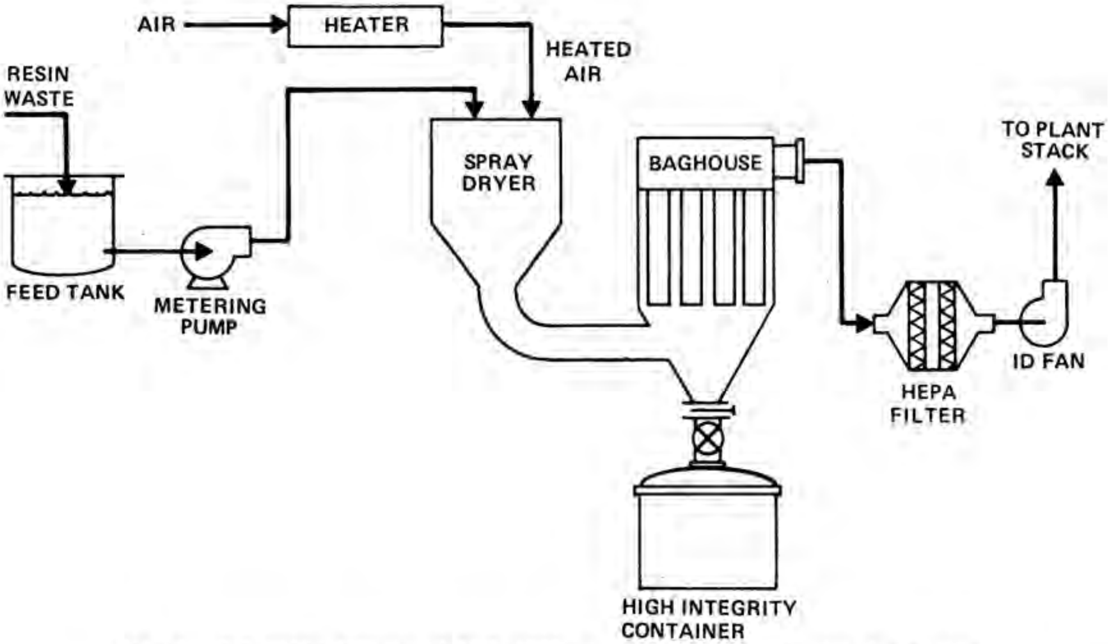

Fig. 1. Schematic diagram of Rockwell's spray dryer volume reduction system.

hot gas stream. The resin particulate is filtered from the gas using a baghouse. Baghouses are rapidly becoming standard particulate removal devices in coal-fired power plants because they are dependable and have high collection efficiencies. The dried resins are collected in a product hopper or, alternatively, in a 0.2-m^3 (55-gal) drum or a high integrity container. The cleaned off-gas is passed through a HEPA filter and into the plant off-gas system.

A 76-cm-diameter spray dryer was used for the tests reported here. This is approximately the same size required for many operating nuclear power plants. In our test system heated air for the dryer is provided by a natural gas burner. At a power plant site the cost of electricity is more economical and an electric air heater would be used. The temperature of the drying air was controlled by the amount of natural gas fed to the burner. Temperatures were measured using thermocouples, and gas flow was determined using an annubar flowmeter. A photograph of one of Rockwell's 76-cm-diameter spray dryers is shown in Fig. 2.

RESULTS OF SPRAY DRYING TESTS

Tests were conducted using four different types of feedstocks: as-received anion resins, as-received cation resins, a 16.5 wt % (dry weight) cation slurry, and a 10.5 wt % (dry weight) anion slurry. The as-received resins are representative of dewatered resins which are normally shipped for burial. The slurries are representative of resins before dewatering operations. Both types of waste may be processed in the Rockwell system.

