REFEREED PAPER

C SEED PURITY OPTIMISATION: AN INSTRUMENTATION SOLUTION TO A PROCESS PROBLEM

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Abstract

Noodsberg has continually experienced a high percentage of crystals through screens at its C centrifugal station. A profit improvement project was undertaken in order to correctly identify the source of this problem and provide a suitable solution. Whilst investigating the concern, it was deduced that the actual C seed purity achieved at the C pan fluctuated by 33% from the target purity. At Noodsberg, obtaining consistent C seed purity was previously not possible due to the lack of automation. The various grades of molasses used to make a C seed were done manually resulting in inconsistent exhaustions on a shift basis. The solution that was implemented focused largely on the automation of the C pan. The results of this automation included a decrease in the average C seed purity deviation from the target by 26.26%, as well as a reduction in the percentage of crystals through screen by mass by 11.8%. The C crystal size has also improved by 20.28% and an average of 2.5 units drop in Target Purity Difference (TPD) was noted (when compared to the corresponding 2016 period). The project was commissioned during week 28 of the 2017 season and the results of the project were tracked for a nine week period. The estimated savings generated by the project for the nine week period is R183 000 with a payback period of approximately 11 days.

Keywords: C seed purity; crystal content; crystal size distribution; C massecuite

Introduction

On a weekly basis, composite samples of C massecuite are sent to the Sugar Milling Research Institute for a variety of analyses. The most relevant of these analyses are those done to determine the Crystal Size Distribution (CSD) of the C massecuite. Once the CSD analysis is performed, the percentage of crystals by mass that could pass through the 120 µm screens is determined. This parameter was noticeably high at the Noodsberg mill. The maximum allowable percentage as per internal standards is 8%, whilst the 2017 season average as at week 27 was 35%. This process parameter then initiated the investigation into how this percentage could be reduced.

During the initial phases of the investigation, it was concluded that the high percentage of crystals by mass through the screens was accredited to the fact that the target C crystal size was not being achieved. The target C crystal size is 130 µm whilst the average for the 2017 period was 113 µm. This posed a problem as a large percentage of the undersized crystals would end up in the final molasses, rather than as saleable sugar. The next step of the investigation was to determine the cause of the undersized C crystals. The size of a crystal is highly dependent on the crystal deposition rate (CDR) and the CDR itself is dependent on the following aspects in pan boiling: circulation within the pan; slurry addition; and the amount of sucrose in the mother liquor. The pan in which the C massecuite was being produced had adequate circulation and the slurry addition was as per the recommended quantities. The C crystal size was trended against the loss across the C centrifugal station, and the results are as shown in Figure 1. It can be seen from Figure 1 that the lower the C crystal size was, the higher the loss across the centrifugal. This trend placed the focus on the amount of sucrose in the mother liquor to improve the crystal size. Whilst the CDR is not monitored at the Noodsberg mill, crystal content is tracked. The correlation between CDR and crystal content can be seen in equation 1.

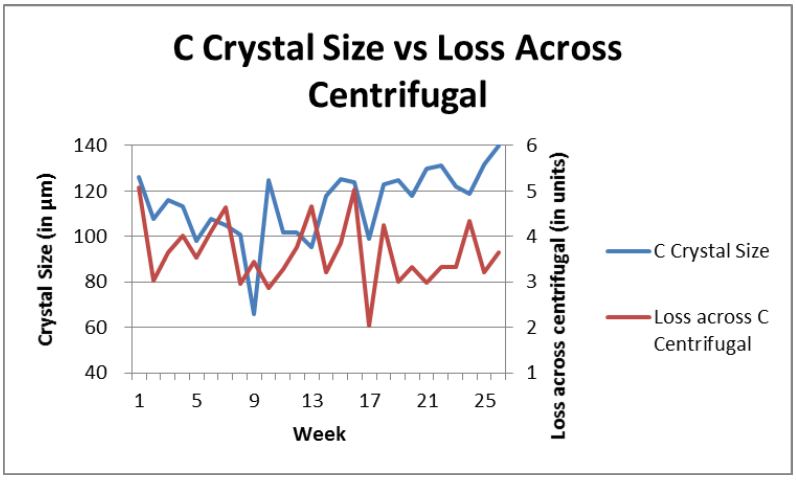

Figure 1. Trend of C crystal size and its impact on losses across the C centrifugals.

