Interpretation of data collected at decanter station of five sugar factories
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INTERPRETATION OF DATA COLLECTED AT DECANTER STATION OF FIVE SUGAR FACTORIES

Subodh Vinayak Joshi

ABSTRACT

The obsolete plate/frame type filter presses for muddy juice filtration were eventually replaced by rotary vacuum filter where baggacillo is essentially required to be added to work as a filtering media and which long stayed in the sugar industry almost for last sixty years!, in spite of various associated problems; perhaps for the reason of simplicity and more importantly for the reason that better alternative technology was not readily available.

The Solid bowl decanter technology has gained wide application for solid-liquid separation in other industries like oil, dairy, chemical, water and sewage treatment etc. and is in existence for more than a century all over the world.

The growing awareness of power cogeneration for sustainable growth of sugar industry in fact has been one of the driving forces to look out for alternative technologies requiring less power and diverting about 1.0% cane of saved bagasse for additional electric power cogeneration.

Based on exhaustive data collected at five successfully implemented decanter installations spread over a period from 1 to 5 seasons corresponding to individual year of decanter installation this paper presents interpretation and review of analytical data.

Keywords: Rotary vacuum filter**,** decanter, muddy juice, centrate, flocculent.

INTRODUCTION

The purpose of this paper is to discuss application of the decanter as an emerging technology for sugar industry that have the potential to improve overall performance of clarification house of sugar factory processing section for increasing the productivity and cost effectiveness. It is interesting to know

Sugar Technologist, Suviron Equipments Pvt. Ltd, G-120, MIDC, Ahmednagar, M.S. - 414111, Mobile- 9158898909, E-mail- contact@suviron.com

the impact of total suspended solid content in various intermediate liquids on operational performance of decanter station.

METHODS

Following mentioned internationally accepted methods are used for determination of various parameters in different intermediate products

Method GS7 – 7 (1994) - The Determination of the Pol (polarization) of Filter Cake by Polarimetry – Accepted

Method GS7 – 9 (1994) - The Determination of Moisture in filter cake by Oven Drying – Accepted

Method GS7 – 11 (1994) - The Determination of the mud solids in juice, Mud and Filter cake by a Gravimetric method – Accepted

Method GS7 – 13 (1994) - The Determination of cane fibre in juice, Mud and Filter cake by filtration method – Accepted

System of technical control for cane sugar factories in India – by N. C. Verma

Lab centrifuge method for Compact Packed Volume (CPV) at 3000 rpm for 3 minutes.

What is Decanter Centrifuge?

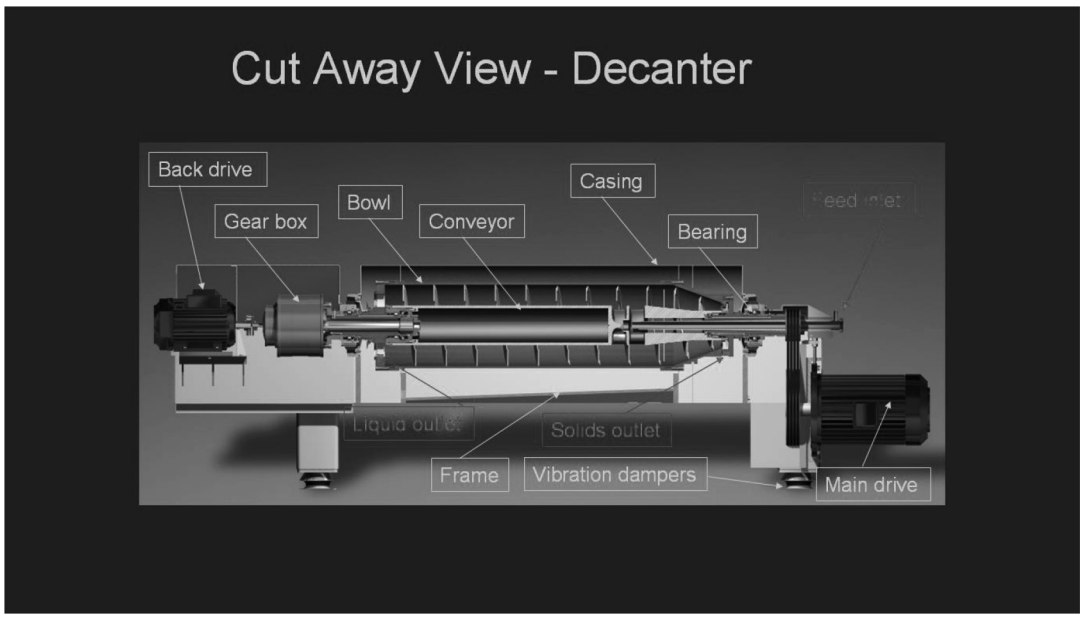
The full name of equipment by virtue of its description is "solid bowl decanter centrifugal machine" commonly termed simply as 'decanter'. Solid bowl - means the centrifugal basket without having any perforation. Decanter – means effecting decantation / sedimentation activity is actually performed in the bowl by applying very high gravitational force of the order of 2650 G by centrifugal action.