The results of the spray drying tests are shown graphically in Fig. 3. In all of the tests, the "nonbound" water, that is, the interstitial water and the free-standing water, was completely evaporated. In addition, a portion of the "bound," or pore water, was removed. The bead resins were found to lose more bound water as drying temperature increased. At temperatures near 100°C, the water loss was only 25 to 30% of the absorbed water; the water loss increased to over 60% at temperatures of 200°C, and complete drying was achieved at higher temperatures in the spray dryer. The fraction of the water removed was, therefore, a function of drying temperature, with the cation and anion bead resins losing essentially the same percentage of water at the same drying condition. Similarly, the amount of water retained by the resins was independent of whether the resins were fed to the spray dryer as an as-received material or as a resin-water slurry. The bulk and tap densities of the spray-dried resins were similar to the bulk and tap densities of the as-received resins. Volume reduction is achieved because the spray-dried product has much less mass (due to water evaporation) than the initial as-received resins.

Figure 3 also shows a comparison of the water loss for convection-dried resins and spray-dried resins. The convection-dried resins were held at temperature for 20 hours, whereas the spray-dried resins were at temperature for only 4 or 5 seconds. Thus, the convection-dried resins lost a considerably greater fraction of water. For example, at 100°C, the convection-dried resins lost 95% of the water; the spray-dried resins lost less than 30% of the water.

Fig. 2. Photograph of 76-cm-diameter spray dryer.

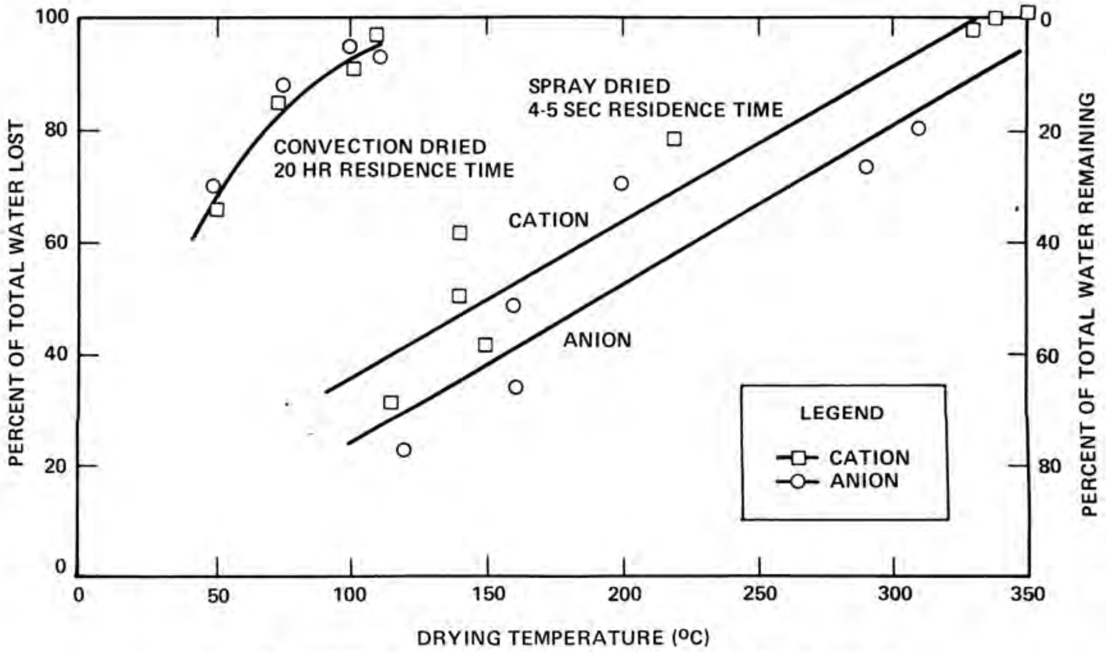

Fig. 3. Percent of bound water lost during bead resin drying.

Ion exchange resins contain a relatively large weight fraction of sulfur and nitrogen (typically in the range of 5 to 10 wt %). Sulfur is found in the cation resins as a sulfonic acid group; nitrogen is found in the anion resins as amine groups. These groups give the resins their distinct ability to selectively remove radioactive ions. However, at high temperatures, in an excess air atmosphere, the sulfur and nitrogen have the potential to form SO_2 and NO_x. Measurements of SO_2 and total NO_x during the spray drying tests indicated that these emissions were negligible.