Equation 1. Crystal Deposition Rate Formula (3)

$$CDR = \frac{(Massecuite\ Flow * Massecuite\ Crystal\ Content) - (Seed\ Flow * Seed\ Crystal\ Content)}{Volume}$$

The project aimed at ensuring consistent C massecuite crystal content in order to achieve optimal CDR. The C massecuite crystal content can be determined as per equation 2.

Equation 2: C Crystal Content Formula (2)

$$C\ Crystal\ Content = \frac{(C\ Massecuite\ Purity - Final\ Molasses\ Purity)}{(100 - Final\ Molasses\ Purity)} * C\ Massecuite\ Brix$$

In evaluating equation 2, the C massecuite purity and brix were observed in order to determine which of the two were frequently out of specification. Upon investigation, it was determined that the C massecuite purity achieved fluctuated largely. This fluctuation can be seen in Figure 2, which shows the deviation of the actual C massecuite purity from the target.

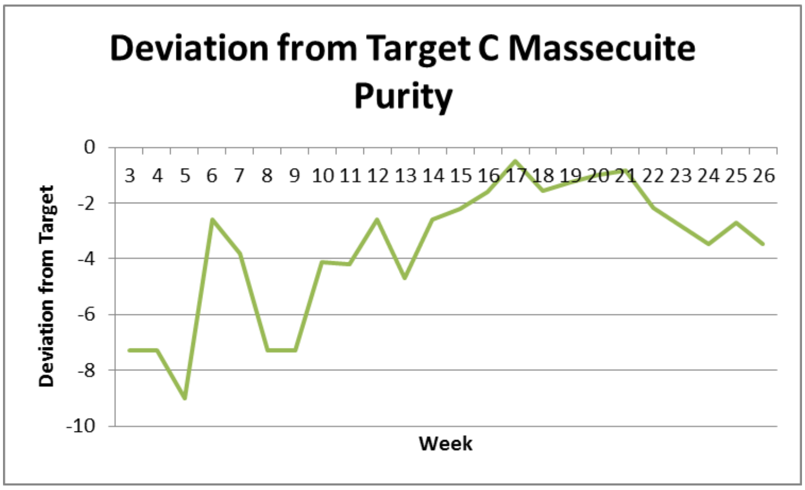

Figure 2. Deviation of C massecuite purity from target.

The loss across the C centrifugal station was trended to confirm that there were large volumes of sucrose being lost to final molasses. Whilst there are three contributing factors to this, i.e. torn screens, high wash water times and small crystals, the purity rise can be largely accredited to the undersized crystals.

C massecuite purity

C massecuite purities are critical when attempting to maximise sucrose recovery at the C station. Whilst the target C massecuite purity is determined by management, it is the pan boiler's objective to achieve this target. In the case that the purity achieved is higher than the target, there is a greater chance of false grain formation and poor exhaustibility of the massecuite (Ninela & Rajoo, 2006). In the adverse case, the crystallisation rate drops and a lower purity translates to higher viscosities which poses a problem during centrifuging, since smaller crystals are formed due to a compromised crystal deposition rate. It is therefore of utmost importance to ensure consistent C massecuite purity to improve the C station efficiency. Achieving the target C massecuite purity will also ensure that a crystal content of 30% will be achieved.

C massecuite is produced by using C seed as the footing and feeding the pan on B molasses. The B molasses purity is highly dependent on the wash times at the centrifugal as this is adjusted to ensure that the required B magma purity is achieved. The B molasses purity fluctuation can be seen in Figure 3 below. For this reason, it is advisable to ensure a consistent C seed purity to achieve the desired C massecuite purity.

