Proc S Afr Sug Technol Ass (2025) 97 : 361-371

OPERATIONAL PAPER

OPTIMISATION OF THE BACK-END OF A STAND-ALONE REFINERY

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Abstract

One of the advantages of a back-end refinery is the recycling of the final run-off back into the boiling house. In a stand-alone refinery, the final run-off is boiled further at the recovery station to recover the remaining sucrose. The performance of this recovery station affects the overall refinery yield. In the Huletts Refinery, the recovery house utilises a 3-boiling scheme to boil down the final run-off. The sugar from the first two boilings is sent to the main raw sugar melter, while the third boiling sugar is melted and recycled into the return syrup. The high colour in the first two boilings increases the colour-loading into the refinery. The third boiling sugar has a risk of both colour and ash recirculation, which will affect the performance of the refinery. Good manufacturing practices, plant modifications, automation and the repurposing of equipment are some of the steps that were taken to optimise the recovery house of the Huletts Refinery. This has resulted in an improved refinery yield, due to the reduction in the final molasses loss-on-melt.

Keywords: Recovery house, optimisation, refinery yield, molasses loss-on-melt

Introduction

The Huletts Refinery (Hulref) measures the overall performance by using the yield, unlike the overall recovery, which is used in sugar mills. The similarity of these two figures is the fact that molasses loss affects them both. The higher the loss, the lower is the yield or recovery, and vice versa. It is also common for the molasses loss to be the biggest loss, in both sets of factories. The main disadvantage of back-end refineries is the complexity of their performance calculations. Schorn (1995) mentioned some complexities when the Malelane sugar mill first separated the raw house and refinery into separate business units.

Compared to the back-end refineries, the stand-alone refinery carries with it the advantage of precise performance calculations. The reported molasses loss in Hulref is based purely on the recovery house performance, where the return syrup or Jet 4 from the white pan house is the only raw material. The optimised performance of the recovery house improves the refinery yield. Over and above dealing with the biggest loss (molasses), some other physical and chemical losses were addressed to improve the performance. This optimisation was done mainly through plant modifications, automation and improving the manufacturing practices.

Over the past few years, a lot of work has been done to improve the performance of the recovery house. Mncube *et al.* (2012) did exceptional work in this plant, which was evident from the improvement in its performance. However, this work was followed by the partial closure of the recovery house, due to some business dynamics, which resulted in the loss of skills. A poorly-performing recovery house affects not only the refinery yield, but also the throughput. It therefore became imperative to turn this plant around. This paper reports on the practical steps that were taken to optimise the plant, as well as their respective impacts.

Team alignment

After the reopening of the recovery house, some manufacturing practices were not effective. This included both operations and maintenance. Finding the product on the floor had become a norm, either as a result of tank overflows or leaks. This had contributed massively to the ash and/or non-pol recirculation, especially in the third-crop station, where the concentration is high. When tackling this problem, it was very important to align the team members, because it involved a change in culture.

The cane-yard personnel and effluent operators in a sugar mill are often despondent because they feel isolated and not part of the main team ([1]Personal communication). This was the same feeling in the recovery house and a few of team members were verbal about being neglected ([2]Personal communication). In order to take the whole team on a journey of change, it was very important to communicate openly and honestly with them. A lot of verbal and written communications were used to effect a change of culture.

The 5S component of leam manufacturing ('Sort', 'Set', 'Shine', 'Standardise' and 'Sustain') was employed to address the issue of non-pol recirculation, as a result of the product on the floor. 'Sort' (the first S component) was simply communicated as 'no product on the floor'. Often, the sump that contained different products would be pumped into the third-crop station. Addressing the leaks and overflows ensured that everything goes where it is meant to go, which is the 'Set' component (the second S). The recovery house was washed from top to bottom, using high-pressure washing machines. After washing, the electrical department fixed the old lights and installed new ones. The whole plant must 'Shine', (the third 'S'). When the place is clean and shining, everyone notices what it is like. Everyone gets to know the minimum 'Standards' (the fourth 'S'), and no-one wants to let it get worse than that. Avoiding a drop in the 'Standards' leads to 'Sustainability' (the fifth 'S'), which is what happened in recovery house, and credit is given to both the maintenance and operations teams.

