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Evaluation of the Neltec Colour Q for measuring the purity of magma from C centrifuga

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FINAL REPORT 2018/201

Evaluation of the Neltec Colour Q for measuring the purity of magma from C centrifugals.

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Sugar Research Australia

REAL-TIME COLOUR

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ABSTRACT

In Australian factories one operator typically manages the high grade fugalling, sugar drying and low grade (C) fugalling stations. The C fugals are managed least effectively as there is no process instrumentation to monitor on line C sugar purity or final molasses purity. Conditions can change rapidly in the C fugals without the operator being aware and poor performance can persist for several hours. Tight control of the C sugar purity is important to avoid high sucrose losses to final molasses or an excessive recycle of impurities in the C sugar (magma or remelt) to the pan stage.

For the 2017 season Isis Mill purchased a Neltec ColourQ 1700CC transducer, which had been recently released on the market to measure the colour (inferred purity), for measurement of the total C sugar magma production of the station. The transducer proved effective for the operators to pragmatically achieve tighter control of the purity of the C sugar magma.

For the 2018 season Isis Mill purchased a ColourQ 1700CC transducer to monitor the colour of the C sugar on the screen within their large capacity fugal.

Extensive testing of the transducer mounted on the fugal and the use of the transducer to assist operators achieve tighter control of the magma purity was conducted. The experiences with the use of the transducer on the magma screw for monitoring the purity of the total C magma production from the station were also assessed.

EXECUTIVE SUMMARY

The Neltec colour transducer provides real time, continuous monitoring of C sugar colour which allows for automation, objective decision making by operators and supervisors, and continuous monitoring of the performance of continuous low grade fugals.

If the C sugar colour drifts outside a pre-set range the operator can be warned to investigate. Issues that may raise this warning include - mixed or fine grain massecuite; highly viscous massecuite (such as from stale cane or insufficient heating), blocked fugal screens that require cleaning, low crystal content massecuite; unstable fugal feed, loss of water pressure or reduction in water temperature.

The test program at Isis Mill to evaluate the Neltec transducer had the following objectives:

1. Determine the accuracy and repeatability of the Neltec device to measure the colour of C sugar produced by No 4 fugal
2. Demonstrate how the Neltec device can be utilised to optimise the sugar and molasses purities of the continuous fugal in real time by:
    a. adjusting the distribution of water between the centrifugal feed system and the spray water onto the basket (for use of the same total water rate)
    b. altering the spray water rate and using a fixed Silvortex (feed conditioning) water rate.

The fugalling conditions that were monitored and controlled during the trials were:

- Fugal load (amps)
- Massecuite temperature
- Feed/wash water temperature
- Feed water (Silvortex) rate
- Spray water rate to the basket
- Neltec ColourQ signal

The Neltec ColourQ transducer can enable labour saving either on the centrifugal station or at the laboratory by providing continuous indication of C sugar purity. It will free up operators to allow closer attention to other aspects of their responsibility and so improve overall factory performance.

While the Neltec signal provides an excellent correlation to ICUMSA colour and magma purity when processing C massecuite of consistent characteristics, the experience at Isis Mill is that a cross-reference between magma purity and the Neltec signal should be undertaken at the start of each shift e.g. just following the calibration of the Neltec transducer with the supplied tile. These results then define an appropriate Neltec set point for the shift to achieve the target C sugar purity. For factories with continuous crystallisers the variation in massecuite properties may be less than those experienced with the batch crystallisers at Isis Mill. A tighter correlation between magma purity and Neltec signal across the season could be expected.

The Neltec transducer proved to be beneficial for measuring the colour of the magma in the screw but variations in magma brix affect the signal. For an effective indication of magma purity the brix would need to be controlled e.g. by using conductivity in a feedback loop. However the experience at Isis Mill is that the transducer is most effective when installed on an individual centrifugal and used for automatic C sugar purity control. It is proposed that for the 2019 season the screw Neltec device will be moved and mounted on No 3 fugal.

The trials at Isis Mill with the Neltec ColourQ 1700CC have shown strong benefit for the operators of the C massecuite centrifugal station for both the measurement of the colour of the total magma stream of the station and when used to directly control magma colour produced by an individual centrifugal. The signal from the colour transducer is highly responsive to changes in processing conditions, e.g. changes in spray water rates to the basket, and so is suitable for feedback control of magma colour. Alarms should be used to define upper and lower limits for the colour signal to warn the operator if a closer inspection is required. It is recommended that the appropriate set point for the control of the colour of the magma is determined at the start of each shift to take account of variations in massecuite properties by cross-checking the signal to a sample of magma analysed in the laboratory.

