RADWASTE DISPOSAL DRUM CENTRIFUGE

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ABSTRACT

During Waste Management '86 the Disposal Drum Centrifuge (DDC), a unique technology for processing radioactive spent resins, was introduced to the public. This novel centrifuge which is patented by Foster-Miller, Inc. reduces the residual moisture of processed spent resin to below as-received levels and also substantially reduces the volume of resin packaged for disposal. The drum or processing bowl of the DDC becomes the disposal container when the filling operation is completed. Rehandling of the processed resin is eliminated. By allowing the centrifugally compacted resin to remain in the processing container, extremely efficient waste packaging can be achieved.

The dewatering results and volume reductions reported during 1986 were based upon laboratory scale testing sponsored by the Electric Power Research Institute (EPRI) and the Department of Energy (DOE). Since the publication of these preliminary results, additional testing using a full-scale prototype DDC has been completed, again under the auspices of the DOE. Full-scale testing has substantiated the results of earlier testing and has formed the basis for preliminary discussions with the U.S. Nuclear Regulatory Commission (NRC) regarding DDC licensing for radioactive applications.

A comprehensive Topical Report and Process Control Program is currently being prepared for submittal to the NRC for review under a utility licensing action. Detailed cost-benefit analyses for actual plant operations have been prepared to substantiate the attractiveness of the DDC. Several methods to physically integrate a DDC into a nuclear power plant have also been developed.

The intent of this renewed presentation at Waste Management '88 is to update the utility industry as to the status of the DDC program and to interest organizations who can assist Foster-Miller with the commercialization of the DDC.

INTRODUCTION

Disposal of radioactive spent resin is a serious problem which contributes to the escalating costs of operating a nuclear utility. Factors such as the enactment of the LOW LEVEL WASTE POLICY ACT OF 1980 (and 1985 amendment) and the closing of all but three commercially available radioactive waste disposal sites are forcing nuclear utilities to implement spent resin waste processing techniques that more efficiently and safely reduce waste volumes.

Three spent resin processing techniques are presently utilized by most of the 90 plus operating nuclear power plants in the U.S. These techniques include:

- Liner dewatering (with or without thermal processing)
- Solid bowl centrifuge dewatering
- Solidification.

Each technique, when originally implemented, represented the best available technology for the given utility. Some or most of these processing techniques have been outdated by changing regulations and ever increasing disposal costs.

Liner Dewatering

Liner dewatering is the simplest and most common resin processing technique presently utilized by U.S. nuclear utilities. This batch process utilizes a steel or high density polyethylene liner that is equipped with internal perforated piping. As resin slurry is pumped into the liner, an external pump applies a vacuum and removes water via the internal piping. This process is typically a vendor supplied service in which the vendor guaranties compliance with existing regulations controlling the allowable volumes of excess free water.

Liner dewatering, while offering a low cost and simple technique for processing spent resins, has two inherent disadvantages. The first disadvantage is that this technique can not completely ensure that the free water content within the liner is less than 0.5 percent by volume (regulation for burial disposal). Recent processing techniques have been implemented which utilize thermal cycling to remove excess water. This thermal approach is effective but requires up to 24 hours to process a single drum.

The second disadvantage of liner dewatering is attributed to the inefficient packaging of the processed waste. Liner dewatering effectively utilizes only 75 to 90 percent of the liner's inner volume. Utilities, in essence, are paying to bury voids.

Solid Bowl Centrifuge

Solid bowl centrifuge processing is a continuous feed operation which produces a dewatered resin with a moisture content that is below that of the as received (manufacturer shipped) product. Compliance with resin moisture content regulations for burial disposal can be guaranteed, barring equipment or process upset.

The primary disadvantages associated with the solid bowl centrifuge fall into three major categories; maintenance, waste volume and process control.

The solid bowl centrifuge is mechanically complex and utilizes tight component tolerances. This results in maintenance requirements which are considered high by nuclear utilities. Personnel exposure, decontamination of equipment and component repairs can only add to the final cost of waste disposal.

