REFEREED PAPER

STEPS TAKEN TO IMPROVE REFINED SUGAR TURBIDITY AT THE PONGOLA SUGAR REFINERY

MASEKO Q, SINGH R AND MOTSA N

Tsb Sugar, PO Box 23, Pongola, 3170, South Africa
masekoq@tsb.co.za singhr@tsb.co.za Motsan@tsb.co.za

Abstract

Pongola mill is a cane sugar mill with a backend refinery with a capacity rating of 32 tons per hour refined sugar output (RSO). The Pongola refinery has a history of occasional refined sugar quality problems. The most problematic quality parameter has been turbidity, which has exceeded the bottler's specification of 20 ICUMSA units on an intermittent basis.

This paper details the measures adopted by Pongola to improve and sustain the production of quality refined sugar to meet the bottler's granular sugar specification. The area of greatest benefit in improving performance has been 'attention to detail' of both operational and maintenance aspects of the refinery filter station.

Keywords: turbidity, refinery, Pongola mill

Introduction

The decolourisation process at the Pongola sugar refinery comprises two clarification processes, namely carbonatation as the primary process followed by filtration through pressure leaf filters and sulphitation as the secondary process again followed by filtration through pressure leaf filters. Generally these two processes at Pongola achieve the required refined sugar colour; however, suspended solids and turbidity specifications have not been met consistently. During periods when the refined sugar does not meet the specification, packing for the industrial market is stopped with consequent market opportunity loss. In addition, customer complaints have impacted negatively on the credibility of the mill as a supplier of bottler's grade industrial sugar.

Sugar specification

Pongola mill produces consumer and industrial grade refined sugar for the local and export market. Refined sugar manufacturers in South Africa have aligned their quality specification with the bottler's specification for granular white sugar. The bottler's specification for turbidity, insoluble solids and colour in refined sugar is shown in Table 1.

The specifications for insoluble solids and colour have remained unchanged over the past five years (Anon, 2010).

Table 1. Bottler's refined sugar specifications.

Bottlers refined sugar turbidity specification		
2004	No Visible Turbidity 20 ICUMSA Units (IU) as a guideline	Nutritive Sweetener Turbidity SM-PR-485
2006	No Visible Turbidity 20 ICUMSA Units (IU) as a guideline	Nutritive Sweetener Turbidity, SM-PR-485
2008	Not more than 20 ICUMSA Units (IU)	Spectro at 420 nm ISBT or ICUMSA GS 2/3-18
Bottlers refined sugar sediment specification		
2004-2008	Less than 7 mg/kg maximum gravimetric insolubles	Nutritive Sweetener Sediment SM-PR-415
Bottlers refined sugar colour specification		
2004-2008	Less than 35 ICUMSA Units (IU)	ICUMSA GS 2/3-10

The most problematic quality parameter at Pongola has been the turbidity specification which has exceeded the bottler's specification of 20 ICUMSA units on an intermittent basis. The bottler's turbidity specification has been tightened up over the past five years. The main changes relate to reading the turbidity on a spectrophotometer at 420 nm instead of 720 nm. The new wavelength has the effect of giving a higher turbidity reading for the same sugar. The 2008 season weekly composite samples of refined sugar turbidity are shown in Figure 1. The step change in performance from September is attributed to the change in method of analyses for turbidity measurement from 720 nm to 420 nm.