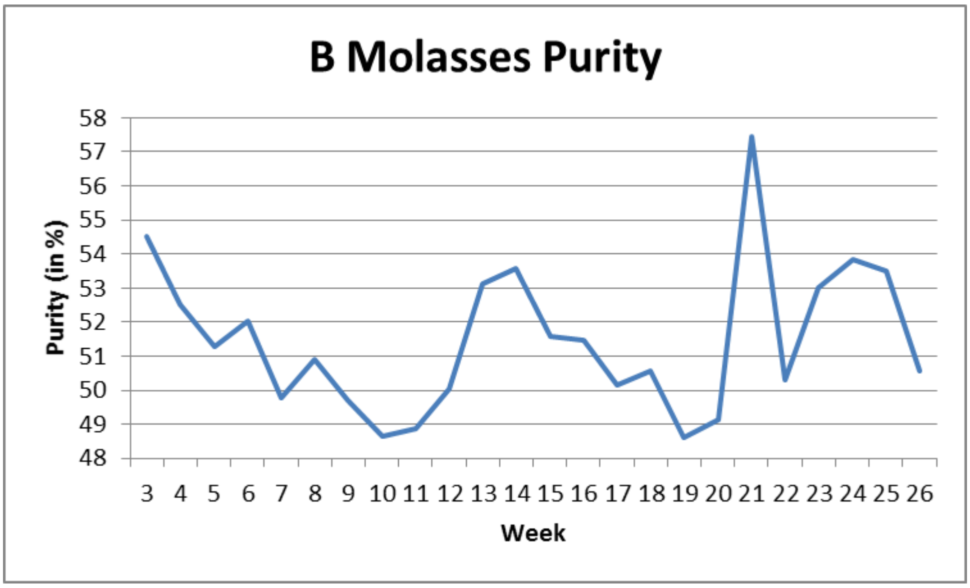

Figure 2. B molasses purity fluctuation.

The C seed purity at the Noodsberg plant was initially calculated on a spreadsheet based on the desired C massecuite purity. It was then suggested that the C seed purity should be controlled based on a calculated target. This target is calculated as follows:

Equation 3. Target C seed purity calculation.

$$Target\ C\ Seed\ Purity\ [1] = (2 * C\ Massecuite\ Purity) - B\ Molasses\ Purity$$

The C massecuite purity is determined by management whilst the B molasses purity is as per operations and B station performance. Therefore, the target C seed purity is subject to change based on management's targets.

Once this change was initiated, it was determined that there was poor control in achieving the desired C seed purity due to the manual nature of the operation.

The project that assisted in the optimisation of the C seed purity will be discussed. The project installation occurred within week 28 of the 2017 season.

C seed purity

C seed is produced using A molasses (or in the rare case, raw syrup) as the footing in the pan and feeding with either A- or B-molasses, depending on the target purity. The option to feed using syrup was also catered for. The volume of each molasses is calculated using the Cobenz formula and the target purity is stipulated by management. Previously, the volumes were calculated on the Distributed Control System (DCS) and recorded. It is the responsibility of the pan boiler to achieve the C seed purity by feeding according to the volumes obtained using the Cobenz formula.

In evaluating the C seed purity against the target prior to system modification, it is evident that there were significant deviations from the target. This can be seen in Figure 1. This warranted an improvement to the control of C seed purity. The average deviation from the target C seed purity is 1.98 units.

The step change in the target purity as per Figure 4 is on account of the fact that at a target C seed purity of 60, the process team were achieving low final molasses purities. However, in observing the actual size of the crystals, the crystals were smaller than desired. The decision was then taken to increase the C seed purity to 65 to sweeten up the seed and provide larger crystals.

