OPERATIONAL PAPER

THE SMRI FACTORY IMPROVEMENT INITIATIVE

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Abstract

Due to the declining trend in the recovery performance of the South African (SA) sugar factories, the Sugar Milling Research Institute NPC (SMRI) implemented a strategy for assisting factories by identifying areas of opportunity to focus on and to provide recommendations for, how factories could return to the recommended best practices. The factory improvement initiative was conducted across the 2022/23 to 2024/25 seasons. It started with desktop audits, which identified the possible areas for improvement, and these were discussed with the factories via on-line meetings, which was followed by the SMRI team visiting the factories.

This paper discusses the key areas of the operations that were assessed for performance improvements in the various factories. The paper is limited to the deviations from best practice that were most common across the industry, in the different sections, namely: extraction, clarification, mud filtration, evaporation and pan house. The recommendations that were given to the various factories are provided in this paper for shared learning across the entire industry.

The recent performance trends show that there has been an improvement in key performance indicators, such as the overall recovery, extraction, undetermined loss, and target purity difference from 2022/23 to 2024/25. Whilst the SMRI is not claiming sole responsibility for the improvement in performance, this intervention is believed to have had a positive impact on the factory operations.

Keywords: factory, improvement, best practice, intervention, recoveries, financial benefit

Introduction

Historical data shows that the average SA sugar mill performance has declined since the 2006/07 crushing season, and alarming levels were recorded in 2021/22. In order to assess the needs of the SMRI members i.e., the SA sugar mills, online surveys were completed by industry stakeholders, and strategic meetings were held with the leadership of all the SA sugar companies. The loss of technical skills, the inadequate maintenance of equipment, the increasing energy costs, budget constraints and climate change challenges were among the cited causes of the poor performance in the mills. A collective responsibility was agreed upon to address this decline and to improve the sustainability of the sugar industry. It was acknowledged that the sugar companies previously had sizeable technical support teams and therefore, the SMRI had been encouraged to focus its efforts on creating novel technologies and opportunities to bring about step-changes in the industry. However, it became apparent that there was an urgent need for the SMRI to assist the sugar factories to improve their technical performance. This led to the birth of an initial three-year intervention, which saw the SMRI refocusing its resources, in order to fulfil the objective of assisting factories to improve their performance and to recover more saleable sugar.

Methodology

The implementation of the SMRI factory improvement initiative was rolled out in the 2022/23 season and started with desktop study exercises and analyses of factory performance. These entailed the use of data diagnostics to identify the key focus areas (the top five bottlenecks) at each of the 12 SA sugar milling factories. Factory performance data for the past 10 years for each factory was used, and key performance parameters such as extraction, Boiling House Recovery (BHR), Overall Recovery (OR), and Undetermined Loss (UDL) were assessed. These were compared and assessed by taking into account the previous season's performance, the factory's benchmark standard, which was the factory's 10-year best performance, and the industry's average performance over the same period. The major areas of poor performance were then identified from this analysis, and the SMRI team engaged with each factory to share the outcomes of the desktop analysis. Based on the identified areas of concern, the SMRI and the factory leadership then agreed on which areas to focus their attention on and how to best support the given factory. This was followed by a physical visit to each of the mills by a team of SMRI experts on various subjects. Technical discussions took place during the visits, and detailed technical reports containing observations, proposed action plans, and short and long-term recommendations to facilitate the improvements were sent to the mills after the visits. On occasions, and as a result of identifying opportunities for improvement during the mill visits, some mills commissioned the SMRI to conduct additional consulting work in order to assist in the identified focus areas. As a way of following up on the progress and action items for improvement, an update performance review (follow-up audit) was done towards the end of the milling season for each mill. This showed the mills how they had performed throughout the season, compared to the rest of the industry and their previous season's performance. This paper discusses the most common themes that emerged across the 12 SA factories in the different sections, namely: extraction, clarification, mud filtration, evaporation, A-station and C-station. The observations that were made during the factory visits and the recommendations given for improvement are highlighted.

Improvements observed since the intervention

The Mixed Juice (MJ) purity trend depicted in Figure 1, shows that the cane quality was somewhat stable from 2017/18 to 2024/25, whilst the industry Overall Recovery (OR) performance had declined from the 2018/19 to 2021/22 season, which suggests that the decline in recoveries was mostly associated with suboptimal factory operations. However, since 2022/23, the industry's downward performance trend has reversed. The average OR has improved from 80.78% in 2021/22 to 82.41% in 2024/25, which represents 1.63% units of improvement, with OR having improved in 8 out of the 12 factories. Whilst the overall industry trends are showing improvement, some mills improved much more than others and even attained their 10-year best performance. Figure 2 shows that extraction, accompanied by a decrease in imbibition, continued to decrease in 2022/23, but that it has since started to improve, with extraction increasing by 0.23 percentage units from 2022/23 to 2024/25, and imbibition increasing from 292 to 313% over the same period. However, it should be noted that the SA factories focused more on maximising throughput than extraction during the 2022/23 and 2023/24 seasons because of the large amount of carryover cane that required processing.

The trends of the losses, as shown in Figure 3, have also started improving, which is encouraging. The Undetermined Loss (UDL) sucrose in cane decreased from 4.39% in 2021/22 to 3.22% in 2024/25, which represents 1.17% units of improvement. The UDL improved in 9 out of the 12 factories. The TPD and losses to final molasses were lagging behind the other parameters, as they were still increasing in 2022/23. However, it is encouraging to note that the losses to final molasses and TPD decreased from 11.42% and

10.2% in 2022/23 to 10.56 and 8.1% in 2024/25, respectively, and it is hoped that this downward trend will continue.

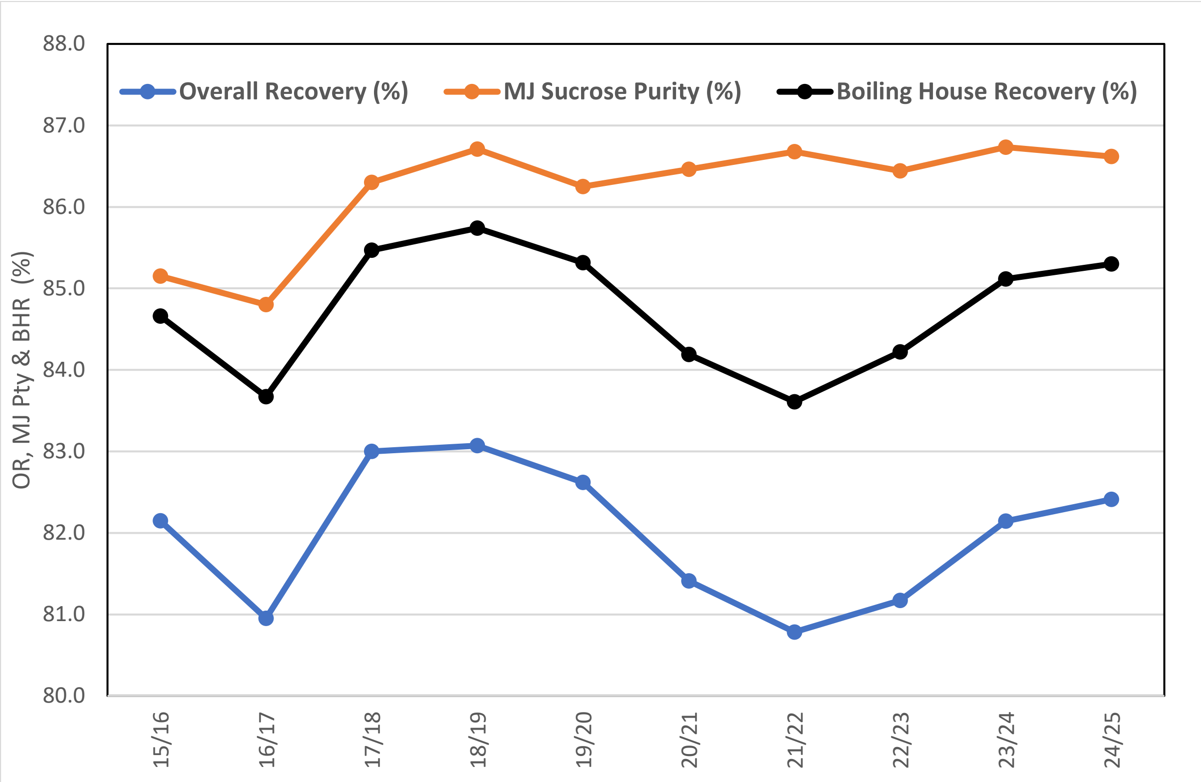


Figure 1. Recent trends of Mixed Juice Purity Boiling House Recovery and Overall Recovery

