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"Cane Juice Purification Processes"

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ABSTRACTS
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Reliability in the Determination of the Content of Insoluble Solids in Mixed Juice

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A representative and reliable measurement of the content of insoluble solids in mixed juice is important, since it strongly affects the calculation of the sucrose entering the boiling house. The following factors must be carefully considered:

- Juice sampling procedure
- Analytical methodology

The insoluble solids content is subtracted from the mixed juice, to obtain a net juice flow and the quantity of sucrose entering the boiling house. In Colombia sugarcane is crushed continuously all around the year, and there is a rainy season when it becomes difficult to determine the content of trash and insoluble solids in cane. This affects the sucrose balance, and results in higher undetermined losses.

This problem is less likely to occur in other countries with seasonal cane harvesting and less affected by rain, where the normal analytical methodologies can be used reliably to evaluate the insoluble solids content.

The standardized methodology for analysis of insoluble solids in juice involves the following steps:

- Continuous sampling of juice: It is important to have a reliable sampler, correctly designed and installed at the right location.
- Sample homogenization: It is important to determine the required time for homogenization and maximum delay - before filtration.
- Sample filtration and cleaning of the filter.
- Drying of the filter until constant weight is achieved.
- Obtain insoluble solids content from weight difference.

Another methodology for quantification of the content of settling solids in juice is a volumetric analysis, where the juice sample is placed in a conic recipient (Imhoff cone), leaving the solids to settle and then determine the volume of mud formed at the bottom after a specified period of time.

With the volumetric analysis it has been observed that the juice volume is less than the mud volume during the rainy season, with values of mud between 60 and 80 % of the total volume. This situation is not reflected on the mud evaluated by mass difference.

Considering the situation discussed above, it was decided to develop an alternative analysis using centrifugation to enhance separation. The centrifugal force compacts the mud, and then the mud mass content can be determined by drying and mass difference.

Table 1 presents the results obtained with the three different methodologies discussed. Differences up to +3-4 % with respect to the standardized methodology are observed in the modified procedure using centrifugation. This difference strongly affects the calculated quantity of sucrose in the juice entering the boiling house, which showed reductions between 2-5 kg per ton of juice, and permitted a significant reduction in the undetermined losses.

Table 1. Comparison of the content of insoluble solids determined with different methodologies and impact in the calculated quantity of sucrose in juice.

A Sedimentable solids (% by volume) Imhoff cone	B Insoluble solids (%) Filtration and mud mass	C Insoluble solids (%) Centrifugation and mud mass	Difference in computed sucrose using B and C insoluble solids data (kg sucrose / t juice)
20	2.80	5.23	- 3
70	4.84	6.52	- 2
75	6.49	10.09	- 5
90	9.97	12.91	- 4

- It can be determined using statistical analysis that the alternative methodology using centrifugation is more reliable.
- The findings help reduce the undetermined losses in the sucrose balance.
- It is important to develop analyses on samples with known content of insoluble solids to determine which methodology gives the most accurate value.

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Bagacillo Removal by the Use of a Vibroscreen to Improve Quality and Color of Sugar

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Technology to increase extraction at mills has increased bagacillo levels in mixed juice. Bagacillo releases coloring matter at high temperature especially after liming. This can be avoided by the use of a vibroscreen device to remove bagacillo from mixed juice. These devices can be called as pre–clarification station. The screen vibrates in three directions – horizontal, vertical and tangential and thus blinding of screens by particles close to the aperture size is avoided and screening efficiency is maximized. It is possible to remove about

70 % of the bagacillo using 60 mesh screens. These vibroscreen devices will help value addition to sugar by way of color improvement, keeping the cost of production low and leading to the profitability of the sugar industry. In the trials conducted at various sugar factories, there was almost total elimination of bagacillo above a particle size of 270 microns and color improvements in sugar up to 20 ICUMSA units were observed. Thus these vibroscreens could be beneficial to improve quality of raw sugar and have shown benefits in improving processing of plantation white sugar by double sulfitation. These vibroscreens can also prevent entry of impurities from milk of lime, filtrate, syrup and seed slurry when using 100 – 120 mesh screens.

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Cane Juice Screening Trials and Use at The Andhra Sugars Ltd.

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There is a growing consumer awareness calling for a reduction in chemical use in sugar processing and the need to cut costs while improving quality. The first step in cutting chemical needs in the initial phase of sugar processing is the need to remove as much of the suspended solids as possible, consequently reducing the quantity of lime, sulfur and other clarification chemicals used.

With this in mind trials were carried out at The Andhra Sugars Ltd. using a Vibroscreen, a pusher centrifuge and a self-clearing filter. Looking at data from these trials we now put the draft juice coming out of the diffuser through a DSM screen that has a 600 micron wedge-wire screen and then through a set of three Vibroscreens having a 170 micron screen. These Vibroscreens substantially remove suspended matter from the draft juice, facilitating an improvement in juice color.

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Rotary Juice Screen

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Continuous juice screening is effected on a cylindrical, rotating welded wedge bar screen, mounted in a horizontal position, sloping towards the discharge end.

A cylindrical rotary drum having 1800/2400 mm diameter in S.S. 304 construction is fitted with a rim located on either end for mounting the entire drum on trunnions. The screening area comprises a cylindrical shape welded wedge bar screen joined together by a bolting arrangement to form a rigid cylindrical shape rotary screen, forming an integral part of the rotating drum. The driving sprocket is fixed on the output shaft of the gearbox and connected to a driven sprocket mounted on the rotating end drum to transmit the power through a heavy-duty chain arrangement. Thrust rollers fitted at the discharge end absorb the lateral thrust. The entire assembly of the drum along with its trunnions is mounted on a fabricated frame.

All parts in contact with juice are in SS 304 construction to withstand corrosion and erosion effects.

The raw juice containing suspended solid particles enters continuously from the feed end of the drum through a distributor. The screened juice is collected in the sloping half-cylindrical shape bottom trough for quick removal. The solid mass keeps on rolling on the wedge bar screen and during its movement towards the discharge end the remaining juice is also screened away, leaving the solid mass on the screen which is discharged for transfer to the mills.

Flat cone S.S. 304 spray nozzles are fitted on a S.S. 304 header, located outside of the screen drum. A timer gives a signal to the pump drive for automatic starting and stopping at predetermined time intervals.

In order to avoid consumption of wash water which eventually increases the evaporator load, a unique system, comprising a SS 304 collection chute for washings located inside the drum, running parallel to the header and a high pressure non-clog pump to deliver the washings to the penultimate mill for pressure imbibition through header, allows effective reutilization of water washings. This improved system further allows clean wedge bar screen at all times, preventing deposition of microbial colonies and also enhancing throughput capacity of the screen by 15 %-20 %.

While the diameter of the screen drum is fixed at 1800 or 2400 mm, the length of the screen varies according to the cane grinding capacity of mill and up to 16 000 tones of cane per day can be handled by a single unit.

Based on actual working experience with 81 installations, having varying fiber and juice loadings, one m^2 screen area allows 300 to 350 tonnes of cane per day.

A wedge bar screen with a 0.5 mm opening allows residual bagacillo content in screened juice in the range of 2.0 to 2.25 g/L on an oven-dry basis, while with a 0.35 mm opening the same is achieved as 1.0 to 1.5 g/L, with a moisture content of 78 to 80 %.

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Effect of Clean Cane on Juice, Syrup and Sugar Color at The Andhra Sugars Ltd

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Clean cane contributes greatly to the improvement of cane sugar color and a reduction in the quantity of the different process chemicals used.

Experience at The Andhra Sugars Ltd. is that with due care being taken to clean cane, it has been possible to have a much lighter colored clarified juice and syrup, thus enabling the production of sugar close to refined quality at a regular plantation white sugar plant without the need of a refinery.