A financial analysis based on the installation of a single Control Unit and four Read Heads for the control of the C sugar purity in four fugals for a typical Australian factory has shown a payback period of 3 years. The main assumption in this analysis is that the improved control results in a reduction in final molasses purity of 0.5 unit.

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1. BACKGROUND

1.1. Issue affecting operation and performance of C fugals in the industry

In Australian factories the one operator manages the high grade fugalling, sugar drying and low grade (C) fugalling. The C fugals are managed least effectively as there is no process instrumentation to monitor on line C sugar purity or final molasses purity. Conditions can change rapidly in the C fugals without the operator being aware and poor performance can persist for several hours. Tight control of the C sugar purity is important to avoid high sucrose losses to final molasses or an excessive recycle of impurities on the pan stage.

For the 2017 season Isis Mill purchased a Neltec Colour Q 1700 transducer which has only recently been released on the market to measure the colour (inferred purity) for measurement of the total C sugar magma production of the station. The transducer proved effective for the operators to pragmatically achieve tighter control of the purity of the C sugar magma.

Importantly, the transducer is designed to monitor the colour of the C sugar on the screen within the fugal. In this application it provides a new control tool for the industry to achieve improved performance of C fugalling.

1.2. C Massecuite processing at Isis Mill

The low grade station at Isis Mill (Figure 1) operates at a C massecuite rate of 5 to 6% on cane, depending on seasonal conditions. That rate requires the use of the Silver 52/30 (No 4) fugal which typically processes massecuite at a rate of 14 to 18 t/h and of the BMA K1100 (No 3) fugal processing at 8 to 12 t/h. The two K1000 machines (4 t/h each) are only used when preparing for maintenance activities, during machine failure / shutdowns of the larger machines or when extra capacity is needed to clear stocks.

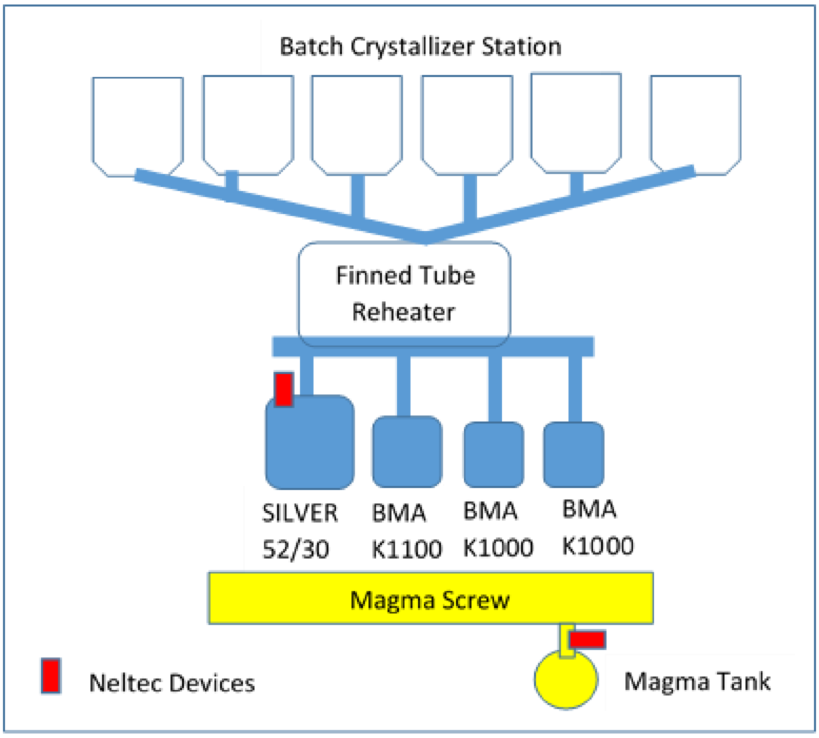

Figure 1. Layout of the low grade crystalliser and fugal station at Isis Mill.

The crystalliser station operates in batch mode with six 70 m^3 crystallisers providing a residence time of 18 to 20 hours. Under normal processing conditions each crystalliser holds the contents of a single C massecuite strike. Molasses lubrication is utilised and the rotation of the cooling coils is normally stopped prior to fugalling in order to avoid aeration of product when massecuite is at low levels. No pre-heating of massecuite is carried out within the crystallisers prior to fugalling. All reheating is conducted in the finned tube reheater.

