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# Two-stage decanter operation for treatment of muddy juice

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**Abstract** A single-stage configuration of a decanter for treatment of muddy juice has not achieved a pol% reject cake below the normal level of 1.6-1.7 generally observed in filter cake from rotary vacuum filters (RVF). The same decanter technology, but in a two-stage configuration, was evaluated. Selection of a two-stage decanter configuration was based on a resemblance to the RVF operation, where the low vacuum zone represents a 'first stage' where heavy filtrate is generated and the high vacuum zone forms a 'second stage' where light filtrate is generated. Data were collected at two-stage decanter installations of eight sugar factories over 7 years. ICUMSA methods were used to analyze intermediate products such as mixed juice, muddy juice, mud slurry, centrate I and II, RVF feed, filtrate returns, filter cake and reject cake for pol, moisture, mud solid, and fibre. The average pol%reject cake was 1.6 and moisture was 68-70%. The average reject cake % cane was 1.9. Assuming pol % cane as 14 and considering that as a base of 100, the pol loss through reject cake % pol in cane was reduced to 0.21 as against an average 0.5% pol loss for RVFs. Simultaneously, a highest insoluble solids separation efficiency of 92-95% across the decanter station was achieved, compared with 70-80% at the RVF where sieved bagasse at 1% on cane is required as a filter aid. In addition to the advantage of a 50% reduction in sugar loss through filter cake, the other main advantage is the generation of additional green power at an attached co-generation power plant using the saved bagasse at 1% on cane. Insoluble solids recycling into the clarification process, which otherwise was occurring through filtrate return of RVF is reduced by 22-25%.

**Key words** Decanter, muddy juice, mud slurry, centrate, flocculant, insoluble solids, filtrate

## INTRODUCTION

Research into the application of solid-bowl decanters on clarifier underflow mud includes Hale *et al*. (1974), Stewart *et al*. (1974, 1976), Ravno and Lionnet (1975), Steindl *et al.* (2010) and Rein (2013). These investigations centered around a single-stage decanter operation that generally resulted in a higher pol% reject cake. Hence, 'two-stage' decanter operations were adopted where the mud solids from the first-stage operation were mixed with hot water to form a mud slurry. The addition of hot water provides a washing effect to the mud solids. This slurry was fed to a second-stage decanter. The pol % reject cake resulting from the second stage operation was 1.4-1.7.

This paper evaluates the application of a decanter machine operated in a 'two-stage' configuration at eight factories across India.

## METHODS AND EQUIPMENT

ICUMSA accepted methods were used for determination of different parameters in the different intermediate products, such as mixed juice, clarifier underflow, filtrate, centrate, filter cake from vacuum filter and reject cake from the decanters. The analytical methods used included:

- Method GS7–7 (1994) - The determination of the pol (polarisation) of filter cake by polarimetry with lead subacetate
- Method GS7–9 (1994) - The determination of moisture in filter cake by oven drying
- Method GS7–11 (1994) - The determination of the mud solids in juice, mud and filter cake by a gravimetric method
- Method GS7–13 (1994) - The determination of cane fibre in juice, mud and filter cake by a filtration method

During each crop season a minimum 100 samples of each intermediate product were collected and analysed immediately after sampling at each factory laboratory.

### Solid-Bowl Decanter Centrifugal Machine

The basic principle of using centrifugal force for solid/liquid separation remains the same. The only difference in this case is that the insoluble solids, when subjected to centrifugal force, get separated from the liquid towards the bowl surface and are continuously pushed towards the discharge end by a rotating helical scroll. The decanted liquid, normally termed centrate, is continuously taken out through a concentric opening at the opposite end. A decanter is illustrated in Figure 1 and the specifications are listed in Table 1.