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The Use of Enzymes in Juice and Syrup Processing

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Enzymes have moved from beyond the realm of specialty biologicals to become industrial process chemicals that are now used in a range of industries. Polysaccharidase, dextranase and amylase, utilization is widespread in the US cane sugar processing industry. Best results from using enzymes in juice processing are achieved when time, pH and temperature conditions in the juice match those for optimum enzyme activity. Consideration as to whether or not to use an enzyme must include the fact that sugar processing is a dynamic situation, where continuously changing conditions effect the enzyme activity at any given point in the process. For example, if a polysaccharide hydrolyase is being used in juice and the goal is viscosity reduction in syrup, it may not be necessary to remove the polysaccharide completely, when a reduction in size of the polymer will achieve the same practical result, minimizing either the time or required enzyme dose. This presentation will explore current practices for use of these enzymes as well as new potentials offered by enzymes for improving sugar production.

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The Use of a-Amylase to Control Starch Levels in South African Cane Sugar Factories

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The use of a-amylase enzymes in some of the South African sugar cane factories to control high levels of seasonal starch in clarified juice has become routine over the last 20 to 30 years. These are marked by the use of genetically modified strains of Bacillus licheniformis which were developed specifically for their heat stable properties.

Five of the 14 factories in South Africa use a-amylase at some time during the season, specifically when rainfall increases from October to December. The normal crushing season generally runs for ten months from March to December. Only one of these factories operates a mill while the others have either one or two cane diffusers in parallel. The recommended point of application is the third or fourth evaporator in a series of about five where conditions (based on studies with a previous generation of enzyme) were found most favorable. Since the last factory trials in this industry were done more than 30 years ago, actual practices have slowly deviated from the initial recommendations. Results of a survey into these practices highlighted some interesting areas where improvements could be made almost immediately.

A recent laboratory study indicated that the current use of a-amylase in the evaporator train is reasonably optimized. However, this study strongly resonated previous suggestions that conditions inside a diffuser might be much better suited to the current generation of enzymes. This topic seems to surface at regular intervals especially since the 14 factories in South Africa currently operate 16 cane diffusers and only three mills.

It has always been accepted (with substantiating evidence) that diffusers generally produce juice with lower levels of starch from the same cane compared to extraction through milling. This is deemed to be due to the higher temperatures used in a diffuser which ensures the complete gelatinization of the starch granules rending these available for hydrolysis by natural amylase enzymes which may be present in significant quantities in the cane. However, these natural enzymes would be deactivated quickly at the high diffuser temperatures.

Diffusers are operated at about 85 °C with the residence time of the bulk of the Brix being about two minutes. Cane diffusers are not generally limed (calcium requirements by the enzyme may therefore not be satisfied) although new generations of enzymes tend to have lower calcium requirements. The low concentration of the diffuser juice (10 - 12 °Bx) should further flavor enzymatic action. The point of application will need careful consideration in order to maximize the interaction time; residual enzymes should be completely removed during subsequent clarification restricting the potential transfer of protein to the raw sugar.

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Juice Heating within the Cane Juice Purification Process

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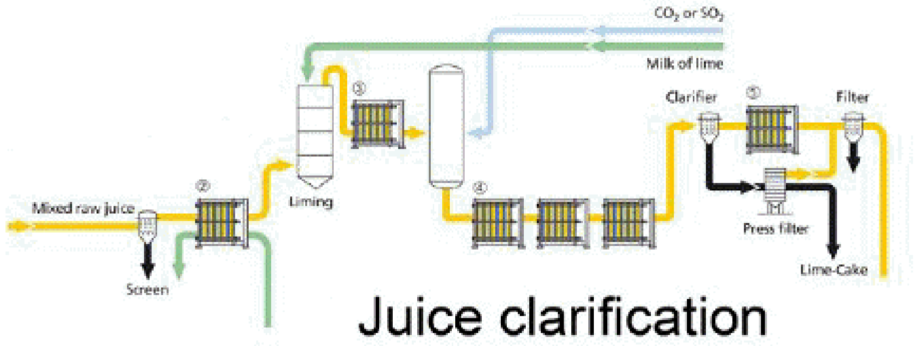
The juice purification process of mixed juice or raw juice is one and the first of a number of clarification options within the overall cane sugar process. Whereas the clarification processes of intermediate and final effect syrups can count on already clarified and filtered juice, the purification process of mixed juice constitutes the initial and crucial process for the quality and quantity of sugar and the success and feasibility of the following processes, i.e. evaporation and crystallization.

“The mixed juice from extraction is preheated prior to liming so that the clarification is optimal. The milk of lime, calcium hydroxide or Ca(OH)2, is metered into the juice to hold the required ratio and the limed juice enters a gravitational settling tank: a clarifier. The juice travels through the clarifier at a very low superficial velocity so that the solids settle out and clear juice exits.”
[Source: www.sucrose.com].



A reliable purification process requires constant and specific conditions of the mixed juice during liming, sulfitation/carbonatation and clarification in terms of temperature and other juice properties. This presentation focuses on the auxiliary heat exchanging applications, and their general thermodynamic specifications. It gives a basic overview of proven heat exchanger designs (Shell and Tube and Plate Heat Exchangers) and discusses their specific features in terms of performance and operational handling. It points out the possibilities of different states of the heating media (steam and water) and outlines a series of references for Plate Heat Exchangers in cane sugar mills worldwide.

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Saccharate Liming at Felixton

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The use of saccharate is not common in the South African industry; most raw sugar factories apply a straightforward liming at ebullition, using milk of lime. The Felixton sugar factory is an exception to this and has been using saccharate for the past two seasons.

The reasons behind the selection of saccharate at Felixton are described.

The plant itself is simple and involves the use of evaporator syrup and milk of lime (10 Baumé), mixed on a volumetric basis using adjustable conductivity probes to control the volumes.

The advantages and disadvantages of saccharate liming, relevant to the processes at Felixton, are discussed. The costs are also estimated. It is concluded that, under the present operating conditions at Felixton, saccharate liming is beneficial.

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Lime Saccharate Trials and Use at The Andhra Sugars Ltd

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			Before Lime Saccharate addition	**After Lime saccharate addition**
1.	Clear juice pH	:	6.95	6.98
2.	Treated Juice Temp.	:	102.5 °C	102.7 °C
3.	P_2O_5 in draft juice	:	286 ppm	287 ppm
4.	Reaction Temperature	:	69.6 °C	69.6 °C
5.	Clear Juice Transmittance % at 560 nm :			

	Before Lime saccharate addition	After Lime saccharate addition	
A	Maximum values	Maximum values	Difference
1.	36.5	52.5	16.0
2.	33.2	50.1	16.9
3.	32.4	49.0	16.6
B	Medium values	Medium values	Difference
1.	32.2	46.8	14.6
2.	32.5	48.1	15.6
3.	31.8	48.5	16.7
C	Minimum values	Minimum values	Difference

1.	30.0	45.0	15.0
2.	30.4	45.2	14.8
3.	30.5	45.3	14.8

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Milk of lime vs. saccharate liming

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The objective of juice clarification is to produce clear juice of the lowest turbidity possible since this implies that fewer impurities would be carried over to the subsequent process streams. Experience in South Africa, Mauritius and Australia indicates that saccharate liming gives lower turbidity but higher mud volume than liming with milk of lime.

One very important aspect that needs to be addressed when using lime saccharate is its preparation. Depending on the chemical and physical conditions under which calcium oxide reacts with sucrose there are three possible structures, namely, mono-, di- and tri-calcium saccharate. Of the three, mono-calcium saccharate is the most soluble and it is this form that should be used in lime saccharate clarification. While the stoichiometric ratio of sucrose to calcium for the formation of mono-calcium saccharate is 6.1:1, in practice a ratio of 7:1 is used thereby maintaining the slight excess of sucrose that is required for the reaction.

In a study carried out in Mauritius, evaluating various liming techniques, namely fractional, intermediate and hot liming involving milk of lime and lime saccharate, the results indicated that intermediate liming was more effective (53 %) than fractional liming with hot liming giving the lowest juice turbidity. In addition all saccharate liming produced much clearer juice (51 %) than milk of lime methods.