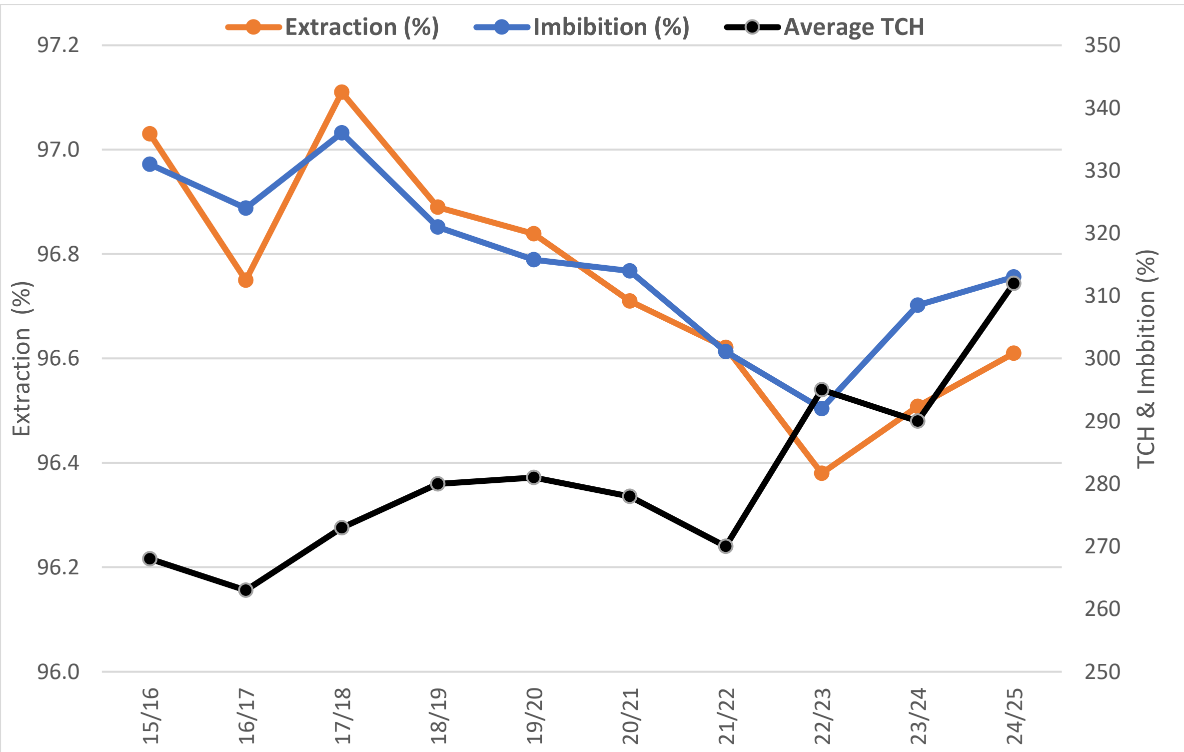


Figure 2. Trends of average TCH, Extraction and Imbibition

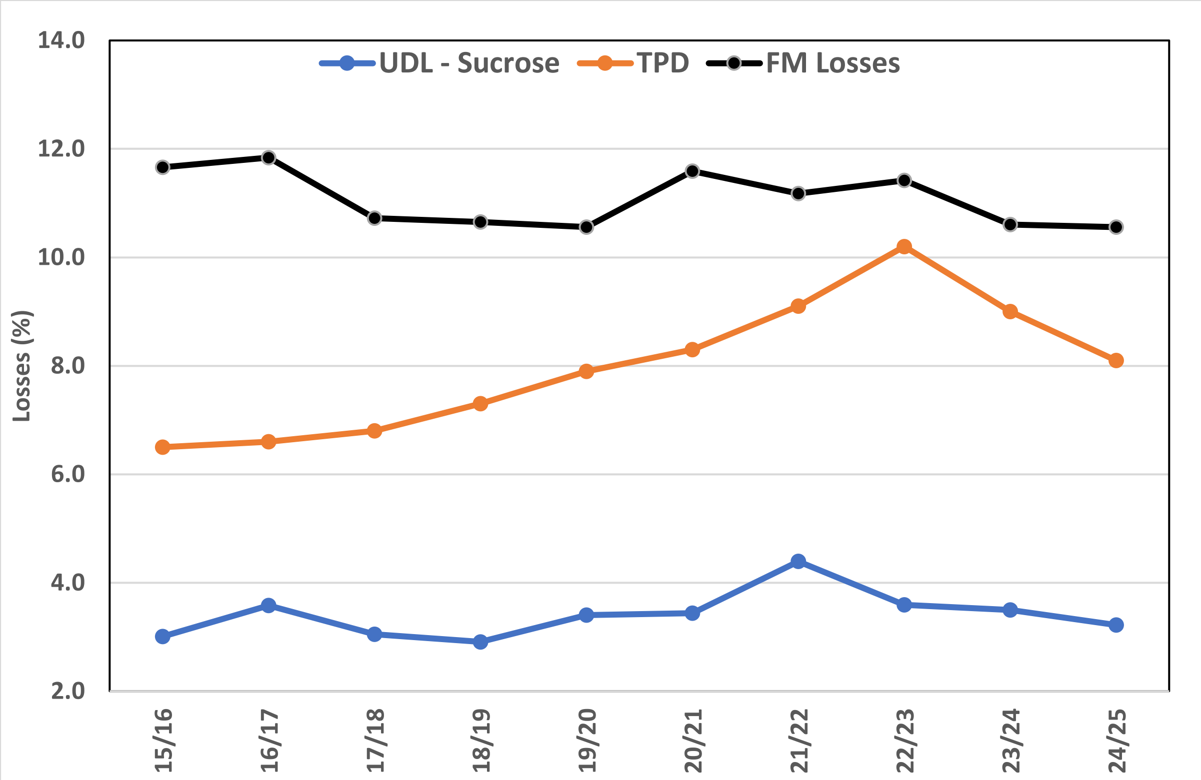


Figure 3. Recent trends of Undetermined Loss, Target Purity Difference, and losses to Final Molasses

The SMRI factory improvement initiative has been running from 2022/23 to 2024/25. The overall aim of this initiative was to assist factories to return to their basic operational practices. Whilst there is evidence that the average technical factory performance of the industry improved over this period, and some factories by a marked amount, it is difficult to gauge how much of the realised improvement in factory performance can be credited to the interventions of the SMRI.

The observations made during the factory visits gave rise to SMRI conducting further investigative work, e.g. evaporator control strategy reviews, continuous pan evaluation, tracer tests, evaporator fouling investigations, diffuser assessments, and factory speed profiling on a contract consulting basis, which no doubt contributed to the improved performance of the factories.

Findings from factory visits and discussions

Extraction

Although the cane throughput and energy management initiatives are the key contributory factors to the reduced extraction performance industry-wide, there are other fundamental areas of operation that the factories can address to obtain better extraction results. Extraction performance, in this context, was limited to diffuser operations where the observations were made. The industry 2024/25 season extraction was 96.61%, with the imbibition % fibre at 313%, an improvement from the 10-year average value of 96.38% and 292 imbibition % fibre. The SMRI team identified the top five most common parameters the factories could rectify to optimise the extraction performance. These are: (1) the low imbibition quantity, (2) the out-of-service bed screws, (3) the low diffuser temperature, (4) the uneven bed level and degree of bed saturation, and (5) the poor diffuser hygiene. In addition, cane preparation showed mixed performance patterns, where some factories did better than others. It was encouraging to observe the Brix profiles being measured throughout the industry, although these were not being used as an effective monitoring tool.

Low imbibition quantity

Imbibition levels as low as 216% on fibre were recorded at the mills, and this was driven by the ‘crush rate is king’ strategy. The high crush rates, meeting cane budgets, and completing the available crop took precedence over performance. In 2022/23 and 2023/24, this was more pertinent because of the high levels of carryover cane. If the juice flows are too high or tank levels are high, the imbibition % fibre is generally reduced. Other reasons for reduced imbibition are energy-related. Meadows (2022) recommends a reasonable imbibition value of 300% on fibre when designing a diffuser, and typical values are in the 300% to 375% range in southern Africa. The higher the quantity of imbibition water added, the higher the extraction, as shown in Figure 2.

Malfunctioning bed screws

Frequently, fewer than 50% of the bed lifting screws were found to be in operation during the factory visits. Bed screws play a vital role in preventing the compaction and blinding of the cane bed, and they assist in juice percolation and must therefore be operational. Typically, five out of a set of 11 lifting screws were operational in the mills, the rest of the screws were either completely removed or tilted out of the bed, due to a pin having sheared. It was a usual occurrence to find that all the bed screws, even in the second set, were not working in the factories. The typical condition of the bed screws observed at the factories is shown in Figure 4.

Figure 4. The state of a partly out-of-service set of bed screws, which was a common observation in factories

One of the challenges experienced by the mills was the steam leaks, which prevented maintenance from taking place on the bed screws while the diffusers were in operation (Figure 5). The necessity for bed screws to be lifted out of the bed when a shear pin breaks, makes complete sealing difficult. Ensuring that such steam leaks are repaired during stop days would assist in avoiding the inevitable loss in extraction, due to bed screws being out of action for long periods. However, it is acknowledged that there were a few mills in which a fair number of bed screws (over 60%) were operational.

Figure 5. A representation of how steam leaks prevented maintenance from being done on the screws, while the diffuser is in operation

Low diffuser temperature

At most mills, the overall diffuser temperature profile was low, with the observed juice stage temperatures averaging approximately 66°C (Figure 6), thus rendering the diffuser susceptible to microbiological activity and reducing its extraction potential. If diffuser temperatures are allowed to drop below 75°C, sucrose loss due to the activity of thermophiles becomes significant (Meadows, 2022). The target temperature to be maintained throughout the diffuser stages is in the range of 80-85°C, with a Draft Juice (DJ) temperature of approximately 65°C. Experience with different diffuser temperatures has confirmed that temperatures higher than this lead to a higher juice colour (Rein, 1995). Even so, it is not considered feasible to operate diffusers at lower temperatures, as losses under these conditions can be severe (Rein,1995). Whilst Scalding Juice (SJ) temperatures are meant to be more than 90°C to heat the cane sufficiently as it enters the diffuser, temperatures ranging between 76-88°C were observed. Low steam pressure, due to evaporator-related challenges, was a common cause.