The repurposing of equipment

Mncube *et al.* (2012) clearly mention the recovery house pan sizes and boiling scheme as an original set-up. As mentioned earlier, a lot of work was done to improve the performance of the recovery house. Dlamini (2018) suggested the reallocation of the heating surface area in the pans ([3]unpublished data). The suggestion was to exchange the first and third-crop massecuite boiling from the original set-up, i.e. a bigger stirred pan to boil the first crop and small pans to boil the third crop. The reason was simply based on the improvement of the throughput. A pan equipped with a stirrer has a few advantages over an unstirred pan, one of which is capacity (Bachan & Webb, 1985).

This de-bottlenecking exercise was done within the maintenance budget, as it only required minor modifications on the pipe network. Feed pipes were altered for the small pans (A and B-pans) to change over from the return syrup feed to the second-crop molasses. In essence, these pans would change duty from the first-crop to the third-crop massecuite boiling. The D-pan, which was initially boiling the third-crop massecuite, would change to the first crop. The return syrup feed to

[1] Main author observed this from various mills in a SADC region.

[2] This was mentioned by a few recovery-house operators

[3] Internal Memo by EM Dlamini, Optimisation Engineer, Technology Group, Tongaat Hulett Sugar SA

this larger pan was already in place for high-purity graining; therefore, no modifications were required on the feed.

More work was required downstream of the pans to align the sugar outlets and molasses run-offs to the respective pan duty. The modification allows the first and second sugar to be combined, remelted and recycled into the main raw sugar melter. The third sugar is melted and recycled into the return syrup. All the run-off syrups are properly separated in a centrifugal station and have dedicated tanks, as per the original set-up.

Changes in the pan duty improved the throughput of the recovery house, which was evident in the return syrup intake. Prior to this modification, the main pan house would often stop pumping the return syrup into the recovery house, due to a full return-syrup tank. An accumulation of return syrup in the white pan house would also result in a throughput reduction for the whole refinery.

Decluttering of the first and second crop feed lines into pans

One of the recovery pan-boilers pointed out the difficulty of having to batch feed the second- and third-crop massecuite pans ([4]Personal communication). It was established that when the pan feed modification was done, the first- and second-crop syrups were tied-in on a common line. In order to avoid mixing these materials, the pans were fed in batches. There was a huge risk of mixing the boilings, due to human error, which would affect the purity profile of the whole recovery house. This needed urgent attention. Figures 1 and 2 below show the common feed and the modification, respectively.