Moreover, handling milk of lime slurry in pumps, pipes, tanks and valves requires more frequent cleaning and constant maintenance than lime saccharate. Additionally, saccharate solutions show an improvement in the pH control of limed juices. Furthermore tests done on juices extracted at the Sugar Milling Research Institute (South Africa) and on all factory juices collected indicated that saccharate liming gave a better quality clarified juice in terms of turbidity, color and phosphate. However, it is reported in Australia that there is a higher calcium level in clarified juice obtained with saccharate liming and this may result in increased scale formation in evaporators when saccharate liming is used. The implications of all the results will be analyzed and discussed.

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Differences in the Factory Performance of Cold, Intermediate, and Hot Lime Clarification Processes in Raw Sugar Manufacture

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From 1995 to 2000 a series of clarification studies were conducted at three Louisiana factories. These studies have had considerable impact in the United States, particularly Louisiana with 100 % of the factories changing from traditional cold lime clarification to intermediate or hot lime clarification. Here we report the final study of a comparative factory investigation of cold versus intermediate versus hot lime clarification at one factory. In cold liming, mixed juice (MJ) was incubated (8 min) and then limed in a lime tank (4 min), both at ~40.5 °C. For intermediate liming, 50 % of the MJ was heated (82-93 °C) before incubation (8 min), then limed in a tank (4 min) at ~65.5 °C. Hot liming was configured very similar to intermediate liming except that incubation time was increased from 8 to 12 min and lime was added immediately after flash heating (101 °C; 30 sec). Overall, both hot and intermediate liming performed much better than cold liming, and hot liming offered some extra advantages over intermediate liming. Dramatically less lime had to be added in hot liming compared to either cold or intermediate liming. Preheating 50 % of the MJ in both intermediate and hot liming consistently removed color, dextran and starch, but silicate levels were not significantly changed. MJ preheating created larger flocs that settled faster and removed more impurities, and only 30 % preheating is required for improvements. The largest flocs and fastest settling occurred in intermediate liming, although significantly ($P < 0.05$) more turbidity removal across the clarification tanks occurred in both hot and intermediate liming compared to cold liming, with better control. Less sucrose was lost across both hot (season av. 0.8 %) and intermediate (1.0 %) lime processes than across cold lime clarification (1.5 %). By operating hot liming, the reduction in sucrose losses alone saved the factory approximately (U.S. $283 000 using 2000 raw sugar prices of 19 cents/lb). Savings were also found in less lime usage and cleaning chemicals for juice heaters.

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Studies on the Action of Polyaluminum Coagulants

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As refiners continue to require higher quality raw sugar, the industry must remain aware of new methods that may be available to improve raw sugar quality. One area of potential improvement is in clarification, where the factory should be able to achieve additional removal of color, turbidity and polysaccharides. Aluminum-based compounds have a long history of use in purification and color removal in other areas. Aluminum sulfate and polyaluminum chloride are the primary chemicals used to treat drinking water. Alum (aluminum potassium sulfate dodecahydrate) and polyaluminum sulfate are likewise primary chemicals used to prepare potable water. A report on the potential of aluminum compounds for raw sugar decolorizing was published in 1999.

SPRI conducted a series of laboratory investigations with five commercial polyaluminum coagulants used in water treatment. Two were composed of only aluminum compounds and three were a blend of cationic aluminum polymers with polyquaternaryamine. All showed a dramatic increase in the ability to remove color, turbidity and polysaccharides from cane juice relative to traditional lime clarification, as show in the table.

A mill experiment was carried out in late 2005, using one of the selected commercial polyaluminum coagulants. The amount added was determined by the concentration of polyquaternaryamine in the sample, which is regulated by the Code of Federal Regulations, and is based on sugar solids. Results showed improvements in removal of turbidity, color and ash, and an increase in pH, when compared to traditional clarification, but not as dramatic as the laboratory studies. Polysaccharide concentration was not improved. Analysis of treated samples showed that there was no aluminum carryover in the clarified juice. These preliminary results showed the potential for the use of polyaluminum coagulants in juice clarification. In retrospect, it was felt that the point of addition of the coagulants had not been optimized, and further work should be done.

Percent removed from mixed juice in the laboratory.

Clarification treatment	Color	Turbidity	Polysaccharides
Lime (control)	34.2	96.9	35.3
A	51.2	99.1	47.6
B	60.5	99.5	47.8
C	73.0	99.6	54.4
D	75.5	99.5	56.1
E	68.6	99.5	52.1

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Mud Transport in SRI Clarifiers

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The high throughput rates and low residence times that are achievable with the New Generation clarifier have focused attention on the need to improve the handling and transport properties in the mud thickening zone. This places more emphasis on the ability of the mud scraper designs to transport the mud towards the centre mud cone.

The investigations into the effects of the clarifier design on mud transport have been conducted using pilot tests and factory trials.

The mud transport efficiency of current flat inclined blades is low at 0.18. It was estimated that the throughput of new generation clarifiers would be limited by the ability of the mud scraper system to maintain the required delivery rate of mud to the mud cone for withdrawal. A number of options for improved transport capacity have been assessed. A hybrid blade design has been developed that combines the existing flat inclined blade with a new lead section with a greater angle to provide a more incisive separation as the blade progresses through the mud layer.

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Mud Thickening in SRI Clarifiers

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The throughput capacity of a clarifier is based on its ability to perform the two-fold functions of clarifying the juice, and thickening and removing the settled mud at a rate to match the factory throughput.

The high throughput rates and low residence times that are achievable with the New Generation clarifier, have focussed attention on the need to improve the settling and thickening characteristics of the mud, and its handling and transport properties in the mud thickening zone. As juice rates increase, the residence time of the mud must reduce to maintain satisfactory mud levels in the mud zone. This places more emphasis on the ability of the mud scraper designs to thicken the mud to an acceptable consistency and to transport the mud towards the centre mud cone in a significantly reduced time.

The investigations into the factors affecting mud thickening have been conducted using pilot tests and two factory clarifiers of similar size. One of the clarifiers was a standard design and the other was a modified design incorporating the New Generation technology.

There appears to be a maximum mud density that can be achieved in the clarifier and this is achieved within 30 minutes. The final density is not dependent on either the depth of mud or the addition rate of flocculant. The results obtained with a settling tube were similar to those obtained directly from the clarifiers. Tests with the settling tube indicated that final mud densities will be lower if the rakes extend the full depth of the mud layer and into the juice. The largest increase in mud density was achieved when a maximum number of rakes was used provided all rakes remained below the level of the mud-juice interface. The speed of the rakes did not affect the final mud density.

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Application of Computational Fluid Dynamics in the Study of Sugarcane Juice Clarifiers

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The application of Computational Fluid Dynamics (CFD) permits the numerical solution of complex flow situations, such as the flow in the juice clarifiers used in the sugar industry, which are otherwise rather unpredictable. This document reviews results that have been reported in the application of CFD to analyze and improve the performance of sugarcane juice clarifiers. The potential application of 'lamellas' for increasing the throughput is discussed.

Two significant applications of CFD in the analysis of cane juice clarifiers have been reported:

- Steindl et al. (2005) presented numerical results on the flow in the SRI single tray clarifier, where CFD has been reported to be useful in the improvement of the design. A 'New Generation' clarifier has been presented as the more recent product, stating that lower residence time (20-30 min) and improved juice quality are achieved.
- Chetty and Davis (2001) presented numerical results on the flow in the Rapidorr 444 clarifier. The effect of installing two deflectors was analyzed numerically, and then tested in one compartment, reporting improvement in the residence time and a better turbidity removal.

The installation of multiple inclined plates, commonly known as 'lamellas', in the settling (or flotation as well) region has proved to be an effective alternative for increasing the efficiency and capacity of water treatment clarifiers. The liquid is forced to rise in the space between consecutive lamellas, observing a channel flow that is less sensible to develop turbulence (the Reynolds number drops because the distance between consecutive plates becomes the characteristic dimension, instead of the clarifier diameter). The hydraulic patterns within the clarifier are also improved as recirculation currents and short circuiting are prevented.