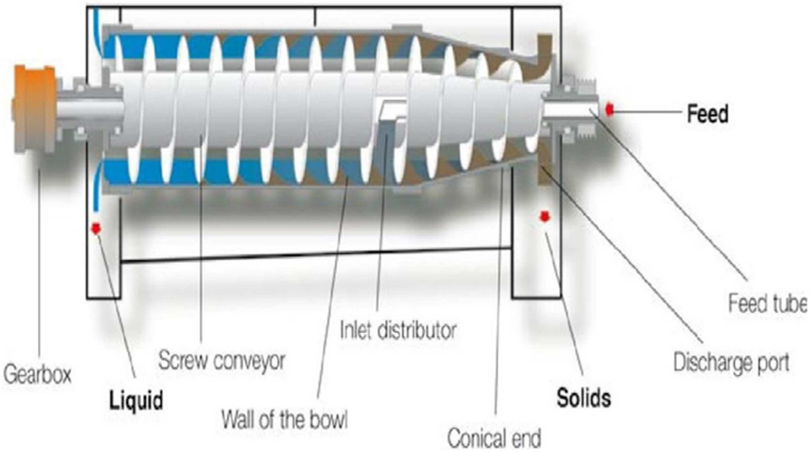


***Fig 1.*** Cut away view of a decanter.

***Table 1.*** Specifications of a decanter.

| Particular | Unit | Data |
|---|---|---|
| Flow configuration | | Counter-current |
| Maximum design temperature | ℃ | 100 |
| Maximum operating speed | r/min | 3250 |
| Centrifugal G force | G | 2675 |
| Bowl diameter | mm | 450 |
| Bowl length | mm | 1910 |
| Liquid outlet type | | 4 plate dams |
| Liquid outlet radius | mm | Adjustable 131 to 134 |
| Solid outlet type | | 10 bushing |
| Main drive motor | kW | 45 with VFD |
| Back drive motor | kW | 11 with VFD |
| Control panel | | Basic core controller |

An interlock is provided to stop the decanter machine and the feed pump motor if the decanter main-drive motor becomes overloaded, the motor becomes overheated, the hood cover is open or if the decanter screw conveyor becomes overloaded.

## Wear and tear protection

Special consideration is given to wear and tear protection at critical places. This has practically proved its importance by having achieved enhanced service life of the decanter machine with a substantial reduction in maintenance. Wear and tear protection is provided at the following likely wear-prone places.

- Tungsten carbide bushings at feed zone
- Tungsten carbide tiles weld-fitted on conveyor leading flights
- Tungsten carbide bushings at solids discharge ports

### Role of differential speed and pond depth

For the first-stage operation, differential speed was kept at 20-25 rpm and pond depth (liquid outlet radius) was kept as 131 mm or 132 mm. This results in a clear centrate and wetter cake - desirable parameters for the first-stage operation.

In the second stage operation, differential speed was kept at 15-18 rpm and pond depth (liquid outlet radius) was kept as 133 mm or 134 mm. This results in a dryer cake - desirable parameters for the second-stage operation.

## DETAILS OF THE TWO STAGE DECANTER SYSTEM

Figure 2 shows a two-stage decanter system.

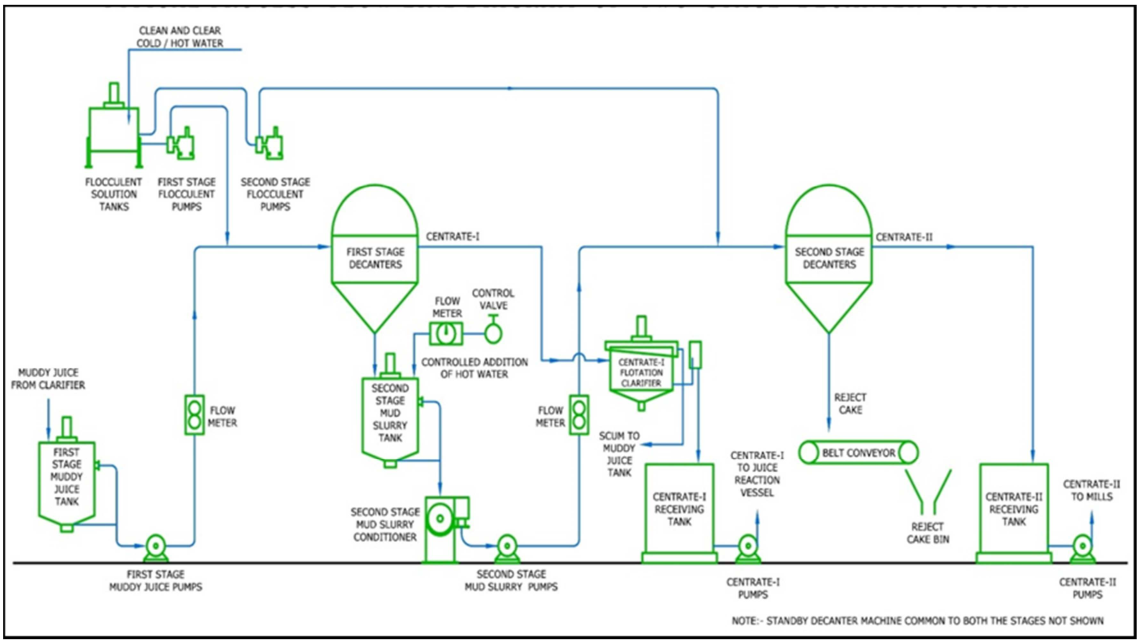


***Fig 2.*** Arrangement for a two-stage decanter system.

### Stage I

Clarifier underflow, i.e. muddy juice from a conventional multitray or short retention type clarifier, is taken to the first-stage muddy juice receiving tank that is provided with a stirrer to homogenously mix the muddy juice. This preconditioned muddy juice is pumped at a controlled rate to the first-stage decanter. At the muddy juice entry of the decanter, a polymer addition connection is provided. The anionic polymer is used for improved solid-liquid separation in the decanter.