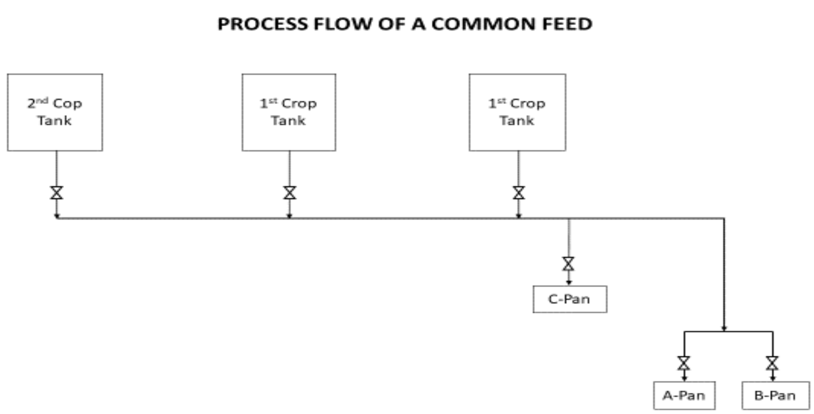

Figure 1. Feed system on a common line

[4] Mark Saunders Recovery House Pan-boiler

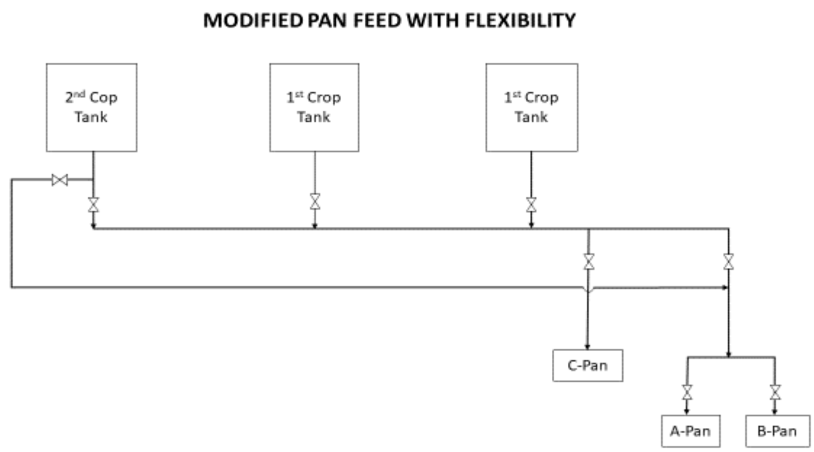

Figure 2. Modified feed system

After improvements on the first-crop boiling, the next bottleneck was the batch feeding of the second- and third-crop pans. The modification significantly improved the overall throughput in the recovery house, and the flexibility of changing the boilings amongst these pans was left in place.

Improvements on HTM production

Other than being a normal boiling house, the recovery house often makes High-Test Molasses (HTM) (Mncube *et al.*, 2012). However, this product is not regularly produced and it is made only on request. The preparation of HTM requires a stirred pan. This means taking a big pan out of its normal duty of boiling massecuite. In the past, it used to take very long to make a single batch of HTM. At times, it would take up to twenty hours. An assessment of this issue revealed that many problems were just related to the pumps, as these were undersized for this duty. It would sometimes take well over ten hours to pump a required amount into the pan. Preparing a batch of HTM suppressed the already stretched boiling capacity.

Inefficiencies in this process could not be accommodated. The pumps had already been stripped and serviced, but there had been no improvement. One pump was then upgraded by increasing the impeller diameter and motor size. No civil work was required. The upgraded pump now takes just below two hours to deliver the raw material, which is a significant improvement from a process that used to take almost two shifts.

It was also established that other delays involved the sampling and calculation of the ingredients. The pan-boilers were required to 'break' the pan vacuum, in order to be able to take samples and restart the pan after sampling. This also had a risk of entraining the pan, when restarting. Sampling is done at least twice for a batch of HTM. To address this delay, D-pan slurry funnel was slightly modified to allow for a double-valve system. That has enabled the sampling of HTM at any point during boiling, without having to 'break' the vacuum. Previously, the calculation of the ingredients was manual, by using a sophisticated formula; however, the calculation has since been computerised, with quicker results.