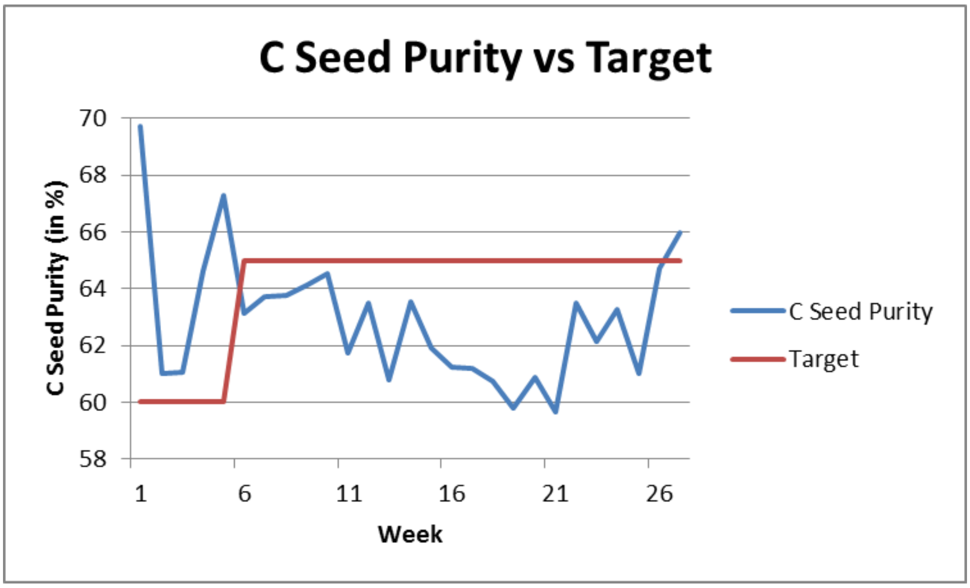

Figure 3. C seed purity: target vs actual prior to modification.

Shortcomings of the existing system

There were two main shortcomings identified in the current system. Firstly, the pan boiling recipe was reliant on the operator to switch between the A and B molasses feed valves during the feed/fill stage. This not only introduced inconsistent results each time the seed was boiled, but it also introduced fluctuations in C seed purities between each shift. The second problem was that the existing system utilised a differential flange mount transmitter to measure the level of the pan. It was noted that the transmitter was located just under the calandria and thus did not account for the volume underneath the calandria. Therefore, the existing control strategy was revised and the recipe was updated such that it used an existing flowmeter to determine the quantity of A/B molasses feeds. The system also required auto-valves to be installed to aid in the control of the feeds.

Control strategy of new system

Whilst the Cobenz formula determines the exact volumes of each molasses required to achieve the target purity, a survey was conducted which concluded the following points:

1. Irrespective of the volume of A molasses required, the pan footing should consist solely of A molasses in order to ensure that the required crystal content of 30% is met (as it may not be achieved at low B molasses purities).
2. The need to ‘sweeten up’ the footing using syrup was not commonly practised at the Noodsberg plant as the A molasses purity was sufficient to achieve the target C seed purity. Syrup was therefore not considered during the formation of the control strategy but was automated for future use.

Considering the first point mentioned above, it can be expected that the C seed purity may not be achieved precisely in the case that the target C seed purity is too low (possibly at a purity of 60) whilst the A molasses purity is high. This is accredited to the fact that A molasses will always be used as footing, irrespective of the Cobenz requirements of A molasses.

Based on the information provided by management and pan boilers, a control strategy was formulated. To overcome the two problems mentioned previously, the new design made use of an existing flowmeter to determine the volume of molasses being added to the pan. The feed valves were then automated to allow for automatic control. The proposed control strategy is as seen in Figure 5.