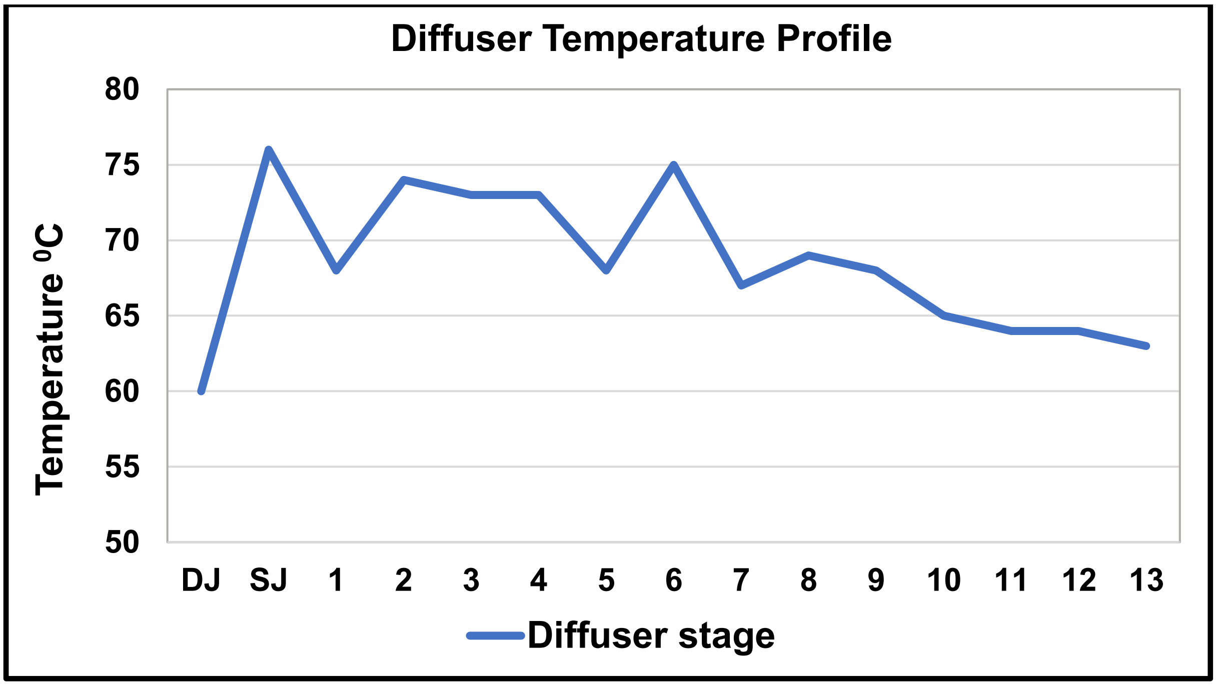


Figure 6. Profile showing a poorly-controlled diffuser temperature, which was typically seen in most factories

Uneven bed and juice level

An uneven bed level across, and along, the length of the diffuser was a common observation in the diffusers throughout the industry. Uneven beds affect the degree of saturation within the bed. The stages observed were either too dry or flooded in the same diffuser. A diffuser bed height should be maintained at a consistent level, and should, in every way possible, be maintained above 1.6 m to increase residence time and extraction. The inconsistency in bed levels, as observed in a factory, is shown in Figure 7.

Figure 7. A combination of photographs taken of one diffuser, showing uneven bed levels with flooded and dry beds, as commonly seen during the visits

In instances where a factory's target bed height is 1.4 m, because of design limitations, the mechanical indicator displayed or diffuser markings indicated even lower levels of 1.2 m across the width of the diffuser. Flooding destroys the Brix profile, whilst a low level of saturation/dry bed reduces extraction. The routine flushing of spray nozzles during stop-days, the checking of stage saturation, and the adjustment of diffuser sprays during operations are recommended. Adjusting diffuser sprays during operations, as recommended by Meadows (2022), helps to advance the spray positions if flooding occurs, and it retards them if the bed is too dry. However, most of the diffusers that were observed did not have adjustable sprays.

Poor diffuser hygiene

Diffuser hygiene is an overlooked best practice driver for good extraction and, as such, is often placed at the bottom of the priority list of where improved performance is sought. This is a mistake, as sucrose loss under these conditions is inevitable. The control of losses, due to lactic acid-producing bacteria, involves keeping the diffuser as clean as possible. The common poor hygiene observations, as shown in Figure 8, included leaking stage pump glands, leaking juice pipes and diffuser troughs, and fermenting sumps in the diffuser bunded area that are left unemptied for long periods. It is important to return the juice to the diffuser as soon as it spills on the floor and to preserve the quality of juice in the sumps.

Figure 8. Juice leak from a front-end pump indicated by the red ring. Poor diffuser hygiene observed in factories during the visits

Cane preparation

It is widely known that cane preparation is the most important variable affecting diffuser extraction and is easily within the factory's control. Preparation determines the 'extractability' of the cane by determining how available the sucrose-containing juice is to the counter-current washing and leaching process that takes place in a diffuser (Meadows, 2022). The better the preparation, the better the extraction. Evidence of coarsely-prepared cane, with large chunks of poorly-shredded cane, was seen in some factories. Meanwhile, reasonably well-prepared long-fibre cane with no apparent unshredded portions of the stalks were observed in other factories. Figures 9 and 10 depict these differences in the observations made in different factories.

Figure 9. Poorly prepared cane at two different factories

Figure 10. Reasonably well-prepared cane at two different factories

The rapid wearing of shredder hammers, which results in poorly-prepared cane (Preparation Index (PI) less than 90), was attributed to the presence of sand and stones in the cane. For mills where washboard adjustments were scheduled and shredder hammers regularly hardfaced and weighed, the degree of cane preparation was fair, with a PI of 91, as opposed to a PI of 89 observed in other mills.

Brix curve

Meadows (2022) states that a Brix curve is an essential tool in the management of proper diffuser operation. A good Brix curve should be smooth, as it drops off steeply after the feed and levels towards the discharge end, as shown by the control plot (depicted in blue) in Figure 11. The green trend in Figure 11 shows an offset (about 1 Brix unit over much of the diffuser), and 8 Brix in Stage 3, instead of 4 Brix. A useful rule of thumb has been given by (Meadows, 2022), namely “4 at 3 and 3 at 4”, i.e. the Brix should be approximately 4% at Stage 3 and approximately 3% at Stage 4. During the mill visits, the Brix curves were mostly conducted once a day by the mills across the industry. However, this did not enable these to be used effectively to control the diffusers, as the recommended interval for effective monitoring is once per shift. Some Brix curves were representative of the poor diffuser performance; for example, whilst the profile shown in Figure 12 does follow the typical smooth curve showing the steep drop-off in the early stages, the Brix at the last stage ranged from 1.71%-2.17% (indicated by yellow and green trends), where this should ideally be below 1%. Impact issues were amongst the challenges that were reported, e.g. several stage pumps being out of commission, flooding across the bed due to very high juice levels, and the inability to control the position of juice return to the bed, thus affecting juice distribution.

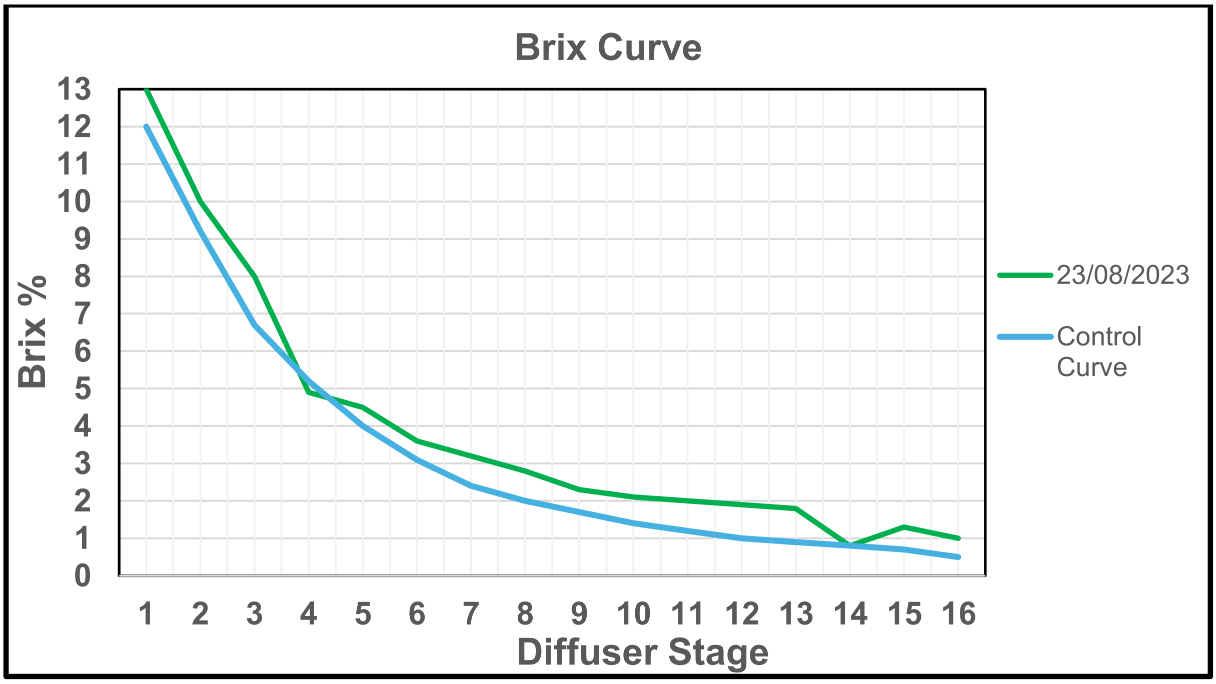


Figure 11. A plot of a Brix profile showing a smooth profile, but with higher Brix values than otherwise required for a good Brix profile