As dewatered solids (resin) are discharged from the centrifuge, the waste product entrains air resulting in a fluffy waste. Waste volumes can increase by as much as 50 percent when compared to existing processing techniques, if further processing (i.e., drum vibration, mechanical tamping) is not implemented.

Process control of the solid bowl centrifuge also presents another major disadvantage over other waste processing systems. Resin slurry feed concentration, internal centrifuge liquid levels and dewatered resin discharge into a waste container must be carefully controlled. The potential for liquid or resin spilling as a result of process control failures increases the risk of operation and maintenance exposure. Recovery from operational failures with the solid bowl centrifuge is also more difficult than alternative processing techniques.

Solidification

Solidification is a batch process which utilizes a secondary agent to bind resin and water into a monolith. Portland cement is the most commonly used solidification agent. Bitumen, masonery cement and thermosetting plastics are also used as resin/water binders. Solidification agents are selected to minimize monolith decomposition, limit leachability and provide waste stability for burial. Solidification containers, due to the stability of the processed waste, can be of simpler construction (i.e. lower cost) than the burial containers which must be used with other resin processing techniques.

Solidification techniques, however, always increase the resin's waste volume. Utilities that employ solidification processes typically produce a spent resin waste volume that is 140 to 160 percent higher than the volume of purchased resin. The cost tradeoff of less expensive containers versus greater waste volumes has lost its attractiveness due to increasing disposal rates and decreasing disposal site availability.

Waste stream chemistry can also generate problems since it influences the resin to binder ratio and, thus, the ultimate long-term stability of the final product. The presence of boric acid, detergents and/or organics in the waste stream can retard or preclude waste stabilization when Portland cement is used as the binder. The process controls associated with the measurement, monitoring and mixing activities of the solidification process can also add to the difficulties in producing a stable waste that is suitable for burial disposal.

DISPOSAL DRUM CENTRIFUGE

In response to the inherent disadvantages of current spent resin processing techniques, Foster-Miller has developed a novel centrifuge which produces a waste product with reduced volume and zero free water. The inner bowl of this centrifuge, the Disposal Drum Centrifuge (DDC), when full of processed resin, becomes the disposal container. Rehandling or repackaging of the processed resin is eliminated. By allowing the centrifugally compacted resin to remain in the container, the waste volume can be reduced by as much as 40 to 50 percent when compared to existing resin processing techniques. Centrifugal processing also produces a dewatered product with zero free water. In fact, DDC processed resin is typically drier than manufacturer shipped resin. The mechanical design of the DDC is uncomplicated, overcoming many of the pitfalls of past centrifuges which have been used for spent resin processing. Maintenance requirements on our full-scale prototype have been low.

Figure 1 is a conceptual illustration of the DDC near the end of its operational cycle. The inner drum with integral top is the disposal container. Radwaste slurry is pumped into the centrifuge through a centrally located hole in the top of the disposal container. Centrifugal action forces the liquid and solids outward to the fine mesh screen which parallels the tapered wall of the disposal drum. Solids are retained by the screen as water passes into the