A numerical analysis of the effect of having lamellas in a juice clarifier has been performed using a commercial CFD code (FLUENT). For the analysis it is assumed that a significant increase in capacity is achievable, and a flow rate corresponding to a vertical flux of 7.5 mm/s is set (three times larger than typical 2.5 mm/s). It is considered that 10% of the flow leaves through the bottom boundary condition, representing the mud flow, while the rest of the liquid corresponds to the clarified juice and is removed uniformly at the top end of the lamellas. Commercial applications often include small orifices at the top of the lamella channels to generate a pressure drop and achieve an even distribution.

Figure 1 presents the geometry considered for the juice clarifier using lamellas and the predicted velocity vectors. It is evident that the lamellas control the recirculation and short circuiting in the top region of the clarifier, where the flow is laminar and the settling process would be potentially improved. Recirculation currents are predicted below the lamellas, which are a consequence of the change in direction of the feed stream and the relatively high throughput with respect to traditional clarifiers. The predicted recirculation currents are considered undesirable, and indicate that it would be desirable to reduce the horizontal momentum of the feed stream. In spite of the recirculation, the vertical velocities predicted at the bottom are low, conveniently favoring the compaction of the mud.

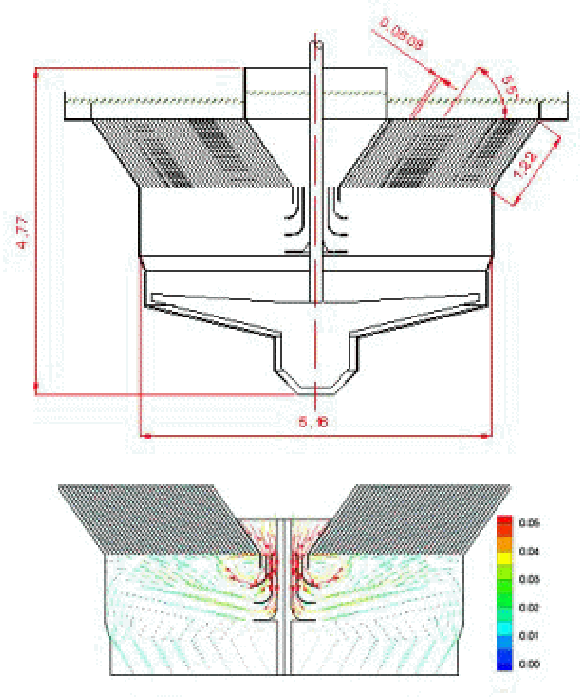

Figure 1. *(a-top) Schematic illustrating an hypothetical juice clarifier using lamellas in the settling region, and (b-right) velocity vectors predicted numerically [m/s].*

It can be concluded that the CFD has proved to be useful for studying and improving the design of juice clarifiers, offering a valuable tool that reduces the need for empirical or trial and error approaches. The opportunity to reduce the residence time, for example by installing lamellas in the settling region, is particularly interesting for sugarcane juice clarifiers, where increasing capacity and minimizing the sucrose inversion and color formation would represent clear benefits for the mills.

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The Short Retention Clarifier

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The short retention clarifier (SRC) incorporating a modern and unique concept of peripheral feed launder and centrally located multiple take-off launders is designed to handle both defecated as well as limed / sulfited cane juice for raw sugar or plantation white sugar manufacture.

The SRC package consists of :

- An improved flash tank for "preparation" of feed juice prior to feeding clarifier

- A clarifier complete with drive, scrapers, feed/take-off launder.
- Flocculant solution preparation tank with a vibratory feeder for automatic feeding of polymer powder.
- Dosing pumps with variable speed drive for automatic proportional dosing of polymer solution.

The flash tank of improved design comprises:

- An upper part, where flashing takes place by virtue of turbulent whirl formation due to the tangential juice entry.
- A middle part fitted with a stationary helix which allows homogeneous mixing of polymer with feed juice.
- A lower part where floc building is accomplished during upward motion, requiring 45 to 60 seconds.

The flash tank simultaneously allows three multiple functions viz. effective air removal, homogenous mixing of polymer with feed juice and more importantly building up thick and heavy flocs from loose and fragile initial flocs. The prepared feed juice" having improved settling characteristics then enters the SRC.

The SRC receives the prepared juice from the flash tank and then passes on to a feed launder which is peripherally located and is indeed a special feature of the design, avoiding turbulence and cross flows. The clarifier consists of a main cylindrical shell, top/bottom cone, peripheral feed juice launder, multiple clear juice take-off launders and a slow moving stirrer shaft rotating at 4 rev/h.

The drive head consist of a motor driven, vertically mounted planetary gearbox directly connected to the central shaft supported by the top cone of clarifier. A steel ball with mounting brackets is fitted at the bottom of the mud boot, which absorbs vertical thrust.

Flocculant solution preparation tank in two sets is used for preparing polymer solution of the desired concentration and is fitted with a medium speed, vertically mounted stirrer. The polymer solution is prepared and stored, for onward use. A low-level audio-visual alarm system is provided.

A settling rate test kit is used to establish the initial settling rate, a basic parameter required for sizing of clarifier. The SRC is available in wide range of capacities, a single unit handling up to 20 000 tons cane per day in the case of a raw sugar plant and up to 8 000 tons cane per day in respect of plantation white sugar production.

The conventional multi tray clarifier can be upgraded by incorporating SRC concepts. The SRC as existing can be upgraded for reducing the retention time by incorporating the unique peripherally located juice feed launder and centrally located multiple clear juice take-off launders together with the improved flash tank.

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Replacement of Lime with Soda Ash in Cane Juice Clarification

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The feasibility of using soda ash in juice clarification to either partially or fully replace lime was tested. After laboratory and pilot experiments in 2001 and 2002 investigating nonsugars elimination in juice clarification, limited trials were organized at a Louisiana mill in 2003 of partial or full substitution of lime with soda ash. Calcium salts of oxalic, phosphoric, carbonic and sulfuric acids of the cane juice are the main components of scale in the industrial evaporators and lowering calcium content (hardness) of the clarified juice is thought of as one way to reduce scaling of the evaporators. The previous tests indicated that even without adding any lime, the inherent calcium content of raw juice is in excess of what is needed for the formation of the clarification-inducing calcium phosphate precipitate. In both tests, the soda ash liquor was continuously added to cold mixed juice, and hot liming then operated as usual. In the first test, the soda ash addition was about 70 kg/hr or about 0.02 % on cane. In the second test the soda ash addition was doubled to about 135 kg/hr or 0.04 % cane, and was high enough that after heating and before any milk of lime addition the mixed juice pH reached the factory pH set point and therefore no milk of lime was added for the duration of the four-hour test.

It was concluded that use of soda ash in clarification is feasible, producing clarified juice with 30-50 % less calcium than conventional liming.

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Effect of Clean Cane on Juice, Syrup and Sugar Color at The Andhra Sugars Ltd

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Clean cane contributes greatly to the improvement of cane sugar color and a reduction in the quantity of the different process chemicals used.

Experience at The Andhra Sugars Ltd. is that with due care being taken to clean cane, it has been possible to have a much lighter colored clarified juice and syrup, thus enabling the production of sugar close to refined quality at a regular plantation white sugar plant without the need of a refinery.

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The Use of Capillary Viscometry to Measure the Concentrations of Flocculant

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This presentation describes the use of glass capillary viscometry to determine the concentrations of the usual clarification flocculant in water and to compare viscosities in juices.

Residual concentrations of the usual clarification flocculants in juice and in sugar can have negative effects. In factories returning clarifier mud to the diffuser, any excess flocculant present in the mud could reduce percolation in diffusers thus promoting flooding. Attempts to quantify residual concentrations of flocculants in juices by conventional chemical analysis have not been successful, mostly because it has not been possible to find a simple analysis yielding a result that could be related clearly to the concentration of flocculant. Capillary viscometry was investigated in an attempt to solve this problem. The technique was also used to determine the concentrations of flocculant in aqueous stock solutions as used in factories before dilution and addition to the limed juice.