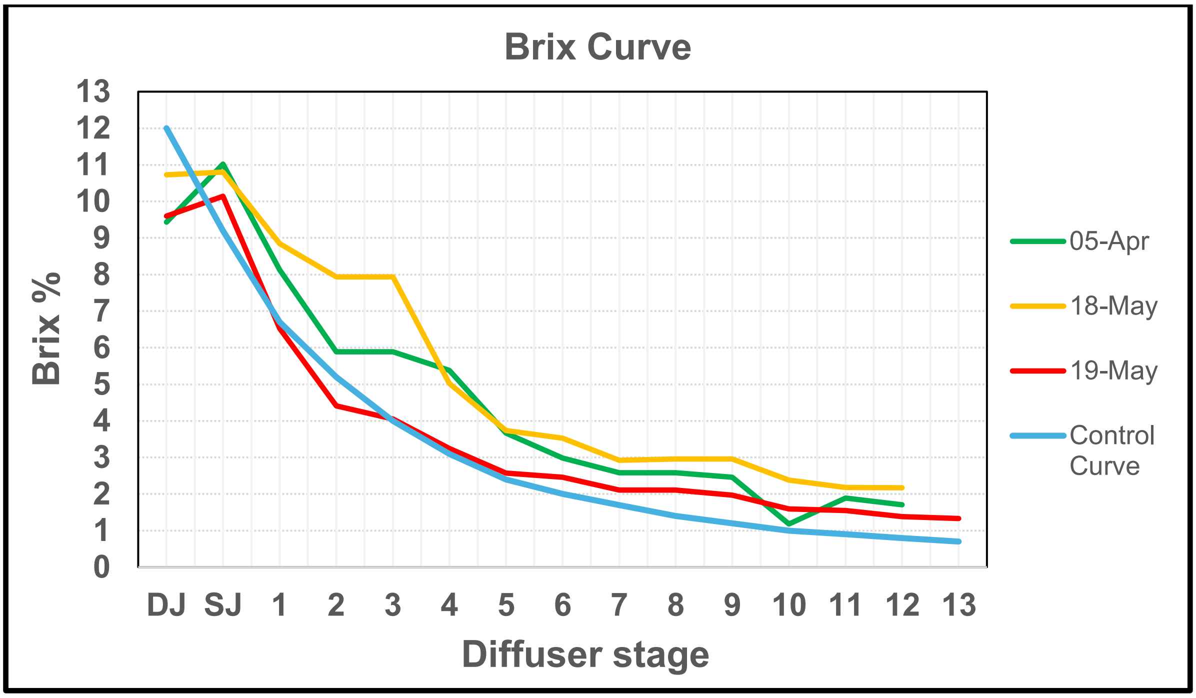


Figure 12. A plot of a poorly operated diffuser showing the Brix profiles across the diffuser stages from a factory

Clarification

The clarification station was an area of focus for seven of the 12 SA factories, which means that in five factories the clarification station was not perceived as an area of opportunity for optimisation. The seven that were audited had mixed performance patterns. The most shared areas of concern, where both good and poor performances were observed, were: 1) the Clear Juice (CJ) quality, 2) the flocculant preparation and quality, and 3) pH control, whilst 4) the juice flow control was generally carried out well across all these factories.

Clear juice quality

The CJ from some of the factory clarifiers looked turbid, with a high level of suspended solids carried over from MJ to CJ (Figure 13). In some factories, the CJ quality was reasonably good, showing a desirable yellow colour.

Figure 13. CJ samples indicating poor quality and the improper settling of mud (left) and good quality (right) observed using a test tube in two different factories

The various reasons for the poor-quality juice included the improper settling of the mud, due to high throughputs, high mud levels, and uneven juice distribution into the clarifiers. Some reasons were simply unknown and needed to be investigated. In addition to aligning the operations with the best practice guidelines, recommendations were made, such as conducting a water-level test for the clarifier launders and conducting a tracer test, to diagnose the causes of the poor performance. Where the recommended standard 'wedge' shown in Figure 14 was used to observe the juice clarity, readings ranging from 12 to 22 were observed. A wedge reading of 15 and above is generally considered to be acceptable (Mbuyazi et al., 2024). In most mills, a clarifier rack for CJ samples was not used. It was recommended that factories also set up a rack of test tubes (preferably tubes with a diameter of 25 mm), with 24 tubes (one for each hour over the day) with a fluorescent light, for the continuous visual monitoring of the CJ quality.

Figure 14. The CJ quality observed using a standard wedge in two different factories, poor (left) and good (right)

Flocculant quality

It was mostly observed that the system used to mix the powdered flocculant into a homogeneous liquid solution was good, but the flocculant solution shown in Figure 15 was full of conglomerates or 'fish-eyes', which indicated the poor mixing of the flocculant. In several factories, this was established to be caused by the stirrer, which appeared to be running very fast for this application, and the choking of the feed eductor (feeder). A low-speed (20 rpm) paddle is recommended for mixing in the flocculant dilution tanks and ageing tanks (Mbuyazi et al., 2024). As a best practice recommendation, the top of the mixing tank, as shown in Figure 16, should be covered to prevent foreign matter from entering the tank, and this was missing in all factories. It was often observed that there was no further dilution of the flocculant in the ageing tank. The recommended practice (Mbuyazi et al., 2024) is first to make the flocculant strength of 0.1-0.2% and then to further dilute the solution to approximately 0.05%, for better dispersion in the limed juice.

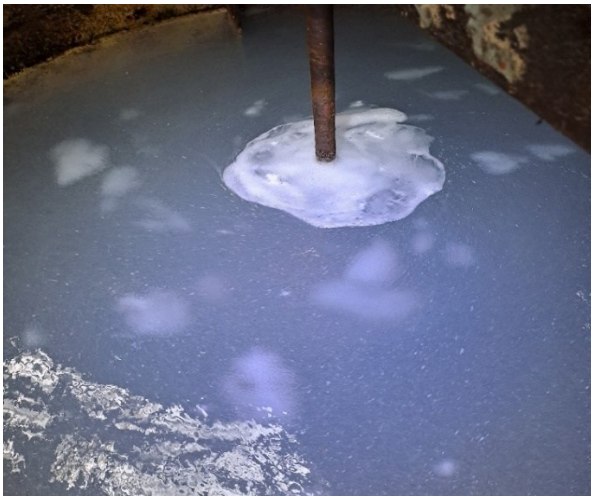


Figure 15. A poorly-agitated flocculant solution in a tank with conglomerates 'fish-eyes'

Figures 16. An uncovered mixing tank exposed to foreign matter ingress

pH control

The pH control at all factories was generally good and responded well to the flow changes, although the pH of the CJs was sometimes found to be higher than the recommended target range of between pH 6.9 and 7.2 (Mbuyazi *et al*., 2024). Good pH control is important for efficient juice clarification. During the factory visits, the control appeared to be good (Figure 17) where the Process Value (red = PV) was often seen to be close to the set point (yellow). The pH measurements from the field probe (in the plant) should be constantly verified against the laboratory, instruments, and it is better to have two field instruments, to cross-check against each other.

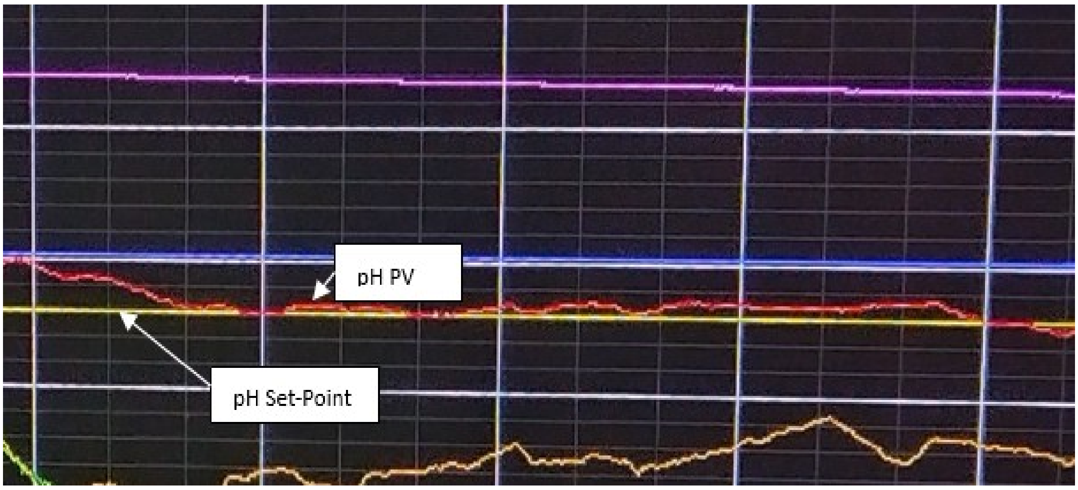


Figure 17. A snapshot of good pH control monitored in a factory control room, typically seen across the industry

Mud filtration

While being mindful of the fact that there are only four factories in SA that still practice mud filtration, it was deemed to be important that this station also be monitored for its performance since it does have an impact, on a bigger scale, on the overall factory performance. The common areas of concern where recoveries could be realised, amongst these four factories were found to be: 1) the pol% filter cake, 2) the filter vacuum and 3) the drum speed. The mud temperature in the filter boot, which is also a good indicator of long mud retention times, or poor mud extraction, which leads to inversion losses, were also monitored.

Pol % filter cake

Poor cake formation was a common observation in all four factories. The cake formed on all the filter drums was thin and wet, with areas that were patchy and areas that were not covered at all, possibly due to the blocked backing screens. The low quantity of bagacillo that was seen to be entering the mud mixer was a major contributor to the poor cake formation, as well as the inability to effectively apply water onto the filters, to the extent that there would sometimes be no water being used on the filters at the time of the visit. This therefore led to inadequate washing of the cake, resulting in poor recoveries at this station. Several spray nozzles needed aligning, in order to face the filter, and there was evidence of a blockage on some, which resulted in the water not being sprayed across the whole filter. It is known that a bagacillo to mud ratio of 0.4 is a good target for good filter cake formation, and can be calculated as shown below:

$$Bagacillo\ Ratio = \frac{Dry\ bagacillo}{Dry\ mud\ solids} \times 100$$

The reported pol % cake was at its worst and very high up at 8.79%, at a particular factory. The rule of thumb as an indication of good pol % filter cake performance is a figure below 1.5%. Photographs showing a typical filter cake and the condition of filter screens are shown in Figure 18.