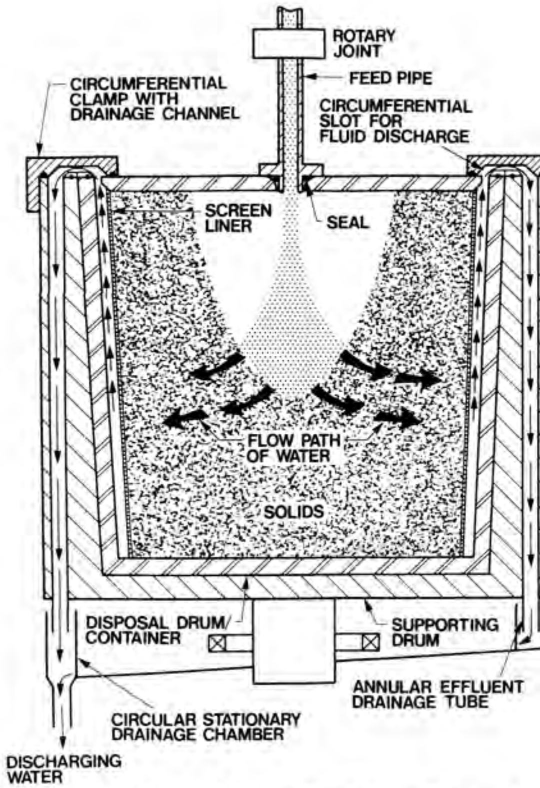

Fig. 1. Disposal Drum Centrifuge Concept.

Fig. 2. Full-Scale Prototype Disposal Drum Centrifuge.

circumferential passage that is formed between the screen and disposal drum wall. The centrifugal action forces the water to migrate to the top of the disposal drum where it discharges through the circumferential drainage slots. Discharging water is channeled into the annular effluent drainage tubes by the circumferential clamp. Gravity forces the water to drop through the effluent drainage tubes and into the stationary drainage chamber. Feed continues until the drum is filled with solids. At this point, operation is terminated, the drum is removed, openings are sealed, a new drum is inserted and the process is repeated.

The latest generation prototype DDC, Fig. 2, utilizes a commercially available waste container as its processing drum. This waste container is similar in size to a 55-gal drum (internal dimensions) and is manufactured by BONDICO NUCLEAR. A Topical Report has been submitted to the NRC to qualify this container as a High Integrity Container (HIC).

The DDC has been designed to accommodate the BONDICO container without affecting its integrity or external structure. The general operation of the prototype DDC is similar to that of the DDC concept illustrated in Fig. 1.

DDC TEST PROGRAM, PROCEDURES AND BASELINE DATA

Using the prototype DDC and an earlier version which utilized a steel disposal drum instead of the BONDICO container, a series of processing tests were conducted at various centrifugal forces (g-levels) ranging from approximately 100 g's to 500 g's. Tests were conducted using two different resins, Ecodex X-203-H (powder) and IRN-150 (bead). Prior to initiating the test program both resins were analyzed for their as-received moisture content. Table I lists these results.

To quantitatively determine the effectiveness of the DDC process, baseline data was developed using the same DDC test resins. Liner dewatering, the most commonly

TABLE I

Moisture Content of As-Received Resin

Resin	Moisture Content of As-Received Resin (% by Weight)	Manufacturer Specified Moisture Moisture Content Range (% by Weight)
Ecodex X-203-H	70.0	60 to 70
URB-150	54.5	50 to 55

employed resin processing technique, was selected as our baseline process.

A 55-gal drum was fitted with dewatering laterals in a similar arrangement and scale to existing dewatering liners. A controlled resin slurry feed using known weights of as-received resin and water was metered into the dewatering liner. Vacuum was applied to the dewatering laterals to remove water. After the initial dewatering was complete, vacuum was reapplied daily until no additional water could be extracted. The weight and the moisture content of the retained resin were recorded and used as our baseline conditions for comparing DDC process performance.

The results of the liner dewatering tests (packing density and moisture content) are summarized in Table II.

DDC testing was conducted using the following procedures:

- Prepare a resin slurry feed by combining known weights of as-received resin and water (10-12 percent resin by weight)
- Bring the centrifuge to the desired g-level
- Meter the resin slurry into the DDC through the stationary feed pipe
- Continue to operate the DDC for 10 minutes after total drum filling is achieved
- Bring the centrifuge to rest, measure the volume of discharged water, measure the weight of the retained resin and collect and prepare a number of samples of dewatered resin for oven drying to determine moisture content.

TABLE II

Summary of Liner DeWatering Test Results

Resin	Moisture Content of Retained Resin (% by Weight)	Packing Density (lb of Bone Dry Resin per Ft^3)
Ecodex X-203-4	78.9	10.5
IRN-150	57.8	17.5

PROTOTYPE DDC TEST RESULTS

Analysis of the prototype DDC test data has been divided into two separate categories:

- Volume Reduction (VR)
- Dewatering.