The approach was tested in the laboratory by measuring the viscosity of sucrose solutions (10 Brix) to which known concentrations of a typical flocculant had been added, against water as the standard; the results were very encouraging with excellent linearity over a range of concentrations of 0 to 20 ppm flocculant.

Aqueous solutions of a flocculant were prepared with concentrations ranging from 0.006 to 0.1% (m/m) and their viscosities obtained, again using water as the standard. Over this wider range of concentration the relationship between concentration and viscosity was logarithmic, with a high correlation coefficient.

The presence of higher than normal concentrations of flocculant in mud could impact negatively on diffuser operations when mud is routed to the diffuser. The use of capillary viscometry to monitor the viscosities of limed juice, clear juice and of the juice in mud, was investigated by measuring the viscosity of catch samples, diluted to 10 Brix, from three factories. There was no evidence of higher viscosities in the juice from mud. Generally, all the juices showed viscosities between 1.3 x 10-3 and 1.4 x 10-3 Pa.s; this compares to a value of 1.29 x 10-3 Pa.s for a 10 Brix pure sucrose solution, indicating that the viscosity of the juices was only about 5 % higher than that of a pure sucrose solution.

It is concluded that capillary viscometry can be used to investigate flocculant applications in the factory. The technique requires calibration with liquids of known viscosities, but it is simple and can be used at the plant. Glass capillary viscometers are readily available at reasonable prices, in a range of capillary sizes; they require careful handling and cleaning.

A number of other factory streams were briefly tested after the work described above; the preliminary results indicate that the technique could be useful throughout a cane sugar factory.

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Control of Color and Removal of Impurities by Polymeric Clarification Technology

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Control of color during purification of cane juice is the predominant goal of sugar industries. A thorough study and R & D work is required to achieve the above target. Refineries have mostly perfected the art / science of color removal but in order to simplify the process and to avoid the heavy cost of capital investment, refineries are required to remove most of color at the raw sugar level. In the sulfitation process of juice purification, technologists do their best to produce good quality clear juice, which is essential for good quality sugar production.

The main colorant types described for cane sugar processing include:

- Plant pigments - phenolics and colorant complexed with polysaccharides.
- Thermal degradation of sucrose - colorant that is formed in process (caramel).
- Alkaline degradation products - colorant that is formed due to excessive pH.
- Maillard browning products (melanoidins) - reaction of amino acids with reducing sugars.

In our experience, by far the largest contributors to sugar color, produced by the sulphitation process or by carbonation (for raw sugar) are the cane-derived pigments. These are HMW polysaccharide-colorant complexes which are formed by a number of polyphenolic molecules, particularly syringic, ferulic and caffeic acids. During milling these form brown iron-polyphenolic complexes. Amino acids are also troublesome organic nonsugars in cane, responsible for melanoidin formation.

Conductivity measures the ionic impurities. Removal of impurities shows a reduction in conductivity. In the present investigation both inorganic and organic impurities have been studied.

The system includes treatment with cationic polymer directly into the existing clarifier after heating the juice and treatment with anionic polymer directly into the clarifier before heating the juice. This is followed by precipitation and settling of ionic impurities and coloring matter like polyphenolic complexes, amino acids, HMW polymers like dextran, gums, etc. which will pass into the mud.

Sparkling treated clear juice from clarifier is sent to evaporators to achieve better quality sugar. The polymeric clarification process as described here is a low-cost solution both from the point of view of capital as well as operational costs in relation to the gains to be made by the mill. These benefits can be summarized as:

- The removal of suspended impurities and turbidity results in lower viscosity of the massecuite, which means faster boiling, increased pan capacity, faster purging, increased centrifugal capacity, a reduction in nonsugar content, leading to a lower final molasses quantity.

- A reduction in sugar loss in final molasses.
- The decolorizing effect of cationic precipitant lowers the sugar color significantly.
- The turbidity and impurity removal results in sugar of lower ICUMSA color, higher keeping quality and suited to special requirements like those of food and beverage industry and exports.
- Lower ash content.
- Better sparkling and clearer crystals.

Data collected by more than 20 reputable sugar industries having a capacity between 7 000 and 12 000 t cane/day show:

- Reduction of ionic impurities by 30 %
- Reduction in color from raw juice to clear juice by 20 %
- Reduction of polyphenolic complexes by 30 %
- Reduction of amino acids by 30 %
- Reduction in gums by 15 %
- Reduction of dextran by 30 %
- Reduction of color in sugar by 25 % to 30 %

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Mud Processing Options

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The two common treatments for mud from the juice clarifier are rotary drum vacuum filters and recycling to diffusers. However other options are available. These include solid bowl decanters, horizontal belt filters and belt press filters.

Some preliminary data on the performance of these alternative options will be presented to demonstrate that these can offer viable technologies for cane sugar factories.

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Mud Recycling to Diffusers

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In the South African industry 10 out of 16 diffusers have clarifier mud routed to them, a process that has been called mud recycling to diffusers; this has allowed the elimination or moth balling of filter stations.

Mud recycling to the diffuser requires physical modifications to the plant, the addition of a scale to weigh the mud, the sampling and analysis of the mud and adjustments to the cane payment system to account for the recycling of the sucrose in the mud to the mixed juice. All these points are described; details of the control philosophy and of the system used to ratably withdraw the mud from a number of operating clarifiers are given. In addition practical operational adjustments made to the clarification station and to the diffuser are described.

The sampling and analysis of mud for pol, Brix and insoluble solids are not easy, are prone to error and require attention to detail. A number of assumptions are required to facilitate the process.

Mud recycling was introduced in 1998 and there are now enough data to carry out a technical evaluation of its effects on important factory parameters such as extraction, recoveries and boiler operation. Some of these evaluations are presented and it is shown that there is no evidence of serious negative effects.

Finally the financial benefits of mud recycling are presented and discussed. It can be concluded that the benefits include increased recoveries and reduced operational costs. In the case of new factories the capital costs are reduced.

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Solid/liquid separation with a Putsch Membrane Filter Press and a Sibomat Screen Filter

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The fully automated Putsch PKF Membrane Filter presses efficiently separate solids from liquids. Clarifier underflow as well as filtrate from the vacuum drum filters can be processed to obtain clean filtrate, leaving a filter cake which is then desweetened, dried and automatically discharged from the press. After additional chemical treatment of the filtrate from the existing rotary vacuum filters, the membrane filter

presses produce low color and low turbidity filtrate. Therefore, instead of recirculating filtrate back to clarification, it can be mixed with clarifier overflow before evaporation.

The fully automatic Putsch Sibomat screen filter easily separates solids, including bagacillo, from highly viscous liquids such as syrup, standard liquor streams etc. and filtrate from vacuum drum filters.

Both filter systems provide a solids free filtrate, which is crucial for premium quality sugar processing.

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Use of Flocculants and Bagacillo in Conditioning of Clarifier Mud

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Bagacillo was recovered from clarifier underflow by screening, washed, dried and compared with bagacillo recovered by screening directly from bagasse. The bagacillo that underwent heating and liming was found especially spongy, absorbing up to about 19 times its weight of juice (5 grams bone dry bagacillo and 95 grams of 15 Brix sucrose liquor). It is expected that in Louisiana finer screening of mixed juice with 0.8-1.0 mm screens would reduce the bagacillo ratio (dry weight of bagacillo /dry weight of non-fiber suspended solids) in clarifier mud to about 0.3 from the present 0.9. That in turn would be expected to reduce the amount of filter cake from 125 lb per ton of cane to about 86 lb, a 30 % reduction, and increase available bagasse by some 16 lb per ton of cane or 2.4 %. Additional benefits would be expected from the reduction of mud volume within the clarifier, better mud settling and easier sweetening off of the filter cake.

