Applications of decanter centrifugals in the beet sugar process

Authors: Mark R. Suhr[1], Phil Thompson[2], [1]MS PROCESSES INTL, LLC, 410 Campbell Ln, Hutchinson, MN 55350 USA [2]Sugar Knowledge International Ltd, 3 Mill Road, Yarwell, Peterborough, England, United Kingdom

Abstract

In the processing of sugar beets into granular sugar many liquid – solid separations are encountered. In selecting the right equipment for the separating step, the underlying principles of the equipment and the process application must be understood. The general operating principles of the decanting centrifuge are highlighted and the proper application points in our industry is discussed, including material selection, dealing with foaming liquids and varying particles sizes for solids. Results from actual applications are included. Capital and operating costs are compared to other separation techniques for evaluation along with other potential benefits that can result from the use of the decanters.

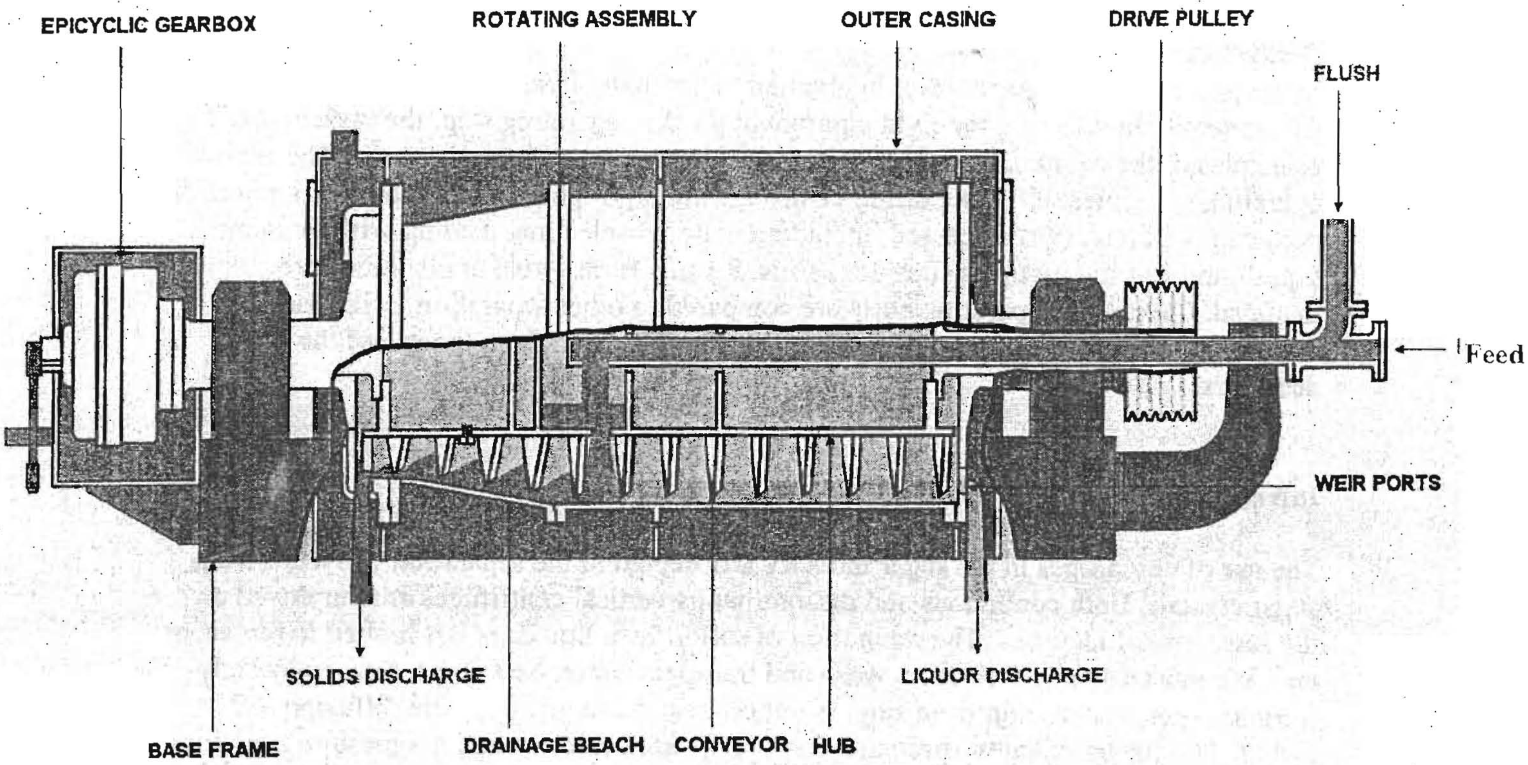
Introduction

The use of centrifuges in the sugar industry is accepted in the separation of syrups from sugar crystals. Both continuous and discontinuous vertical centrifuges are employed on the sugar end of factories. The separation of solids from liquids is not limited to our sugar end. We must separate soils from wash and transport water, beet chips, tops and weeds from transport water, pulp from sugar solutions, sand and grit from the diffusion and carbonation juices, calcium carbonate and precipitated calcium and magnesium salts from sugar solutions, filter aids such as diatomaceous earth or perlite from sugar solutions and sludge from water treatment. There are many different types of equipment used to accomplish these required separations. The use of the decanting centrifuge is a separation devise that may be overlooked in examining and selecting the right equipment for the demands of the sugar industry.

The solid bowl decanting centrifuge is simply improving the separation resulting from gravity by increasing the relative separation effect utilizing the centrifugal force created by rotating an object. This increase “G” force can be as high as 1800. Applications in the sugar industry will have considerably lower “G” forces; normally 500xG is able to efficiently handle our needs.

A typical decanter schematic is attached illustrating the major component including the rotating assembly, the bowl and the helix screw or conveyor, the outer casing, the base frame, the epicyclical speed reducer and motor. The feed, solid and liquid components are also highlighted.

A TYPICAL SOLID BOWL DECANTER CENTRIFUGE



In reviewing the decanter construction it is clear that centrifugal force is used to separate denser solid material from lighter liquid. There is some confusion how the denser solids are conveyed. The speed reducer or gearbox is used to create a differential between the bowl and the conveyor. For example, if the speed reducer ratio is 115:1 and the bowl speed is 1000 RPM the differential is 1000÷115 or 9 RPM. This means the conveyor is rotating at 1000-9 or 991 RPM and thus the solids will be screwed to the outlet. It is equivalent to a typical screw conveyor moving solids in a stationary housing at 9 RPM.

