RADWASTE DISPOSAL DRUM CENTRIFUGE

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ABSTRACT

Proper treatment and packaging of spent radioactive ion-exchange resins from nuclear plant operations has been recognized as a concern for many years. Dewatering techniques have frequently failed to guarantee acceptable levels of free standing liquid in burial containers, and have generally not been successful in reducing the presence of "interstitial water" bound to resin media. Furthermore, most available processing techniques have not resulted in any substantial volume reduction of the waste. In fact, there has normally been a volume increase when packaging resin, due either to void volume in the container or to the addition of a solidification media.

In response to these process deficiencies, Foster-Miller, Inc. (FMI) has conceived and patented a novel type centrifuge for reducing the residual moisture content of resin below as-received levels, and substantially reducing the volume of spent ion-exchange resins prepared for disposal. The drum/bowl of the Disposable Drum Centrifuge (DDC) doubles in function as the terminal disposal container, thus eliminating rehandling after the dewatering task, and optimizing the efficiency of overall packaging operations.

The centrifugal action of the DDC results in a final waste product that will consistently retain considerably less free water than is permitted by regulations, while significantly reducing the residual (interstitial) moisture of the material. Centrifugal compaction can reduce the ultimate burial volume by as much as 55%, thereby yielding a VR = 2.2. An analysis of the DDC's economics indicate that a typical BWR employing DDC processing can easily save in excess of $600,000/year in resin packaging and disposal costs, based on present transportation and disposal cost schedules.

Because the DDC design is simple to operate, does not expose any complex rotating centrifugal components to radioactive materials, and does not require complex seals, it overcomes many of the liabilities of present centrifuges. Operational availability is expected to be very high, while maintenance requirements are expected to be very low. The actual disposal drum will be licensed as a High Integrity Container (HIC), thereby permitting direct burial of the centrifugally dewatered and compacted resin waste.

INTRODUCTION

Proper disposal of the nuclear industry's spent resins has been recognized as a serious problem in terms of waste volume and levels of free water remaining in the disposal liner. In the more than 70 operating nuclear power plants in the United States, three methods are utilized for preparing the spent resin for burial disposal. These methods are:

1. solid bowl centrifuge dewatering;
2. liner dewatering;
3. solidification.

Each of these techniques possess certain undesirable characteristics. Solid bowl centrifuge dewatering can reduce the moisture content of the spent resin to a level which is lower than the as-received product. The discharged dewatered product, however, typically becomes fluffy in nature as it entrains air and frequently increases the waste volume by as much as 100%. Liner dewatering effectively utilizes only 75 to 90% of the liner's inner volume and cannot ensure the 0.5% free water requirement. A lingering fear of liner dewatering excess free water is either realized or suspected by many waste management personnel. Solidification techniques always increase the total volume of spent resin and its long-term stabilization remains somewhat undefined.

In response to the process deficiencies associated with current spent resin processing techniques, FMI is developing a novel type of centrifuge for reducing waste volume and water content of this low level radioactive waste. This device, the DDC, allows the drum of the centrifuge to double in function as the terminal storage/disposal container. Rehandling of the processed resin is eliminated. By allowing the centrifugally compacted resin to remain in the processing container, the disposal volume can be reduced by as much as 55% when compared with present processing techniques. Centrifugal processing also produces a final 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 that have been applied to this application. Maintenance requirements are expected to be low.

DESCRIPTION OF THE DDC

Figure 1 is an illustration of the DDC near the end of its operational cycle. The concept uses the final disposal drum as the centrifuge bowl. This tapered disposal drum with integral top is mounted inside a supportive spinning container. Because of the outside supportive drum, the disposal drum can be fabricated from one of the materials currently used for HIC construction. Radwaste slurry is fed through a central feed pipe that is self-sealing to the rotating drum. A rotary joint provides the mechanism for connecting the revolving feed pipe to the stationary feed line. Centrifugal action forces the liquid and solids outward to the fine mesh screen liner which parallels the tapered wall of the disposal container and provides a 1/8- to 1/4-in. flow path for the exiting liquid. Solids are retained by the screen liner as fluid passes through the screen to the disposal container wall where it migrates to the top (larger diameter) of the container. Fluid passes through the cover's circumferential drainage slot and is directed into the annular effluent drainage tube of the supporting revolving drum by means of the circumferential channel clamp. Gravity forces the separated fluid to discharge from the rotating supporting drum into a 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.