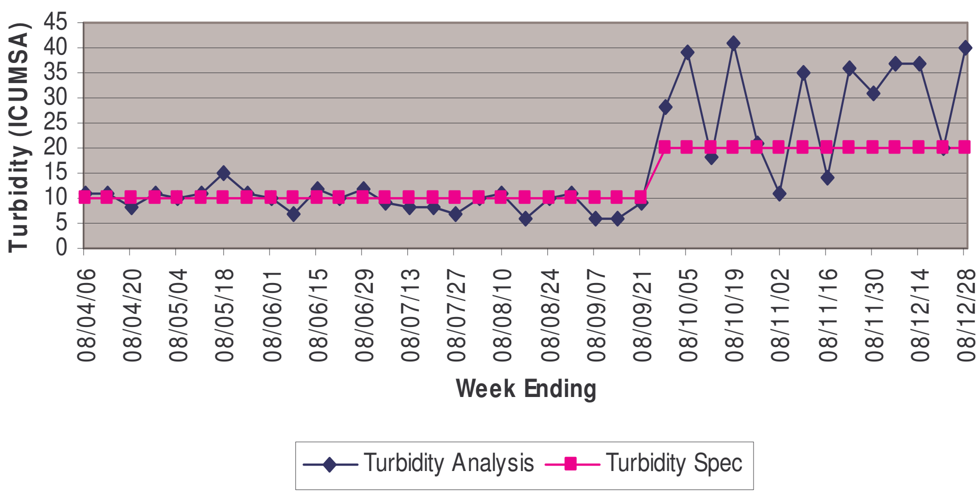

Figure 1. 2008 season refined sugar turbidity.

Turbidity

Turbidity and insoluble solids are a measure of microscopic particulate matter in refined sugar. The ICUMSA turbidity measurement is a spectrophotometric technique that measures absorbance at 420 nm and is an indication of suspended matter in a sugar solution. Insoluble solids are also a measure of particulate matter; however, it is a gravimetric technique. Lightweight suspended matter like bagacillo will influence the turbidity reading more than the insoluble solids reading. A heavy contaminant like a rust particle will influence the gravimetric reading more than the turbidity reading.

Turbidity is an optical characteristic or property of a liquid, which in general terms describes the clarity or haziness of the liquid. Turbidity is not colour related, but relates rather to the loss of transparency due to the effect of suspended particulates, colloidal material, or both. Bennet (1974) describes turbidity as the suspension of impurity particles greater than 0.1 μm in dissolved sugar solution. The composition of the particles covers a wide range of organic and inorganic materials and includes some colloidal impurities (Moodley and Schorn, 1997). A small amount of calcium carbonate/sulphite precipitate breakthrough from the sulphited filters will feature as an increase in turbidity and large amounts of contamination will feature as both high turbidity and high insoluble solids.

Other contaminants that can impact on turbidity are amorphous silica, calcium oxalate, calcium aconitate, coagulated proteins, polysaccharides, bacteria and moulds. Calcium salts of oxalate and aconitate are cane quality related. The other mentioned compounds are associated with stale cane or poor sanitation within the factory.

Bagacillo or mud particles resulting from poor juice clarification contain insoluble silica. This silica becomes solubilised at very high pH. This condition occurs in the carbonatation saturators where the pH is 11 to 12. In solubilised form the silica is not removed by the refinery filters and passes through to the pans. The ideal conditions exist in the second, third and fourth refined sugar boilings where it precipitates out at the lower pH and higher concentration and manifests as a high turbidity level (personal communication[1]).

Filtration equipment at Pongola Refinery

Pongola refinery uses rotary leaf pressure filters for the filtration process followed by candle filters that act as the goalkeeper for the removal of turbidity from the filtered liquor prior to crystallisation. The rotary pressure leaf filters are used by many of the South African sugar refineries for carbonatation and sulphitation filtration. Filtration in a pressure leaf filter is essentially solids retention on a porous filtration medium supported on a permeable membrane. This permeable membrane is generally a polypropylene filter cloth which in turn is supported on a rigid frame. The technique employed at the Pongola refinery uses the precipitate formed during carbonatation as the filter medium whilst on

[1] Ish Singh, Tsb Sugar, Pongola, South Africa (2009).

the secondary filtration stage pre-coat is used to form a filter medium on the filter cloth surface. Figures 2 and 3 show examples of the filters installed at Pongola.

Figure 2. Rotary pressure leaf filter at Pongola.

Figure 3. Polish candle filter at Pongola.