Operation:

The feed is introduced to the rotating assembly from a static feed tube. Chemicals, such as flocculants or surfactants can be added at this point as well, if needed. There are varying details of construction on the chemical addition to allow optimum results In addition a flushing connection is available to allow flushing of uneven build up of solids in the machine noted by excessive vibration, or to clean up the machine before shut down or service. The feed liquid is accelerated up to the rotational speed of the bowl and the heavy, larger particles are quickly settled at the wall of the bowl and lighter, smaller particles are layered further from the wall. The conveyor transports the solids to the discharge end and the solids are plowed out the discharge chute to the external collection/transport devise(s). The discharge end is conical and allows the liquid to drain back into the pool. The portion of the conical section outside the pool is often referred to as the drainage beach or simply the beach. The lower the pool height the more drainage of the liquid from the solids is possible with a reduction in clarifying capacity. The liquid, referred to commonly as the centrate, leaves the decanter opposite the solids over the adjustable weir or pool level control point.

The machine is a relatively simple devise. The process and machine have adjustments that affect the overall performance. Just as in a sugar factory the adjustments almost always improve one parameter at the expense of another and the optimum is usually a compromise of the adjustments. The typical variables are:

Variable	Change in variable	Separation effect	Capacity	Maintenance/efficiency
Feed rate	Increase	Lower recovery of fine particles, less residence time; centrate has more suspended solids	Increases throughput, Often dryer solids due to fine particles leaving with centrate	More power to accelerate the liquid More torque to convey the solids lower separation efficiency
Bowl speed	Increase	Improved separation to point where hindered settling controls over Stokes law setting	Improved solids capacity as differential speed is increased	Depending on solids a dryer or wetter solid cake may result. If fine particles increase they will be wetter due water carrying capacity increase. More maintenance- higher wear rate, more power and speed reducer torque required
Pool depth	Increase	Improved centrate quality by increased clarifying volume/depth	Wetter solids due to less drainage time and more captured fine particles	Adjustment is manual and with the machine off line; more mass to rotate. Less speed reducer torque to convey the solids
Differential speed	Decrease	Less turbulence improves settling	Less solid capacity, Dryer cake	Requires a reducer change out or modification, lower wear rates and more speed reducer torque to convey the solids.

