Wheels of Progress: Rotary Press Selection for Plum Island

John K. (Jake) Earle

The Commissioners of Public Works (CPW) of the City of Charleston, South Carolina, is an agency responsible for providing sewer service and wastewater treatment for Charleston and parts of the surrounding area. The majority of this treatment effort is accomplished at the 36-million-gallons-per-day (MGD) Plum Island Facility adjacent to Charleston Harbor. The Plum Island Facility historically managed treatment residuals on-site using a five-hearth incinerator built in 1969 as part of the original primary-treatment-only plant. Dewatering was initially accomplished with vacuum filters.

In 1984 the plant was modified to incorporate secondary (activated sludge) treatment of the primary effluent, and belt filter presses were installed to dewater the combined primary and waste activated sludge. With the advent of more stringent regulations (including the Federal 503 Rules), the CPW decommissioned the incinerator in 1993 and began hauling dewatered residuals to a landfill approximately 45 miles away.

In 2000 the CPW commissioned a study of long-term biosolids management options with the goal of developing a cost-effective, reliable residuals management program that would minimize environmental and community impacts. This study concluded that with proper consideration of all factors affecting the Plum Island facility, a new thermal oxidation process was the option best suited to meet the CPW's long-term needs (Malcolm Pirnie, unpublished).

A decision was made to replace the belt presses with high cake-solids dewatering equipment. In August 2002 an evaluated bid process was used to select a centrifuge for installation at Plum Island. The selection process included consideration of capital cost, physical configuration to fit into the existing sludge building, and base of installed units. The result of this process was selection and purchase of a Westfalia Model 635 centrifuge and initiation of a project to install it in a new structure outside of the present residuals processing building in support of replacing the belt presses.

After this process had begun, the CPW's wastewater engineers and operators became aware of the rotary press after noting that Fournier Industries had been awarded the Water Environment Federation's Innovative Technology award for 2002. After extensive evaluation, the rotary press was selected for installation at Plum Island to replace the belt presses. The centrifuge installation continued and both dewatering technologies will be used.

John K. (Jake) Earle, P.E., is a wastewater plant engineer with the Charleston (S.C.) Commissioners of Public Works, assigned to the city's Plum Island Facility. He is a member of the Water Environment Federation and the Water Environment Association of South Carolina.

Methodology

Pilot studies were used to compare centrifugation of the Plum Island facility residuals with dewatering by the rotary press. Field inspections were made by site visits where centrifuges and rotary presses were installed and in operation. Cost assessments focused on differences in polymer and power cost.

Results

The Plum Island Facility treatment residuals historically have been determined to be approximately 60 percent primary and 40 percent waste activated sludge.

<u>Centrifuge Trials</u>

Three centrifuge manufacturers—Alfa Laval Sharples, Humboldt, and Andritz-Ruthner—were selected for pilot testing to dewater the Plum Island plant residuals over a one-year period from May 1998 through May 1999. The intent of the pilot testing included verifying the feasibility and effectiveness for dewatering Plum Island sludge, and generating potential design data for a full-scale centrifuge installation (Hazen & Sawyer, May 1999).

Each manufacturer provided a trailer-mounted centrifuge dewatering unit with polymer mixing and feed equipment, sludge feed pump, and discharge conveyor. Due to the constraints of mounting a unit for mobility, all of the units tested were smaller than the ones proposed for ultimate installation. A summary of the pilot test results is shown in Table 1, and a compilation of the required 19 runs is shown in **Table 2**.

Table 1 – Plum Island Centrifuge Trial Summary

Average Results	Sharples	Humboldt	Andritz
Cake (% Total Solids)	25	25	26
% Recovery (Capture)	90	99	97
Polymer (Dosage lb/dry ton)	24	18	26