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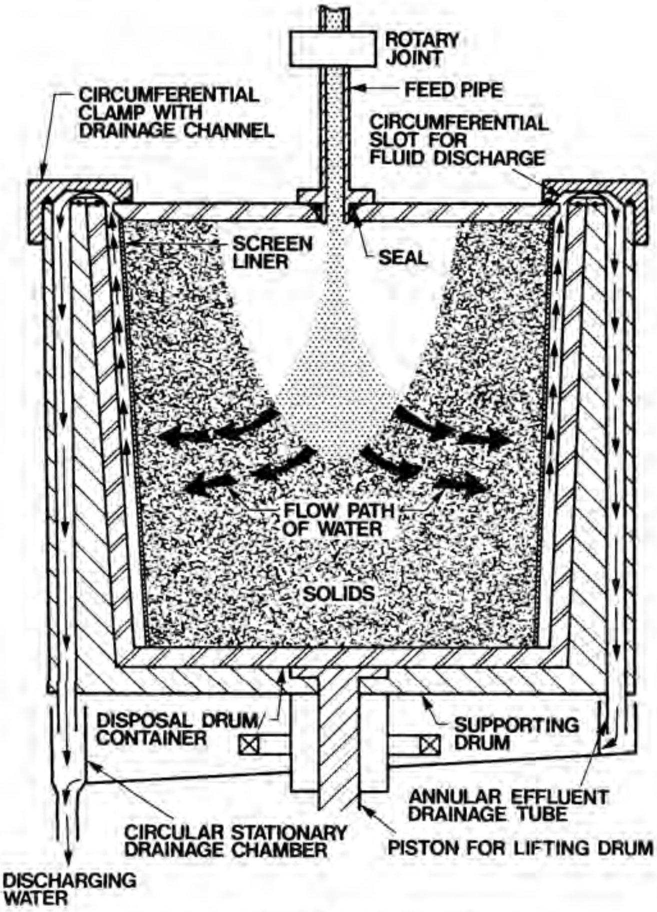

Fig. 1. Disposal Drum Centrifuge

DDC TEST PROGRAM/PROCEDURES

Under Department of Energy (DOE) sponsorship, a pilot-scale (1/3 to 1/6 scale) DDC was designed, fabricated, and tested. The active container (centrifuge bowl) of the pilot-scale DDC was 12 in. in diameter by 12 in. high. DDC pilot-scale testing was conducted at various g-levels ranging from 80 to 450 gs and using two resins, IRN-150 (bead) and Ecodex X-203-H (powder). A total of 18 runs were conducted on the pilot-scale DDC.

Prior to initiating any of the test programs both resins were analyzed for their as-received moisture content. DDC tests were then conducted using the following procedure:

1. prepare a resin slurry feed by combining known weights of as-received resin and water to form a constant slurry concentration (this concentration may vary with resin type);
2. bring the centrifuge to the desired g-level;
3. meter the resin slurry into the DDC through the stationary feed pipe;
4. continue to operate the DDC for 5 min after total drum filling is achieved;
5. bring the centrifuge to rest, measure the volume of discharged water and collect and prepare a number of samples of dewatered resin for oven drying to determine moisture content;
6. repeat this test procedure for different g-levels and resins.

To quantitatively determine the effectiveness of the DDC approach, the DDC test results must be compared to process results obtained by liner filtration and solid bowl centrifuge processing. Such baseline data was established under an earlier EPRI sponsored program. This baseline data included results from liner dewatering/packing density tests and solid bowl centrifuge product density (packing density) tests.

The equipment and procedures used in establishing the EPRI sponsored baseline data are briefly described in this report for reference only. For further details refer to EPRI project 2414-3, Final Report December 1984.

Laboratory-scale liner dewatering tests were conducted using a filtering liner that was fabricated from a 1/2-gal plexiglass cylindrical container. A perforated 5/8-in. OD plexiglass tube was placed at the bottom of the 1/2-gal container and extended through the side walls of the container. The 5/8-in. plexiglass tube was stuffed with cotton to prevent resin from discharging with the water that was removed by vacuum.

A controlled resin slurry feed using known weights of received resin and water was metered into the dewatering liner. Vacuum was applied to the perforated pipe to remove water. After the initial dewatering was completed, vacuum was reapplied to the drum at least twice a day. When no additional water could be removed, the total quantity of removed water was measured and the retained resin was analyzed for its moisture content.

No special test apparatus was required to simulate the dewatered solids produced by a solid bowl centrifuge. The dewatered resin produced during centrifugal filtration tests was manually rehandled to generate a simulated solid bowl centrifuge dewatered resin. The packing density of this dewatered resin was determined by pouring the processed resin into a container of known volume.