A Neltec ColourQ 1700CC transducer was installed on the magma screw to measure the colour of the magma for the whole station for the 2017 season. A second unit was installed for the 2018 season; this time on No 4 fugal. Figure 2 shows a photograph of the Neltec unit above the magma screw and Figure 3 shows the position of the Neltec unit on No.4 LG Fugal.

Figure 2. Transition from Magma Screw to Tank and Neltec unit in position.

Figure 3 Layout of Neltec unit on No.4 Low Grade Fugal.

1.3 Description of Neltec Colour Q 1700 Transducer.

Neltec Denmark A/S developed the ColourQ 1700CC sensor to measure the sugar colour inside continuous centrifugals. The instrument essentially consists of an illuminator and a detector. The lamp in the illuminator sends light to the surface of the sugar. Reflected light is collected by the detector and split into different wavelengths – including 420 nm. Based on a calibration, the instrument can calculate colour from the strengths of the signal at various wavelengths (www.neltec.dk). Once calibrated the instrument has very little "drift" and a routine calibration check is all that is required to confirm correct operation. The position of the sensor on top of the centrifugal can be shifted inwards or outwards so that any position from the bottom of the basket to the upper rim can be selected for measurement. The preferred location for C centrifugals is close to the top rim in order to provide measurement of the sugar leaving the basket.

The colour measurement system consists of three parts – the measurement head; a local control station near the centrifugal; and the control cabinet with a PLC and computer. The generated 4-20mA signal is provided to the factory's DCS. Isis Mill has additionally connected a monitor, a keyboard and mouse to the control cabinet, enabling the operators to see the results graphically (Figure 4). Results of colour measurements are presented as a light brown live plot. The target colour range is defined by the green colour band. The dark blue live plot is a measurement of the high-speed variation in the colour and can be indicative of unstable feed or "streaking" of the massecuite/crystal up the screen.

Figure 4 Graphs displaying the output signal from the Neltec transducer on the magma screw (top left), No 4 fugal (top right) as 3 minute real-time displays. The bottom display is a combined 3 hour real-time display.

The operator cleans the windows of the measurement head every shift prior to undertaking a simple calibration check using a calibration tile. The entire exercise of cleaning and calibration check takes less than 3 minutes and is the only routine maintenance required. The calibration process is discussed later.

The signal can be calibrated to align with the ICUMSA colour range however, Isis staff opted to maintain the data set based on the initial factory calibration. The signal range for the instrument for No.4 fugal was 0 to 800 while the transducer above the magma screw had a range of 0 to 4000. The difference in range for the two devices is due to the nature of the material passing the read head. One is almost dry crystal while the other is puddled magma. Figure 5 below shows the control cabinet PLC and computer where all Neltec read heads are connected. TeamViewer access is provided to Neltec which makes any remote calibration and troubleshooting possible.

Figure 5 Neltec Control cabinet PLC / computer.

1.4 Experience with the Neltec ColourQ 1700CC in the 2017 season

In 2017 the Neltec ColourQ head was placed on the outlet of the magma screw (refer Figure 2). The operators used the colour signal (inferred magma purity) to manually adjust fugal settings to hold the signal in the target range. While this proved beneficial, there were a few obstacles to overcome, viz.,

- Vapour from the fugal outlets drifted across the light pathway and occasionally disturbed the signal. An exhaust fan was required above the screw to draw away the vapour to ensure the light path was uninterrupted by vapour;

- The action of the screw caused small waves in the magma transition trough and that action was evident in the response from the ColourQ unit (signal bounce). A baffle plate on the magma transition from the screw to the tank, as in Figure 2, was required to effectively smooth the flow;

- Changes in magma brix also affected the signal so that the melter water application needed to be monitored. Small flowmeters were purchased to monitor and control magma mixing and melter water flows. At Isis Mill the magma brix is also 'controlled' by utilising the output signal of the magma pump VF drive. Adjusting the melter water to maintain a constant pump speed was also effective in optimising the magma brix.

With the introduction of the Neltec device, the sampling of magma for purity analysis was changed from the traditional composite sample taken to the laboratory at the end of the shift to a procedure at the start of the shift involving: -

- firstly, clean and check the calibration of the Neltec instrument;
- secondly, during a period of steady fugal operation (10 minutes after calibration) the Neltec signal was recorded and a snap sample of magma collected from the mixer for laboratory analysis; and
- thirdly, based on the purity of the magma sample (usually supplied within the hour) the operator selects the required Neltec operating setpoint and band of operation (DCS algorithm discussed later) for the rest of the shift.