Feed solid concentration	~30 %	Typically between 15 to 35% Higher solids in the proper range result in improved efficiency of solids removal	Limits are hindered settling at high concentration	Lower flow rates, higher feed solids result in lower hp but can be limited by torque on speed reducer for solids removal
Feed temperature	Increase	Lowers viscosity generally improving separation effects	Allows capacity to increase	Improves by lowering viscosity and reduces settling resistance, if venting is insufficient and vapor pressure is increased poorer performance will result

SMBSC Experience:

Two decanters with a third in reserve have been separating wastewater solids. The decanters have proved resilient reliable with little attention required for trouble free operation. The third machine has yet to be put into operation. In fact, studying the performance of the decanter indicates one machine can remove all the solids at 14500 tons beets sliced per day rate and typical tare loads. The decanters have proved to be acceptable and preferred method of mud removal over the digging of ponds. Initially the solids were scheduled to be removed as generated because of environmental restrains concerning odor control and to increase pond holding capacity for the increase tonnage schedule for the facility.

In the review of acceptable methods to economically remove solids from the wastewater stream as it was being generated the acceptable method appeared to be belt presses. The review of this technology appeared to meet the needs of the mud solid removal as generated but with increased labor and chemical usage. Searching for an alternative we investigated the solid bowl decanter. We trialed it for several six weeks in the middle of campaign on a slip stream from the wastewater clarifier and were pleased with solid removal rate, the low maintenance and the low operator intervention.

The flexibility of the decanter has been remarkable. The mud solids have also been stackable and there has been no noticeable odor generated from the mud. The mud is contained inside a pole building and is field applied only as needed or approximately twice a week. This local accumulation has reduced cost by allowing efficient loading of trucks and hauling turn times.