In the conventional centrifugal machine used for separating sugar crystal from mother liquor either in batch or continuous where mother liquor by application of centrifugal force passes through the screen openings. The decanter although is centrifugal machine does not have any perforations over the rotating basket. The basic principle of using centrifugal force for solid/ liquid separation universally remains the same. The only difference is that the insoluble solids when subjected to centrifugal force get separated from liquid towards bowl surface and are continuously pushed towards discharge end by a rotating helical scroll. The decanted liquid is continuously taken out through a concentric opening, normally termed as centrate.

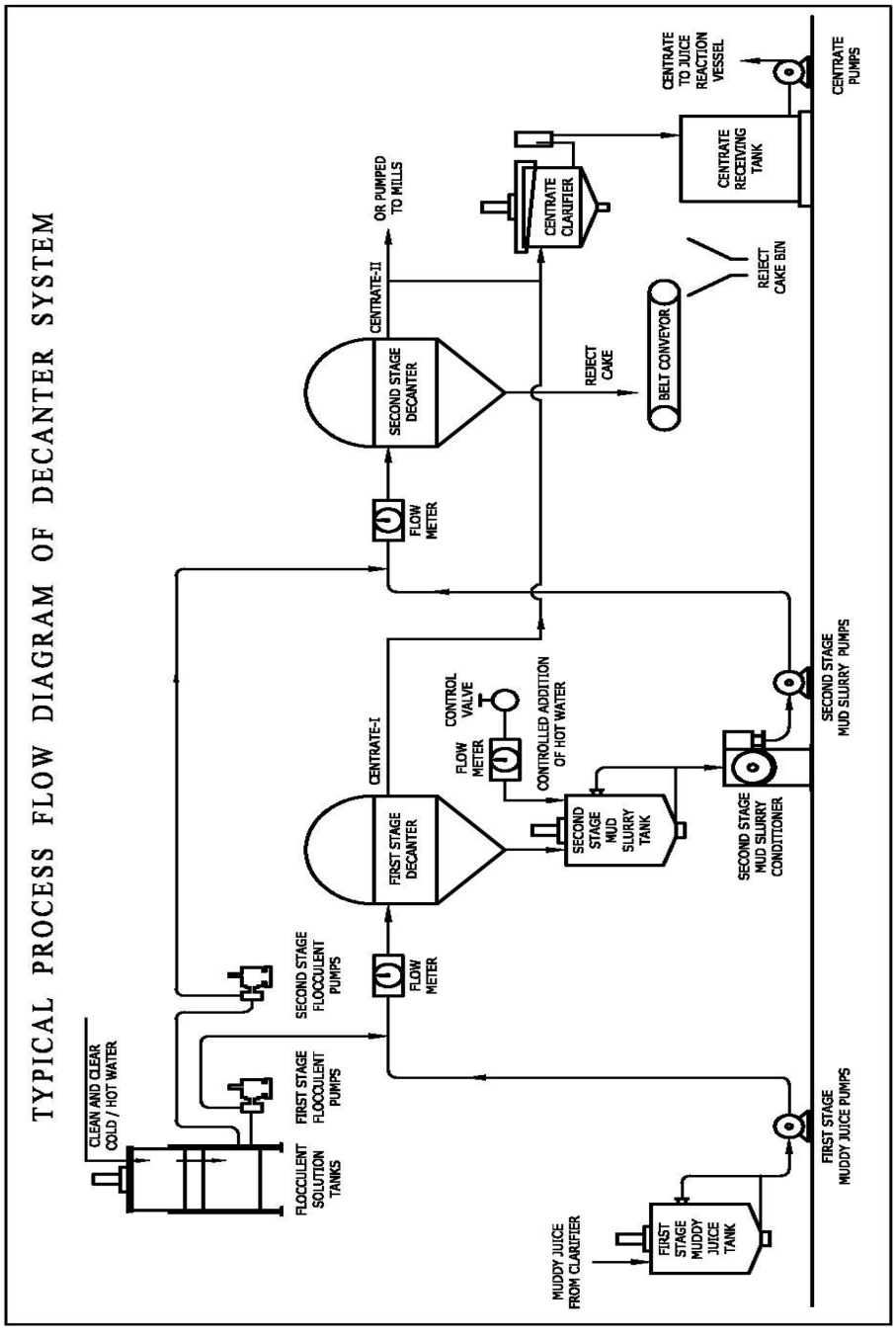
Principle of working

Separation takes place in a horizontal cylindrical bowl equipped with a screw conveyor. The feed enters the bowl through a stationary inlet tube and is accelerated smoothly by an inlet distributor. The centrifugal force that stems