Volume Reduction

The DDC produced packing densities for Ecodex X-203-H and IRN-150 resins are plotted as a function of centrifugal force in Fig. 3 and 4, respectively. Liner dewatering packing densities are superimposed on these graphs for comparative purposes.

Processing of Ecodex X-203-H on the prototype DDC produced a waste which has a VR that ranged from 1.43 to 1.95 when compared to our baseline data obtained using liner dewatering. IRN-150 processing on the prototype DDC produced a VR that ranged from 1.13 to 1.26 when compared to the liner dewatering packing density. The range in VRs obtained with the powder resin (Ecodex) indicates that higher g-levels will produce higher VRs. The VRs obtained with bead resins appear to be relatively unaffected by the g-levels tested. Optimum VRs with bead resins apparently are obtained at g-levels of less than 80 gs.

Resin Dewatering

The moisture content of the retained resin produced by the prototype DDC is plotted as a function of centrifugal force in Fig. 5 and 6 for Ecodex X-203-H and IRN-150, respectively. The moisture content of the as-received resins and the moisture content of the liner dewatering products are superimposed on these graphs for comparative purposes.

DDC processing of Ecodex X-203-H produced a dewatered resin that contained 4 to 14 percent less water than the as-received resin. Liner dewatering produced a processed resin that had 13 percent more water than the as-received resin.

IRN-150 processing on the prototype DDC resulted in a dewatered resin that contained 0 to 5 percent less water than the as-received resin. Liner dewatering produced a resin that had 6 percent more water than the as-received resin.

All of the prototype DDC test runs, regardless of g-level, produced a resin with a moisture content that was considerably less than those produced by liner dewatering. In fact, all but two of the DDC test runs produced a dewatered resin that was drier than the as-received resin. This process capability virtually assures compliance with the free water regulations for burial containers not employing solidification techniques (0.5 percent free water by volume for containers not certified as HICs, 1.0 percent free water by volume for HICs). Water not liberated by centrifugal forces

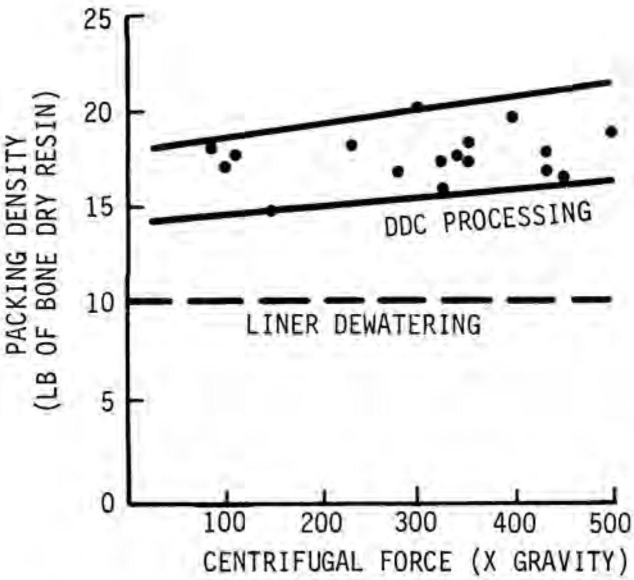

Fig. 3. Ecodex X-203-H Packing Density Test Results.