TEST RESULTS

Moisture Content of As-Received Resin

Prior to initiating the DDC test program, the test resins (IRN-150 and Ecodex X-203-H) were analyzed for their as-received moisture content. Table I lists the actual as-received moisture content of each resin along with the as-shipped moisture content range specified by the manufacturer.

TABLE I

Resin Moisture Content As-Received

Resin	Moisture Content As-Received (% by Weight)	Manufacturer Specified Moisture Content Range As-Shipped (% by Weight)
IRN-150	54.5	50 to 55
Ecodex X-203-H	64	60 to 70

Baseline Data

Liner Dewatering Test Results

The results of laboratory-scale liner dewatering test results (packing density and dewatering) are summarized in Table II. Moisture content of the retained resin was determined by oven drying. Packing densities are expressed in terms of pounds of as-received resin per cubic foot to normalize the retained resin moisture content which does vary with processing technique. The ratio of this packing density from two different processing techniques would equate to the relative change in waste volume that can be achieved by changing from one processing technique to the other. A process which has a packing density of 40 lb/ft^3 will utilize only half the volume to dispose of equal quantities of waste when compared to a processing technique that produces a packing density of 20 lb/ft^3. The powder resin packing densities reported in Table II assume a 25% loss in drum volume (15% for internal piping and 10% for incomplete filling). The bead resin packing density assumes a 15% loss in drum volume (5% for internal piping and 10% for incomplete filling).

TABLE II

Summary of Liner Dewatering Test Results

Resin	Moisture Content of Retained Resin (% by Weight)	Packing Density (lb of as-Received Resin per ft^3)
IRN-150	58.0	34.6
Ecodex X-203-H	76.8	27.8

Solid Bowl Centrifuge Test Results

Solid bowl centrifuge packing density tests were performed using resins that had been dewatered by centrifugal filtration at 500 gs. The dewatered resin was manually reduced to a flowing powder and poured into a separate container. Resin weight was adjusted for moisture content to convert back to the as-received moisture content and divided by the container volume. The resulting packing density was then adjusted for a 10% loss due to incomplete packing. The packing density for Ecodex X-203-H was 27 lb/ft^3.

DDC Tests

Both resins were processed at gravitational force levels ranging from 81 to 453 gs. The pertinent data and results from these tests are summarized in Tables III and IV for Ecodex X-203-H and IRN-150, respectively. Analysis of this data has been divided into two separate categories:

1. volume reduction;
2. dewatering.

TABLE III

DDC Test Results with Ecodex X-203-H Resin

Run	g-Level[1]	Resin (% Moisture)[2]	Packing Density (lb/ft^3)[3]
1	115	60.9	49.7
2	300	54.9	57.2
3	390	52.0	56.4
4	104	60.7	48.6
5	274	52.3	48.3
6	453	54.2	49.2
7	81	61.7	50.8
8	233	54.3	50.8
9	336	51.6	51.4

[1] g-level at bowl wall.
[2] By weight.
[3] Pounds of as-received resin per cubic foot.

TABLE IV

DDC Test Results with IRN-150 Resin

Run	g-Level[1]	Resin (% Moisture)[2]	Packing Density (lb/ft^3)[3]
10	103	54.3	42.6
11	253	52.4	45.4
12	415	52.2	44.6
13	104	55.4	42.0
14	231	54.6	41.5
15	378	52.1	41.7
16	93	52.7	49.3
17	233	52.6	49.9
18	283	52.5	49.9

[1] g-level at bowl wall.
[2] By weight.
[3] Pounds of as-received resin per cubic foot.

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 Figs. 2 and 3, respectively. Liner dewatering packing densities and solid bowl centrifuge packing densities have been superimposed on these graphs for comparative purposes.

Processing of Ecodex X-203-H resin on the pilot-scale DDC produced a Volume Reduction that ranged from:

1. 1.74 to 2.22 when compared to the solid bowl centrifuge packing density;
2. 1.69 to 2.15 when compared to the liner dewatering packing density.

IRN-150 processing on the DDC test centrifuge produced a Volume Reduction that ranged from 1.21 to 1.42 when compared to the liner dewatering packing density.

The range in Volume Reductions listed above is attributed to variations in g-level.