VOLUME REDUCTION

The evaporation of water from low-level waste reduces the volume of the waste. The amount of volume reduction is a function of the type of waste and the condition under which the waste was dried. For example, anion bead ion exchange resins have a volume reduction of a factor of 3 as compared to dewatered (as-received) resins if all of the bound water is lost. If less bound water is lost, the corresponding volume reduction is reduced (to factor of 2 or less). Table I summarizes the volume reduction factors that have been demonstrated for the Rockwell spray dryer system. This table compares the initial volume of waste with the final volume of the spray-dried product solids collected at top density and with the final volume of the spray-dried solids that have been solidified in Dow polymer (a type of solidification matrix). The spray-dried product is also compatible with cement or asphalt solidification matrices.

The final waste form that is acceptable for burial is dependent on the activity and radionuclides in the waste. Concentrated salt slurry, such as 25 wt % sodium sulfate, is reduced to about one-half its original volume. Boric acid slurry and dewatered resins are reduced to about one-third their original volume and resin slurries to about one-sixth their original volume.

TABLE I

Demonstrated Volume Reduction Factors for Spray-Dried Low-Level Wastes

Type of Waste	Initial Volume (m^3)	Product Volume	
		Dry Powder (m^3)	Powder Solidified in Dow Polymer (m^3)
Na_2SO_4 (25 wt %)	1.0	0.48	0.57
H_3BO_3 (12 wt %)	1.0	0.29	0.29
Powdered resin slurry (9 wt % dry basis)	1.0	0.29	0.17
Bead resin slurry (10.5 wt % dry basis)	1.0	0.17	0.13
Dewatered bead resins (35 wt % dry resin)	1.0	0.35	0.30

ECONOMIC ANALYSIS

One method for disposal of ion exchange resins that is commonly used is to dewater the resins in a high integrity container (HIC) and ship the container to a burial site for disposal. In the economic analysis presented here, this method of disposal is compared to disposal of spray-dried resins. In the spray-drying alternative, spent power plant resins are dried and loaded into HICs and shipped to burial. A volume reduction factor of 2 is used for the sample calculation. Additional cost bases are given in Table II.

TABLE II

Example of Cost Bases for Disposal of 170 m^3 (6000 ft^3) of Ion Exchange Resins Per Year

Cost Base	Dewatered Resins	Spray-Dried Resins
Waste volume	170 m^3/yr (6000 ft /yr)	85 m^3/yr (3000 ft^3/yr)
Water activity	7 μCi/cc (0.2 Ci/ft^3)	14 μCi/cc (0.4 Ci/ft^3)
Volume reduction factor		2
Disposal container	4.5 m^3 (160 ft^3) HIC w/ internal plumbing; 2.8 m^3 (100 ft^3) waste volume	4.5 m^3 (160 ft^3) HIC w/o internal plumbing; 4.1 m^3 (145 ft^3) waste volume
HIC cost	$6,500/HIC	$4,500/HIC
Disposal site	Barnwell, SC; 1984 rate schedule	Barnwell, SC; 1984 rate schedule
Distance to disposal	800 km (500 miles)	800 km (500 miles)
Transportation costs	$0.90/km ($1.50/mile) $250/day cask rental	$0.90/km ($1.50/mile) $250/day cask rental
Labor	$25/hr	$25/hr
HICs required	60	21
Total activity	20 Ci/HIC	58 Ci/HIC
Surface activity (calculated)	3.6 R/hr	7.2 R/hr

The cost calculations have been divided into three categories: in-plant costs, transportation costs, and burial costs. In-plant costs consist of the cost of HICs and operating and maintenance costs. Transportation costs consist of the cost per distance and the cask rental charges. Round trip transportation has been chosen for representative burial rates. Burial costs consist of the cost of burial in shallow land sites. In this case the Barnwell site has been assumed. As an example of the economic analysis, a power plant producing 170 m^3 (6000 ft^3) of ion exchange resins per year is used, the resins having an activity of 7μCi/cc (0.2/Ci ft^3).

A summary of the economic analysis is presented in Table III. Substantial cost savings can be achieved in all three cost categories. The volume reduction is large enough that the increased costs due to higher activity in the dried waste are not significant. The costs for disposal of 170 m^3 (6000 ft^3) per year of dewatered resins are estimated at $1,066,300 per year. The costs of spray drying and disposal of this same waste are estimated at $428,600 per year. Thus, an annual savings of $638,000 per year can be realized using the spray dryer system.