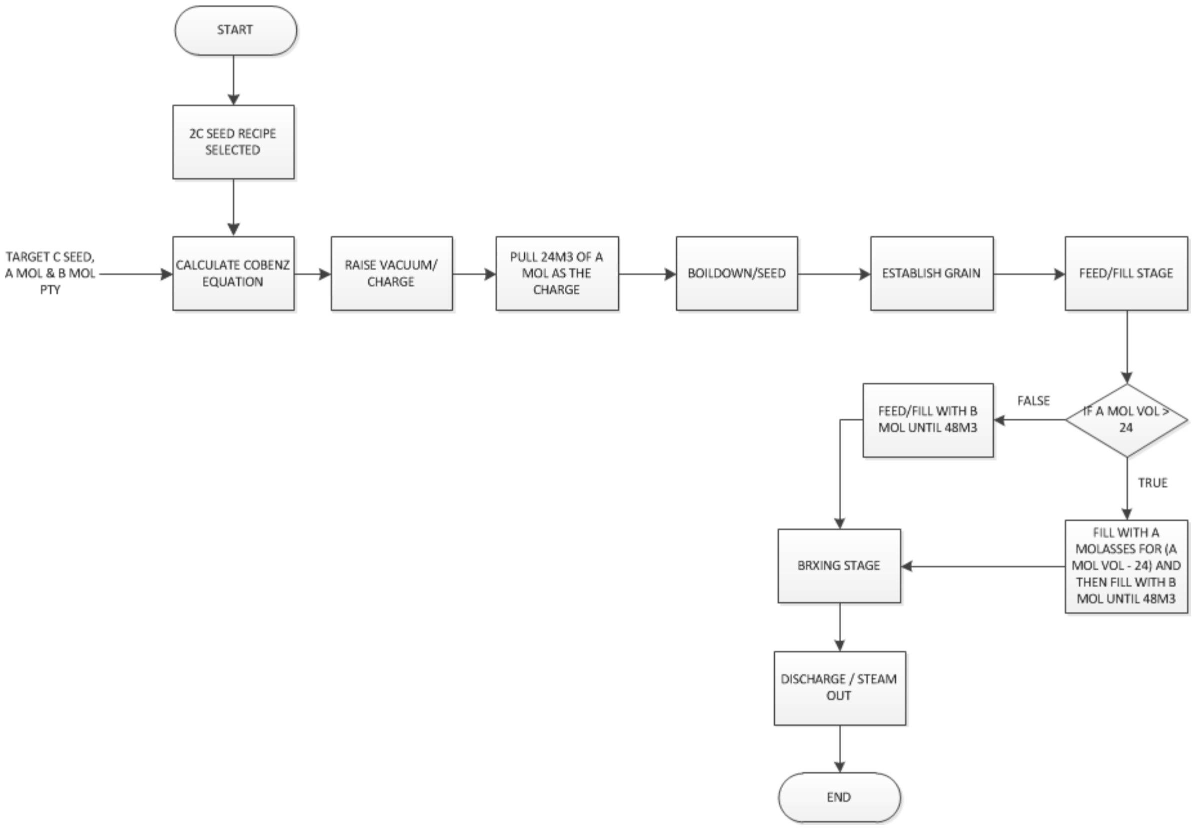

Figure 5. 2C seed purity control strategy.

The control for the system begins as the existing pan boiling sequence begins. The operator will select the 2C seed recipe. The operator will also be required to enter the target C seed purity, as well as the A and B molasses purity. The A and B molasses purity is determined by 4-hourly laboratory tests. The software will then calculate the volume of A and B molasses required to achieve the target purity by using the Cobenz [1] formula. The pan will begin its first stage (Raise vacuum and charge) and it will always pull 25 m^3 of charge. At this point, the software will automatically open the A molasses auto-valve until the integrated value on the flowmeter reads 25 m^3. The software will then close the auto-valve and resume the Boildown/Seed and Establish Grain steps as usual. At the Feed/Fill stage, the software will evaluate whether the volume of A molasses used at the charging stage is equal to the volume stipulated by the Cobenz formula, using the measured integrated volume. If it has reached the required volume, the B molasses auto-valve will open and the pan will Feed/Fill using B molasses. If the volume of A molasses has not been reached, the software will open the A molasses auto-valve and close this valve once the amount of A molasses required has been reached. The software will then resume the boil using B molasses. The Brixing and Discharge stages will remain as normal. The C seed purity is measured on a shift basis and recorded at the laboratory.

Results

The system was successfully commissioned in week 28 of the 2017 season and the results of the installation are reported in this section.

C seed purity

The C seed purity has noticeably increased after the installation. Whilst the purity still fluctuates, the deviation from the target has reduced by 26.26%. This can be seen in Figure 6. The green bar indicates the point at which the new system was commissioned.

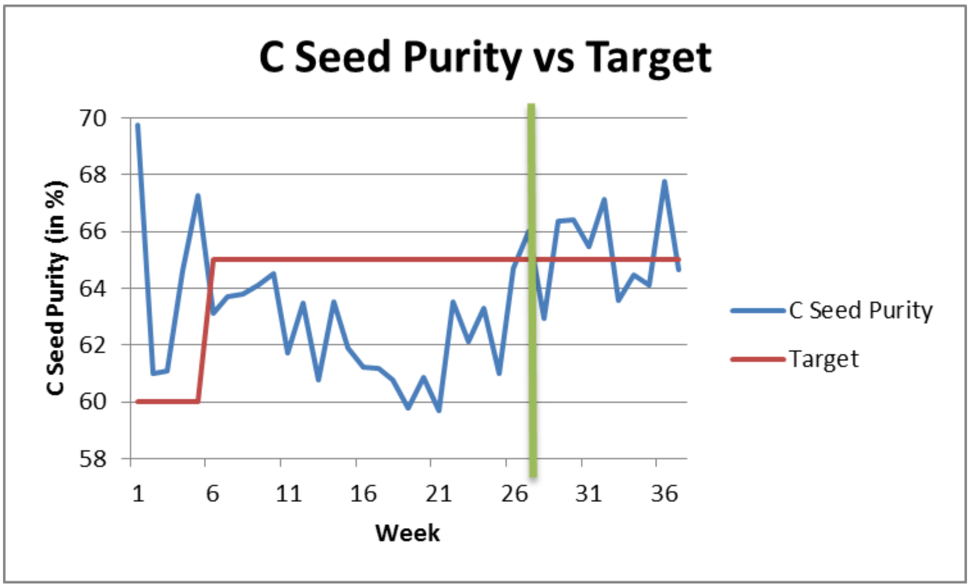

Figure 4. C seed purity: before and after modification.