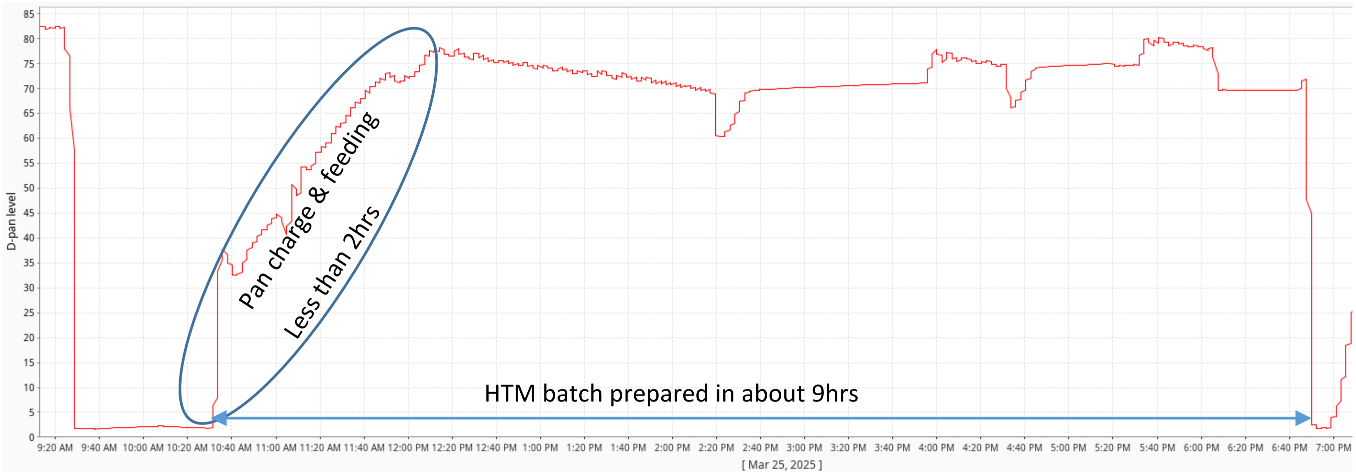

Figure 3. Improved pan cycle for HTM preparation

Figure 3 above shows the improved pan cycle for HTM production. The pan feed has been reduced to less than two hours, by using the upgraded pump. With these improvements, each batch can now be done in eight hours, as opposed to the previous 18-20 hours.

Pan control system upgrade

The recovery house was using a stand-alone system for the pan control. The system had difficulty with automation, data logging, general troubleshooting, etc. The unavailability of spares was also a problem and this was a risk to the plant. The system was therefore changed to DCS. The new system enabled the addition of more control loops. More points that highlight the issues with the previous system versus the new are mentioned in Appendix A ([5]Personal communication).

This system upgrade allowed for the full automation of the D-pan boiling cycle, with a view to implementing it on all pans. A new pan curve was developed by using a quadratic equation. The curve controls the brix and the level during the pan feeding stage and the brix-to-strike part. The automation has taken away the risk of human judgement and improved the consistency and quality of the massecuite. One cannot overemphasise the importance of consistent pan-boiling. There is enough literature on the work that has been done on pans over the years, and the dominating reasons have been either to achieve a consistent performance or to improve the energy. Figures 4 and 5 below show the difference in the boiling trends, before and after automation.