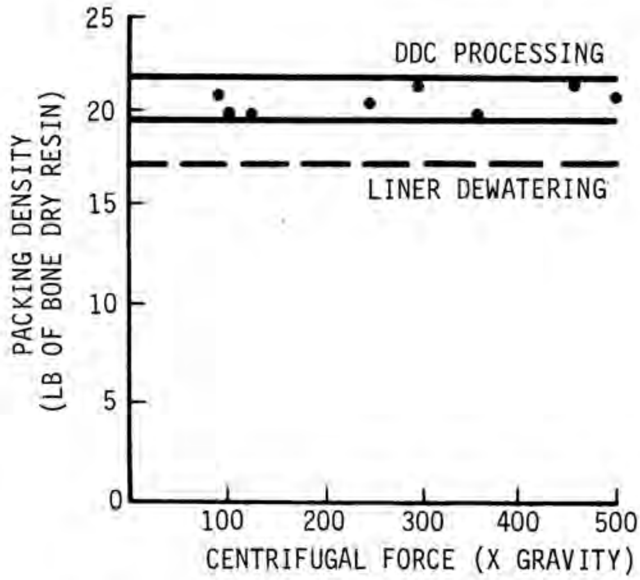

Fig. 4. IRN-150 Packing Density Test Results.

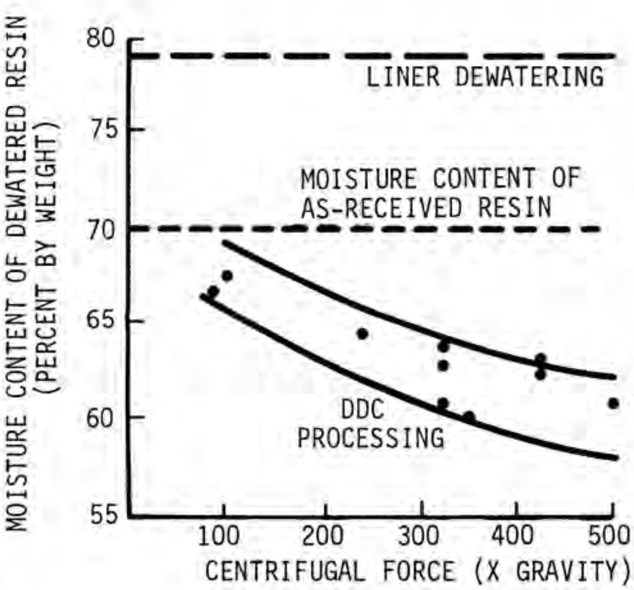

Fig. 5. Ecodex X-203-H Dewatering Test Results.

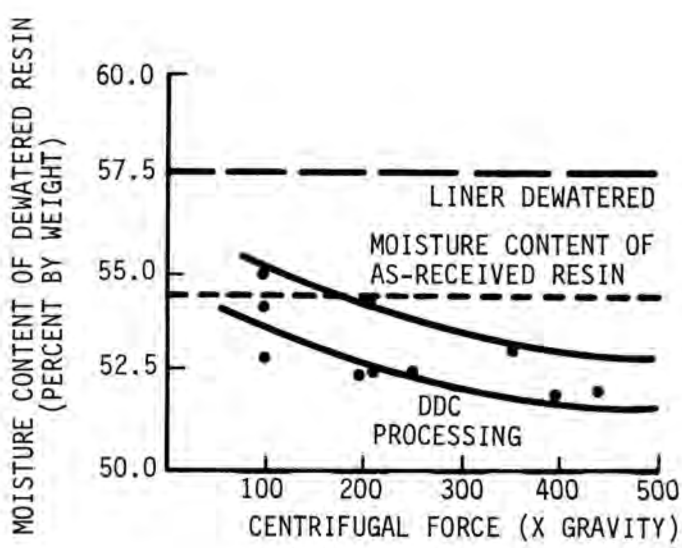

Fig. 6. IRN-150 Dewatering Test Results.

TABLE III

Summary of DDC Test Results

	Ecodex X-203-H	IPN-150
As-received moisture content (% by weight)	70.0	54.5
Moisture content using liner dewatering (% by weight)	78.9	57.8
Moisture content using DDC (% by weight)	60.0-67.5	52.1-55.0
VR using liner dewatering	1.0	1.0
VR using DDC	1.43-1.95	1.13-1.26

ranging from 100 to 500 gs is unlikely to reappear as free water in a one-g environment.

A summary of the prototype DDC test results including as-received resin moisture content and liner dewatering test results are compared in Table III.