Initial filter optimisation work

The bottler's new turbidity specification predicated that lower turbidity levels in refined sugar were required. The analysis by the SMRI of first, second, third and fourth sugars have identified residues of calcium sulphite and calcium carbonate as the main cause of high suspended solids and turbidity. The origin of the residue has been attributed to break-through of solids during the carbonatation and sulphitation filtration processes. Hence attention was focussed on filter station operating and maintenance practices. Some of the findings and steps taken to correct them were:

- The rotary filter leaves/frames on inspection were found to be clogged with solids. This was due to solids leaking through poorly sewn filter cloths. The frames were boiled in a caustic solution and high-pressure cleaned to remove solid build-up. Sewing standards were reviewed and tightened up to ensure the correct fit of the filter bags onto the frames. A template frame was issued to the bag supplier to ensure that the bags were manufactured according to the correct dimensions.
- Analyses of the 'A' melt showed high turbidity levels. Further investigation revealed that the refinery sweet water stream which was being used for magmatising 'A' sugar contained a high level of suspended matter. The use of this stream was temporarily stopped. The origin of suspended matter in sweet water was identified as originating from poor performance of the de-sweetening press filters. Maintenance standards were reinforced to improve performance of this station.
- Analysis of centrifugal wash water showed high levels of suspended solids (8 to 20 ppm). The Pongola refinery utilises third and fourth effect evaporator condensate for wash water at the centrifugals. During periods of condensate shortage (e.g. mill stops), potable water was used as makeup. This stream has since been eliminated.
- The pre-coating cycle was optimised using the qualitative filter paper test and the filters were only sweetened on (accepted) when the filter paper test showed no visible suspended matter deposits. This was used to identify leaking frames and these were then marked and isolated.
- Pongola has evaluated different grades of filter aid. During the 2009 season a medium grade of filter media composed of a blend of diatomaceous earth and cellulose cotton fibre was trialled. Initial results showed significant improvement and in the 2010 crop it was decided to convert to a finer grade of pre-coat.

Figure 4 shows refined sugar turbidity for the 2009 season.

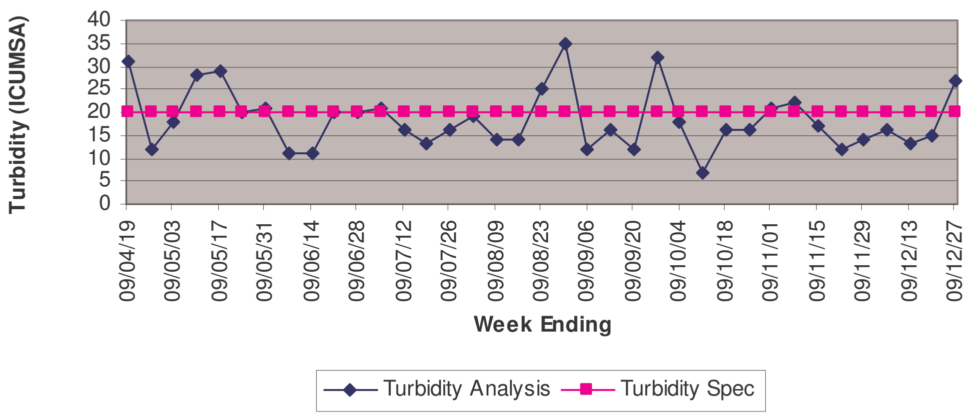

Figure 4. 2009 season refined sugar turbidity.

Improvements and challenges faced in the 2010/2011 season

The refined sugar turbidity for the 2010 crop is presented in Figure 5.

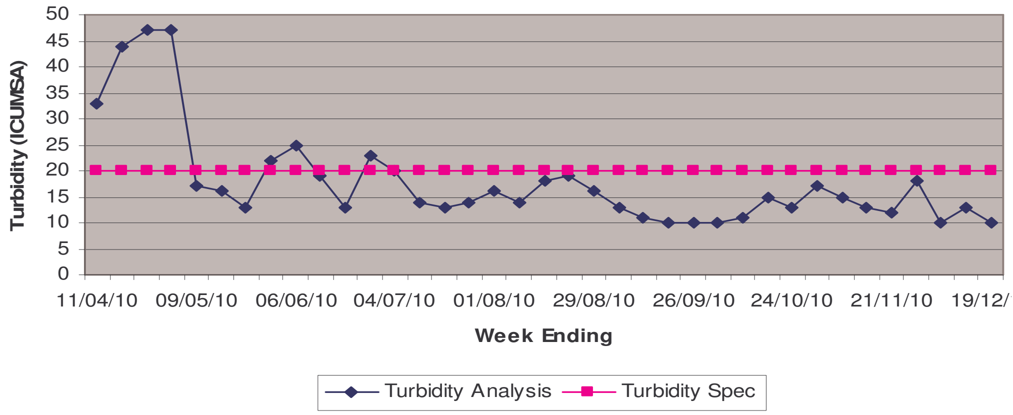

Figure 5. 2010 season refined sugar turbidity.