Percentage of crystals by mass through 120 µm screen

The results obtained after the modification were compared to that which was achieved in the 2016 season for the same period (week 28 to week 35). The 2016 average was 43.8%. Figure 7 depicts the crystal size achieved in comparison to the 2016 season whilst Figure 8 clearly illustrates the reduction in the percentage of crystals by mass through screens during the 2017 season. In week 28, the crystal size achieved (140 µm) was the best for the entire season.

Weeks 31 and 34 for the 2017 period show a higher percentage of loss. In week 31, the Noodsberg plant embarked on commissioning the production of sugar with a reduced quality in comparison to refined sugar. This resulted in the short-striking of pans to assist with the spillages that had occurred due to the change in operations, which increased stock levels. In week 34, there was a significant increase in the dextran levels. In 2016, the dextran level was 236 ppm, whilst in 2017 it was 437 ppm.

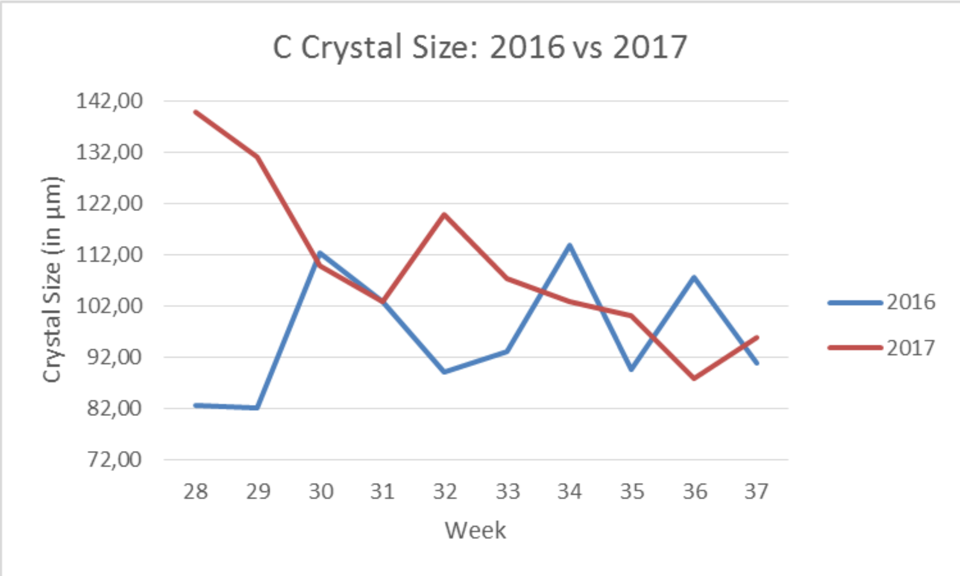

Figure 5. Evaluation of C crystal size between the 2016 and 2017 seasons.

Considering the various external factors which have hindered the crystal growth, the results obtained overall prove the benefit of the project.