The decanter machine rotates at 3250 r/min generating a force of 2650 G. The decanter has one feed inlet and has two outlets, one for the liquid centrate and another for solids discharge, i.e. mud cake.

The centrate I discharged from the first-stage decanter operation has a Brix and purity comparable with that of the mixed juice, but with a lower insoluble solids content of 0.35%. This centrate, containing a high amount of air, is then fed to a flotation clarifier. The clear, but of turbid nature, centrate coming out of this clarifier has a negligible insoluble-solids content is then recycled to the mixed juice reaction vessel . Scum collected from the flotation clarifier is sent back to first-stage muddy juice tank.

## Stage II

Mud solids discharged from the first-stage decanter are mixed with a controlled addition of hot wash water in the second-stage mud slurry preparation tank. This is provided with a mechanical stirrer for proper mixing of mud solids and the contents are further homogenised at the mud slurry conditioner. Mud slurry is then pumped at a controlled rate to the second-stage decanter.

The reject cake from the second stage decanter has a pol of 1.4-1.7 % and a moisture content of 68-70 %

Centrate II generated at the second-stage operation has a brix of 3- 5 and a purity of 55-65. This centrate is recycled for mill imbibition use. Considerable steam economy is gained by reducing the requirement of hot imbibition water by 7-8% cane, without affecting the pol % bagasse by dividing centrate addition along the milling tandem.

In a rotary vacuum filter both light and heavy filtrate, approximately 13-15% cane, is recycled back to the process. With the decanter system only centrate I, approximately 7-9% cane, is recycled back to the process and centrate II, approximately 7.5-8.5% on cane, is used as mill imbibition water. Thus, the total load on the evaporators is reduced and steam economy is achieved as was seen at Daund Sugar Pvt. Ltd (Giramker *et al.* 2016).

Details of the operating parameters, including the differential speed and pond depth of the decanter, are given in Table 2. A brief summary of the results obtained at eight factories is given in Table 3. An overall performance of a two-stage decanter system, based on crop season averages of the daily results from the eight factories, is given in Table 4.

***Table 2.*** Typical operating parameters of two-stage decanter operation.

| Parameter | Unit | Values | |
|---|---|---|---|
| | | Stage 1 | Stage 2 |
| Muddy juice flow rate | % cane | 8-12 | 10-12 |
| Decanter polymer usage for sulphitation plant | ppm on cane | 6-8 | 3-4 |
| Decanter polymer usage for defecation plant | ppm on cane | 3-5 | 2-3 |
| Differential speed of decanter | rpm | 20-25 | 15-18 |
| Actual power consumed by main drive | kW | 20 | 20.5 |
| Actual power consumed at back drive | kW | 0.1 | 0.2 |
| Wash water quantity | % Cane | 7-8 | |
| Centrate I quantity | % Cane | 7-9 | |
| Centrate II quantity | % Cane | 7.5-8.5 | |

The muddy juice % cane was 8-10% on cane with a short retention time clarifiers and 10-12% on cane with conventional multitray clarifiers. Hence, we assume the average muddy juice flow rate of 8-12 % on cane for both the types of clarifiers.

If there is more than one decanter at each stage, then the total input flow, i.e. muddy juice and hence decanter polymer, is divided proportionately.

For a defecation plant, the polymer consumption at the decanters is less than for a sulphitation plant.