TABLE III

Summary of Economic Calculations for Disposal of 170 m^3 (6000 ft^3) of Ion Exchange Resins per Year

Transportation	Dewatered Resins (per year)	Spray-Dried Resins* (per year)
In-Plant	$ 471,000	$181,500
Transportation	118,500	41,500
Burial	476,800	205,600
Total	$1,066,300	$428,600
Annual savings = $638,100 per year		

*Volume reduction by a factor of 2

A similar analysis can be made in which the quantity of resins produced at the power plant is varied while other variables are held constant. The results of these calculations are shown in Fig. 4. In this figure the annual savings are plotted versus the quantity of dewatered resins which are spray dried. Calculations were made for volume reduction by a factor of 2 and 3. The annual savings increase from about $275,000 per year at a throughput of 70 m^3 (2,500 ft^3) per year to about $1,600,000 per year at a throughput of 425 m^3 (15,000 ft^3) per year. These substantial cost savings make the spray dryer a very attractive investment.

REFERENCES

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2. "Standard Test Methods for Physical and Chemical Properties of Particulate Ion-Exchange Resins," D 2187-77, American Society for Testing and Materials, Philadelphia, Pennsylvania

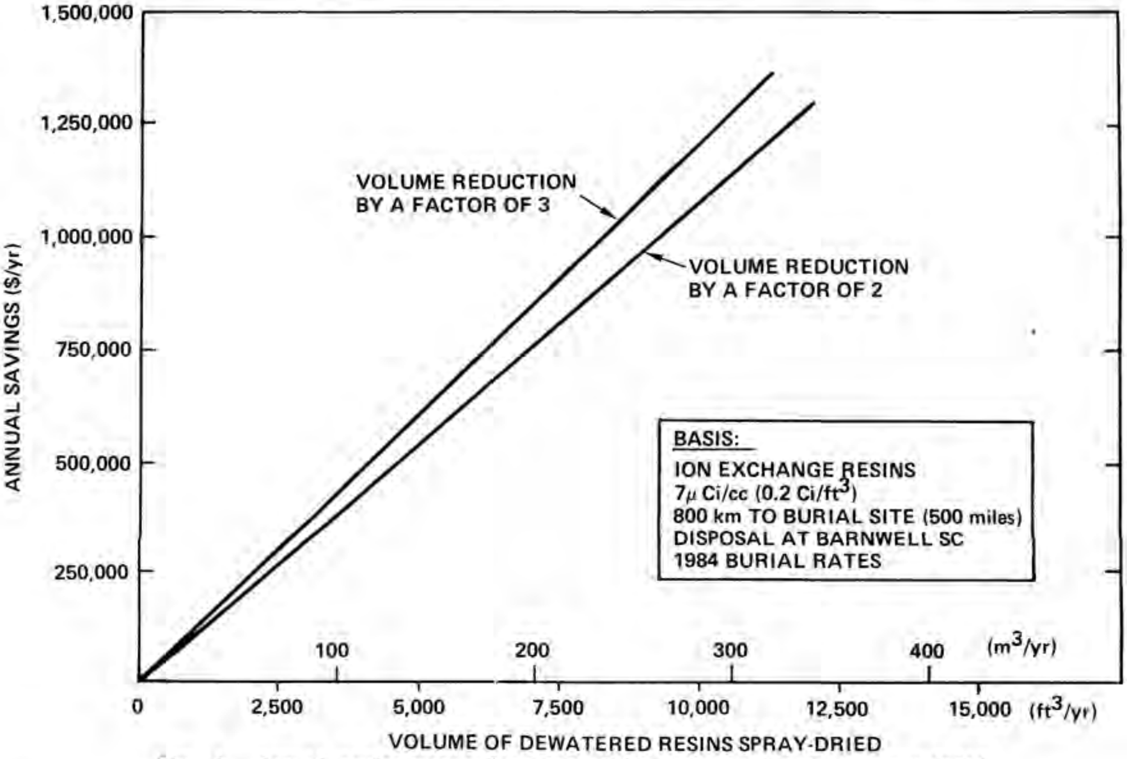

Fig. 4. Annual savings as a function of the volume of resins spray-dried