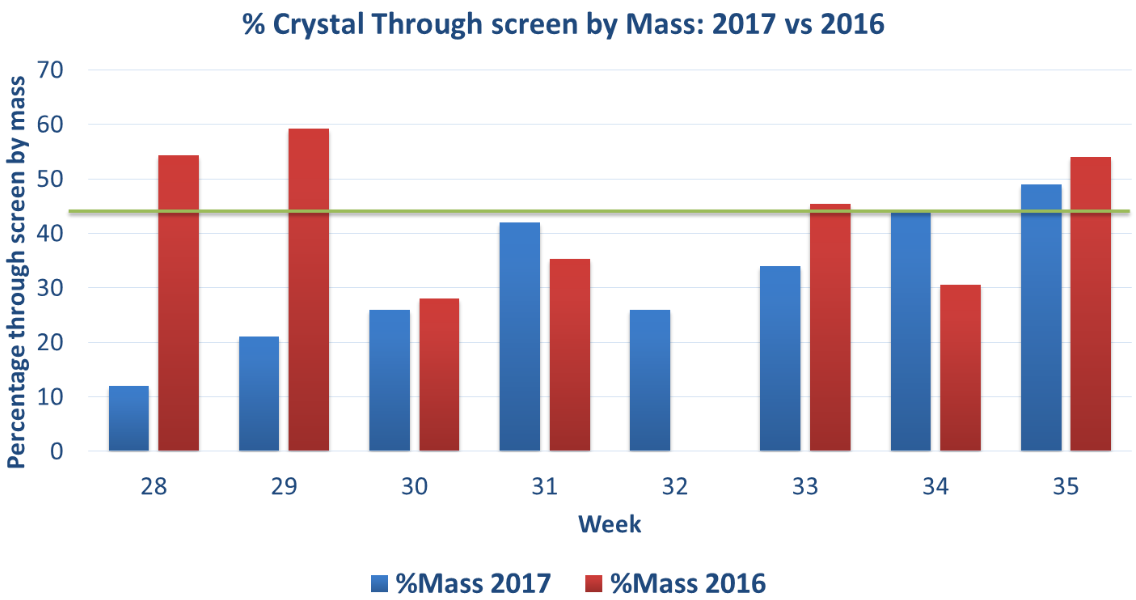

Figure 6. Percentage crystal through screen by mass: 2016 vs 2017[1].

[1] Data for week 32 for the 2016 season is not available.

TPD

The TPD for 2017 was trended against the results obtained in 2016. It was noted that there was an average drop in TPD of 2.5 units. This data can be seen in Figure 9 below. It can be estimated that a 1 unit drop in TPD equates to R1 million in savings per season (Ninela and Rajoo, 2006).

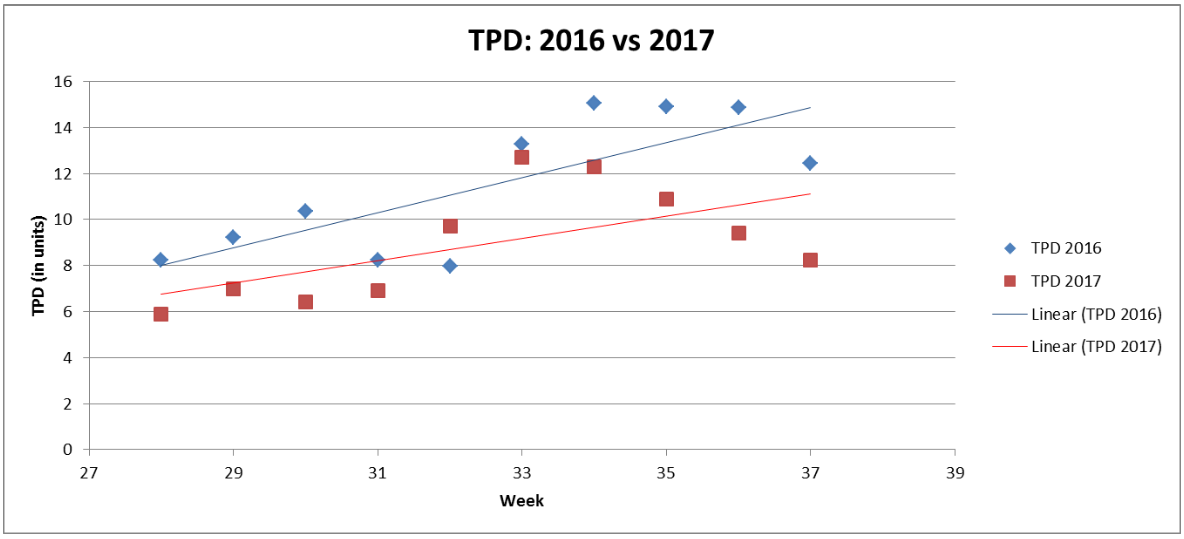

Figure 9. Target purity difference trend indicates a drop in the 2017 period.

Return on investment

Cost

The major costs related to the project included the cost associated with the installation of the automatic valves. The total cost of the project amounted to R20 662.84.