***Table 3.*** Results of the two-stage decanter operation at eight factories.

| No. | Factory and year of installation | Intermediate liquid | Total insoluble solids % | Fibre % |
|---|---|---|---|---|
| 1 | Gangakhed Sugar And Energy Ltd. 2009 | Mixed juice | 0.67 | 0.16 |
| | | Muddy juice | 8.38 | 2.26 |
| | | Mud slurry | 6.90 | 2.13 |
| | | Centrate I | 0.07 | 0.004 |
| | | Centrate II | 0.13 | 0.01 |
| 2 | Hemarus Industries Ltd. (Olam Agro) 2010 | Mixed juice | 0.72 | 0.18 |
| | | Muddy juice | 8.24 | 2.14 |
| | | Mud slurry | 6.30 | 2.02 |
| | | Centrate I | 0.06 | 0.004 |
| | | Centrate II | 0.18 | 0.09 |
| 3 | Vitthalrao Shinde SSK Ltd. 2011 | Mixed juice | 0.78 | 0.19 |
| | | Muddy juice | 5.65 | 1.46 |
| | | Mud slurry | 6.32 | 1.34 |
| | | Centrate I | 0.10 | 0.005 |
| | | Centrate II | 0.11 | 0.085 |
| 4 | Shree Chhatrapati Shahu SSK Ltd. 2012 | Mixed juice | 0.68 | 0.17 |
| | | Muddy juice | 5.76 | 1.96 |
| | | Mud slurry | 5.44 | 1.74 |
| | | Centrate I | 0.05 | 0.003 |
| | | Centrate II | 0.12 | 0.01 |
| 5 | Lokmangal Mauli Industries Ltd. 2013 | Mixed juice | 0.71 | 0.17 |
| | | Muddy juice | 8.70 | 2.18 |
| | | Mud slurry | 7.10 | 1.98 |
| | | Centrate I | 0.07 | 0.004 |
| | | Centrate II | 0.18 | 0.01 |
| 6 | Athani Sugars Ltd. 2014 | Mixed juice | 0.82 | 0.17 |
| | | Muddy juice | 7.88 | 1.64 |
| | | Mud slurry | 6.52 | 1.48 |
| | | Centrate I | 0.08 | 0.005 |
| | | Centrate II | 0.25 | 0.015 |
| 7 | Daund Sugar Ltd. 2014 | Mixed juice | 0.65 | 0.16 |
| | | Muddy juice | 7.80 | 1.85 |
| | | Mud slurry | 5.51 | 1.79 |
| | | Centrate I | 0.05 | 0.003 |
| | | Centrate II | 0.20 | 0.01 |
| 8 | Lokmangal Sugar, Cogen and Ethanol Ltd. 2015 | Mixed juice | 0.72 | 0.21 |
| | | Muddy juice | 8.87 | 2.40 |
| | | Mud slurry | 7.35 | 2.25 |
| | | Centrate I | 0.08 | 0.003 |
| | | Centrate II | 0.15 | 0.05 |

**Table 4.** Average results achieved across the 8 sugar factories.

| Parameter | Value |
|---|---|
| Insoluble solids removal efficiency across decanter station | 92-95 |
| Reject cake % cane | 1.9 |
| Pol % reject cake | 1.6 |
| Moisture % reject cake | 68-70 |

These data were collected from performance test certificates as well as laboratory test reports provided by each factory.

## DISCUSSION

Table 3 shows that the dry insoluble solids varies from factory to factory depending upon variables such as cane variety, region, cane-harvesting method, wedge-bar opening of the rotary juice screen, etc. Normally, insoluble solids in muddy juice are 5-9 % w/w.

The factors influencing the pol % reject cake include:

- Pol % cane. Sugar content in sugarcane varies from 11 to 15%, correspondingly reflecting on the purity of mixed juice and subsequently on the purity of muddy juice. The sugar content in the muddy juice will have direct influence on the sugar content of the mud solids discharged from the first-stage decanter and will have an impact on de-sugarisation of mud slurry at the second stage.
- Use of polymer at juice clarifier and compactness of muddy juice. Whatever the type of clarifier, multitray type conventional or SRTC, polymer is invariably used to thicken muddy juice. In a conventional clarifier, polymer is dosed at the rate of 0.5-1 ppm, while at SRTC, due to short retention times, polymer is generally dosed at 2-4 ppm.

To minimise the pol % mud slurry at the first stage, it is desirable to have maximum compactness and consistency of the first-stage muddy juice feed:

- Type of juice clarification. By virtue of density difference of precipitate as in the clarification process adopted, i.e. juice sulphitation for white-sugar manufacture or defecation of juice for raw-sugar manufacture, muddy juice varies in consistency. In the case of liming only (defecation process), the compactness of muddy juice is on the lower side, due to the lower density of calcium phosphate precipitate formed during the liming process. Calcium sulphite precipitate formed during the sulphitation process allows more compactness of muddy juice due to its higher density.
- Type of clarifier used for juice clarification, i.e. SRTC or multitray. SRTC, by virtue of its design features, achieves uniformly higher mud consistency at the single point for muddy juice withdrawal. However, in the case of multitray clarifiers with multiple muddy juice withdrawal points, mud consistency varies from each compartment. We have further seen that mud compactness at SRTC is generally higher by 10-15% compared to compactness of combined muddy juice from all compartments of a conventional multitray clarifier.
- Quantity of wash water used. The quantity of clear wash water of 80-85 ℃ is inversely proportional t o the pol % reject cake.
- Quantity of bagacillo present in muddy juice. Bagacillo has a tendency to retain sucrose. If a lower quantity of bagacillo is present in muddy juice, then the pol % reject cake will be accordingly lower, as will the moisture.