from the rotation then causes sedimentation of the solids on the wall of the bowl. The conveyor rotates in the same direction as the bowl but at a different speed thus pushing the solids towards the conical end of the bowl. The cake leaves the bowl through the solids discharge openings into the solid discharge zone of casing. Separation takes place throughout the entire length of the cylindrical part of the bowl and the decanted liquid leaves the bowl by flowing over adjustable plate dams into the liquid discharge zone of casing.



OPERATION AND DATA COLLECTION AT DECANTER STATIONS OF FIVE SUGAR FACTORIES



1. Gangakhed Sugar & Energy Ltd.

Gangakhed Sugar is 6000 TCD greenfield sugar plant adapting various latest technologies like Decanter system, Short Retention Time Clarifier, Two roller mill tandem, fully DCS plant with 30mW cogeneration and 60KLPD distillery. Decanter system for muddy juice treatment was commissioned in year 2009-10 seasons *i.e.* a first full scale commercial installations with no Rotary vacuum filter at all.

At Gangakhed sugar there are total 04 nos. decanters of model SGDM 400 without BCC out of which 02 nos. are working for first stage operation and 02 nos. for second stage operation.

2. Hemarus Industries Ltd. (Olam Agro India Ltd)

It is 3500 TCD greenfield sugar plant implementing latest technologies like decanter system, Short Retention Time Clarifier, Two roller mill tandem, fully DCS plant with 20mW cogeneration. Decanter system for muddy juice treatment was commissioned in year 2010-11 seasons with no Rotary vacuum filter at all.

At Hemarus; the second installation there are total 03 nos. decanters of model SGDM 400 without BCC out of which 01 no. works for first stage operation, 01 no. for second stage operation and 01 no. as a common standby for first and second stage.

3. Vitthalrao Shinde SSK Ltd.

It is a 12 year old plant having 8000 TCD crushing capacity, 28 MW cogeneration plant & 60 KLPD distilleries where complete Solid Bowl Decanter System is installed to gradually replace all the existing Rotary vacuum Filters in phased out manner.

At this 3rd installation commissioned in the year 2011-12 season there are total 04 nos. decanters of model Sugar Dec 400 without BCC out of which 02 nos. work for first stage operation, 02 nos. for second stage operation which are suitable corresponding to 6000 TCD crushing rate.

4. Lokmangal Mauli Industries Ltd.

At this 5000 TCD greenfield sugar plant employing latest technologies like decanter system, fully DCS plant with 30 MW cogeneration. Decanter system for muddy juice treatment was commissioned in the crushing season 2013-14 with no Rotary vacuum filter at all.

At Lokmangal there are total 05 nos. decanters of model Sugar Dec 400 without BCC out of which 02 no. work for first stage operation, 02 no. for second stage operation and 01 no. as common standby for first and second stage.

The entire system together with decanter mounting structure was initially designed to suit plant expansion upto 7500 TCD as and when required and accordingly one decanter of latest model Sugar Dec 400 with BCC automation is now installed on already provided mounting structure while taking up plant expansion activities in the current year.

5. Shri Chatrapati Shahu SSK Ltd., Kagal

It is a 32 year old plant, having 5500 TCD crushing capacity, 22 MW cogeneration plant & 45 KLPD distilleries where complete Solid Bowl Decanter system is installed to gradually replace all the existing Rotary vacuum Filters in phased out manner.

At this 5th installation, there are total 03 nos. decanters of latest model Sugar Dec 400 with BCC automation out of which 01 no. for first stage operation, 01 no. for second stage operation and 01 no. as common standby for muddy juice corresponding to 2500 TCD plant capacity commissioned in the year 2012-13 season.

Initially this system with 1+1 combination of decanter operation was meant to operate for 2500 TCD crushing capacity. However the same fully automatic decanters having BCC control were later subjected to rigorous and meticulous capacity tests and it is found that this fully automatic decanter model with BCC control was capable to handle muddy juice corresponding to 5000 TCD without harming performance results.