DDC PLANT INTERFACING

The DDC process can be either a vendor-supplied process or one that is a fixed plant installation. Regardless of how the DDC is implemented, the DDC's rather simple overall process and operating requirements make this system a much easier process to integrate into a nuclear utility than solidification or solid bowl centrifuge processes. Plant interfacing requirements are basically similar to those required with liner dewatering.

A process and instrumentation schematic illustrating one of many potential DDC plant interfacing systems is presented in Fig. 7. In operation the spent resin is kept in suspension within the storage tank by recirculating the resin through plant plumbing and back into to storage tank. The DDC is turned on and once it has reached the desired rotational speed, resin slurry is diverted to the DDC metering pump and recirculated back to the spent resin tank. When all flows have been stabilized the three-way valve above the DDC is switched from the recirculation position to the DDC feed position. Separated water discharging from the DDC is temporarily held in the collection tank and returned to the utility's water system. When the DDC drum/container is filled with resin, the three-way valve above the DDC is switched to recirculation. Resin slurry recirculation is then terminated as flush water is introduced into the DDC piping system. The three-way valve is cycled to the DDC feed position to permit flushing of the DDC feed pipe. The flushing is then terminated, the DDC is stopped, the DDC container is removed, a new container is inserted and the operation is repeated.

DDC ECONOMIC EVALUATION

The following economic evaluation compares the DDC process using the BONDICO NUCLEAR, 55-gal waste container to each of three differently sized dewatering liner processes (80, 120 and 170 cubic feet). Both bead resins and powder resins have been included in this analysis. Specific factors addressed by this analysis include:

- Waste characteristics
- Burial
- Internal container volume
- Transportation costs
- Burial costs (including surcharges and handling fees)
- Container costs
- Waste packaging efficiency
- Curie content
- Contact radiation levels
- VR factors.

Waste data from the Brunswick Nuclear Power Plant (1985) and EPRI Report NP-3370, the most current burial rates (January 1988) for both the Barnwell and Hanford burial facilities, and the VR factors generated during prototype DDC testing at 400 to 500 g's have been used to form the foundation for this analysis. Transportation costs have been based on a 600 mile shipping distance and on current vendor charges for shipments to Barnwell. All wastes are packaged in High Integrity Containers.

This analysis did not take into consideration such costs as plant modifications, vendor services costs, or waste processing operation costs.

The EPRI NP-4757 Radwaste Campaign Cost Program modified to reflect the most current burial costs and costs for non-sited region generators was used to generate the total disposal cost for both processing technologies considered.

The results of the economic evaluation are graphically illustrated in Fig. 8. The costs plotted on the y-axis of this graph represent the costs to dispose equal quantities (volumes) of as-received resins. DDC processing of powder resins results in a disposal cost that is 44 to 60 percent lower than liner dewatering. Savings decrease as the dewatering liner increases in size. DDC processing of bead resins is less