Figure 18. Poor filter cake formation with the damaged screen area commonly observed in the factories

Filter vacuum

Most of the filters had poor vacuum readings, which indicated ineffective sealing, as depicted in Table 1. Both the high and low vacuums read well below the required operating vacuums; for example, at one factory, where low and high vacuum should have read -20 kPag and -40 kPag, respectively, they read -15 kPag and -18 kPag. This is an indication of leaks, which could be the reason for the insufficient vacuum. In a well-operated filter station, it is expected that a sufficient vacuum is maintained to efficiently pull the mud onto the drum and draw the filtrate through the cake into the receivers.

Table 1. Records of high and low vacuum readings taken from a factory vs the recommended target values for receivers and filters

Vacuum Readings	Gauge Readings (kPag)	
	High	**Low**
Filtrate Receivers	-49	
Receiver Target	-50	-30
No 1 Filter	-23	-18
No 2 Filter	-32	-26
Filter Target	-30	-10

Drum speed

The drum rotational speeds were usually too fast for the minimum and maximum recommended drum speeds, as shown in Table 2. Higher filter speeds must be adjusted to the recommended speed, in order to improve the filter performance. Slower speeds are recommended, as this enables the filter to pick up a thicker layer of cake and to give a longer time to wash out the sugar and dry the cake. This was part of the reason for the inadequate washing of the cake, and hence the high losses at the filter station.

Table 2. An example of high/fast filter speeds observed at a factory

Filter Number	Minutes/Revolution (Min/Rev) Recommended Ranges 3-5
2	2.58
4	2.40
5	1.52

Evaporation

The sub-optimal operation of evaporator stations was a problem in several factories, and this was recognised by a prolonged failure to achieve and maintain the desired syrup Brix. The most common problematic operational aspects that were observed by the SMRI team are reported in this section, as well as suggestions on how to improve their performance.

Evaporator feeding systems

In most cases, the feeding arrangements used for Kestners and Robert vessels were not the ideal external feed ring-type arrangements (Figure 19). The feed ring ensures the uniform distribution of the feed around the vessels, which promotes plug flow and good circulation. An external feed ring can be removed easily and cleaned during the stop-days.

Figure 19. Evaporator external feed ring with feed risers

Pressure drop between effects

In several cases, the pressure drop between the last two effects in the evaporator train was quite high. This phenomenon causes high juice velocities into the last effect, as well as a high degree of flashing, which results in entrainment. If this high-pressure drop is persistent, installing a small juice flash tank between the last two effects can help to reduce the amount of flashing into the last effect (Dlamini & Bindoff, 2013).

Incondensable gas removal

Ideally, there should be the separate removal of light and heavy Incondensable Gases (IGs). IG removal is important, as 0.5% air by mass in the steam will reduce heat transfer in the calandria by up to 13% (Allan, 1979). In most cases, the IG was removed by using a single pipe that extended down the calandria. This is not efficient, and the SMRI recommendation is to have separate removal of light and heavy IGs, and these manifolds should have their nozzles facing upwards in the calandria. Where IG are vented into atmosphere, it is important to regularly check for the quantity and type of fluid coming out of these vents. Liquid can come out through these vents if there is poor condensate drainage in the vessel.

Monitoring of the heat transfer coefficient

It was found that most factories did not have a habit of checking the Heat Transfer Coefficients (HTCs) across the evaporator train on a regular basis. The regular checking of the HTCs is highly recommended, as it is a good way of detecting the poorly-performing evaporators that should be prioritised for cleaning. The installation of condensate flowmeters, coupled with the monitoring of temperatures and pressures, can allow for the online calculation of HTCs and avoid off-line calculations that require some time to implement.

Level and BrixBrix control

There were challenges with evaporator control strategies, in terms of the juice level and Brix. Brix control was unstable in most cases, probably due to the improper tuning of the control loops, or a long dead-time in the control loop (Figure 20). It is recommended that the steam control valve for BBrix control should be located after the last bleed.

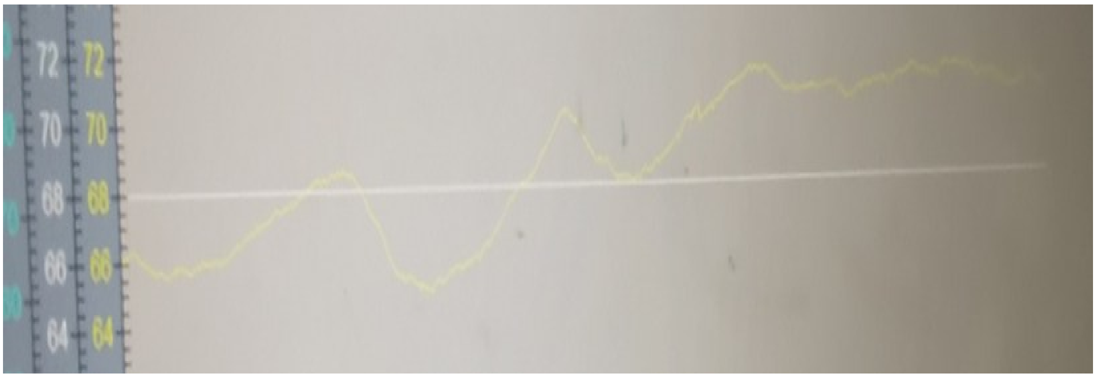


Figure 20. Brix control trend over a 4-hour period (the white line is the set point and the yellow line is the process value)

For Robert vessels, the ideal juice level should be between 30 to 40% of the tube height (Hugot, 1986), but this was not consistently achieved by most factories. Low levels should be avoided as they will cause localised overheating and then spouting.

Entrainment monitoring

Another issue that was encountered was the monitoring of entrainment from the evaporators, which is mostly based on analysing the condensates from the intermediate effects, and so entrainment from the final effect would not be detected. Whilst it was not possible for the SMRI team to examine the entrainment separators during operation, it is strongly recommended that pressure drop monitoring be installed across entrainment separators, especially the Metex screen types, as this would be an easy way of knowing when they start to foul. The use of isokinetic sampling of the vapours is the ideal way of identifying the source of this problem (Beale & Stewart, 1962).

General pan house issues

It is generally believed that there is much greater potential for improvement in the operations of boiling houses than in the extraction plants across the SA industry. The SMRI team visited the factories with this in mind. This section reports on the observations and recommendations that were made for the improvement of BHRs.

Performance targets

In most cases, the basic operating targets, as listed in Table 3, were not achieved, which resulted in poor exhaustions, high losses to molasses and high TPDs.

Table 3. General pan house operating targets

	A-station	B-station	C-station
Massecuite Brix at strike	92 – 94 °Brix	94 – 96 °Brix	97 – 98 °Brix
Purity drop on strike	18 – 20%		
Overall purity drop across all stations	> 50%		
Purity drop on cooling	> 2%		
Purity change on heating			0%
Purity rise on curing	< 2%		
Magma purities		90 – 92%	82 – 84%

It was sometimes reported that massecuite strike Brixes were intentionally slackened to avoid massecuite flow problems in the crystallisers; however, this should not be the case if all the equipment were designed properly. Most factories also did not do purity profiles of the Nutsches, from strike to curing. With the availability of the SMRI Mini-Nutsch filter and the SMRI-NIRS[1] analysis technology, it should be relatively easy and quick to do these purity profiles and they will be informative to improve the exhaustions, in terms of which areas require more focus.

Massecuite crystal quality

Pictures of crystals in samples of the seeds and massecuites showed that their quality was at most not good . The variation in crystal sizes was often huge, with the presence of substantial false grain, as shown in Figures 21 A to D. When the starting seed quality was poor, it usually resulted in poor massecuite. Despite the widespread use of wide monitor casings in the B-station, the quality of the B-magma was not good in some cases, which could have been due to poor quality slurry being used, the use of the wrong slurry addition point in the boiling cycle, and generally-poor boiling conditions in the pan, which allowed the formation of false grain. Another major concern was that these photographs were not viewed by pan boilers and their managers on a regular basis. Ideally these photographs should be reviewed during the morning meetings, to identify the corrective action, where necessary, with regards to how the boilings are conducted.

In several cases, it was found that the slurry used was not uniform, because it had been produced under inconsistent conditions (Figure 22). The factories were urged to stick to the approved SASTA method of preparing the slurry (Anon, 2009) and that this operation should be carried out under the quality control of the laboratory. Factories were encouraged to send slurry samples to the SMRI to check that their equipment produces the required quality slurry when the correct procedure is being followed. There were cases where factory microscopes did not have the facility to measure the crystal sizes and these factories were urged to rectify this as soon as possible. Factories were also encouraged to make use of a polarising UV-filter on their microscopes to improve the visibility of false grain on the pictures. The storage of historical crystal photographs in most cases was not good, with no, or limited, historical

[1] Near Infra-red Spectroscopy

pictures being available. Factories are encouraged to provide for a sufficient capacity for the storage of historical crystal pictures, if they should be required for troubleshooting.