The results indicate that turbidity had slipped and was above specification for the first four weeks of the 2010/11 crop. The demand for export sugar necessitated further filter optimisation work. A project management approach was adopted to address the shortcoming. Using knowledge from previous investigations in 2008 and 2009, a team of operations and engineering staff 'homed-in' on the filter station. It quickly emerged that off-crop filter maintenance had declined due to the loss of experienced staff.

Operations and maintenance investigations

Samples of liquor into and out of each filter were analysed. At the same time visual checks were conducted on the gauge glasses, and 'passing' frames were then isolated. This helped to pinpoint the problem filters which were then isolated and taken off for inspection and cloth replacement. During inspection the following emerged:

- Pongola uses a tight weave (PY026) polypropylene filter cloth. During inspection of the filters it was discovered that the problematic filters were in fact made from a different type of material. It was established that batches of cloth type with a coarser weave were being supplied (PY0701). This cloth type is better suited for higher liquor throughputs, but at the expense of high insoluble matter in the filtered liquor. This situation was corrected by confirming and agreeing on the material specification with the supplier.
- It was noted that the sewing of the filter cloth on the filter leaf was not done properly. Gaps were left at the drainage stud. This was corrected, and quality control checks were done on all frames installed on the filter concerned.
- The proper operation of a pressure leaf filter requires a consistent, uninterrupted feed at a given pressure to ensure the filter medium remains attached to the filter cloth. It was discovered that filter supply tanks ran empty on occasion and collapse of

the filter medium from the filter cloths was likely to be occurring. The solution to this problem was to install a cascade flow/level control loop to provide a continuous supply of liquor to each filter.

- The existing pre-coat tank volume was inadequate to ensure the complete pre-coating of the filter with one charge. The tank also lacked a stirrer. To overcome this problem, a bigger tank of 10 m³ with stirrer was installed during the off-crop. This significantly improved the pre-coating step. To fit in with the mill's energy savings objective, filtered liquor rather than condensate was used to make up the pre-coat suspension.

During filter cloth replacement, the filters were inspected for defects that could cause filter aid or solids breakthrough. The filter internal piping was pressure tested. The findings and corrective action taken are shown in Table 2.

Table 2. Maintenance issues.

Findings	Corrective action
Filter head	
• Frequent breakages of gauge glass and leaks of product.	• Sight glasses were changed from safety glass to Pyrex to ensure clear visibility and strength.
• Inadequate sealing of 'O' ring seals.	• The 'O' rings were changed from double to triple to prevent leakages.
• Frame isolating valves were passing and leaking.	• Reliable sight glass valves were installed to ensure that passing frames were isolated.
Trunion	
• Trunion shafts were cracked and leaking.	• New trunion shafts were manufactured from stainless steel mechanical tubing, instead of being rolled from plate.
• The tubes inside the trunion shaft were leaking.	• The element tubes were changed from class 1 to class 2 with a pressure rating of 500 kPa, and they were expanded on the tube plate to ensure adequate sealing.
• Trunion wheels were seized.	• New trunion wheels were manufactured with plain bronze bushes, instead of roller bearings.
• Incorrect type of packing.	• Replaced asbestos packing with white food-grade packing.
• Product leak ingress into worm gearbox.	• Worm wheel bearings were moved from inside the worm box, and mounted on the outer face. A wiper seal was also installed on the gear wheel to prevent carryover of oil onto the guard.
Filter element	
• Leaking drainage studs.	• The internal copper tubes were changed from Class 1 to Class 2 to cater for 500 kPa maximum pressure.
• Seals on drainage studs were inadequate.	• The internal elements were pressure tested to 450 kPa to ensure that there were no leaks.
• Copper pipes were leaking.	• A pressure testing kit was developed for testing of individual internal copper pipes.