Table 2 – Plum Island Centrifuge Trial Data

	Sharples			Humboldt			Andritz		
	Polymer	Cake	Recovery	Polymer	Cake	Recovery	Polymer	Cake	Recovery
	#/Ton	% TS	%	#/Ton	% TS	%	#/Ton	% TS	%
	25	26.6	98.7	18	27.1	98.3	27	26.7	98.8
	28	24.1	98.2	13	22.8	98.2	27	27.5	98.3
	23	23.3	73.0	17	25.2	98.4	27	27.7	98.7
	20	24.8	81.8	14	24.5	98.3	27	27.3	99.1
	23	24.4	89.7	13	21.5	98.2	27	29.0	98.8
	18	23.8	95.8	11	20.7	98.2	27	28.0	98.0
	25	25.0	93.3	16	24.7	99.6	24	27.5	98.7
	26	25.1	97.5	24	27.7	97.7	25	27.8	98.7
	25	25.3	88.0	21	26.5	99.1	29	26.4	97.9
	25	26.2	98.0	18	27.2	99.0	22	26.3	99.0
	24	27.4	98.1	15	25.3	99.1	26	25.3	99.0
	24	26.7	97.8	27	25.8	98.7	26	27.4	97.7
	26	27.2	94.6	18	25.0	98.0	25	24.9	97.9
	26	25.4	94.7	18	23.3	98.6	27	23.3	97.4
	29	26.6	78.1	15	22.4	99.3	27	24.3	96.6
	26	24.9	89.8	15	23.1	99.4	27	24.8	97.7
	23	25.1	91.6	20	27.9	98.9	27	26.7	91.1
	20	26.3	71.2	21	25.0	99.3	26	25.8	92.6
	22	25.4	73.9	20	24.7	99.9	26	22.7	95.2
Average	24	25	90	18	25	99	26	26	97

Rotary Press Trial

Over a two-week period from February 6 to March 5, 2003, trials were conducted of the Fournier Rotary Press for dewatering of both Plum Island and Daniel Island residuals. The trial equipment was trailer mounted, complete with a control room and testing lab. All equipment used was professionally installed and in extremely good working order. The same PLC-based controls were used as in full-scale installations. The drive unit for the press was full size, exactly as in full-scale installation.

Three configurations of dewatering channel were installed on the output shaft of the drive unit for testing various sludges, and each channel was full-sized. Scale-up for a plant installation consists only of installing additional channels. Due to this configuration, there was a high degree of confidence in the pilot test results, since the pilot equipment exactly represented what would ultimately be installed in the dewatering facility.

For the Plum Island residuals, the rotary press generated sludge cake during 30 separate runs as shown in Table 3. All of these were successful at generating dry sludge cake (average 25.5 percent), with good solids capture (average 98.2 percent) and low polymer consumption (avg. 10.5 lb/ton).

Table 3 - Plum Island Rotary Press Trial Results

Plum Island Mixed Primary/WAS Rotary Press Trial
Summary Results
Ciba 7557 Polymer
CV (2") Rotary Press Channel

Date	Polymer Lb/dry ton	Feed Sludge % Solids	Feed Sludge Rate gpm	Cake % Solids	Solids Capture %	Dry Lb/Hr Per Channel	Dry Lb/Hr 6Ch Press	Ton/Day 6Ch Press
27-Feb-03	10.9	3.2	8.7	25.9	97.5	138.5	831	10.0
27-Feb-03	10.7	3.3	9.1	25.4	96.7	147.9	887	10.6
27-Feb-03	10.9	3.2	8.7	25.8	99.7	141.6	849	10.2
27-Feb-03	10.7	3.3	8.5	24.1	95.5	136.2	817	9.8
27-Feb-03	10.9	3.2	10.6	21.6	99.7	174.3	1,046	12.5
27-Feb-03	10.4	3.4	10.6	22.4	98.5	179.8	1,079	12.9
27-Feb-03	10.7	3.3	10.7	21.6	98.5	176.2	1,057	12.7
28-Feb-03	10.8	3.3	10.4	25.1	99.1	171.4	1,029	12.3
28-Feb-03	10.8	3.3	10.3	26.5	99.7	171.0	1,026	12.3
28-Feb-03	10.7	3.3	10.6	25.0	98.8	174.9	1,049	12.6
28-Feb-03	10.7	3.3	10.5	26.8	95.7	168.1	1,008	12.1
28-Feb-03	10.6	3.3	7.7	29.2	99.1	130.1	781	9.4
28-Feb-03	10.8	3.3	8.1	28.1	96.3	130.1	781	9.4
28-Feb-03	10.8	3.3	8.2	29.2	99.7	136.5	819	9.8
28-Feb-03	10.7	3.3	8.1	28.3	99.7	136.3	818	9.8
1-Mar-03	9.7	3.6	7.7	25.4	99.7	142.5	855	10.3
1-Mar-03	9.9	3.6	8.0	27.2	99.7	144.5	867	10.4
1-Mar-03	9.6	3.7	7.8	27.3	97.8	143.4	860	10.3
2-Mar-03	11.7	3.4	8.4	27.6	96.7	139.9	840	10.1
2-Mar-03	11.9	3.3	8.7	30.7	95.8	140.3	842	10.1
2-Mar-03	10.6	3.3	8.6	28.2	97.0	140.7	844	10.1
3-Mar-03	9.1	3.9	8.7	26.9	98.7	169.0	1,014	12.2
3-Mar-03	8.1	4.3	8.0	28.5	98.4	174.0	1,044	12.5
3-Mar-03	8.4	4.2	8.6	27.7	99.3	183.4	1,100	13.2
6-Mar-03	11.7	3.0	13.3	22.9	99.3	203.3	1,220	14.6
6-Mar-03	11.6	3.0	13.1	21.9	92.7	186.7	1,120	13.4
6-Mar-03	10.9	3.2	14.3	21.5	98.4	230.7	1,384	16.6
6-Mar-03	10.9	3.2	15.5	20.4	99.7	253.0	1,518	18.2
6-Mar-03	10.4	3.4	15.5	20.5	99.7	265.0	1,590	19.1
6-Mar-03	10.6	3.3	11.3	22.3	99.7	191.1	1,147	13.8
Average	**10.5**	**3.4**	**9.9**	**25.5**	**98.2**	**167.3**	**1004.1**	**12.0**