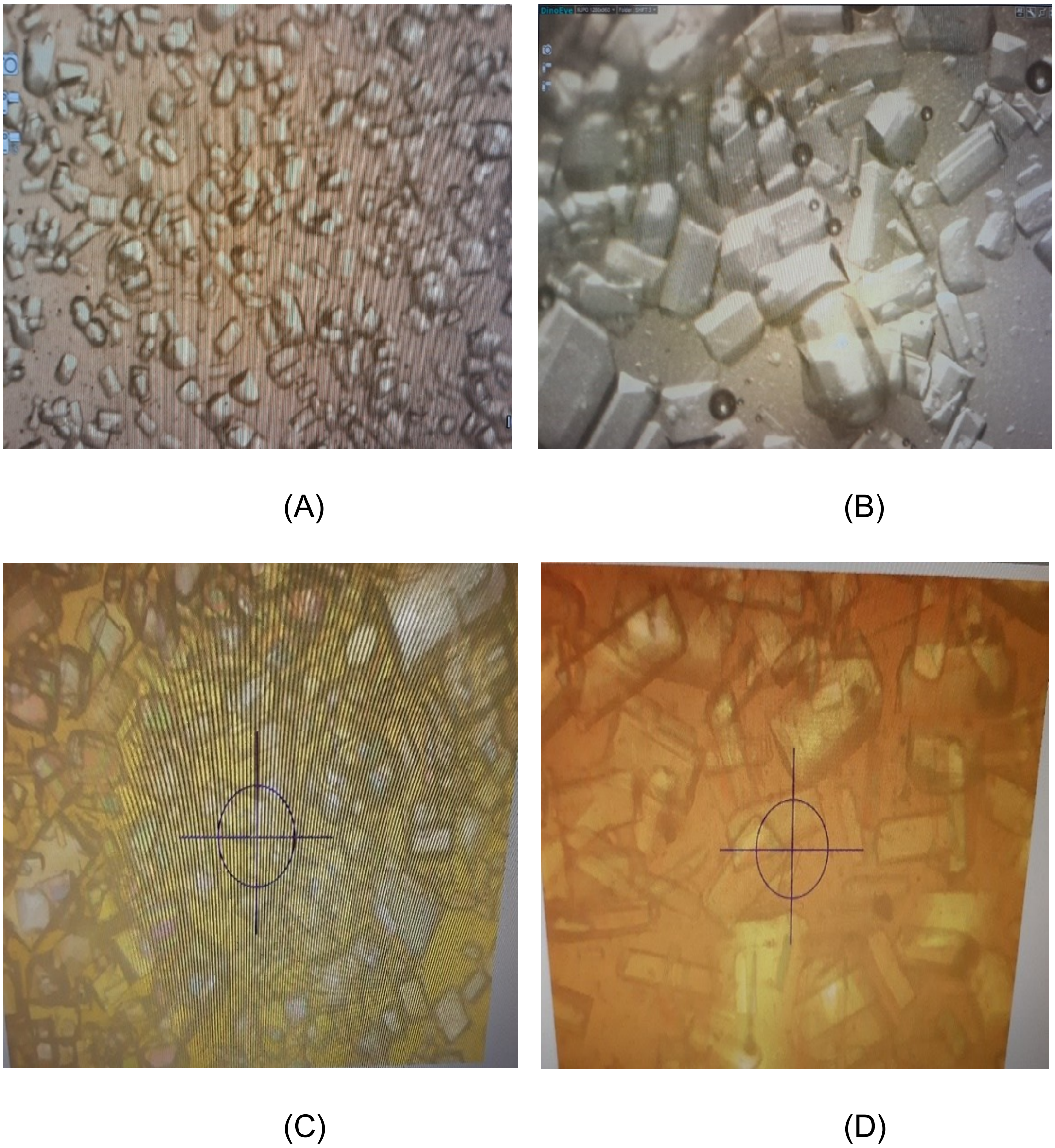


Figure 21. Pictures of different seeds and massecuites (A) B-magma, (B) A-massecuite, (C) C-seed and (D) C-massecuite

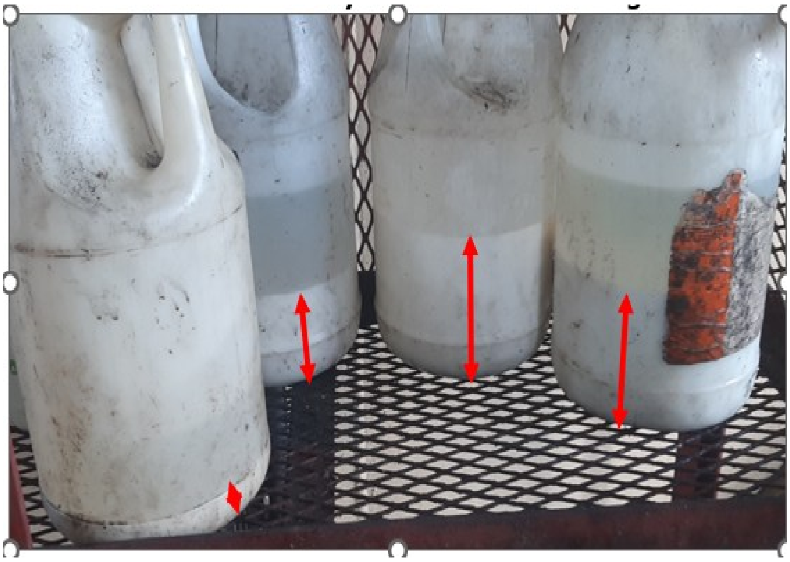


Figure 22. Inconsistent slurry preparation

Manual control of pans

Batch pans are mostly boiled manually due to the inadequate instrumentation available in the pans. The reproducibility of good boilings would be achieved more often with automated boilings than with manual boilings. It is strongly recommended that the pan instrumentation be improved and to allow for the implementation of automated boilings by implementing properly developed boiling recipes. Control loops being put on manual was another problem that was encountered in the continuous pan operations. The following control loops in continuous pans should always be put on automatic mode for consistent operation:

- calandria pressure control;
- evaporation rate control; and
- compartment feed control

The compartment Brix profile in the C-CVPs did not follow the recommended Brix profiles in most pans (Figure 23), as per the SMRI best practice guide (Love, 2023). In addition to the control loops being put on manual, this could also have been caused by the poor quality of the instruments being used for monitoring, as well as some probes being located in inappropriate places in the pans, for example, near internal steel work (proof sticks, ladder rungs, baffle plates etc.) that give noisier signals than other probes, thus causing an offset in the readings. Factories were urged to check for such types of interference during their stop-day inspections. It was also found that the on/off proportional control for feed and water on the continuous pans was sometimes not set correctly, in order to give about a 50% valve open time.

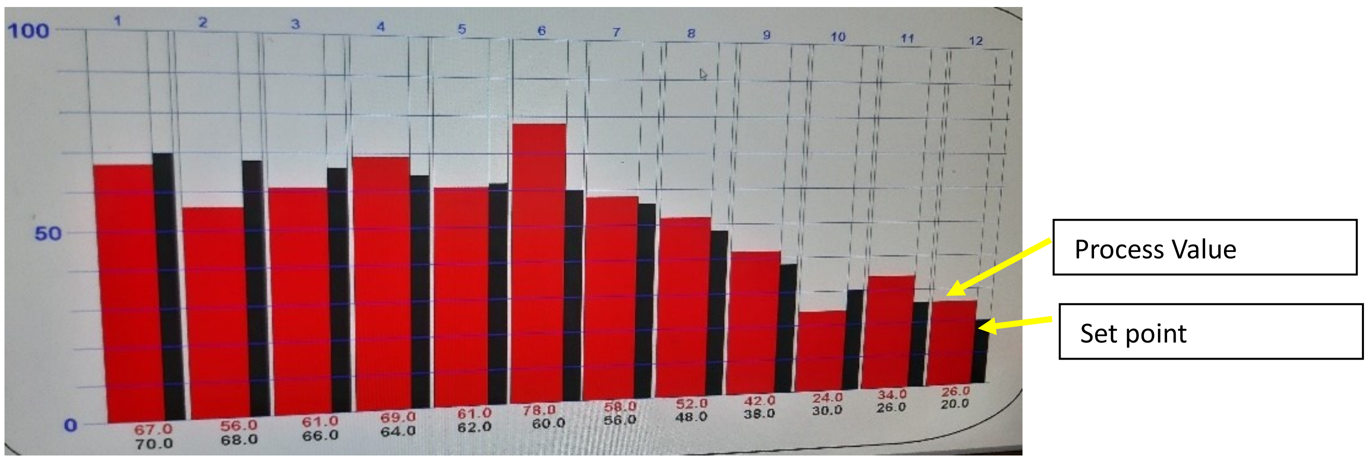


Figure 23. Actual versus set point Brix profile in a C-CVP

General operating issues

With regards to the construction of the pans, the following design issues were often picked up:

- The sight glasses for the entrainment return were located in obscured locations, which makes it difficult for operators to see if there is entrainment occurring.
- Pan steamings being dropped onto the massecuites. These should rather be routed to molasses tanks, remelt or steaming tanks and rateably pumped into a remelter.
- The lack of pan volume indications. These are needed, particularly when cutting over or drawing in magma.

Some operators had a habit of leaving the proof sticks extended, which draws air into the pans and some proof sticks were not sealing properly into the pan. These bad operating practices need to be stopped. With regards to the A- and C-cooling crystallisers, in most cases it was found that there was hardly any further exhaustion of massecuites taking place, despite there being sufficient available capacity. Some of the reasons for the poor performance of crystallisers were:

- no cooling water being used due to leaking elements;
- no cooling water being used due to the reheater being bypassed;
- low operating levels;
- The uncontrolled lubrication of massecuites; and
- broken crystalliser shafts

A-station

On several occasions, the elongation of A-massecuites was encountered, due to the recycling of impurities. In some cases, this was linked with the processing of carry-over cane and long burn-to-crush delays. An A-seed prepared by graining with slurry (rather than by using B-magma) was seen to have substantially less crystal elongation, which indicated that it was the recycled impurities, rather than the impurities in the syrup, that were the likely cause of the crystal elongation. Elongation causes difficulties in curing and it causes the passage of crystals through the screen. The van Hengel (1983) boiling scheme was recommended as a means of dealing with this problem.