[5] Thanda Msane, Instrument Trainee Engineer at Hulref

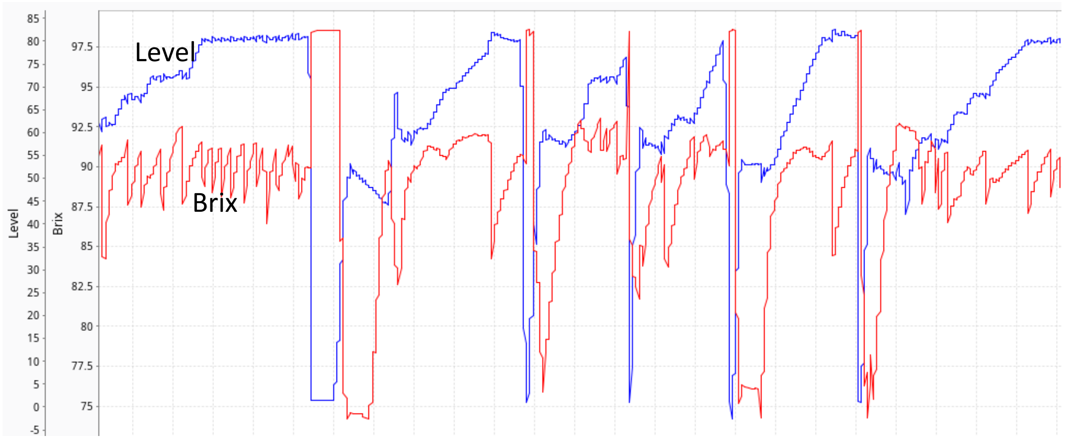

Figure 4. Brix and level trends before automation

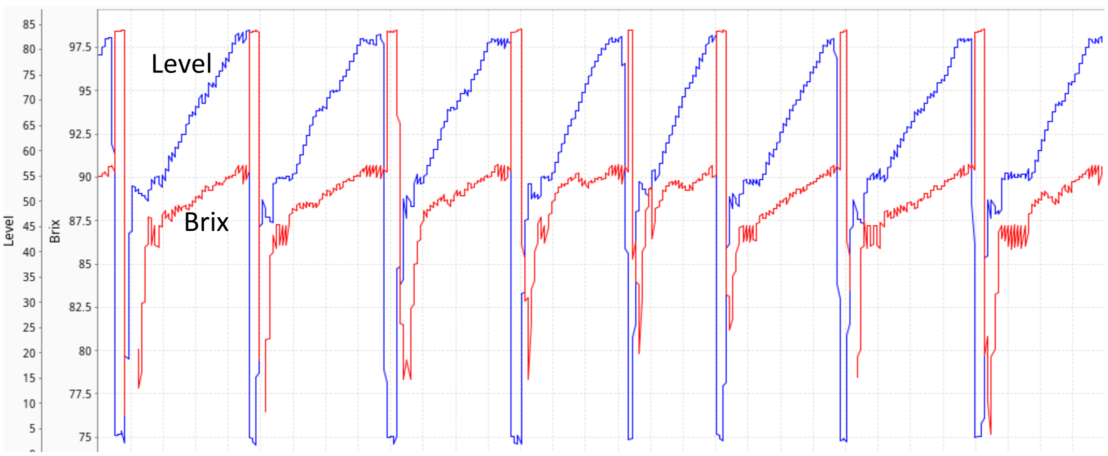

Figure 5. Brix and level trends after automation

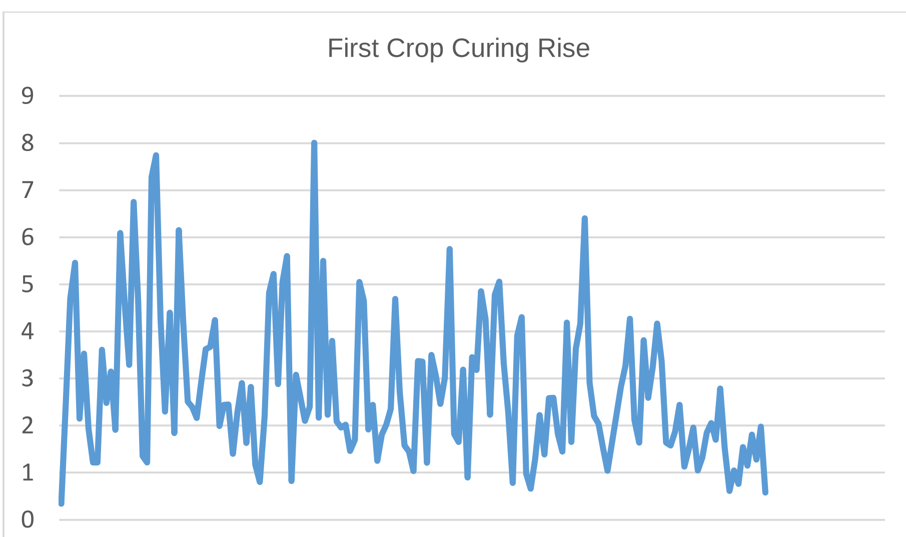

Figure 6. First crop curing rise for 2024/25 season

Figure 6 above illustrates the curing rise in the first-crop for the entire 2024/25 season. There is a noticeable drop in the curing rise towards the end of the season, which coincides with pan automation.