Subsequent to establishing decanter capacity of existing setup being already adequate for 5000 TCD, the ultimate plant capacity desired to be achieved in phased out expansion program, it is now concluded that no additional decanter is required to be added. Only minor changes in muddy juice / mud slurry pumps, pipe and pipe fittings shall be carried out for the current season to operate at 5000 TCD capacity.

TABLE 1 – FACTORY WISE DATA OF SOLID AND FIBER ANALYSIS

Name of the sugar factory		1 Gangakhed Sugar And Energy Ltd.			2 Hemarus Industries Ltd. (Olam Agro)			3 Vitthalrao Shinde SSK Ltd.			4 Shree Chhatrapati Shahu SSK Ltd.			5 Lokmangal Mauli Industries Ltd.		
A	Year of installation	2009			2010			2011			2012			2013		
B	Plant cap.- TCD	6000			3500			6000			2500 expandable to 5000			5000 expandable to 7500		
C	Project category	New Greenfield (No R.V.F.)			New Greenfield (No R.V.F.)			11 years old plant to replace working R.V.F. in two phases			32 years old plant to replace working R.V.F. In two phases			New Greenfield (No R.V.F.)		
D	Co-gen cap. MW	30			20			28			22			33		
E	Mud handling Eqp.	only decanter			only decanter			decanter and R.V.F.			decanter and R.V.F.			only decanter		
Sr. no.	Intermediate liquid	solids %		dry fiber %	solids %		dry fiber %	solids %		dry fiber %	solids %		dry fiber %	solids %		dry fiber %
		CPV v / v	dry w / w		CPV v / v	dry w / w		CPV v / v	dry w / w		CPV v / v	dry w / w		CPV v / v	dry w / w	
01	Mixed juice	7.7	0.67	0.16	7.8	0.716	0.18	8.75	0.78	0.19	8	0.68	0.172	7.4	0.71	0.17
02	Sul. / def. juice	7.5	0.70	0.17	7.25	0.66	0.16	8.75	0.73	0.183	7.4	0.58	0.164	7.2	0.65	0.16
03	Muddy juice	57	8.38	2.26	64	8.24	2.14	48.25	5.65	1.457	47.8	5.76	1.962	58	8.70	2.18
04	Mud slurry	47	6.90	2.13	52.9	6.30	2.02	42.75	6.32	1.34	37.2	5.44	1.74	48	7.1	1.98
05	Centrate 1	3.0	0.35	0.02	2.9	0.31	0.04	6.75	0.33	0.01	2.9	0.304	0.026	2.3	0.31	0.02
06	Centrate 2	3.0	0.13	0.01	7.8	0.644	0.09	2.87	0.11	slight	1.2	slight	slight	3.1	0.18	0.01
07	Clarified centrate	0.55	slight	slight	0.5	slight	slight	0.5	slight	slight	0.32	slight	slight	0.4	slight	slight
08	Cen. I clarif. scum	54.23	5.7	0.01	56.6	7.40	0.20	30.25	4.61	0.11	30.2	3.29	0.14	55	5.4	0.11
09	R.V.F. feed	-	-	-	-	-	-	44.25	5.92	2.477	42.8	5.064	2.33	-	-	-
10	R.V.F. filt. returns	-	-	-	-	-	-	9.375	0.92	0.17	6.8	0.78	0.136	-	-	-

Table no. 2 - Factory wise operating results

Sr. no.	Description	Unit	Gangakhed sugar And Energy Ltd.	Hemaraus Industries Ltd.	Vitthalrao Shinde SSK	Shree Chhatrapati Shahu SSK	Lokmangal Mauli Industries Ltd.
			Values				
01	Pol % reject cake	%	1.4 to 1.6	1.4 to 1.6	1.4 to 1.5	1.4 to 1.6	1.3 to 1.5
02	Moisture % reject cake	%	67 to 70	67 to 70	68 to 70	67 to 70	67 to 70
03	Solid removal efficiency across decanter station	%	93 to 94	95 to 96	95 to 96	95 to 96	93 to 94
04	Reject cake % cane	%	1.7 to 2.0	1.7 to 2.0	1.8 to 2.0	1.9 to 2.0	1.8 to 1.9

Similar data shall be collected at Daund Sugar Ltd. (6000 TCD) and Athani Sugars Ltd. (7500 TCD) during crushing season 2014-15

DISCUSSION

1. **Suspended/Insoluble solid contains fiber, mud, soil, precipitate of calcium phosphate, sulphate etc.**
   From table no. 1 it is observed that dry suspended (insoluble) solids varies from factory to factory and also depends upon variables like, cane variety, region, cane harvesting method, wedge bar opening of Rotary Juice Screen etc. Normally suspended (insoluble) solids in muddy juice are found in the range of 5 to 9 % w/w.