Savings

Whilst curing rise can be used to determine the savings, it is dependent on three variables: state of the centrifugal screens; crystal size; and wash water times of the centrifugal station. In the event that the centrifugal screens are torn, the curing rise will inevitably increase. This is independent of the size of the crystals – which is what the project aims to optimise. In the event that the process requirements for C magma purity changes, the wash water times will change and hence, affect the curing rise. For these reasons, a formula was deduced which focused solely on the savings achieved by achieving the desired crystal size. The calculation for the sucrose lost to molasses uses the previous season as the benchmark. The average percentage through screen by mass for the same corresponding nine weeks in 2016 was 44.48%. The loss was then calculated by determining the difference between the 2016 average percentage through screen by mass and the percentage achieved in 2017.
In order to obtain the amount of sucrose lost to final molasses, the following formula was devised:

$$Sucrose\ lost\ to\ molasses = Density * Massecuite\ Volume * \ Crystal\ Content/100 * (2017\ Percentage\ through\ Screen\ by\ Mass - 44.48)/100$$

A factor of 40% was then applied to the financial returns based on the conservative assumption that 40% of the sucrose could have been recovered as saleable sugar. The raw sugar price for the period was R7406.77 per tonne of raw sugar. The formula for the financial returns is as follows:

$$Savings = R7406.77 * 0.4 * Sucrose\ lost\ to\ Molasses$$

The savings per week is shown in Figure 10.The total savings over the nine week period equated to R182 933.

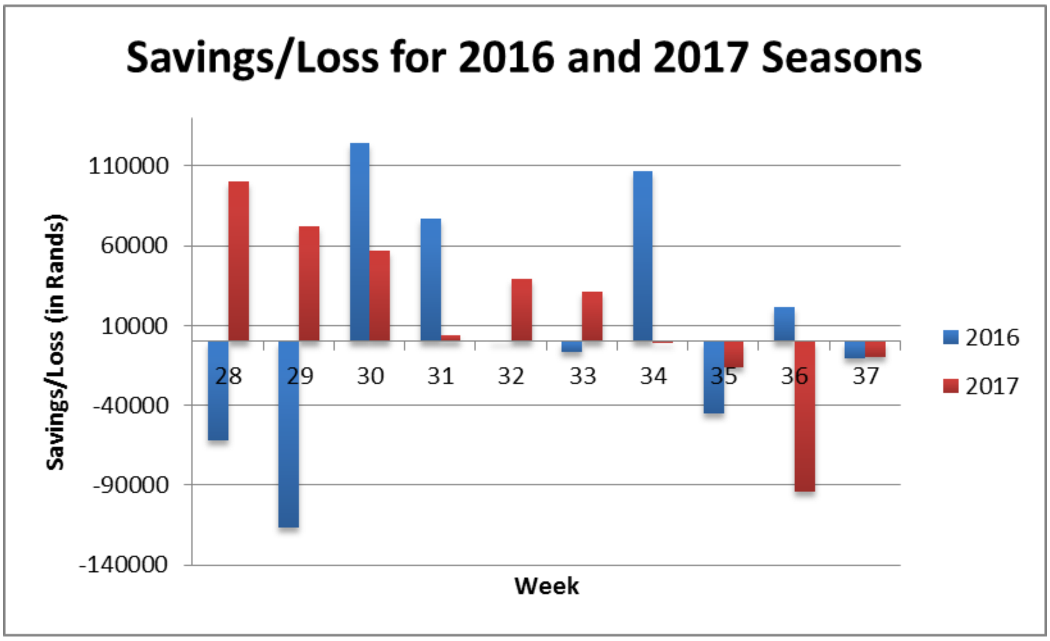

Figure 7. Financial savings for 2017[2].

Conclusion

C seed purity is an important parameter to control when attempting to maintain the size of C crystals. In focusing purely on ensuring consistent C seed purity, it can be noted that the C crystal size has increased, which has reduced the amount of sucrose lost to final molasses. The results of the project reiterate the success of the project. The project has reduced the C seed purity deviation from target by 26.26%; reduced the percentage of crystals by mass through the screens by 11.8% and improved the C crystal size by 20.28%. The project has also shown a saving of R182 933, with a payback period of 11 days.

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[2] Data for week 32 for the 2016 season is not available.