A series of laboratory filtration tests was carried out with a number of commercial flocculants - both anionic and cationic ones - and their effect on clarifier underflow (clarifier mud) filtration rate was measured. Contrary to some previous reports, the high molecular weight anionic flocculants were found superior to the cationic flocculants. The same flocculants that are effective in the juice clarification stage were found also effective for mud conditioning at 10 mg/L mud. At that addition level, the filtration rate is increased with respect to the no-flocculant case by up to five-fold.

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Microbiological Losses on Mud Handling

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The mud filters are a generally overlooked part of the extraction process in a sugar factory. Like other points early in the extraction process, they are subject to microbial infections when the operation is not carefully monitored. These infections can be detected by checking for lactic acid levels in the filtrate. Significant losses, including microbial, can be expected if filters are operated outside their design parameters. Of practical interest are microbial losses that occur when sprayer water or mud temperatures are too low. Discussion will focus on detection, control and implications of microbial loading at the mud filters.

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Filtrate Clarification at The Andhra Sugars Ltd

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In an effort to improve the color of sugar being produced The Andhra Sugars Ltd. designed and built a filtrate clarifier to handle the filtrate from the vacuum filters and the scum generated at the flotation clarifier.

This very simple piece of equipment has been giving very satisfactory performance with lower chemical consumption and operating costs.

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Filtrate Flotation Clarification

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Juice clarification is an important step in cane sugar production. Suspended solids and some dissolved compounds are separated from raw juice, forming a mud that is de-sweetened in vacuum filters. The filtrate, representing about 20 % of raw juice, is normally returned to the raw juice tank, before clarification. The reason for this return is the high turbidity and suspended solids content in the filtrate. To avoid this return, a further clarification must be done in order to obtain a clear solution. This can be done by a flotation clarification system. Using pilot plant units, experiments were undertaken in two Louisiana sugar mills during the 2004 and 2005 seasons. Before the trials, lab tests were done to evaluate flocculant performance with filtrate using different mixtures and pH values. The best results were obtained with the application of 15 mg/kg filtrate of cationic flocculant (PCS3011) and 3 mg/kg anionic flocculant (PCS3012) at natural pH. These flocculants were applied to filtrate in both trials. During the 2005 season a Pro-Tec clarifier was installed in Cora Texas mill to clarify the filtrate (Brix 9.7; purity 87.6; pH 9.7; color 14 900 IU; turbidity 1 400 NTU; suspended solids (>1.2 mm) 1 680 mg/L). The filtrate at 66.2 °C flowed through the clarifier at 11.2 gal/min, corresponding to a residence time of 20 minutes. A quantity of 78 mg/kg filtrate solids of H_3PO_4 was added to the filtrate. The scum formed was removed through a skimmer, forming a compact mud representing 1.9 L/100 L filtrate. The quality of clarifier filtrate obtained was good enough to be sent to the evaporators. A reduction of 79.1 % and 68.9 % was achieved respectively in turbidity and suspended solids. An increase of 1.1 points of purity and a decrease of 14.8 % in color was also observed. Due to operational conditions the filtrate outflow temperature was only 66.2 °C; however there was no significant sign of fermentation in the clarifier as the lactic acid concentration showed little change (from 814 to 819 mg/kg solids). The advantages of filtrate clarification in a sugar mill are: the return of filtrate to the main clarifier is avoided (increase in clarification capacity, less sugar destruction due to recirculation); the quality of filtrate improves resulting in better operation after the clarifiers and an increase in recovered sugar.

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Filtrate clarification by a mud settling process

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The introduction of the vacuum filter to the sugar industry has created other serious disposal problems of contaminated, low purity dirty filtrate because it could not be sent forward for direct evaporation. It is normally mixed with fresh raw juice for carrying out further clarification. Since the last decade, although effort is being made to evolve a system which can consistently produce clear juice to be taken directly to evaporator, none of such processes could meet the required clear juice quality parameters using simple techniques. Perhaps the sugar industry had to wait until a SRC concept was successfully implemented.

Filtrate juice from the vacuum filter is treated in a conventional reaction tank after addition of phosphoric acid in the range of 25-30 ppm on cane and heating up to 80 °C. The second stage heating is done up to 104-105 °C prior to sending the treated filtrate juice to the flash tank of the SRC.

Treatment of low purity filtrate and high purity fresh raw juice in two separate independent streams offers the following advantages:

- Improvement in boiling house recovery. The purity rise of 3-4 units has the advantage of an improvement in boiling house recovery.
- Increase in clarification house capacity. The system is ideally suited to plant expansion by 20 % without necessitating replacement/addition of various items in the clarification section. The initial huge installation cost for replacing or adding various equipment in clarification house can be avoided.
- Improvement in performance and capacity of vacuum filter. Mud from the filtrate clarifier is more compact offering improved performance at the vacuum filter station by increasing the thickness and porosity of filter cake.
- Reduction in colour-imparting de-gradation products. The low purity filtrate having more nonsugars induce color development in a long retention time conventional juice clarifier, while the treatment of filtrate is accomplished within a short time and hence the risk of increasing the color imparting degradation products is reduced.
- Reduction in CaO content. The early treatment of phosphoric acid with milk of lime, precipitates the soluble CaO and hence the clear juice resulting from the filtrate treatment has shown a reduction in CaO content.
- Increase in the capacity of existing juice clarifier. As the filtrate returns are separately treated, the capacity of the existing juice clarifier is increased to accommodate additional load of treated raw juice, to the extent of 20 %-25 %.

Reduced risk of microbial sucrose inversion in main juice clarifier. Since the filtrate which is highly contaminated with microorganisms is not mixed with fresh raw juice, the risk of sucrose inversion due to microbial activities during the long residence time in the main juice clarifier is greatly minimized.

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The Effects of Iron and pH on the Color of Clarified Sugarcane Juice: Ramifications and Potential Application in Decolorizer Technology

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The effects of iron (Fe^{3+}) and pH on the absorbance spectra (200-750 nm) of juice and syrup were investigated. For comparison, model systems made to resemble cane juice or syrup were fortified with 3,4-dihydroxy-cinnamic acid (caffeic acid) with or without L-glutamine (L-GLN) and treated with 100 mL $FeCl_3$ (0.5 M). The mixtures were titrated to pH 10.0 against 0.01 N NaOH; samples were taken every +0.5 pH unit. Apparent color, calculated as (Absorbance x 1000)/(Brix x density) was plotted against mole equivalents of NaOH and pH.

With clarified juice and syrup in the range from 300-500 nm, absorbance drops then increases with pH. Samples exhibited endpoints at pH = 3.5, 5.5, 7.5, and 8.0. The sharpest increase occurs at pH = 5.5; logarithmic behavior ensues at 8.0. With syrup, the apparent color (420 nm) was within the range of 3 000-25 400 from pH 3.0-10.0. There appears to be little significant change in the spectra above or below this range.

When added to juice, syrup, or a caffeic acid model, $FeCl_3$ causes a sharp color increase. For example, when added to syrup, the range of apparent color changes to 17 000-34 000 when examined from pH 3.0-10.0.

Titration indicates that acid-iron complexes have lower Indicator Value (IV) than the parent phenolics. Models without L-GLN turn dark green, but with L-GLN, yield a dark green evolving into a black insoluble material.

The model system without the L-GLN behaves as a pH indicator, colorless when acidic, blue when intermediate pH, purple when alkaline, and orange when strongly alkaline. Systems with L-GLN were not as sensitive to pH; it was concluded that in juice or syrup, amino acids react with phenolics to yield high molecular mass materials with low IV.

When amino acids are present, addition of the $FeCl_3$ causes the precipitation of insoluble material. This fine black material can be filtered. Application of flocculant (anionic and cationic) was tested to determine if this material could be coagulated and removed by filtration.