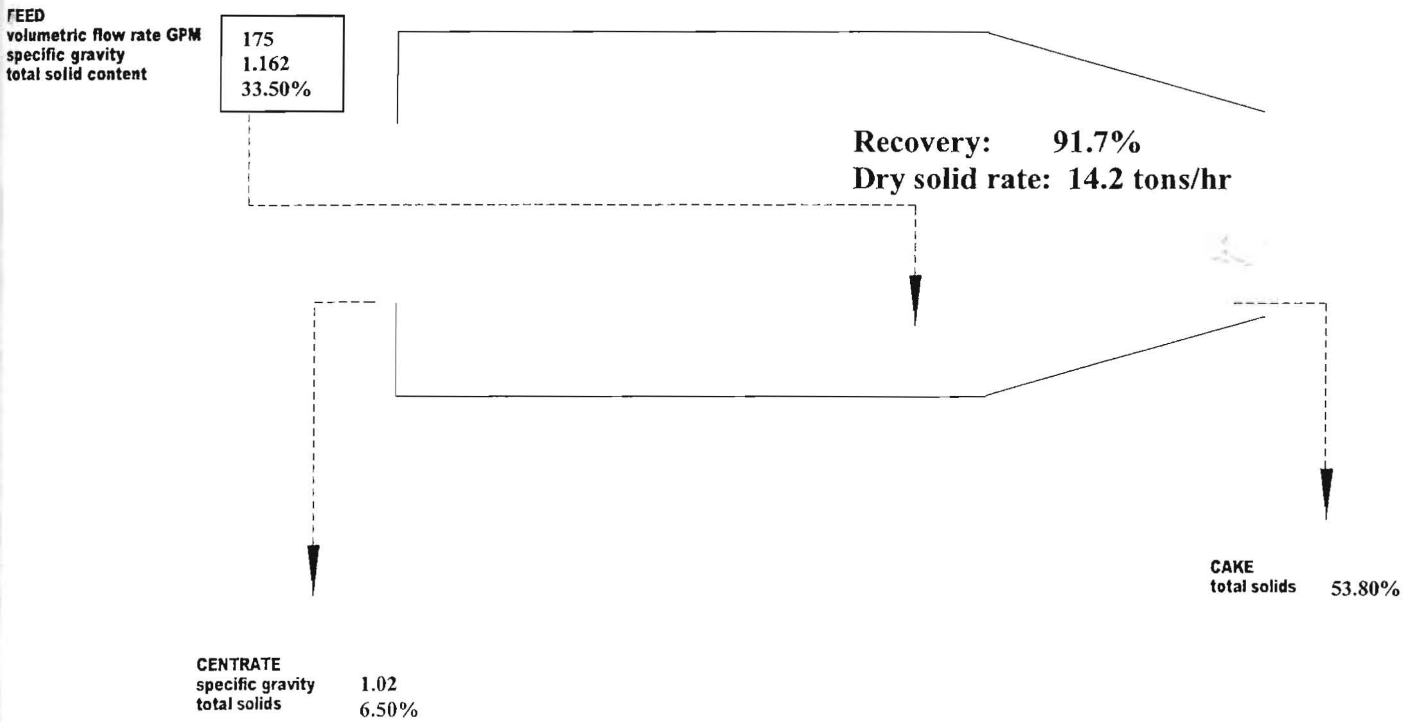
Mud conditioning

There is no mud conditioning from the clarifier to the decanters. The clarifier has little settling aid as well. Polymer addition is in the 1 ppm range when added. pH control is maintained only in the beet washing system and if sufficient anaerobic water is not returned to the wash water loop the pH is allowed to drop to values as low as pH 4.5 in the clarifier underflow. SMBSC has tried to operate the decanters without utilizing the concentrating effect of the wastewater clarifier and found that 50 to 60% of the solids could still be removed. The decanter has been fed with very low pH and a highly active gas generating, anaerobic feed. The reduction in lime usage is nearly $100,000 per year.

Decanting

The decanter operates most effectively when the mud solids are maintained above 15%. It is typical to remove over 90% of the solids with high feed concentrations. At a 5 to 8% suspended solids feed the removal rate will drop to 50 to 60 %. The foamy centrate has caused SMBSC to use more antifoam than planned. The decanter can be fitted with a choke to reduce the foam and eliminate part of this chemical usage. This is planned to be incorporated during the next normal maintenance outage. If the feed pH is maintained above 7 then that chemical usage is nearly eliminated. The amount of fine clay particles has resulted in a centrate that is higher in solids than planned. It can be treated chemically with a combination of cationic and anionic polymers to produce a stable floc and a clear centrate. Economically that is still being investigated. It is difficult to predict how much chemical may be needed due to the low solids in the feed currently, but at typical feed concentrations greater than 15% the removal rates are greater than 90% removal without chemical usage. If the pH is maintained above 7 in the clarifier, the conditioning of the mud feed may be improved so that a sufficiently clear centrate is produced without any chemical addition.

Typical material balance around the decanter with approximately 30% in the feed:



Maintenance

Maintenance has been less than plan. The decanter supplier, Broadbent, guaranteed an operating campaign without major repairs or wear. The proper selection of material, including the use of ceramic and barite as well as regular replacement of the consumable plows on the mud solids have resulted in costs less than planned. The total cost over three campaigns has been less than $115,000 or $37,000 per campaign. This maintenance cost may be less if the plows were routinely replaced. If these plows are not replaced timely additional bowl wear and vibration problems are encountered. The factory now is planning to replace them every 8 weeks of operation.

Capital

The capital required is dependant on the factory. The footprint needed for the decanters is relatively small for a sugar factory. The use of a mud storage building for freshly generated mud solids has a pollution control and aesthetic benefit. It is not essential but is included in the cost estimate.
The decanter building is a minimum structural for ancillary equipment and the decanters. It is not large enough to house other equipment not designed for the mud removal system. It is designed to limit vibration transfer. Properly maintained, there is little vibration felt when the decanters are in service.