The usage of pan movement water was found to be higher than necessary. This was more evident in continuous pans, where the number of compartments held on water was unusually high. In these instances, pan boilers were encouraged to slow down the evaporation rate in the pan, rather than holding the pan on water, which results in a wastage of steam.

C-station

Evidence of Maillard reactions on the C-massecuite was quite prevalent. The massecuite looked reddish brown, foamy and gassy (Figure 24). The monitoring of the Fructose/Glucose (F/G) ratios across factory streams is usually another good indicator of the existence of Maillard reactions, which is reflected by an increase in the F/G ratio. The Maillard reaction is caused by a high Brix, high temperature, and low purities. Therefore, it is very important to control the boiling temperature of the C-massecuite. Rein (2007) recommends that C-massecuite should exit the pans at no more than 63°C.

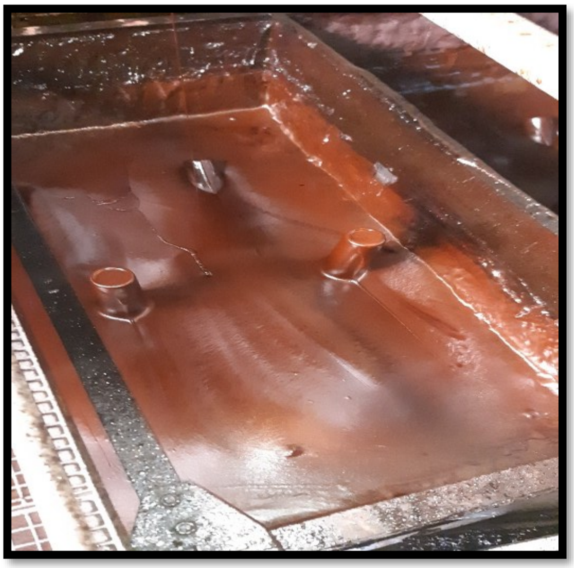


Figure 24. Evidence of the Maillard reaction in C-massecuite in the crystallisers (reddish colour)

The C-massecuite reheater was found to be a problematic unit operation in several factories that resulted in the reheaters being bypassed, which contributed to the high TPDs. The most common problem with reheaters was the leaking tubes, either in the reheaters or in the calorifiers, which suggested that there were problems with the quality monitoring in the water treatment systems. Another problem was that the factories struggled to get massecuite to flow through the reheaters, due to the poor designs. Sometimes C-massecuite Brixes were deliberately kept lower than the ideal, for ease of flow of the massecuite. This was discouraged, as it reduces C-massecuite exhaustion. Rather, the equipment design challenges that are encountered with high Brix massecuites should be properly addressed. In some cases, the high Brix massecuite from the crystallisers was lubricated to reduce the viscosity of the massecuite into the centrifugals. However, it was often found that the lubrication of massecuite was not done in a properly controlled or automated process, and therefore excessive water or molasses was used during the lubrication process, which resulted in the massecuite been too dilute (Figure 25).

(A) (B)

Figure 25. Lubrication of the massecuite with (A) water and (B) molasses

In some instances, the C-massecuite crystal content was found to be higher than the ideal target of 25 to 28% (Love, 2023). This increases the production of C-massecuite and increases viscosity. C-magma purities were mostly found to be on the higher side of the target range of 82 to 84%, due to over-washing in the C-centrifugals, which increases the losses of sucrose to molasses and results in the final molasses Brixes being lower than the recommended minimum target of 82 °Brix (Rein, 2007).

It was also often found that factories targeted a C-seed purity, rather than a C-massecuite purity. Consequently, the C-massecuite purity just followed the B-molasses purity, as can be seen in Figure 26, which was plotted by using data from a factory. A good practice would be to determine a target C-massecuite purity by using a desired crystal content, which should ideally be in the range of 25 to 28%, and the latest Reducing Sugars (RS) to ash (RS/Ash) ratio in MJ. Figure 26 shows what a targeted C-massecuite purity would have been for this particular factory. Targeting a C-massecuite purity will generally ensure a consistent crystal content, which should result in a better TPD. As found by Ninela and Rajoo (2006), boiling C-massecuite purities higher than the target C-massecuite purities leads to poor TPD results.

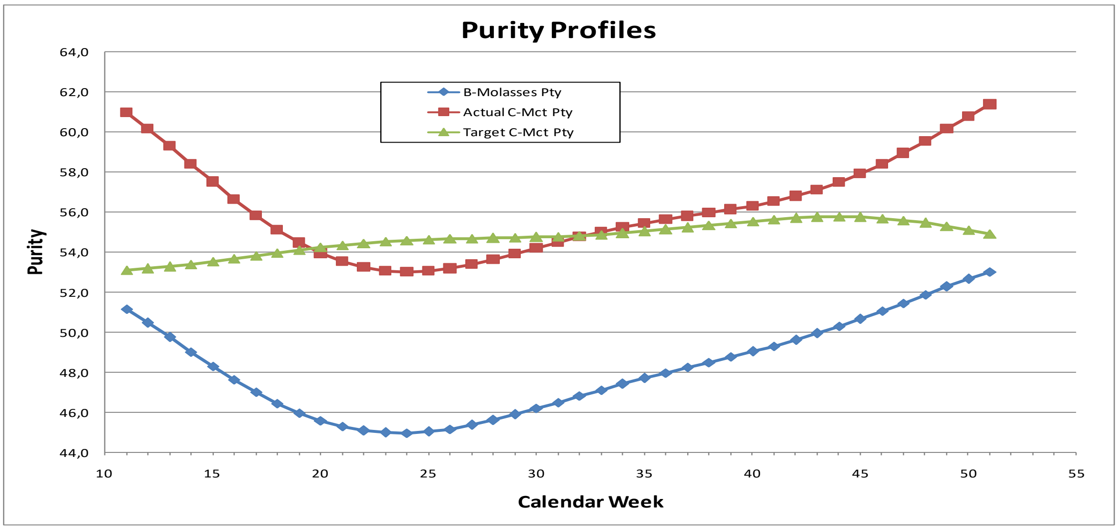


Figure 26. Relationship between B-molasses and C-massecuite purities

Batch centrifugal machines

High purity rises across batch centrifugal machines was a major challenge in most factories. These were caused by factors, such as an excessive amount of water being used for washing in order to achieve the raw sugar specifications, or for the benefit of the downstream back-end refinery. Some of the water spray valves did not close off tightly after washing, which resulted in water dripping into the basket. This is probably not serious while the centrifugal is in the high-spin cycle, but during the plough-out, the water falls onto the sugar being discharged, dissolving some of the sugar and causing lumps. Spray nozzles need to be set at a slight angle, so that there is no overlapping in the spray pattern. Sometimes the water sprays were not aligned properly, or they were bent, resulting in an overlap in the spray pattern and causing excessive sugar dissolution. This was partly caused by using in-house fabricated spray pipes, instead of using the spray pipes supplied by the original equipment manufacturer (OEM).

The plough settings were often not correct, which resulted in sugar being left behind after ploughing, as shown in Figure 27. Therefore, in some cases, the screen wash cycle was disabled in order to improve exhaustions, but this increases the risk of screen blinding. Leaking massecuite valves were sometimes an issue and resulted in massecuite leaking into the sugar.

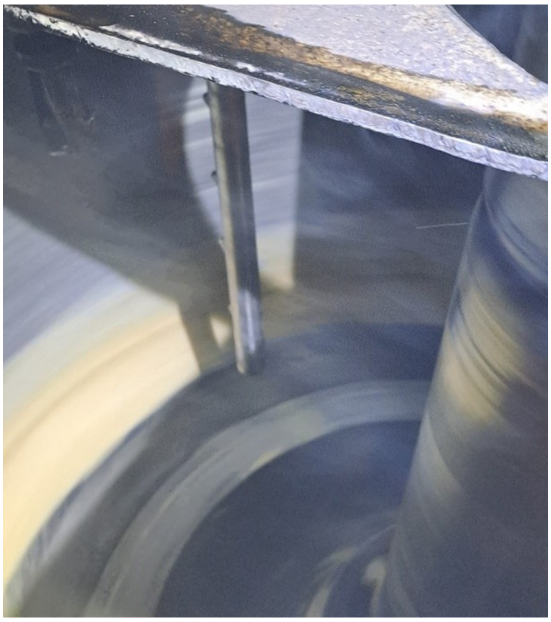


Figure 27. A-Centrifugal – showing sugar left behind after ploughing

The poor grain size distribution in the massecuite is another cause of high purity rises on curing. The small false grain crystals in the massecuite dissolve quickly in the centrifugals and also pass easily through the screen holes. When there is a high purity rise on curing, the molasses should be routinely analysed for crystals, to determine the integrity of the screen.