Previously the laboratory analyses of the composite sample only provided an assessment of the production for the previous shift, which is not conducive to good control outcomes.

2. PROJECT OBJECTIVES

The project sought to undertake the following objectives:-

- Determine the suitability of the Neltec Colour Q to produce reliable measurements of the purity of the C sugar (or magma) for:-
    - Total C magma production from the station, and
    - The C sugar in an individual fugal.
- Determine the sensitivity of the colour signal to parameters such as magma brix and distance between the transducer lens and the sample.
- Provide recommendations to Australian Mills on the preferred application and implementation of the transducer and a cost/benefit assessment.

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1. Outputs

The outputs from the project are: -

- Knowledge of the correlation for C sugar magma between the Neltec colour signal and ICUMSA colour, and also the Neltec colour signal and magma purity
- The calibration methodology and the recommended frequency of undertaking referencing to laboratory analysis of magma purity
- The suitability of using the Neltec colour signal for automatic control of the process conditions in a C massecuite fugal
- The suitability of using the Neltec colour transducer for monitoring the purity of the C sugar magma as produced by the whole station
- Recommendations for the preferred method of installation of the colour transducer

- Cost/benefit analysis of using Neltec colour transducers for controlling the operation of the C fugals.

The information provide by this project will be used by Production Managers in applying colour transducers for controlling and monitoring the operation on the C fugal station.

No further research work is required before other mills can adopt this technology.

3.2. Outcomes and Implications

The main outcome is improved management of the C fugal station in Australian factories providing better control of the sucrose loss to final molasses (by avoiding overwashing of the C sugar) and better control of the quantity of impurities recycled to the pan stage. These changes would provide increased sugar production and less cost in manufacture, resulting in increased profitability.

There are no direct environmental benefits or costs.

From a social aspect, the fugal station operators have better control over a key parameter and so will have improved outcomes and job satisfaction.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1. Industry engagement during course of project

The main determination from the project is that the colour transducer can be used successfully to automatically control the purity of the C sugar produced by individual massecuite fugals. In undertaking this control the magnitude of the sucrose loss to final molasses is also controlled indirectly. Thus, by use of the colour transducer for automatic control of the process variables (e.g. water addition rate, motor load) to maintain a consistent output of C sugar at the target purity, tighter control of impurities recycled to the pan stage and sucrose losses in final molasses can be achieved.

While the colour transducer can be used effectively to measure the colour (purity) of the C sugar magma for the whole station, the preferred application is to use the transducer to control the process operations of individual fugals.

To date there has been no communication with any of the SRA Adoption Officers.

The information available for adoption by the Australian sugar industry is listed in the Outputs.

A paper has been prepared for presentation at the 2019 ASSCT Conference. As well, QUT will present a seminar on the results at the Research Seminars to be held in the five main cane growing regions in March/April.

4.2. Industry communication messages

The communication message from the project is summarised in the first paragraph of section 4.1. It is repeated here for completeness.

The main determination from the project is that the colour transducer can be used successfully to automatically control the purity of the C sugar produced by individual massecuite fugals. In undertaking this control the magnitude of the sucrose loss to final molasses is also controlled indirectly. Thus, by use of the colour transducer for automatic control of the process variables (e.g. water addition rate, motor load) to maintain a consistent output of C sugar at the target purity, tighter control of impurities recycled to the pan stage and sucrose losses in final molasses can be achieved.

5. METHODOLOGY

5.1. Application on the total C sugar magma production of the station

The methodology for this phase of the project was to:

- Modify the current system for flow of the total magma production to provide a more consistent presentation of magma to the transducer. While it was still manageable, it was noted in 2017 that the colour signal had a small bounce caused by the screw wave motion exiting the magma mixing screw.
- Develop a relationship between magma colour and purity and assess the sensitivity to magma brix and distance of the lens from the sample.
- Monitor and document the use of the transducer by the operators in controlling the settings on the C fugal station and establish the preferred method of implementation.
- Monitor the effect of signal calibration each shift.

5.2. Application on the C sugar production in an individual fugal

The methodology for this phase of the project was to:

- Purchase a transducer head to be used with the existing control computer and install it onto one of the fugals
- Develop a calibration relationship between the colour signal and the C sugar purity and evaluate the influence of various fugal operating scenarios such as increased water application, increased steam addition and air ingress into the top of the fugal on the colour signal.
- Evaluate the suitability of the signal for use as a control parameter, e.g. to modify the wash water application rate or to control to a C sugar purity set point value.