Site Visits

Four sites were visited to observe operational centrifuge installations and obtain feedback from operation and maintenance personnel, as well as managers. The sites featured centrifuges from four different manufacturers and ranged in age from two to eight years of operating experience. A total of five sites were visited with operational rotary presses.

General Observations

At each site visited, an attempt was made to solicit objective opinions in the form of informal discussions of all aspects of the centrifuges or rotary presses. Opinions were taken from all available personnel, including operators, maintainers, and managers. Ease of operation and maintenance were key subjects. Rotary presses were noted to be easy to maintain, whereas there were numerous comments to indicate that centrifuges were more maintenance intensive. The rotary press units were significantly quieter than centrifuges. Odors were fairly low in most facilities.

Discussion

Rotary Press Operating Principle

The rotary press technology was devised by a Canadian government agency in 1992 and was licensed to Fournier Industries for marketing and further development (McKay and Fournier, 2002). Because of the sound of its name, the rotary press is sometimes confused with a screw press when in fact it operates quite differently. Another misconception is that the dewatering channels on the rotary press somehow incorporate a converging or narrowing channel. The following explanation attempts to provide a more accurate understanding of how this equipment works.

The principle of operation is relatively simple. After dosing with polymer to promote flocculation (typical of dewatering processes), sludge is pumped into a hollow cavity between porous screens as shown in Figure 2. Free water (filtrate) passes through the screens and a cake begins to form inside the cavity. The screens are in constant, slow rotation and are able to “grip” the dry cake (via frictional force) near the outlet, extruding it continuously through a pressure-controlled port. A septum separates the inlet side of the cavity from the outlet.

Specific features that give the Fournier Rotary Press its performance characteristics include the stainless steel chrome plated screens and a robust, force-multiplying gearbox. These make it possible to produce a dry cake with reduced power consumption and low wear on machine parts.

Centrifuge Operating Principle

While centrifuges are common, having been used in wastewater treatment since the 1930s (U.S. EPA, 2000), for the sake of completion, a brief discussion of the operating principle will be made. Solid-bowl centrifuges operate as continuous feed units, which remove solids by a scroll conveyor and discharge liquid over a weir (U.S. EPA, 2000). The solid bowl, into which is inserted the spiral conveyor (See Figure 3), is rotated together with the conveyor at high speeds. These two combined units are often called the rotating assembly.

Higher specific-gravity material (i.e. solids) is displaced to the bowl periphery by centrifugal forces. The bowl is conical shaped on one end, corresponding to the tapered end of the scroll.