   In case of Rotary Vacuum Filter solid retention factor i.e. suspended solid removal efficiency is found in the range of 70 to 75 % and at integrated decanter station same is found in the range of 93 to 96 % and hence suspended solid recirculation across clarification house is much less as compared to Rotary Vacuum Filter. Avoiding unnecessary recirculation of sugar and non-sugar is ultimately beneficial for achieving improved clarification house performance.

2. **Effect of fiber on decanter capacity**
   From table no. 1 it is observed that fiber % in total dry suspended (insoluble) solids varies from 25 to 34 % w/w. It is therefore advantages to reduce this fiber content to the maximum extent possible in order to minimize the total solid loading on decanter. This can be achieved by adding rotary juice screen having lesser wedge bar opening as a second stage screening arrangement *i.e.* "fine" screening. At Krishna SSK Niyamit–Athani second stage Rotary juice screen was installed in the year 2012-13. and observed residual bagacillo content in first stage screened juice ("coarse" separation) as 0.208% w/w on oven dry basis adapting wedge bar opening of 0.5 mm and 0.132% w/w on oven dry basis in second stage screened juice ("fine" separation) by providing wedge bar opening of 0.35 mm.

   It is concluded that there is 35 to 40 % reduction in bagacillo content (fiber) in the juice going to process house and which will proportionately reduce fiber solid loading on decanter system.

3. **Suspended solid separation efficiency**
   Suspended solid separation efficiency is influenced by feed flow rate, suspended solid concentration, pH, pond level inside the decanter bowl, differential speed of bowl and conveyor, conditioning of muddy juice, polymer dosage, temperature of muddy juice, temperature of dilution water and stabilized flow. Referring to table no. 1 it would be observed that solid separation efficiency measured across entire decanter station varies between 93 to 96%.

4. Brix, purity and suspended solid content in Centrate

- Centrate I

The purity of the centrate 1 and of clear juice almost found the same which indicates that the first stage indeed acts as extension to main juice clarifier. Brix of Centrate I varies from factory to factory corresponding to mixed juice brix and mud consistency.

The average pH of centrate 1 is observed in the range of 6.50 and 6.7 which shows very negligible drop in pH from preconditioned muddy juice.

From table no. 1 dry suspended solid in unclarified centrate I observed in the range of 0.25 to 0.5 % which is almost 50 % of suspended solids, 0.6 to 0.85 % as found in RVF filtrate returns. Further solid separation takes place at flotation clarifier where the suspended solid content in the clarified centrate is effectively brought down to negligible level. This will totally avoid suspended solid loading on main juice clarifier.

- Centrate II

The purity of centrate II is found in the range of 55 to 70 which varies according to mixed juice and muddy juice purity as well as consistency of muddy juice. Brix of Centrate II varies in the range of 2.0 to 3.5 Deg.

From table 1 dry suspended solid in unclarified centrate II observed in the range of 0.05 to 0.2 % which can be recycled to mills with or without clarification or alternatively the combined centrate I and II, after clarification, containing negligible solid content can be recycled to juice reaction vessel.

5. Factors influcing pol % Reject cake

5.1 Pol % cane

Region wise it is generally observed that sugar content in sugarcane varies 11 to 15 % which will correspondingly reflect on purity of mixed juice and subsequently on purity of muddy juice. The sugar content in the muddy juice will have direct influence on sugar content of solids discharged from 1st stage and will have impact on de-sugarization of mud slurry at 2nd stage, the main functional duty of this final stage where the discharged solids could be better termed as 'exhausted' cake which indeed is a 'reject cake'; synonymous to a term final molasses used for 'exhausted molasses'.

5.2 Use of settling polymer at juice clarifier

Whatever may be the type of clarifier; be it a 4-4-4 type conventional or SRTC settling polymer is invariably used for thickening of muddy juice. At conventional clarifier polymer dosing at the rate of 0.5 to 1ppm is used while at SRTC where due to short retention time polymer dosing at the rate of 3 to 4 ppm is generally practiced.

To minimise pol % mud slurry at 1st stage itself it would be desirable to have maximum compactness / consistency of 1st stage muddy juice feed.

5.3 Type of juice clarification

By virtue of density difference of precipitate as per clarification process adapted *i.e.* juice sulphitation for white sugar manufacture or defecation of juice in case of raw sugar manufacture the variation in muddy juice consistency is observed. In case of only liming (Defecation process) compactness of muddy juice is on lower side due to lesser density of only calcium phosphate precipitate formed during liming process while calcium sulphate precipitate formed during sulphitaion process allows more compactness of muddy juice due to higher density of Calcium Sulphate precipitate.