Linking the small crystallisers

Third-crop cooling crystallisation was done in batches, by using four crystallisers. Over the years, batch crystallisers have been replaced by the continuous type (Rein, 2006); however, the batch-type vessels had remained at Hulref. Rein (2006) mentions the disadvantages of batch crystallisers, one of which is the increased labour requirements. This operation was found to be labour-intensive and it was risky, in terms of safety. In addition, curing from these vessels followed a first-in, first-out method which was based on operator manual records. These records were not always accurate, which would affect the massecuite retention time and therefore, the exhaustion. Massecuite spillage was another problem with this type of operation. It was therefore decided to link these crystallisers and convert them into a continuous type.

These crystallisers are installed very close to each other, with a gap of about 300 mm. This made it easier to cut windows and installed overflow chutes, in order to link the flow of massecuite from the receiving crystalliser to the next one. The chutes in each crystalliser (inlet and outlet) have different depths, to allow a gravity flow from crystalliser to crystalliser. Baffle plates were also installed in the centre of each crystalliser, to force a plug-flow of the massecuite. This modification is illustrated by Figures 6, 7 and 8 below:

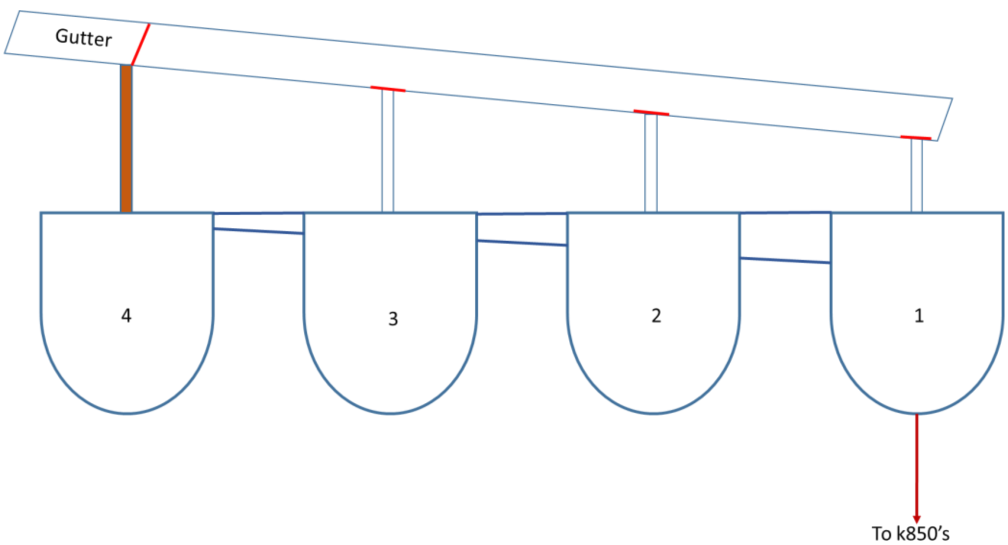

Figure 7. Front view of crystalliser

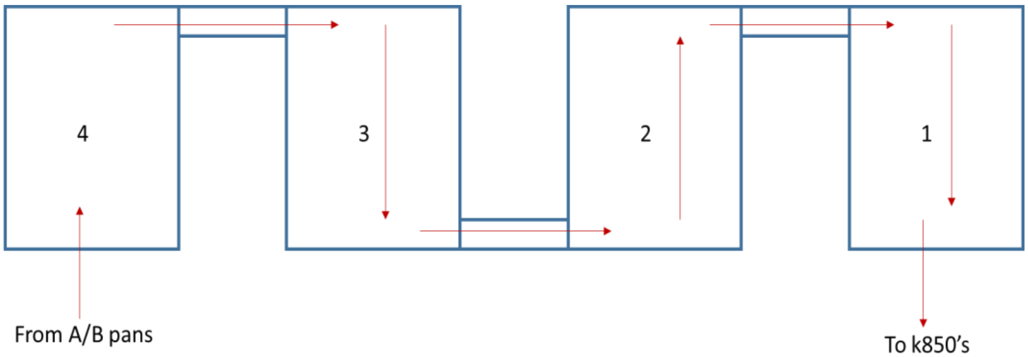

Figure 8. Top view of crystallisers

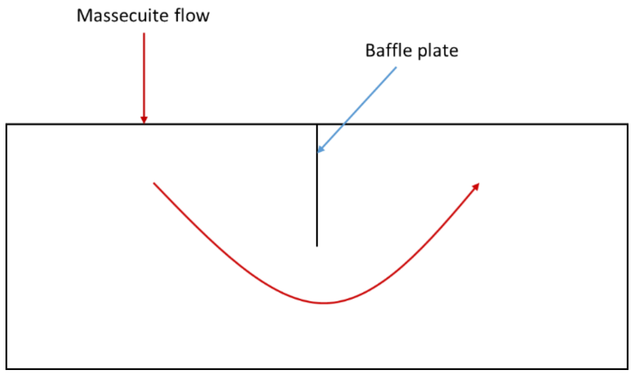

Figure 9. Side view of the crystalliser

Other interventions

Molasses seals

The centrifugation process utilises BMA K850 machines across all crops. These machines have rubber seals just under the tip of the basket, to eliminate the escape of molasses into the sugar chamber. As expected, the rubber wears away and requires replacement. Regular inspections of these seals need to be done, and they must be replaced as and when required. The chamber itself also needs to be inspected for leaks. Molasses escape onto the sugar not only increases the colour, but it also comes with ash recirculation, especially on the third crop. The practice of seal inspection and replacement has since been put in place, through scheduled maintenance.

Centrifugal screens open area

First-and second-crop massecuite curing was done with a 14% Open area (OP) screen whilst the third crop was done with a 7% screen. When investigating the difference on both screens, it was established that the difference was the slot length. 7% screens have a slot length of 2.67 mm versus 1.82 mm for 14% screens. The width is the same, at 0.06 mm. However, the 14% screen has a greater number of slots, and hence a higher open area. The test was then conducted by installing different screens in two machines and curing the same massecuite. Wash water was shut in both machines, whenever molasses sampling took place. A 14%-screen produced high brix molasses and the purity was a unit lower than its counterpart. The 7%-OA screen has since been discontinued and only the 14% screen is used.