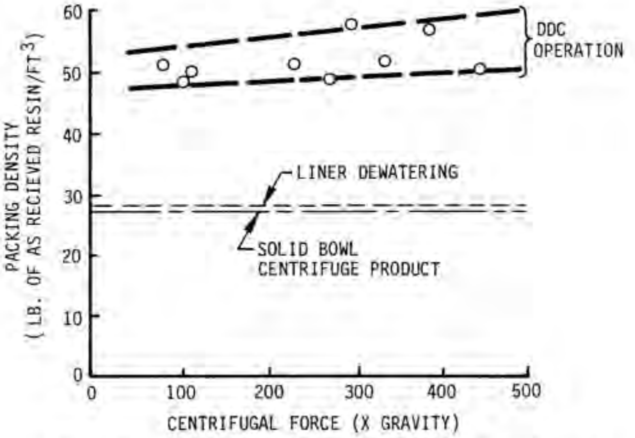

Fig. 2. Packing Density of Ecodex X-203-H as a Function of Centrifugal Force

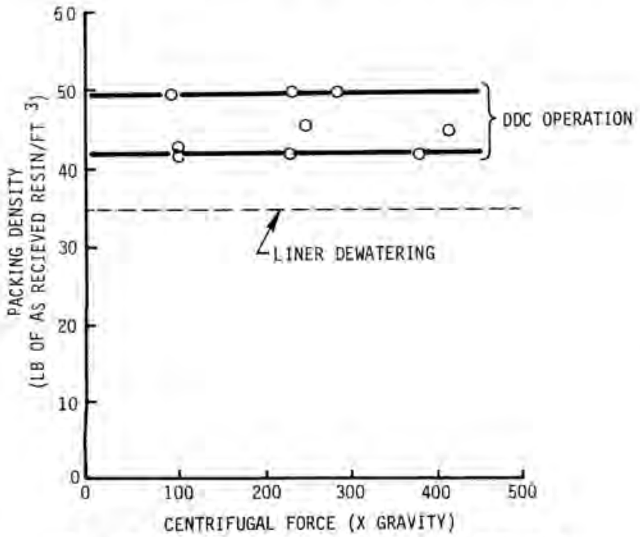

Fig. 3. Packing Densities of IRN-150 as a Function of Centrifugal Force

Resin Dewatering

The moisture content of the retained resin produced by DDC processing is plotted as a function of centrifugal force in Figs. 4 and 5 for Ecodex X-203-H and IRN-150 resins, respectively. The moisture content of the as-received resins has been superimposed on these graphs for comparative purposes.

The results of Ecodex X-203-H dewatering by pilot-scale DDC processing and laboratory liner dewatering can be quantified thusly:

1. DDC processing produced a resin with 8.4 to 42.8% less total water than the as-received resin;
2. liner dewatering produced a resin with 86% more total water than the as-received resin.

The quantitative results from IRN-150 processing with the pilot-scale DDC and the laboratory liner dewatering apparatus are as follows:

1. DDC processing produced a resin which contained from 3.6% more water to 11.7% less water than the as-received resin;

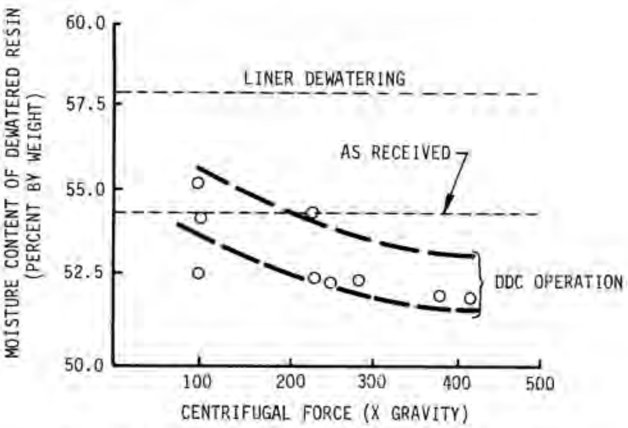

Fig. 4. Moisture Content of IRN-150 as a Function of Centrifugal Force

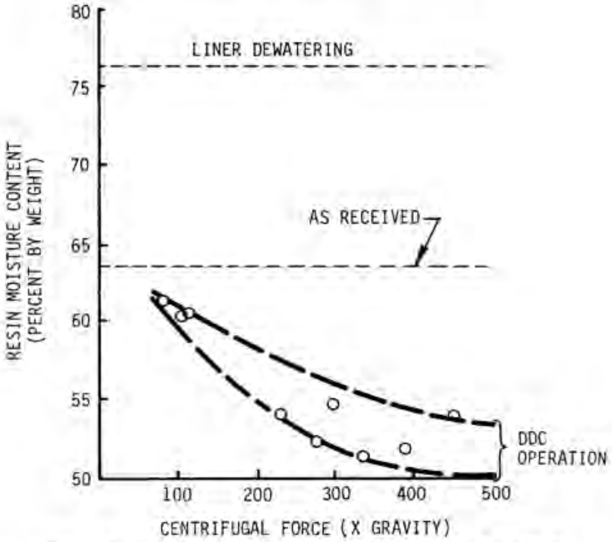

Fig. 5. Moisture Content of Ecodex X-203-H as a Function of Centrifugal Force

2. liner dewatering produced a resin with 14.6% more water than the as-received resin.