As feed is continually added, the thinner liquid above the solids (centrate) flows over a circular weir partially covering the end of the

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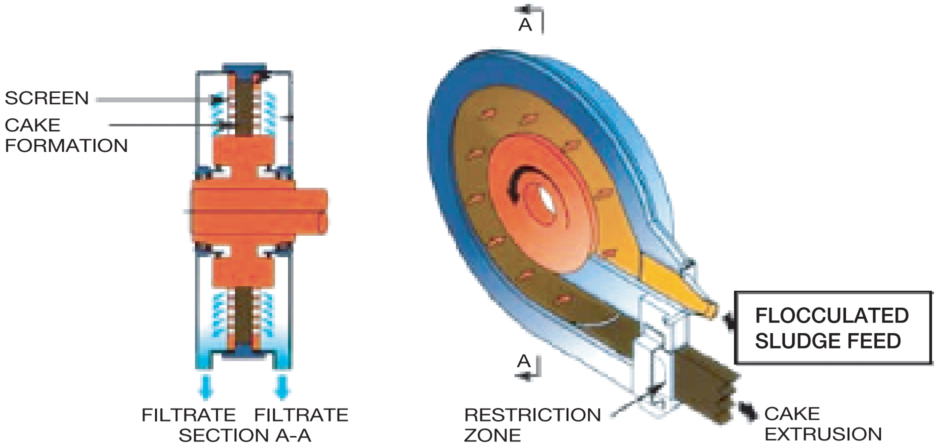
Figure 1 – Cutaway View of a Rotary Press Channel



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bowl away from the conical end. A slight differential in speed is created by "slowing down" the scroll portion of the rotating assembly, and the resulting motion of the scroll against the outer wall of the bowl forces the solids to the cone-shaped end, up the slope, and out of the ponded centrate, then out of the bowl where they are able to fall by gravity.

Comparison Chart of Centrifuge and Rotary Press Features

Based on observations, the rotary press can be compared to the centrifuge on a number of points. Table 4 lists the advantages and disadvantages of centrifugation as described in the U.S. EPA Technology Fact Sheet on Centrifuge Thickening and Dewatering. Corresponding to each point are observations made of the rotary press during the evaluation period. The author's comments on the EPA centrifuge points are in italics.

Throughput Comparison of Centrifuge and Rotary Press

The data in Table 3 for the Plum Island pilot study shows that generally, as throughput increases, cake solids decrease for the rotary press. For desired cake solids, this dictates the rate at which material can be processed. The average cake solids result achieved in the centrifuge trials was 25.3 percent, which compares closely to the rotary press average cake solids of 25.5 percent. Accordingly, the average results obtained from the rotary press trial is used for further comparison, including a throughput of 1,108 dry pounds per hour (See Table 3).

The Westfalia Model 635 centrifuge being installed at Plum Island has not yet been started up; therefore, design criteria is used to estimate expected throughput. All of the centrifuges used in the pilot tests were smaller; therefore, the feed rates were less than the design values of the Model 635. The design feed rate range is 67-150 gallons per minute (gpm) at feed solids concentrations from 2.2-4.8 percent.

Since centrifuges normally are operated at less than maximum rated capacity to reduce polymer consumption (EPA, 2000), it is assumed that two-thirds of the max feed rate, or 100 gpm, will be the normal feed rate. Applying this to the average feed solids concentration from the rotary press trial of 3.4 percent and the 95.3 percent average recovery from centrifuge trials gives the following hourly throughput, once up to operating speed and conditions:

100 gal/min * 8.34 * 1.005 * .034 * .953 * 60min/hr = 1630 dry pounds/hour

Note: Specific gravity of sludge assumed to be 1.005 as used here and in rotary press data calculations (Metcalf & Eddy, 1991)

Automation

Centrifuges can be fully automated, but starting the bowl and putting feed into the machine are usually performed manually (U.S. EPA, 2000). The parameters typically adjusted during operation are feed rate, polymer dosage, and scroll differential speed (GEA Westfalia, unpublished). All of these values are typically monitored on control screens, along with the resulting change in torque.

Centrifuges are subject to vibration, which must be monitored with sensors. Nonuniform feed solids can cause vibration due to an imbalance of material in the bowl. Wear of mechanical parts can cause excessive vibration. Controls for the centrifuge will shut the unit down if an out-of-specification vibration is observed. While remote starting and stopping of a centrifuge is certainly possible, this was not observed at any installations.