Centrifugal screen checks

In raw sugar mills, screen changes are usually time-based. This practice might lead to waste in the recovery house operations, since the machines are alternated. The run times are not equal amongst these machines. Routine inspections are therefore paramount. Previously, inspections were conducted by the maintenance staff only, but now the operational staff have been trained to check the screens. The screens can now be checked in between the pan strikes.

Slurry containers

A few common mistakes are made with the slurry operations, i.e. from preparation, to handling and injecting it into the pan. All of these can easily affect the quality of the slurry. The good work done on pans could be in vain, if the slurry quality is not kept constant. In this case, the prepared slurry was decanted into 20-litre containers. Pan-boilers would then take the required amount for graining from the 20-litre container after 'shaking' it. The effectiveness of shaking of a 20-litre container is subjective to each Pan-boiler, and therefore the possibility of inconsistent quality of slurry is high. These containers were removed and replaced with 5-litre containers which are easy to handle. An improvement was evident, even in the white-pan house, as the MA and CV became more consistent. These parameters are not measured in the sugar from the recovery house; however, a consistency in the grain size was witnessed after the intervention on slurry handling.

Summary of the performance

The overall performance of the refinery had once been high in the past. This performance had dropped over the years, for many industrial reasons. However, Hulref needed to adjust internally, in order to absorb the external factors. A few other interventions were carried out across the factory to improve the overall yield. There is no doubt that the improved performance of the recovery house contributed to the refinery yield. Table 1 below shows a 3-year history of the recovery house performance.

Table 1. A 3-year history of the recovery house performance

Year	2022/23	2023/24	2024/25
Molasses%melt	4.19	2.94	2.50
Molasses Purity	62.94	60.35	60.55
Pol loss%melt	2.01	1.41	1.21

The drop in molasses percentage on melt translates into the higher exhaustions achieved in the recovery house. The pol loss, as a percentage in melt, also confirms a greater recovery of sugar. Over the years, the molasses purity has dropped from the mid-60s to just below 61%. This is not abnormal for a stand-alone refinery. Moodley *et al.* (1996) specified the difficulties involved in reducing the refinery molasses to below 74%.