All of the 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 one of the 18 DDC test runs produced a resin that was equal to or drier than the as-received (manufacturer shipped) resin moisture content. This processing capability virtually assures compliance with the less than 0.5% (by volume) free water regulation for burial disposal. Water not liberated by centrifugal forces ranging from 100 to 400 gs is unlikely to reappear as free water under a one "g" environment.

DDC ECONOMIC EVALUATION

The economics of the DDC were analyzed for both bead and powder resins. This study used waste data (waste volumes, characteristics, etc.) from the Brunswick Nuclear Power Plant and from EPRI Report NP-3370. The objectives of this economic analysis were:

1. determine the most economical DDC container size by evaluating the relative disposal cost savings associated with different DDC container sizes;
2. compare the disposal cost economics of the selected (size) DDC to those costs associated with liner dewatering.

The analysis was performed using the most current burial rates for both the Barnwell and Hanford burial facilities (rates as of 1/31/86) and considered:

1. waste characteristics;
2. burial and internal container volume;
3. transportation costs;
4. burial costs including all surcharges and handling fees;
5. relative costs of carbon steel containers;
6. waste processing packaging efficiencies;
    a. dewatering - 80% container fill volume;
    b. DDC - 95% container fill volume;
7. average volume reduction (VR) factors compared to dewatering;
    a. bead resin (IRN-150): DDC VR = 1.3;
    b. powder resin (Ecodex): DDC VR = 2.0.

Because sufficient data did not exist, several factors were not included in the economic sizing analysis. These factors include:

1. waste processing labor costs;
2. relative costs of HICs;
3. labor costs associated with container handling requirements;
4. plant modification costs.

The container sizes considered for this evaluation were a standard 55-gal drum (DOT 17-H), 50-ft^3 liner, 80-ft^3 liner, and 120-ft^3 liner.

The results of the DDC economic analysis indicate that for both bead and powder resin, the 55-gal size container is the most economical (with respect to disposal cost savings) of the four container sizes evaluated. Results of this study also indicate that DDC processing with this size container could reduce disposal costs significantly when compared to liner dewatering. Figs. 6 and 7 show relative transportation and disposal costs (on a per cubic foot basis) by type of processing method for bead and powder resin, respectively.