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Separation of sugar colorants for further identification and quantification in sugar processing

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The objective of this study was to separate colorants in sugar products for further analytical work to identify the chemical nature of colored compounds, especially those having more affinity for sugar crystals. The approach used to this study was as follows:

- Fix the colorant compounds in granular activated carbon
- Remove the colorants with solutions of different polarities and alkalinities.
- Separate and wash the absorbent between each colorant desorption

Ten solutions were prepared at different concentrations and/or alkalinity: NaOH 0.025M and 0.5M; ethyl alcohol at 15 an 25 % v/v, at low and high alkalinity: DMF (N,N dimethylformamide) at 50 and 100 % v/v; acetonitrile at 50 and 75 %v/v, at low and high alkalinity. By analyzing UV spectra of the extracted samples, it was concluded that there is a selective desorption of compounds using these solvents. This method was applied on synthetic colorants as HADP, melanoidins and caramels. Another study was done on raw sugar affination to observe the colorants that remain preferentially in the sugar crystals after affination. Approximately 43 % of colorants (at 330 nm) present in raw sugar have a higher affinity for sugar crystals. It was observed that some of these colorants remain in the refined white sugar. Probably these colorants are removed during the refining process, for example in decolorization step using granular carbon. This was observed in other studies done on decolorization with carbon. In this study, colorants before and after decolorization, in the chemical regeneration effluent and those remaining in the carbon was analyzed by this method. It was concluded that colorants removed with DMF and acetonitrile present a high affinity for granular carbon and remain in the carbon after chemical regeneration.

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Cane Juice Sulfitation at The Andhra Sugars Ltd

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The design of the sulfiter and the treatment of the juice play a very vital role in clarification of the juice. To get better results the juice is shock-limed to a pH of 9.0 / 9.2 and then neutralized to 7.1 / 7.2 pH by the addition of SO2. The use of a continuous film-type sulfur burner has provided the advantage of maintaining a very uniform SO2 gas concentration. With the use of refrigerated air for the burning of sulfur, sublimation of sulfur is eliminated, thereby avoiding choking of the gas pipes normally experienced with most conventional sulfur burners. This system of juice sulphitation has given good reaction of the juice with the reactants like milk of lime and SO2 used in the process of sulphitation, resulting in a better clarification efficiency and improved clarity of juice.

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Some Hard Lessons with Membrane Filtration

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Florida Crystals Corporation

Florida Crystals Corporation has had a commercial scale membrane filtration system at the Okeelanta mill / refinery since 1997. At 250-300 gal/min permeate (on clarified juice), its capacity is small compared with the mill but it has given us the opportunity to learn about commercial scale operating problems on a variety of process streams and to use it to produce a variety of direct consumption products. The process streams may be either from the raw operation or the refinery.

The purpose of this brief report is to outline some of the issues and problem that we have had, but not necessarily to give the solutions, which would be different in other mills or refineries. Suffice to say that this is not an easy technology to incorporate into a raw sugar operation.

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Evaluation of a magnetic ion exchange (MIEX®) resin for application within sugar factory processes

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Raw sugar colorants encompass a wide variety of chemical classes and arise as sugarcane derived plant pigments of low molecular weight and as high molecular weight polymeric products from chemical and/or enzymatic transformations during mill processing. The various origins of color have made it very difficult to develop a single, widely applicable, decolorization technology.

Ion exchange technologies are commonly applied within sugar refineries to remove large quantities of color, enabling white sugar production. However, such technology has not become routinely applied within sugar mills. Here we describe some preliminary results using an ion exchange technology which is being progressed towards a commercial process for sugar mill application.

Orica Advanced Water Technologies have developed a proprietary MIEX® resin used within commercial drinking water treatment plants to remove negatively charged dissolved organic carbon impurities. There are eight operational plants currently using MIEX® resin, with another seven under design and construction. BSES Limited and Orica Advanced Water Technologies are jointly investigating the utility of this resin for sugar factory decolorizing applications.

The MIEX® resin has key advantages over conventional ion exchange processes.

- *Bead chemistry:* The resin is a strong-base macroporous ion exchange resin, containing an evenly dispersed magnetic particulate which results in each bead acting as a weak magnet. This provides aggregation behavior in solution and allows the design of process solutions which operate in a continuous fashion.
- Rapid decolorization kinetics: The small bead size (200 mm diameter versus conventional resins of 500-2000 mm) provides enhanced surface area to volume ratios and permits rapid colorant uptake. This process requires smaller resin quantities and smaller inventories relative to conventional ion exchange, as less resin can meet performance objectives.
- Process flexibility: MIEX® resin can be used in various formats, including continuous stirred contactors, fluidized beds and conventional column systems. The upcoming mill trials will test a fluidized bed format which is a higher performance version of traditional chromatography in which the resin column is run with an "upside down" or bottom to top flow. The magnetic qualities of the resin allow higher flow rates and efficiencies than for existing resins. Continuous processes can also be developed, and further economic advantages exist in minimizing resin quantity and requiring a smaller footprint for mill installation.

Proof of concept activities have demonstrated that the MIEX® resin behaves similarly to water treatment systems for the decolorization of sugar mill process streams. Laboratory trials have established proof of chemistry across all points of the sugar mill from juice to syrup. Characterization of resin performance for the intended mill applications has been performed, with assessments of resin quantities required to treat process streams and associated volumes, as well as longer term stability under process operating temperatures and regeneration regimes.

The net result of this work is the design and development of a prototype system to be tested within a sugar factory during the 2006 crushing season. This system will test the utility of a fluidized bed system for decolorizing various mill process streams.

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Options, Benefits and Constraints in the Application of Ion Exchange Systems, Especially for Softening

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Researchers in the sugar industry have shown interest in ion exchange systems for as long as the technology has been available - at least sixty years. Yet, except for decolorization in the production of refined sugar, it has not become close to being a routine unit operation in raw sugar production. On paper, the benefits of softening seem very real and the reasons for not applying the technology will be discussed.

The drive towards production of high quality direct consumption sugar at the mill seems to have spurred renewed interest and there have been several reports along these lines. These reports will be outlined and the additional process complications inherent in ion-exchange systems presented for discussion. Another topic will be the potential for "reverse softening" or the removal of divalent (and higher) anions (e.g. sulfate and aconitate) rather than removal of divalent cations (e.g. calcium and magnesium).

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Bleaching of Sugar with Hydrogen Peroxide

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Adding hydrogen peroxide directly in the vacuum pans is sometimes done to reduce massecuite viscosity and sugar color. That way peroxide contacts or reacts with all color bodies present in the massecuite. Treating only the 5 % of color bodies that eventually adhere to the outside and become part of the sugar should in theory reduce the peroxide requirement 20-fold with a comparable decolorization effect. The concept has been tested in a series of experiments. A set of commercial sugar samples were obtained from two Colombian mills and were treated with 100 mg hydrogen peroxide/kg sugar. The color of the sugar was reduced on average by 18 %, from 223 IU to 182 IU. Application of 3 000 mg hydrogen peroxide/kg 1 800 IU Louisiana raw reduced its color to 822 IU, a 56 % reduction. Similar relative reductions were found by bleaching affined raws, producing bleached sugars with 214-266 IU. The color of all bleached and un-bleached sugar increased after 6 months of storage but the color advantage of bleached sugars was retained. In another set of tests in a Louisiana mill, hydrogen peroxide at a 1 700 mg/kg sugar dose was applied directly in the A-sugar centrifuge producing sugar with 260 IU color. Adding a small amount of sodium hydroxide to the hydrogen peroxide offsets the lowering of pH that otherwise results from bleaching with hydrogen peroxide alone.

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The Application of WSM Technology to produce Direct White Sugar from Raw Cane Juice at Felixton Mill in South Africa

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The patented White Sugar Mill (WSM) technology is a result of a research and development joint-venture entered into by Tongaat-Hulett Sugar Limited and South African Bioproducts Limited in 1998. The WSM technology produces white sugar directly from raw cane juice, thereby eliminating the refining process, with all its associated costs; and it unlocks the value of the sugars currently found in molasses. Furthermore the technology enhances sugar recovery and allows a liquid fertilizer that is high in nitrogen and potassium to be produced. The technology applies a combination of membrane filtration, ion-exchange demineralization and ion-exchange decolorization, after conventional juice clarification to produce a high quality juice from which white sugar may be crystallized.