Assumptions for the estimate are:

The decanters will require the feed and the centrate to be pumped. Pumps will be of high chrome construction. Back-up pumps are included. The piping will be of 3CR12 quality or abrasion resistance on the feed side.

The decanter sizing is based on a beet slice campaign of two million tons and a 4% tare with the tare at 80% dry substance. This will require the mud solid system to remove 320 tons solids a day for a 10, 000 ton per day factory or 64,000 tons for the campaign

The building will have two levels and will be new.

A storage type building will be present.

Electrical supply will require minimal changes; no new transformer etc.

Estimate for the Decanter installation:

Description of the item	Installed cost	Accumulating total cost
Two decanters capable of 300 gpm with 20 to 30% solids in the feed discharging 18 to 24 tons per hour dry solids only one operating	$700,000 includes mounting test out and training	$700,000
Pumps, two centrate and two feed pumps incl. piping, valves, vents etc.	$ 100,000	$800,000
Structure for decanters and pumps solid removal system and electrical, including overhead crane	$ 250,000	$1,050,000
Mud storage building	$200,000	$1,250,000
Solids handling, including sampling points access points for maintenance, etc	$125,000	$1,375,000
Electrical, lighting, instrumentation including flow meters etc.	$ 70,000	$1,445,000

This is a very robust installation with full back up capability. Additionally the capacity on the decanters and transport systems are sized to accept substantial higher solid loading. A less redundant system could be installed for no more than $1,000,000. For security reasons, two smaller decanters could be used with a loss of partial production for maintenance.

Economic impact to yearly operating budget will use straight line depreciation of 10 years for equipment and 20 years for the building.

The cost of hauling the solids will vary but for comparison the price will be fixed at $3.50 ton of wet solids. Hauling freshly generated mud with the use of the storage building resulted in a much lower handling cost than from mud digging and hauling from a pond. We have fixed $3.5 as the hauling cost but $2.5 was the true cost. Actual handling cost from the pond was $6.15 for relatively dry mud solids. Using 20% mud solids from the ponds is data from "Operational and Economic Considerations of using a belt press for dewatering soil washed from sugar beets," Kallstrom, D.L, Carlson, J.L., Gruenuich, D.P., and Larson, D.O. Proceedings from 31st ASSBT biennial meeting, 2001.

We will assume a 50% dry substance from the decanter and 20% dry substance from a pond. This will vary considerable. A recently cleaned pond had a total handling cost of $6.15/wet ton with mud solids averaging near 45%.

Economic comparison of pond cleaning, belt presses and decanting for a 2,000,000 ton campaign and 4% tare (80% bone dry solids, bds):

Description	Decanter	Mud presses	Mud pond cleaning	Mud pond cleaning w/ actual total cost**
Tons of dry solids introduced with the beets	64000	64000	64000	64000
% dry solids in the mud	50%	50%	20%	45%
Polymer cost per ton dry solids	------	$4.00	-------	
Other operating cost incl. electrical, labor	$.26/ton electrical at 0.05/kWh; $1./ton defoamer	At least 1 person, full time Used $20/hr with benefits	------	
Tons of mud to be moved	128,000	128,000	320,000	142,000
Mud solid hauling cost at $3.50/wet ton*	$448,000	$448,000	$1,120,000	$875,000
Polymer cost		$256,000		
Other cost	$80,640	$96,000		
Maintenance cost, including ancillary equipment	$75,000	$100,000		
Depreciation	$122,000	$140,000		
Total annual cost	**$725,640**	**$1,040,000**	**$1,120,000**	**$875,000**
Corrected for only 90% removal on decanter	**Add $112,000** **$837,640**	**$1,040,000**	**$1,120,000**	**$875,000**

*actual truck hauling cost for freshly generated mud solids, ** includes all costs, including two mile haul and digging equipment, operators at $6.15/wet ton

Adding mud solid removal equipment not only reduces environmental concern about odor generation it is also cost effective! The total COD to be treated by the facilities treatment system is reduced by removing the mud solids as they are generated. The removed mud solids have a high organic load of greater than 20% that can no longer contribute to the biological loading of the ponds. Additional the water in the mud solids is high strength and is 50% of the total solids being removed.