• The joints between the trunion and the elements were not sealing.	• The washers on the drainage studs were changed from mild steel to copper to prevent leaks and to ensure that frames were secured. • Reinstated fibre washer on the drainage studs. • Changed all defective drainage studs. • Ensured all drainage studs were tightened and torqued to 200 Nm. • Replaced all open nuts with end capped nuts on the drainage studs.

A concerted effort was made to correct the defects in the table. In addition new maintenance schedules were drawn up incorporating daily, weekly and stop-day checks and adjustments on all critical components of the filters.

Filter automation

In order to optimise filter station performance and sustain filtered liquor quality, the following conditions needed to be continuously monitored and controlled:

- Operating pressure
- Temperatures
- Flow rates
- Operating cycle time
- Sweetening off and washing times
- Pre-coating times
- Turbidity of filtered liquor
- Filter sluicing water pressure.

The Pongola filter station was lacking the necessary instrumentation to monitor the above process conditions. The information supplied by operators was not reliable, and during investigations of filter station performance, it was established that operator errors were being made, *viz*:

- Filters operated in excess of maximum operating pressure, resulting in breakthrough.
- Flow rates were erratic and inconsistent, resulting in filter cake dropping off.
- Filters were not pre-coated properly and were brought online too early, resulting in filter aid/solids breakthrough.
- Filters were not sweetened off properly during the sweetening off cycle, causing excessive solid build-up on the filter cloth, resulting in filters pressurising prematurely.
- Wash water pressure was well below the required 500 kPa to ensure effective cloth washing.

The filter disc tests indicated that operator error was still a significant source of contamination and served as the motivation for Pongola to proceed with automation of the filters.

Implementation of automation control strategy

Automation of the filter station was necessary to provide management with the proper diagnostic information to operate and optimise the filter station on a continuous basis. Pongola based its automation control strategy on a similar strategy successfully implemented at the Malelane refinery.

The key features of the control strategy were:

- Automatic sequencing of the various steps of the filter operation.
- Real time monitoring of critical parameters, i.e. turbidity, flow, pressure, and filter cycle times.
- Filter sweetening off times, washing times and pre-coating times were programmed in the control strategy.
- Supply tank level and cascade flow control to ensure steady state process conditions.

Implementation of the control strategy necessitated the installation of field instrumentation for measurement and control of key process conditions, *viz*:

- Magflo meters to measure and control flow rates.
- Temperate indication to monitor and control temperatures.
- Pressure transmitters to monitor and control filter cycles, and sluicing water pressure.
- Online turbidity meters on individual filters to monitor and control turbidity.

A typical display screen with the relevant process operating parameters is presented in Figure 6.

Automation challenges and way forward

Previously, all the filters at Pongola refinery were operated (sweetened off, washed, pre-coated, brought on line and monitored) manually without any form of control or indication of liquor quality. The automation program was successfully completed and hot commissioned at the end the 2010 season. The following challenges are still to be overcome:

- Insufficient liquor buffer tank capacities (filter supply) result in erratic flow rates, i.e. feed to filters cannot be maintained.

- Delays are experienced in sweetening off filters due to insufficient filter supply tank buffer capacity. Pongola does not have a cloudy liquor tank. Sweetening off of high brix liquor is diverted to filter supply, which not only creates a bottleneck, but increases the solids loading on the primary filters. It is recommended that a cloudy liquor tank be installed to overcome the buffer capacity and bottleneck, and also to ensure a steady state process.

- Work still has to be carried out to confirm the turbidity meter operating range. Preliminary testing of the turbidity meters was very promising, and showed good response in range 0 to 1000 Fomazin Turbidity Units (FTU). At this stage the turbidity meters have been merely used as a diagnostic tool to evaluate the performance of the meters and interaction with the process, and to compare with laboratory turbidity results. The turbidity measured by the instrument is in the near infrared range, and measured in FTU, whereas standard laboratory turbidity measurements are carried out by the ICUMSA method, determined at 420 nm. A comparison will have to be drawn between the turbidity as measured online in FTU units versus the ICUMSA 420 nm method, under steady state processing conditions. This will enable the operation of the filters in an optimal turbidity range, ensuring that the required liquor turbidity is achieved to meet the bottler's tight turbidity specification of 20 units at 420 nm, and suspended solids of 10 ppm.
- The accuracy of the turbidity meters is affected by dissolved gases and bubbles. The challenge here is to degas the sample liquor stream before presenting it to the turbidity meter. Degassers have been installed' however, the effectiveness is still to be tested and confirmed in the 2011 season.