5.4 Type of Clarifier used for juice clarification *i.e.* SRTC / 4-4-4 conventional clarifier

In case of SRTC by virtue of it's design features uniformly higher mud consistency is achieved at single point muddy juice withdrawal. In case of 4-4-4 clarifiers however at 04 nos. muddy juice withdrawal points variation in mud consistency from each compartment is generally observed. It is further observed at either types of clarifiers at different factories that mud compactness at SRTC is generally higher by 10 to 15 % as compared to compactness of combined muddy juice from all compartments of conventional 4-4-4 clarifier.

5.5 Quantity and quality of dilution water used

Use of dilution water of 80 Deg. C is inversely proportional to pol % reject cake, obviously for the reason that better degree of washing is affected.

5.6 Quantity of baggase present in muddy juice

Baggacillo having a property to absorb the juice (sugar) has tendency to retain soluble sugar. If less quantity of baggase is present in muddy then the pol % reject cake will be accordingly lower.

6. Why "Two stage" operation

I Stage – It indeed acts like an extension to main juice clarifier-(subsider)

At Clarifier which is "static" the solid separation occurs only by natural gravitational force *i.e.* **ONE – "G"** requiring residence time of 45 to 60 min. in case of SRTC and 2 to 3 hours in respect of conventional 4-4-4 clarifier.

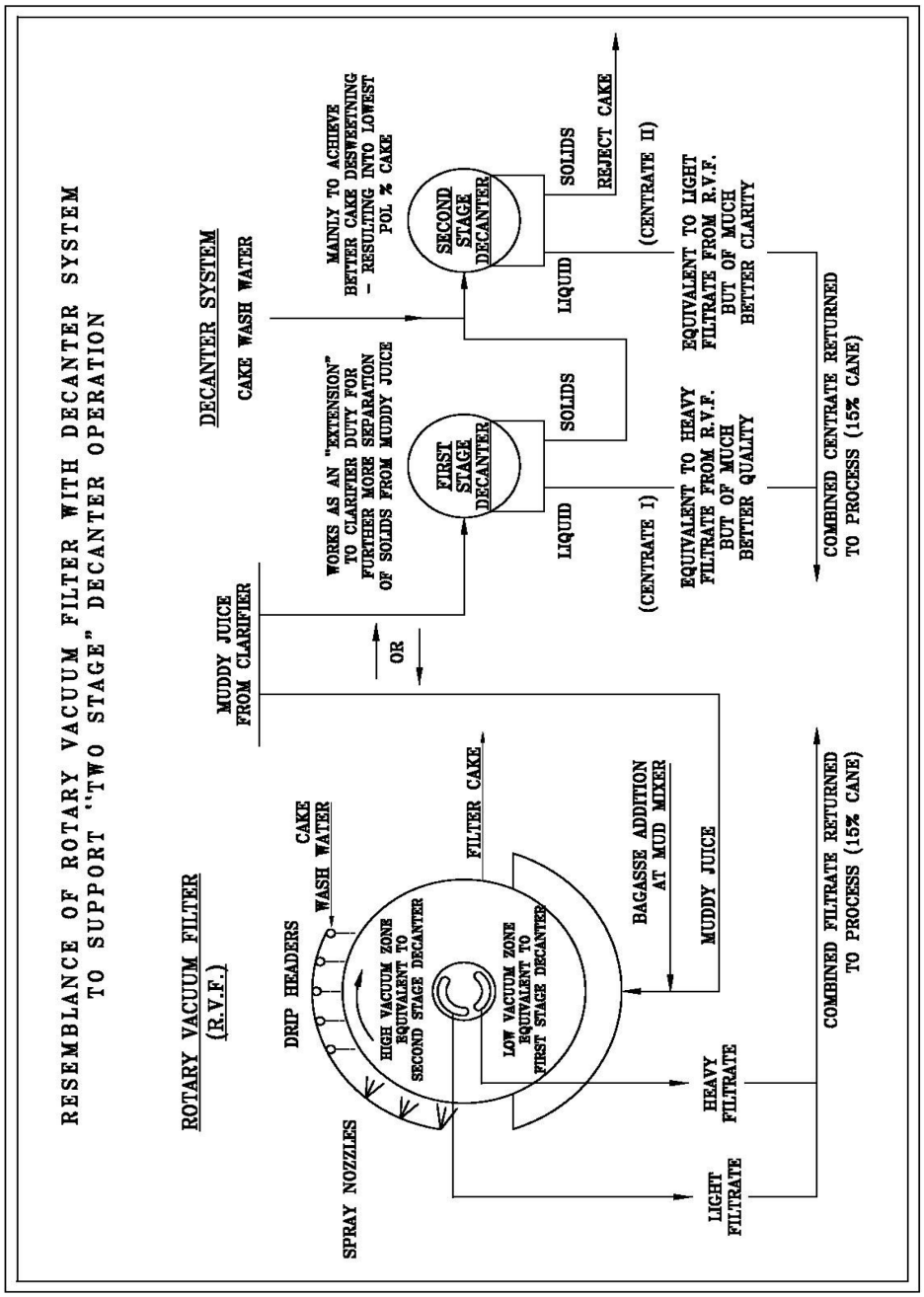
At decanter further solid separation takes place because of much higher "G" factor of the order of 2650 where solid are instantly separated just within a few seconds.