The technology has been piloted successfully in both South Africa and Brazil over a number of years, and in 2005 the first full scale WSM plant was built and commissioned at Felixton Mill in South Africa. The WSM technology can either be applied to a greenfields application, or as is the case with Felixton, retrofitted to an existing factory.

A summary of the WSM technology is presented, with specific reference to the WSM installation at Felixton, and the WSM technology is compared to conventional refining technology. The data presented includes a combination of piloting results and actual factory performance data. In addition the equipment used by the Felixton WSM plant and operational experiences in running the WSM process is described.

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Direct Production of White Sugar

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Conventional technology used in the processing of sugarcane involves extraction of juice from the sugarcane, clarification of the raw juice extracted, concentration to a syrup and crystallization of the sugar in the syrup. Because of the color bodies in the juice, the sugar produced generally has a light brown color. This requires that it be refined in a further process to produce white sugar conforming to consumer requirements.

Various processes have been proposed which will enable the raw juice to be purified to the extent that white sugar can be crystallized directly. These processes all require the use of a membrane separation process as a first step. Membrane separation is a costly process, requiring the use of considerable pumping effort, resulting in high capital and operating costs. A new process has been developed which uses granular activated carbon to purify clarified juice from cane sugar mills. In this process, juice is contacted with hydrogen peroxide before passing through activated carbon (GAC) in fixed bed columns. After passage through the GAC columns, juice is treated with cationic and anionic resins in order to remove ash in solution and reduce juice color.

Results of tests during the 2004 and 2005 seasons in a Louisiana cane sugar mill (St. James) are presented. In 2005 a set of three columns was installed: two columns with granular activated carbon and one column with ion exchange resins. The first carbon column, with 15 L of carbon, worked as a pre-filter to protect the second column with 30 L carbon. Both columns contained Calgon Activated Carbon Type CaneCal 12x40. The resin column was charged with 5 L of an anionic strong base resin (Purolite A510) and 12 L of a cationic strong acid resin (Purolite C150). Clarified juice (Brix 14.3; color 9 070 IU, turbidity 212 NTU, ash 3.5 g/100 g solids, pH 7.2) was fed at a flow rate of 1 BV/h (on total carbon) to this system. The working carbon cycles were of 6 days, including regeneration. Before the second column the juice was heated at 85 °C and mixed with a solution of hydrogen peroxide (1 000 mg H_2O_2 /kg solids).

After each cycle, carbon was washed and regenerated using a newly developed chemical regeneration scheme. Resin cycle varied between three and four days. After each cycle, resins were washed with condensate water followed by regeneration with NaCl and NaOH. Average analysis of final treated liquor was: Brix 13.9; color 1 680 IU; turbidity 165 NTU, ash 4.0 % on solids; pH 6.0. A reduction of 81.4 % in juice color was obtained (75.6 % on carbon columns and 24.1 % on resins). A turbidity decrease of 22.1 % and hardness (calcium and magnesium) reduction of 88.4 % was observed.

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Plantation White Sugar Production in Brazil

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White sugar production in Brazil can be considered a deviation of the traditional sugar production process due to a lot of particularities. The Brazilian alcohol program allows the adoption of certain conditions not considered economical by others countries, like:

- Starting the crop season with low quality sugar cane milled for alcohol and not for sugar production;
- One hundred percent utilization of primary juice only for sugar production;
- Deviation of most of the recycles for alcohol production (filtrates, B molasses, melted sugar, etc);
- Two massecuites boiling process;
- No exhaustibility of final molasses (final molasses purity higher than 60%);

Beside that, the quality of the plantation white sugar produced receives variable classification according to the demand for domestic or export market. The main parameter used to differentiate the various sugar types is ICUMSA color, and in consideration the sugar is identified as:

Type 1 (Plantation white)	< 100 IU
Type 2 (Plantation white)	< 150 IU
Type 3 (Plantation white)	< 200 IU
Type 4 (Plantation white)	< 400 IU
VVHP (raw sugar)	< 450 IU (without sulfur)
VHP (raw sugar)	> 700 IU (without sulfur)

Of course many others parameters are included in the specification like, polarization, moisture, ash, sulfur content, insoluble matter, turbidity, magnetic particles, black spots, starch, dextran, etc, but are always of minor relevance than color.

The conventional bleaching agent used is still sulfur dioxide associated with more or less phosphoric acid addition as function of the cane quality processed and the sugar quality desired. Sulfur dioxide is added to the juice, to lower its original pH of 5.2 to the 4.2 - 4.6 range. The sulfitation process is normally carried out using an absorption column where, because of the high solubility of SO_2 in water, absorption levels up to 99.5 % may be obtained. The main objective of sulfur addition is:

- inhibit reactions that cause color formation;
- to coagulate soluble solids;
- to produce CaSO3 (calcium sulfite) precipitate;
- to decrease juice viscosity and, consequently, viscosity of the syrup, massecuite, and molasses improving the evaporation and crystallization operations;

The sulfur consumption is variable during the crop with cane maturity but as an average can be estimated to be in the range of 100 to 150 g/tonne of sugar. The addition of phosphoric acid occurs before liming in a dosage around 100 g/ton of sugar, and for lower color sugars (100 and 150 I.U.), syrup flotation is widely applied by the sugar mills. During syrup flotation phosphoric acid is normally applied in a dosage of 50 g/tonne of sugar, but syrup sulfitation (double sulfitation) is never utilized.

This procedure is sufficient to reach the sugar color desired while keeping the sulfur dioxide content in the sugar under the specification and below 15 mg/kg. The sulfited juice is limed to pH 7.2 and heated to 105 °C, followed by 2 g/tonne cane of polymer addition and settling in a conventional clarifier (2.5 - 3 hours retention) or trayless clarifier (1.0 -1.5 hours retention).

The treated juice is then evaporated and the syrup produced (treated or not) is sent to the crystallization station. The boiling process is conducted in two or three massecuites, in batch or continuous vacuum pans. Massecuites concentrations are often below 93 °Brix, 86 to 90 purity, with crystal content around 50 %, and most of the time viscosity problems are not seriously identified, except in the rainy season due to occasional dextran formation. Massecuite centrifuging is done in batch conventional centrifuges, washing the sugar with superheated water or a combination of condensates and vapor during a period of time no longer than 30 seconds.

On the raw sugar side the emphasis must be credited to the high quality of VVHP sugar as related to the conventional VHP raw sugar, which due to its low ICUMSA color allows the complete elimination of the affination stage and many other refining benefits.

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Organic Cane Sugar

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The market for organic food products is expanding rapidly and the demand for organic sugar is high, for retail, ingredient and industrial uses. In the USA the National Organic Program (NOP) of the USDA sets the rules for both agricultural and industrial operations, with input from the National Organic Standards Board (NOSB). These rules are not necessarily technically based and do not allow certain practices and greatly restrict the use of process chemicals. The product sugar must also meet the high standards required for a premium food product. In many aspects the regulatory issues dominate the technical options. A summary of the procedures used to achieve these goals will be presented, with emphasis upon juice purification techniques.

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A New Strategy for Sugar in Mauritius

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Mauritius as a cane sugar producer had so far been relying for production of raw sugar and its export of this sugar mainly to the EU under the ACP/EU Sugar Protocol. Now with the substantial decrease in price of sugar in this market by 36 %, emphasis will henceforth be laid on more and more value addition in the sugar prior to its export. A new strategy is being prepared to produce, inter alia, a wider variety of direct consumption sugar in the form of specialty, industrial and white refined besides traditional raw sugar. This strategy, which forms part of the establishment of sugar cane clusters in the context of a multi-annual adaptation action plan for the Mauritian sugar sector, will be presented.