The purity of the centrate I and of clear juice was almost the same as would be expected. The brix of centrate I varied from factory to factory, corresponding to the mixed juice brix and mud consistency. The average pH of centrate I was 6.5-6.7, showing a very negligible drop in pH from preconditioned muddy juice.

The purity of centrate II was 55 to 65, and varied according to the mixed juice and muddy juice purity, as well as the consistency of the muddy juice. The Brix of centrate II varied from 3.0 to 5.0.

Insoluble solids separation efficiency might be influenced by the feed flow rate, insoluble solids concentration, pH, pond depth inside the decanter bowl, differential speed of bowl and screw conveyor, conditioning of the muddy juice, polymer dosage, temperature of muddy juice, temperature of wash water and stabilised flow. This needs to be studied in detail.

Solids separation efficiency measured across the two-stage decanter station varied from 92 to 95%. In the case of RVF solids removal efficiency is 70-80 % (Hugot 1986; Rein 2007).

Table 3 shows that the proportion of fibre to the total insoluble solids content in mixed juice varies from 25 to 34 % w/w. It is, therefore, advantageous to reduce this fibre content to the maximum extent possible in order to minimise the total solids loading on the decanter. This can be achieved by adding a rotary juice screen with a smaller wedge bar opening, i.e. 350 µm, to act as a second-stage screening arrangement. At Gangakhed Sugar and Energy Ltd. a second-stage rotary juice screen (RJS) was installed for the 2015-16 season and results were encouraging:

Fibre analysis at rotary juice screens installed at milling tandem:

a) Fibre content of screened juice at the outlet of 500 µm opening RJS = 0.14-0.17%
b) Fibre content of screened juice at the outlet of 350 µm opening RJS = 0.05-0.06%

Total insoluble solids content of mixed juice going to process:

a) Before installation of 350 µm opening RJS = 0.65-0.70%
b) After installation of 350 µm opening RJS = 0.50-0.55%

Total insoluble solid reduction of 0.15% was observed, perhaps because some of the closely associated and adhered insoluble solids other than fibre was likely to get removed at the RJS along with fibre solids. However this aspects needs further study.

Clarifier underflow muddy juice % cane:

a) Before installation of 350 µm opening RJS = 8-9%
b) After installation of 350 µm opening RJS = 5.5-6.5%

Reject cake % cane:

a) Before installation of 350 µm opening RJS = 2.0%
b) After installation of 350 µm opening RJS = 1.4%

Power consumption at decanter station:

a) Before installation of 350 µm opening RJS = 0.55 kW/tch
b) After installation of 350 µm opening RJS = 0.35 kW/tch

We observed that there was a 35-40% reduction in bagacillo content in the juice going to the process, effectively reducing the loading of the fibre solids and total insoluble solids on the decanter system.

A recent development of hot juice screening using a 120 µm opening has further reduced the total insoluble solids content of muddy juice - this could result in reject cake % cane reducing to 1.0%.

Figurees 3-5 show the installation and decanter outputs at Daund Sugar Pvt. Limited.

***Fig 3.*** Two-stage decanter station at Daund Sugar Pvt. Limited.

***Fig 4.*** Centrate I after clarification.

***Fig 5.*** Free-flowing reject cake.

## CONCLUSIONS

Content of insoluble solids in clarified centrate returns is much less than in combined filtrate returns from RVF, resulting in a significant reduction in solids loading on the juice clarifier, which in turn will improve solid/liquid separation efficiency at the existing juice clarifier. After recycling clarified centrate back to juice reaction vessel, we found no increase in colour in clear juice from main juice clarifier.

Subsequent to the successful operation of the system over 7 years, it can safely be concluded that the two-stage decanter is a proven technology that will eventually replace the old RVF technology. The system has significant potential to improve insoluble solid/liquid separation, resulting in enhanced overall performance of the entire clarification house. There can be increased productivity and sustainable growth of a co-generation power plant by using the saved bagasse at 1% on cane to produce additional green power.

The latest developments in further screening of raw juice at the milling station itself (350 µm opening), as well as hot juice screening (120 µm opening) before or after the juice reaction vessel, would reduce the solids loading on the decanter.

At factories facing a serious problem with abrasive sand in the raw juice, such prescreening may be useful in preventing wear and tear at the decanter machine.

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