II Stage – Where actual De-sugarization & De-moisturization takes place.

Solids discharged from I stage are homogeneously mixed in hot water at mud conditioner to form a slurry which allows washing effect.

This slurry fed to II stage allows de-sugarization as well as de-moisturization at same high **2650 "G"** factor discharging the solids as final reject cake.

Synonymous example in sugar industry for stage wise de-sugarization could be cited as, viz. three stages of pan boiling are required to crystallize out maximum sugar from syrup, the first mother liquor and B heavy molasses as final stage mother liquor. Similarly in order to extract maximum sugar from sugar cane the milling tandem comprises of 4 to 5 mills *i.e.* stages.



Cost economics of Decanter system over Rotary Vacuum Filter (RVF) per ton of cane

Commercial benefits are calculated based on following considerations:

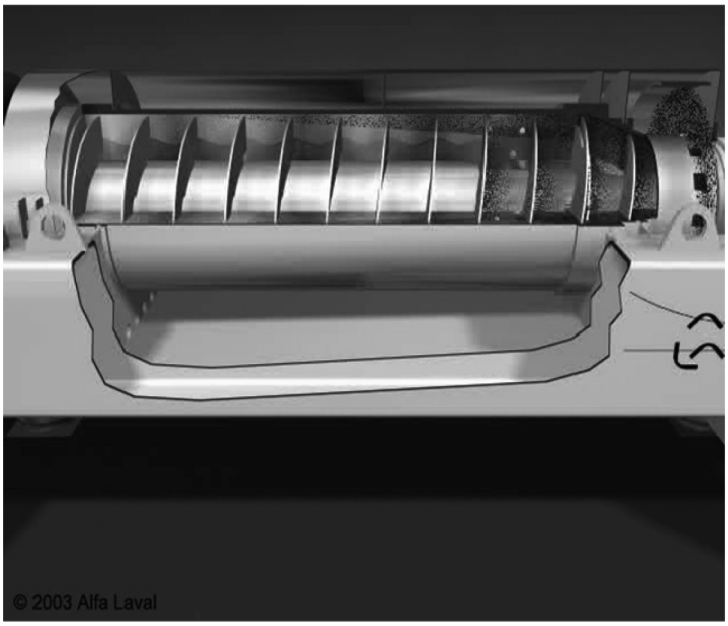
Base:

1.0	Rotary Vacuum Filter	
1.1	Pol % filter cake	: 1.9*
1.2	Filter cake % cane	: 3.7
1.3	Pol-loss through filter cake % cane	: 0.0703
	* Normally pol % filter cake is found in the wide range of 1.6 to 2.2 according to low/high recovery zone and prevailing operating conditions, hence average is considered.	
2.0	Decanter System	
2.1	Pol % reject cake	: 1.6 max
2.2	Reject cake % cane	: 1.9*
2.3	Pol-loss through reject cake % cane	: 0.0304
	* Reject cake % cane varies in the range of 1.8 to 2%, according to low/ high recovery zone and prevailing operating conditions, therefore average is considered.	
3.0	Sugar price	: Rs.28000 per Ton
4.0	Electric power tariff	: Rs.5.69 per K.W.H.
5.0	Specific steam consumption of power house turbine	: 5.5 Ton per M.W.
6.0	Steam generation per ton of bagasse	: 2.5 Ton
7.0	Price of polymer	: Rs.325 per Kg.
8.0	Sugar recovery % cane	: 10
9.0	Crop days per season	: 150