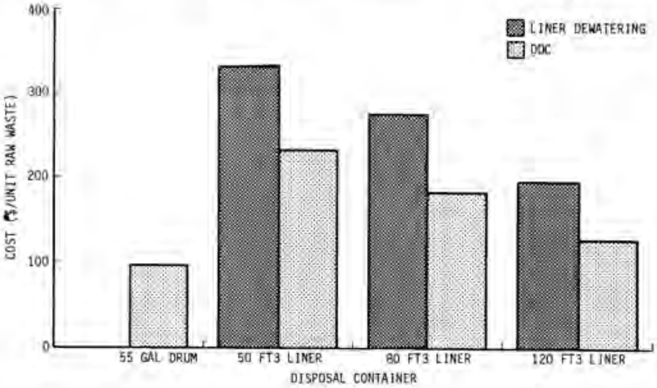

Fig. 6. Average 1986 Disposal Cost - Bead Resin - Dewatering versus DDC

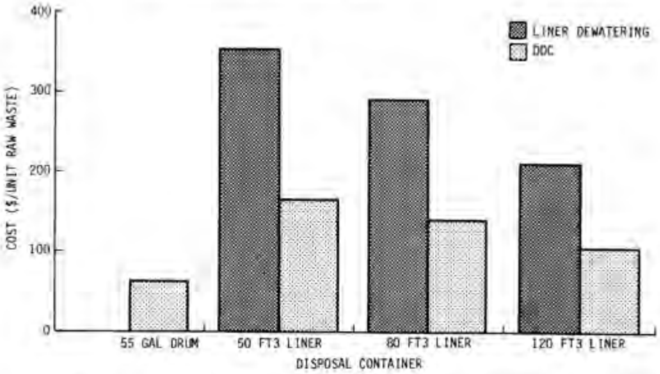

Fig. 7. Average 1986 Disposal Cost - Powder Resin - Dewatering versus DDC

To determine the economic advantages of the DDC relative to liner dewatering, an analysis was performed to establish disposal costs for the reference plants from 1986 through 1993. Burial rates were assumed to escalate at 15% annually, which is reasonable based on past experience. General rates (container costs, transportation, etc.) were assumed to escalate at 6% annually. General surcharges, added as a result of the recently passed Amendment to the Low Level Waste Policy Act, were also included in the analysis. Figure 8 shows the annual disposal costs associated with a 55-gal DDC versus a 120-ft^3 dewatering liner (the most efficient dewatering liner analyzed).

A present worth analysis was performed to determine the total disposal cost savings (based upon 1986 dollars) which could be achieved by using the DDC to process wet waste in lieu of liner dewatering. According to this analysis, the average BWR plant using the 55-gal DDC, instead of dewatering in a 120-ft^3 liner, could reduce bead resin disposal costs by about \$2 million and powder resin disposal costs by about \$5.5 million over the 1986 to 1993 time period.

FUTURE DDC PROGRAM AND MARKETING OPTIONS

The DOE is presently sponsoring a Phase II program for the development, fabrication and testing of a full-scale prototype DDC. This activity is scheduled for 1986 and 1987.

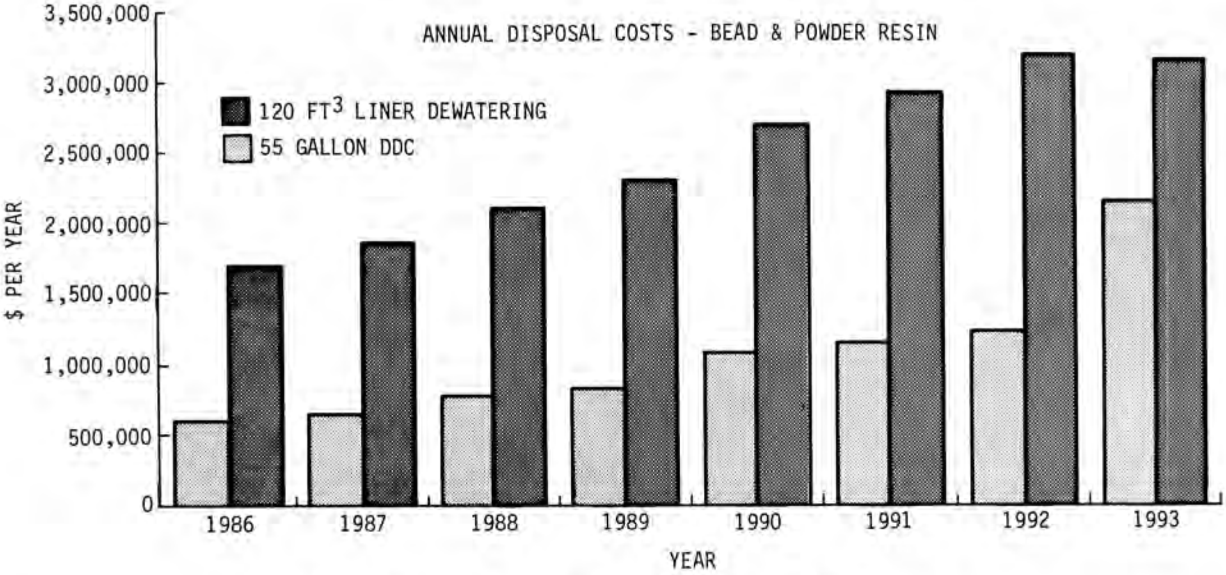

Fig. 8. 55-gaL DDC versus 120-ft^3 Liner Dewatering

Several marketing options are currently being evaluated with respect to cost, plant operational factors, projected market response, changing regulatory requirements, etc. Some of the commercialization options currently being considered include marketing the system as:

1. a fixed, in-plant installation to be purchased by the utility;
2. a portable skid-mounted unit which could be transported to and from a plant's waste processing area when required - purchased by the utility;
3. a portable skid-mounted unit - leased to the utility;
4. a trailer-mounted system operated by a vendor services company.

Various options to design the disposal drum as a HIC are currently being evaluated. Designing the DDC container out of carbon steel for use with a HIC overpack is also being considered.