An additional analysis of cleaning ponds and operating the decanters at only 55% efficient is also presented. It demonstrates for the same operating assumptions of tons of beets and tare that it is still a cost effective solution. It is not as environmentally friendly solution. Thus the decanter offers more flexible if feed concentration can not be maintained and part of the solids must be sent to ponds.

Description	Decanter	Mud pond cleaning	Mud pond cleaning*
Tons of dry solids introduced with the beets	64000	64000	64,000
% dry solids in the mud	50%	20%	45%
Polymer cost per ton dry solids	------	-------	
Other operating cost incl. electrical	$.26/ton electrical at 0.05/kWh; $1./ton defoamer	------	
Tons of mud to be moved	70,400 by decanter 160,000 by pond cleaning	320,000	142,000
Mud solid hauling cost at $3.50/wet ton*	$246,400 $560,000/$437,000	$1,120,000	$875,000
Polymer cost			
Other cost	$40,320		
Maintenance cost, including ancillary equipment	$75,000		
Depreciation	$122,000		
Total annual cost	**$1,043,720/ $921,000***	**$1,120,000**	**$875,000**

* Again using total handling cost and higher solids

Other applications

SMBSC has successful employed for two juice campaigns is the separation of filter aid and the sluice water from standard liquor filter cleaning cycles.

The benefit of recovering sugar water reduces BOD_5 in the water storage ponds or wastewater treatment plant. The sugar recovery improves extraction. The chromatographic separation and juice refining run at SMBSC has a water deficit. This water is ideal to use in the facility. It reduces the deficit by recycling adequate quality water. Overall it reduces water treatment problems and softening constraints as well as heating costs for replacement process water.

The filter aid that is recovered from the decanter is dry and can even be dusty if the pool level is maintained too low. The solids are of sufficient quality to interest suppliers of the filter aid.

The solids are no longer accumulating in the ponds. This produces another cost savings.

The use of the decanter has been used only during the juice campaign. The installed priced is less than $50,000. It could be used during beet slice to recover the filter aid for reuse and continue to supply water to the MDS plant thus reducing the overall evaporation needs in the factory. This is true if the sluicing of the filters is performed on water.

The decanter is not always the correct choice. SMBSC chemically softens the molasses used in the chromatographic separation. The calcium carbonate formed in the softening process was removed with a decanter. The particle size and liquid viscosity makes a successful separation cost prohibited at this point by decanting. Conventional filtration is used. However the decanter can remove the solids from the sluicing without difficulty.

The decanter in water treatment can be used in cleaning ponds. The solid materials can be hydraulically moved from the ponds to the decanters. The solids can be increased from the pond's 20% level to the 50% level. This will significant reduce transportation and land application cost. It will not limit odor generation.

The decanter was successful used in the process of re-burning the calcium carbonate produced during carbonation and purification. This process minimizes the limestone consumed. The de-sugared calcium carbonate cake was made into slurry to ease transport to the rotary kiln. The decanter separated the transport liquid for reuse and produced a sufficiently dry cake to allow direct injection into the kiln.

It is very effective at removing the pulp material in raw juice and can improve the extraction.

It can also remove pre-lime sludge and avoid re-dissolving salts as well as handling a difficult filtering mud. A screen section for washing can be added to reduce losses.

The different applications become easier to accept after the decanters have performed so well in handling an abrasive material from the wastewater. The maintenance and power consumption are not high. (Often believed by non-users). The foot print is small and installation costs are generally less compared to "normal" equipment choices.

Conclusion:
The decanter is a type of equipment that can be successful used in the sugar industry. It is robust and has a large operating range. Maintenance is reduced with proper material of construction. There are multiple applications and several installations already performing well.

The use of decanters reduced the overall cost structure in removing mud solids from the conventional pond removal systems. It requires little operation attention and maintenance is minimal. It reduces odor issues by removing the solids as generated. It removes the total COD/BOD to be treated by the system. The solids leave with 50% high strength water in it. Also the mud solids are typically greater than 20% organic that is not able to contribute to the biological loading.

There are additional applications that will prove valuable to the industry in improving operations and reducing their cost structures.