Rotary Vacuum Filter	Decanter System	Per ton cane	
		Profit	Loss
1. Additional sugar recovered due to reduced sugar loss through cake			
The sugar loss % cane through filter cake is works out as 0.0703% cane.	The sugar loss % cane through reject cake works out as 0.0304% cane.	The reduction in sugar loss shall be 0.0399 (0.0703 - 0.0304) % cane. Considering sugar price Rs. 28000 per Ton the gain per ton cane works out as 0.0399 / 100 =0.000399 x Rs. 28000 =	
		Rs. 11.17 Profit	

<table>
<tr><td colspan="4">2. Additional revenue by direct bagasse saving @ 1% cane*</td></tr>
<tr><td rowspan="2">At Rotary Vacuum Filter 1% cane of sieved fine bagasse is required to work as filtering media to achieve best results.</td><td rowspan="2">Bagacillo not at all required.</td><td>This will result in net bagasse saving @ 1% cane i.e. 0.01 tons per ton cane which will raise 0.025 tons of steam to generate 4.54 K.W.H. of electric power as per following calculations :
1) Steam generation Ratio at bagasse fired boiler = 2.5 ton of steam per ton of bagasse burnt.
2) Specific steam consumption of power house turbine = 5.5 Ton of steam per MW
Considering prevailing tariff of Rs. 5.69 per K.W.H., the additional electric power generated results into extra revenue of,</td><td></td></tr>
<tr><td colspan="2">*Confirmed as per calculations and supported by well known reference at page no. 251 of Handbook of cane sugar engineering by Peter Rein.</td><td>Rs. 25.83 Profit</td><td></td></tr>
<tr><td colspan="4">3. Electrical energy saved due to reduced power requirement</td></tr>
<tr><td rowspan="2">Since the time of introduction of RVF in Indian sugar industry in late sixties no data is available in respect of actual energy consumed at RVF. It is therefore fair to consider a generally industry accepted power consumption ratio as 0.7 KWH/TCH.</td><td rowspan="2">It is observed at M/s. Chhatrapati Shahu SSK, Kagal that by using fully automatic decanter with BCC and operating the same at its full capacity w.r.t. solid handling, the power consumption ratio is found as 0.4 KWH/T.C.H.</td><td>The reduction of power consumption ratio by 0.3 KWH/T.C.H. the net saving on account of reduced power consumption works out as = Rs. 5.69 x 0.3</td><td></td></tr>
<tr><td>Rs. 1.77 Profit</td><td></td></tr>
</table>

Rotary Vacuum Filter	Decanter System	Per ton cane	
		Profit	Loss
4. Cake transportation cost, reduced due to lesser quantity of reject cake			
Assuming filter cake % cane as 3.7	Average reject cake % cane as considered is 1.9	The reduction in transportation cost of cake due to lesser cake % cane by 1.8% on cane = 0.018 tons per ton of cane. Considering transportation cost as Rs. 50 per ton, the gain works out as Rs. 50 x 0.018 =	
		Rs. 0.9 Profit	
5. Chemical consumption			
Not required for Rotary Vacuum Filter.	Chemical requirement will be approximately 0.012 Kgs per ton cane, maximum.	Additional cost on account of chemical requirement @ 0.012 kgs/ton cane at the unit rate of Rs. 325/- per Kg. works out as,	
			Rs. 3.9 Loss
TOTAL PROFIT/LOSS PER TON OF CANE		**Rs. 39.67**	**Rs.3.9**
NET PROFIT FOR TON OF CANE		**Rs. 35.77**	
Additional profit realized per 100 Kg sugar bag		**Rs. 36.00**	
In addition to profit as quantified above there are other direct and indirect benefits like very high solid removal efficiency of more than 96%, thereby lesser recirculation of mud solids, less colour value of recycled centrate than that of filtrate returns, higher purity of combined centrate than combined heavy and light filtrate returns and reduction in viscosity etc.			



Cross Section of Decanter Machine

Sample of clarified centrate

Scum from centrate clarifier

Reject cake

CONCLUSION

1. Techno economic evaluation of the system indicates a reasonable pay back period and therefore this technology will be better placed in near future.
2. Purity of combined centrate returns is higher than combined filtrate returns which will result in to proportionate increase in clear juice purity to an extent.
3. Dry insoluble solid content in clarified centrate returns is much less (negligible) than in combined filtrate returns, resulting into good reduction in solid loading factor on juice clarifier which in turn will improve solid/ liquid separation efficiency at existing juice clarifier.
4. After recycling clarified centrate back to juice reaction vessel no colour increase in clear juice from main juice clarifier was observed.
5. More importantly the brix and quantity of combined filtrate returns and combined clarified centrate returns being almost same there shall not be any additional evaporation load.

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