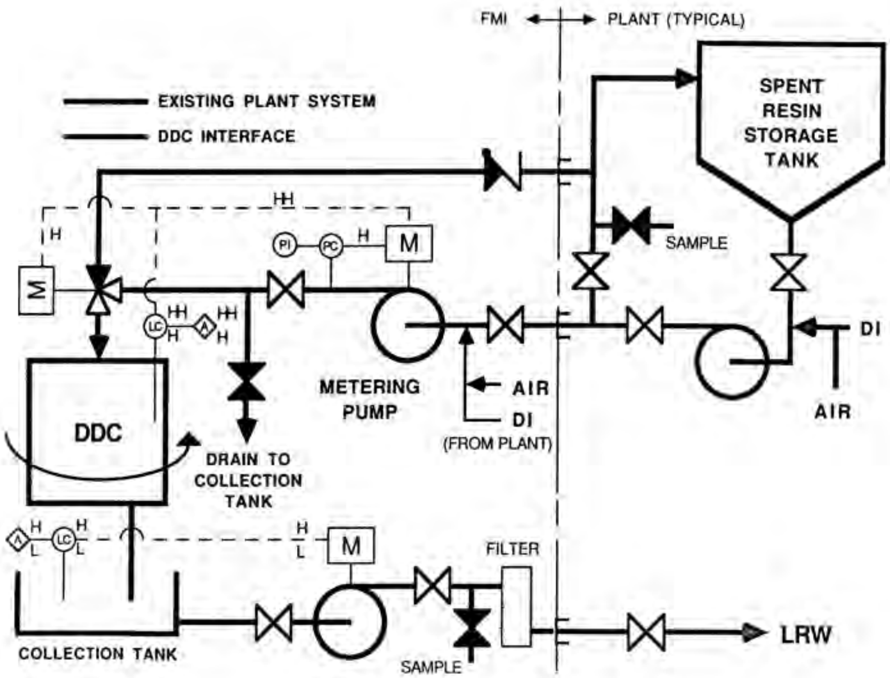

Fig. 7. Disposal Drum Centrifuge - Plant Interface.

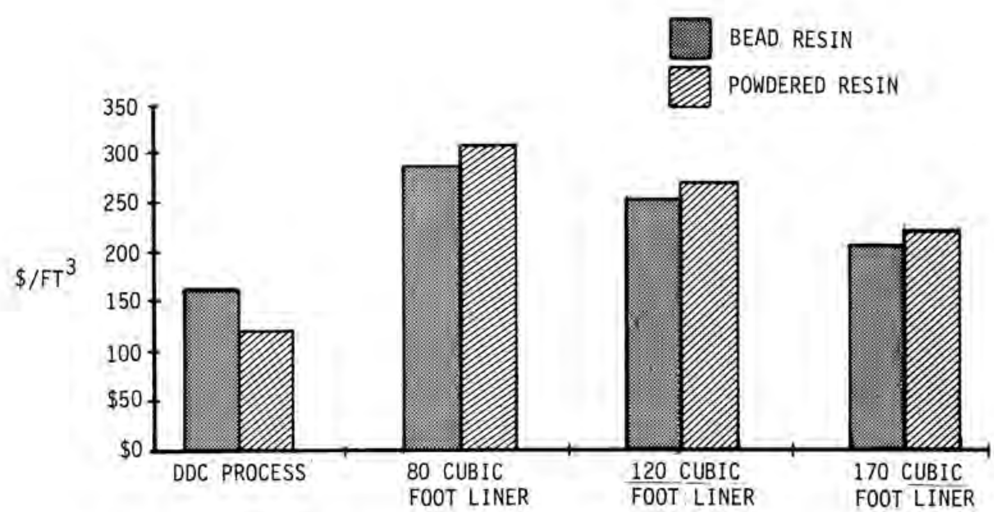

Fig. 8. Relative Cost to Dispose Equal Quantities of Pre-Processed Resin.

dramatic, but nevertheless is still significant. Disposal costs can be reduced by 18 to 43 percent.

The projected costs savings in terms of 1988 dollars that can be attained by employing DDC processing instead of liner dewatering for the average BWR and the average PWR are summarized in Table IV. The range in savings is again a function of the size of the dewatering liner.

FUTURE DDC ACTIVITIES

Future activities scheduled for the DDC include:

- Selected DDC testing with chemically exhausted resins to confirm the same favorable DDC process capabilities demonstrated to date

TABLE IV

Project Cost Savings (1988)

	Waste Volume (ft^3/year)	Cost Savings ($/year)
Average BWR	Power - 3,958 Bead - 2,814	400,000 - 966,000
Average PWR	Powder - 316 Bead - 869	65,000 - 150,000

- Preparation of a DDC Topical Report and a DDC Process Control Program for submittal to the NRC.

Phase I and Phase II of this DDC program have been funded by the DOE under the Small Business Innovative Research (SBIR) technology development program. Foster-Miller is currently completing Phase II of this SBIR program while seeking Phase III funding from non-Government sources to support marketing, sales and vendor related services to the nuclear industry. We welcome the opportunity to discuss strategic partnering arrangements with interested organizations.