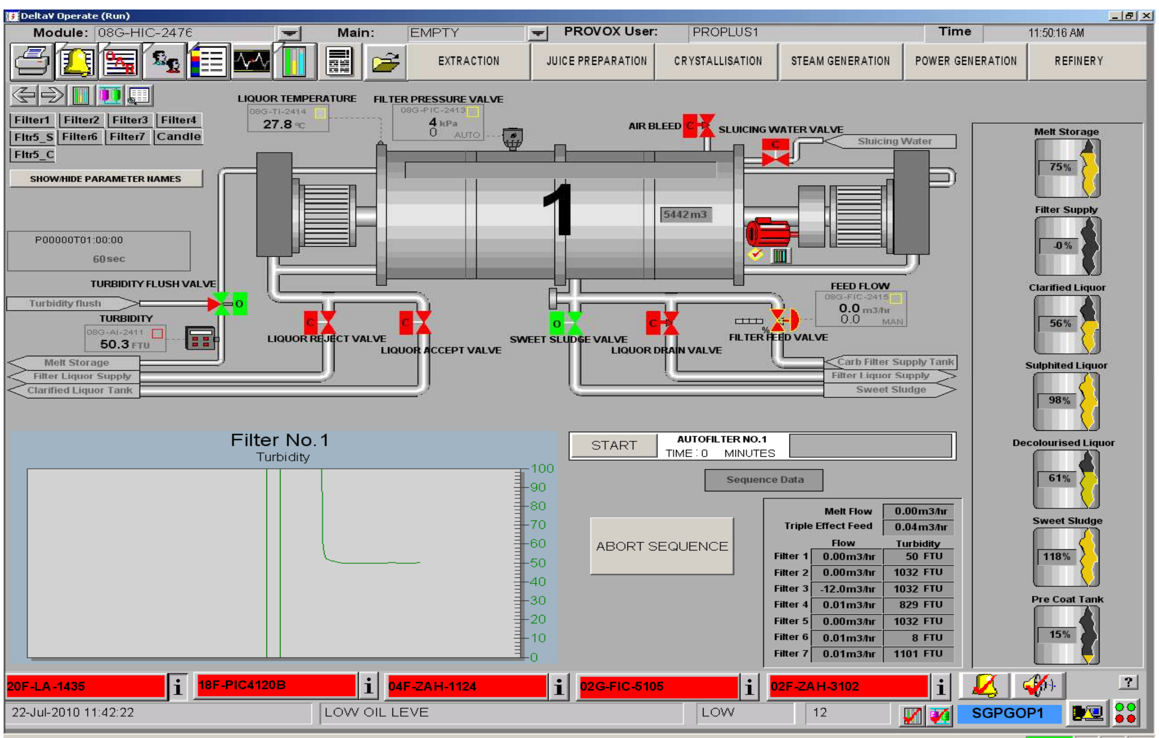

Figure 6. Typical pressure leaf filter on Distributed Control System (DCS) display screen.

Conclusion

This paper highlights that a project management approach is an effective way to bring together multifunctional teams to solve ongoing operational problems. The greatest benefit has been derived from an 'attention to detail' focus for operation and maintenance personnel. The implementation of the automation program was run in parallel with the sugar quality improvement project. The automation of the filter station has provided the diagnostic information to identify out of control situations on a real time basis.

Acknowledgements

The authors would like to thank the operational and maintenance personnel at Pongola mill for their contributions, especially Mr. Trevor Endres for the project management approach and for motivating for the paper to be written, and Mr. Ish Singh for his support in writing this paper.

REFERENCES

Anon (2010). *Beverage Product Specifications*. January 2010, Granular Sucrose Specifications, 1-8.

Bennet MC (1974). Physical chemistry of phosphatation and carbonatation. *Int Sug J* 76: 40-44.

Moodley M and Schorn PM (1997). Steps taken at Malelane to improve refined sugar quality. *Proc S Afr Sug Technol Ass* 71: 189-193.