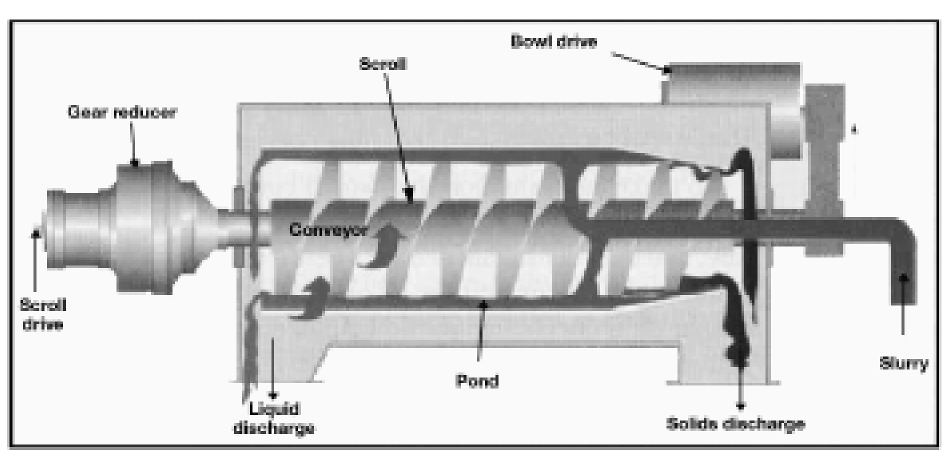
The rotary press operates at a constant pressure in the cake formation zone (See Figure 2). A pressure sensor feeds a signal that is used by the controls to speed up or slow down the feed pump to maintain the desired pressure. The rotational speed of the screens can be varied, and a resulting change in pressure near the cake outlet can be observed.

Polymer dosage can be varied at specified intervals and the effect observed on the outlet pressure and the torque. This can be done manually or programmed into the controls. Overall, the controls for the rotary press are very adaptable to automation, as observed at most of the installations. The units can be remotely started and stopped, as observed at one installation.

Plum Island Solids Production

Figure 4 shows Plum Island solids production since detailed records of landfill receipts began being recorded. Samples of cake for each trailer load of residuals are analyzed for total solids and an average number applied to the recorded weight to determine the total mass of dry solids. Regression analysis was applied to this data to project solids production estimates for the next few years.

Figure 2 – Cutaway View of Typical Centrifuge



Source: Ireland and Balchunas, 1998

Table 4 – Comparison of Rotary Press to Centrifuge Attributes

Centrifuge Advantages (EPA, 2000)	**Rotary Press Comparison** A. = Advantage, D. = Disadvantage
May offer lower overall operation and maintenance costs and can outperform conventional belt filter presses.	A. Outperforms belt filter presses based on pilot results. Low operation and maintenance costs.
Require a small amount of floor space relative to their capacity.	A. Largest rotary press units are compact and can be configured to fit irregular spaces.
Require minimal operator attention when operations are stable.	A. Require very little operator attention.
Operators have low exposure to pathogens, aerosols, hydrogen sulfide or other odors. Are easy to clean.	A. Very low human exposure to pathogens, aerosols, hydrogen sulfide or other gases. A. Internal cleaning cycle can be automated. Manual cleaning cycle easy to initiate.
Can handle higher than design loading and the percent solids recovery can usually be maintained with the addition of a higher polymer dosage. *Can handle higher than design flow rate and maintain efficiency.*	D. Can be operated at higher throughput than design but cake solids may be reduced. Increased polymer does not overcome reduced cake solids. A. Solids recovery not significantly affected.
Major maintenance items can be easily removed and replaced. Repair work is usually performed by the manufacturer.	A. Major maintenance items can be easily removed and replaced in the field by plant maintenance personnel. Special training not required.
Centrifuge Disadvantages (EPA, 2000)	
Have high power consumption and are fairly noisy.	A. Low power consumption (20 HP for largest unit). Very quiet.
Experience operating the equipment is required to optimize performance.	A. Optimum settings are determined at startup and programmed into controls. Operation is easy to understand. Optimization of polymer dose can be programmed into controls.
Performance is difficult to monitor because the operator's view of centrate and feed is obstructed. *This can be remedied by design.*	A. Flocculated feed can be observed in sight-tube. Centrate samples are easy to obtain. Note: These features could be provided on a centrifuge design.
Special structural considerations must be taken into account. As with any piece of high speed rotary equipment, the base must be stationary and level due to dynamic loading.	A. Special structural considerations are not needed. Essentially there are no live floor loads as the equipment operates at 0.5 to 2.5 rpm.
Spare parts are expensive and internal parts are subject to abrasive wear.	A. Wear item spares are inexpensive. Internal parts are less subject to wear because of low speeds, and sludge movement across major components is minimal (metal screen "grips" cake).
Start-up and shutdown may take an hour to gradually bring the centrifuge up to speed and slow it down for clean out prior to shut down.*New designs can incorporate automatic start and shutdown cycles.*	A. Start-up and shutdown is short duration. Periodic, short wash cycles are programmed into normal operation.