Furthermore, the visible change in the plant is evident e.g. the additional storage of the return syrup in tanks that were allocated for other products (invert cisterns), as a result of the tank filling up, has been eliminated. Only allocated factory tanks are now used. In addition, there has been a notable drop in the number of centrifugal machines that are used. The second and third crops are consistently using one machine each, and the first crop uses the second machine intermittently. Dry floors are also evidence of a well-performing plant. The performance of the recovery house has improved, mainly based on the back-to-basics approach mentioned by Dlamini (2016).

Conclusion

Turning around the performance of a plant is not a one-man-show, but it requires the whole team to be involved. This was also not just a short-term project, but a long-term project, with short- and medium-term milestones. Each milestone that is reached does not translate into an overall achievement, but there is a continuous improvement. All milestones are celebrated to ensure that the team remains motivated.

Acknowledgements

The authors of this paper would like to thank the management of Tongaat Hulett Sugar South Africa for approving this work for publication. Many people were involved in this work. The authors also thank all teams involved in this work i.e. maintenance, laboratory and operations (mainly Senzo Gwabuzela and Mark Saunders). Their support has been amazing.

References

Bachan L and Webb B (1985). Assessment of a stirrer installed in a low-grade pan at Noodsberg. *Proc S Afr Sug Technol Ass* 85: 39-42.

Dlamini EM. (2016). Vicious cycles in factory operations. *Proc S Afr Sug Technol Ass* 89: 416-423.

Mncube FS, Rambukus Z and Muzzell D (2012). Optimisation of recovery house operation at the Hulett Refinery. *Proc S Afr Sug Technol Ass* 85: 378-387.

Moodley M, Schorn PM and Singh I (1996). Off-crop refining at Malelane. *Proc S Afr Sug Technol Ass* 70: 189-194.

Rein P (2006). *Cane Sugar Engineering*. Verlag Dr A Bartens KG, Berlin, Germany.

Schorn PM (1995). The splitting of Malelane factory into separate raw-house and refining operations. *Proc S Afr Sug Technol Ass:* 177-180.

Appendix A

Summary of points supporting DCS upgrade

Before DCS Automation

- Each Yokogawa controller operated independently, with no central monitoring or coordinated control of pans.
- It was difficult to apply advanced control mechanisms such as interlocking, sequencing, or batch management.
- There was no centralized historical data logging or trending for crucial process parameters including level, brix, vacuum, and temperature.
- Troubleshooting process issues was difficult due to a lack of recorded operational history.
- Operators were required to monitor local indications and manually adjust setpoints and valves.
- Increased likelihood of human error and delayed responsiveness to process disruptions.
- Operators needed to be physically present at each pan's controller or pneumatic panel to make adjustments.
- Inefficient personnel use, particularly during crucial tasks such as pan boiling or discharge.
- Pneumatic control lacked accurate, automated timing and sequencing which affected product quality and compromised safety.

After automation

- All pans and loops are now controlled and monitored using a single control room interface.
- Improves pan-operational coordination, optimizes workforce usage, and enables faster response to process conditions.
- Enhances process consistency, product quality, and operational safety.
- Continuously record vital parameters for trending, analysis, and troubleshooting.
- Identifies process irregularities early and supports performance optimization.
- Automated setpoint control and valve actuation reduce human error.
- Operators prioritize supervision and exception management over routine adjustments.
- Centralized alarm system provides prioritizing, logging, and operator instruction.
- Improved situational awareness under normal and abnormal settings.
- The DCS console allows operators to remotely control pans, alter setpoints, and acknowledge alarms.
- Automated sequences, such as door discharge, can reduce operating risks.
- Interlocks and permissive controls can avoid harmful operations, (e.g. opening a pan door under vacuum).
- Integrated control and data availability facilitate optimization and energy-saving strategies.