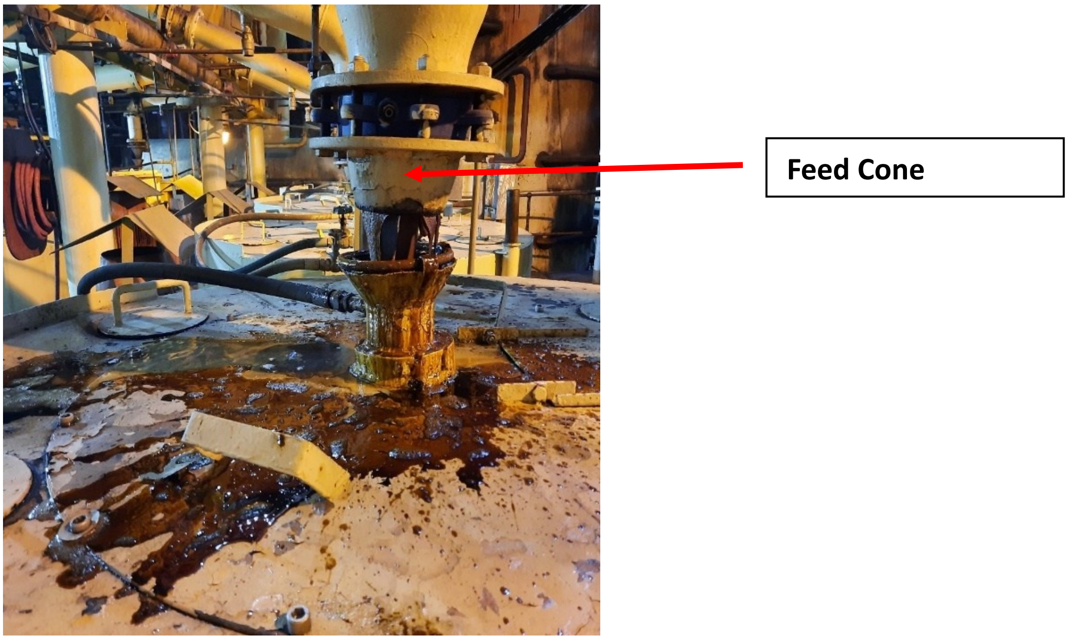
In most factories, there was no display on the centrifugal floor of the centrifugal wash water temperature and pressures. This is important information for centrifugal operators to know, so that they can halt operations and raise an alarm if these parameters fall outside of the desired range. A water pressure of at least 400 kPa and a temperature above 85°C is considered to be acceptable for good centrifugal operations (Rein, 2007).

Continuous centrifugal machines

In most cases, lubrication (lube) rods are no longer used due to the discontinuation of iris valves, and because water is added outside of massecuite in the feeding cone. This is inefficient, as there is no proper mixing of the water and the massecuite, which results in the separation of the two as soon as the mixture reaches the spinning basket (Figure 28A). Factories were encouraged to reinstate the use of lube rods. The design and construction of 'lube rods' is described in the paper by McEvoy and Archibald (1975).

Butterfly valves (as opposed to iris valves) are now commonly used to feed the centrifugals, therefore appropriately sized feeding cones are necessary to direct the feed into the machine and to contain the water that is added within the resulting 'rope' of massecuite. Feeding cones were often found to be either oversized and not yielding a good 'rope' of massecuite into the centrifugal, as shown in Figure 28B, or undersized, resulting in the build-up of massecuite in the crystallisers. Often the feed into similarly sized centrifugals was found to be disproportional. In addition, there was no monitoring of the water flow into the various centrifugals, which implied that the ratio of massecuite to that of wash the water would be different for each centrifugal. It was recommended that factories should monitor and control the wash water flow to each centrifugal.

(A)



(B)

Figure 28. (A) C-centrifugal water addition and (B) oversized feed-cone

It was mentioned earlier that factories were encouraged to determine Nutsch purity changes across the various unit operations in the pan house. With the SMRI-NIRS and SMRI Mini-Nutsch it should be possible to do numerous TPD analyses during each shift and for each machine. This practice will indicate the worst-performing machine, which should then be attended to for optimisation.

There are still a few factories that do not use wide monitor casings to produce B-magma. Wide monitor casings are known to minimize crystal breakage, and these factories were encouraged to move towards the use of wide monitor casings.

Summary of recommendations

The ultimate aim of the SMRI factory improvement initiative was to assist the sugar factories to return to well-established operational best practices and, thereby, to improve the technical performance. The most common deviations from best practices that were observed in the different sections of the factories have been discussed in detail in this paper. This section summarises the overall recommendations across the factory sections:

Extraction

- Cane preparation should be closely monitored and adjustments should be made to the cane preparation equipment, when deemed necessary.
- Factories should improve the imbibition levels to 300 to 375% on fibre. Where energy efficiency is a concern, investigations should be done to improve the energy efficiency.
- All lifting screws should be operational.
- Diffuser operating temperature should be between 80 and 85^{o}C across the diffuser stages.
- Instrumentation to monitor and control the bed level should be installed and operational to assist with minimising incidents of flooding in the diffuser.
- Operators should frequently monitor the diffuser and take the necessary steps to mitigate flooding and dry bed conditions.
- The hygiene of the diffuser should be improved e.g. leaks should be repaired quickly and diffuser sumps should be kept empty by using a level control.
- Brix curves should be determined regularly and used effectively to control the diffuser.

Clarification

- Ensure the Juice flow conditions into the clarifiers are not turbulent.
- There should be proportional juice distribution to different clarifiers, based on their operating volumes.
- Flocculant should be prepared under recommended conditions, as per Rein (2007)
- pH measurements from the field probe should be constantly cross-checked against the laboratory instruments, and there should preferably be two field instruments to cross-check against each other.
- The mud level should be monitored frequently and kept at an optimal level.
- The clarity of juice should be monitored frequently by using a standard clarity wedge, and hourly samples should be displayed on a test-tube rack.

Mud filtration

- It should be ensured that the vacuum system is operating correctly, so that the desired low- and high-vacuum pressures can be achieved.
- The filter drums should rotate within the recommended speed range.
- Water sprays should be set properly and be in a good operating condition.
- It should be ensured that there is sufficient bagacillo added to the mud, in order to obtain the desired mud-to-bagacillo ratio.

Evaporation

- A feed-ring type of feeding arrangement is recommended when using Kestners and Robert vessels.
- A juice flash vessel should be installed between the last two effects in the evaporator train, if there is a consistently high pressure drop between these vessels.
- Light and heavy IGs should be removed separately from the calandria and vented to the atmosphere or into a common manifold.
- Factories should monitor HTCs regularly and move towards the implementation of monitoring these online.
- The setpoints for level and Brix controls should be set properly and the control loops should be tuned properly. Factories can consult the SMRI for assistance with improving the evaporator control strategies.
- Isokinetic sampling should ideally be used for the identification of entrainment in vessels.

Pan House

- Factories should strive to achieve the key performance targets, as listed in Table 3.
- The Nutsch purity profiles across the various sections of the pan house should be measured routinely.
- Seed should be prepared correctly, and quality control on slurry production should be in place to provide a good starting point for massecuite production.
- All microscopes should have the facility to measure the crystal size and it is recommended that a polarising UV-filter be used for clear visibility of the false grain.
- Absolute pressure control in the vacuum pans should always be maintained on auto-mode, with the tail-pipe temperature override implemented.
- Factories should move towards the automatic boiling of all batch and continuous pans to achieve the reproducibility of good boilings.
- Compartment Brix profiles in all continuous pans must follow the recommended profiles, as outlined in the SMRI best practice guides for these pans (Love, 2023)
- Entrainment returns in the pans should be located externally and fitted with sight glasses in areas where they are clearly visible.
- Pan steamings should not be dropped onto the massecuites. These should be diverted to a steamings tank and rateably pumped to a remelter.
- There should be clearly-demarcated level indicators on the pans.
- Proof sticks should have a proper seal and should not be left extended.
- Leaking cooling elements in the crystallisers should be repaired as soon as practicable.
- Operating levels in the crystallisers should be as high as possible, and circulation through horizontal crystalliser banks should be such that the massecuite flow does not short-circuit. For example, the massecuite should flow from left to right and top to bottom.
- The lubrication of massecuites should be carefully controlled.
- Crystallisers should be properly maintained.

A-Station

- The use of pan movement water should be monitored carefully and controlled.

C-Station

- C-massecuites should exit pans below 63°C to minimise the onset of Maillard reactions.
- Final molasses should be stored below 40°C to minimise the onset of Maillard reactions.
- The quality of heating water treatment for the reheater should be monitored carefully.
- The lubrication of massecuites should be done by using the first molasses purged from a centrifugal in a classification process before the blow-up tank.
- Rather than targeting a C-seed purity, factories should determine a target C-massecuite purity using a desired crystal content in the range of 25 to 28% and the latest RS/Ash ratio in MJ.

Batch centrifugals

- The over-washing of the sugar should be avoided at all times.
- Water spray valves should be closed tightly.
- Spray nozzles need to be set at a slight angle, so that there is no overlapping in the spray pattern.
- Ploughs should be set properly to avoid sugar being left behind after ploughing.
- Screen wash cycles should not be disabled.
- Massecuite feed valves should close tightly, to avoid massecuite dripping into the sugar.
- Centrifugal wash water temperature and pressure should be prominently displayed on the centrifugal floor.
- Molasses should be routinely checked for crystals, to determine the integrity of the screens.

Continuous centrifugals

- Lube rods should be used for the more effective addition of water into the massecuite.
- Feeding cones should be sized correctly and feeding valves should be set properly, so that there is a roping effect of massecuite into the centrifugal.
- The massecuite should be distributed proportionally across different machines, running in parallel.
- The centrifugal wash water flow should be measured and controlled.
- TPD analyses should be conducted regularly for each C-centrifugal machine.
- Wide monitor casings should be used for the curing of B-massecuite.

Conclusion

The feedback on the first three years of the SMRI factory improvement initiative from the industry stakeholders has been overwhelmingly positive. The expertise, insights and collaborative approach to assisting factories with their improvement goals have been cited as beneficial, and the actionable and relevant recommendations given during the plant visits have been a welcomed success factor in this process. With the support of the SA sugar factories, the SMRI has decided to continue to offer the factory improvement initiative in subsequent seasons. It is acknowledged that factories are unique in their characteristics and that they have different challenges; therefore, going forward, a tailored approach will be used to meet the unique needs of each factory.

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