For cost estimates, an average of the projected production from 2003 through 2007 is used, or 4,464 dry tons per year.

Polymer Consumption

Centrifugation subjects flocculated sludge to high G forces and "plowing" action as the scroll moves solids to the discharge end of the bowl. Centrifuges are generally noted to require more polymer per pound of dry solids processed. This dosage increases as throughput increases to maintain capture efficiency (U.S. EPA, 2000). The centrifuge trials for Plum Island resulted in average polymer usage of 22.7 pounds per dry ton.

By comparison, the rotary press process appears to be much more gentle to the flocculated sludge. This is seen in the lower polymer usage observed in the Plum Island trials of 10.5 pounds per dry ton (Table 3). Discussions with operating personnel and the technician operating the mobile unit indicate that a wide range of polymers gives good dewatering results with the rotary press. This supports use of polymer trials to determine a cost-effective polymer selection.

Applying a budget estimate polymer cost of $1.87 per dry-equivalent pound to the estimated annual sludge production at Plum Island of 4,464 dry tons results in a significant anticipated annual cost savings as follows:

(22.7-10.5) lbs/dry ton * 4464 tons * $1.87 = $101,842 (say $102,000 for comparison)

Power Consumption

In the near term, until a thermal process is implemented, the operating schedule for first the centrifuge, then the rotary press is assumed to be similar to the current belt press schedule. This follows a weekly pattern corresponding to landfill operating schedules. Once the units are started, they run more-or-less continuously until the weekly production of residuals is processed. If two weeks per year are allotted for more extensive maintenance, this results in 50 weekly periods requiring processing of:

4,464 / 50 = 89.3 dry tons per week.

For the centrifuge, using the 1,630 dry pounds/hour determined previously, the weekly hours of processing time are determined as follows:

89.3 dry tons per wk * 2000 lb per ton / 1630 lb per hr = 109.57 say 110 hr per week

For the rotary press, using the 1,108 dry pounds/hour determined previously, the weekly hours of processing time are determined as follows:

89.3 dry tons per wk * 2000 lb per ton / 1108 lb per hr = 161 hours

For evaluation of power consumption, any startup time without sludge feed is ignored in the interest of being conservative, although it is expected that the rotary press startup time will be shorter.

The centrifuge installed at Plum Island has a total horsepower of 175. Applying a conversion factor of 0.75 gives a kilowatt (kw) estimate of 131. Applying this to the Plum Island historical average of $0.04 per kilowatt-hour (kwh) gives the following annual power cost estimate:

$0.04 per kwh * 131 kw * (110 hrs/wk * 50 wks) = $28,810

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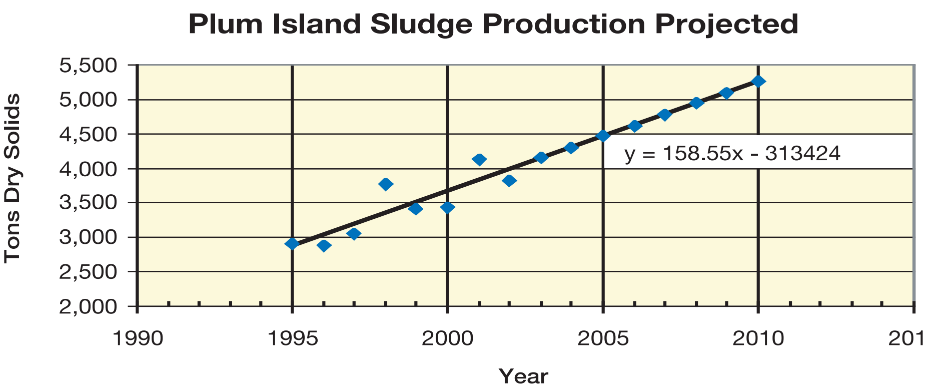
Figure 3 – Projected Plum Island Residuals Production



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The six-channel rotary press that will be installed has a total horsepower of 21.5 (20 hp drive plus 1.5 hp flocculator). Applying the conversion factor gives a power demand value of 16 kw. For the rotary press, startup time before applying feed is expected to be shorter, but to be conservative this time difference is ignored. Therefore the estimated throughput of 1,108 dry pounds per hour is used to determine total electrical cost for annual processing as follows.

$0.04 per kwh * 16 kw * (161 hrs/wk * 50 wks) *= $5,152*

From these calculations, it is estimated that using the rotary press to dewater the Plum Island residuals will result in savings of approximately $24,000 per year. Two rotary presses will be installed to provide redundancy and excess capacity to perform routine and major maintenance. Once the rotary presses are installed, the centrifuge will be maintained as supplemental solids processing capacity.

<u>Total Polymer and Power Cost Savings</u>

Total cost savings of approximately $125,000 per year are expected for operation of the rotary press at Plum Island, based on reduced power and polymer consumption. Other factors that will determine annual operation and maintenance cost differences are operator time required and maintenance time and material. These costs will be collected over time for further comparisons of operating experience using the centrifuge and the rotary press at Plum Island.

Conclusions

The rotary press was selected for retrofitting into the residuals dewatering building at the Plum Island facility to replace the belt presses. Automation, extended hours of operation, and low operator attention are expected to offset throughput differences. The modular nature of the rotary press and the ability to fit it into irregular spaces make it ideal for this application and will result in significant construction cost savings. Quietness of operation, effective containment of odor and the demonstrated suitability for automation and unattended operation were key factors in the decision, as was ease of maintenance.

Installation of a backup/standby centrifuge will continue as planned. This combination of advanced equipment will provide a unique opportunity for detailed comparison of associated costs over time. Savings of at least $125,000 are expected annually.

The normal operation will be to use the rotary presses for daily residuals processing. The centrifuge will be useful in the event the rotary press operation is interrupted for any reason, and the higher throughput of the centrifuge will enable accelerated processing of backlogged residuals.

The centrifuge will be operated on a planned schedule to maintain its operational effectiveness. Reducing the run time will spread maintenance costs out over a much longer period. Operating the centrifuge at off-peak hours will minimize the power cost impact. Polymer trials and other optimization means will be investigated to keep polymer costs as low as possible.

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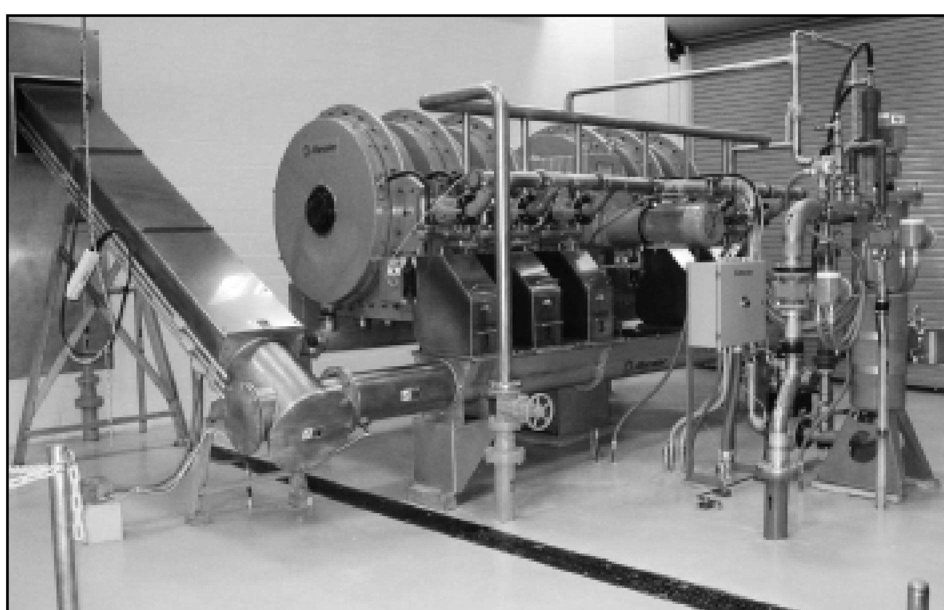

Figure 4

This rotary press at the Daniels Island Facility is similar to the one which will be operated at the Plum Island Facility.