6. RESULTS AND DISCUSSION

6.1. Installation of the Neltec ColourQ 1700 transducer onto fugal No 4 in the 2018 season

For the 2018 season the second read head was purchased and installed directly on the top of No 4 fugal. The bracket shown below in Figure 6 can slide back and forth in the position shown and the read head itself can pivot to provide the desired positioning of light contact with the basket.

Figure 6 Preparing for installation of Neltec Read Head on No.4 LG Fugal

Figure 7 shows the transducer on No 4 fugal and the light beam directed in the top section of the basket. The light was directed at a point 25 mm down from the top of the basket.

Figure 7 The Neltec transducer on No 4 fugal and the light beam on the basket.

Figure 8 below shows the Button box with push button and signalling lamps which is used in the calibration procedure. Also shown is the calibration arm and tile. It's important to follow the calibration process on a shift basis to maintain the integrity of the signal output.

Figure 8 Button box with push button and signalling lamps, calibration arm with tile

6.2. Calibration procedure

The procedure for calibrating the transducer is as follows: -

- Press the black button for 5 seconds.
- The green light will turn off and the orange light will start to blink.
- Move the read head to the calibration position.
- Install the calibration arm as shown in Figure 9 below.
- Clean the four glasses with water on the front of the read head together with the calibration tile with a wet tissue, followed by a dry tissue to remove the water.
- Press the black button for 5 seconds to start the calibration process.
  The orange lamp will stop blinking and be illuminated for 10 seconds during calibration.
  The orange lamp will start blinking again after calibration is complete.

- The instrument read head can then be re-positioned back into operation and locked in.
- Press the black button for 5 seconds and measurement will restart.
- The green light will come on again to indicate that measurement is underway.


Figure 9 Positioning of the Read Head and Calibration Tile on No.4 Fugal and screw during the calibration process

6.3. Arrangement of the control systems and colour transducer on No 4 fugal

The purity of the C sugar in No 4 fugal is adjusted by a combination of water added with the feed massecuite termed Silvortex water and water sprayed onto the lower section of the fugal basket termed spray water. (See Figure 10).

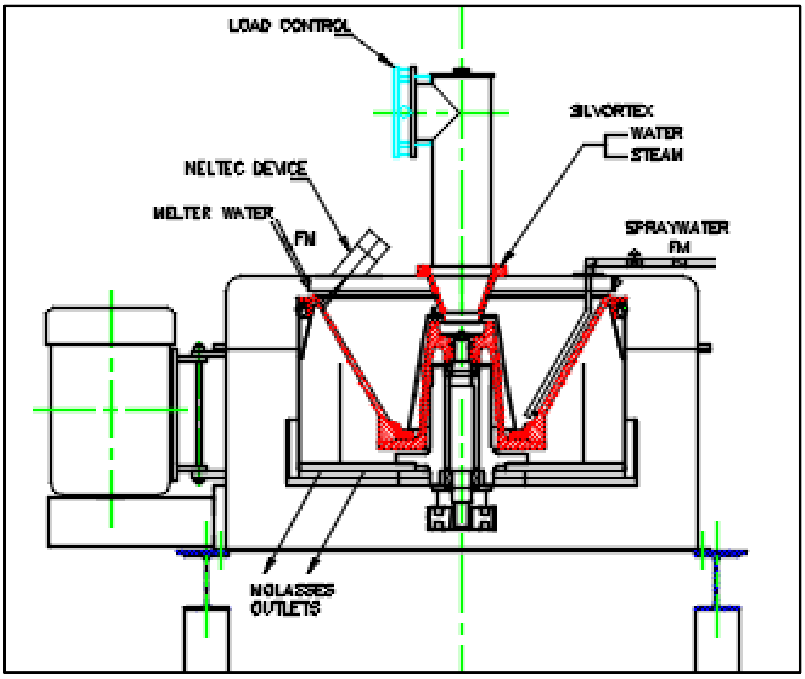

Figure 10 **Overview of No.4 LG Fugal**

The Silvortex unit on the feed entry into the machine consists of a double cone arrangement at the entry to the bell assembly rather than the traditional probe water application. A steam / water eductor is used to place water at 90℃ between the two cones at the point of entry into the bell assembly. The high temperature of the top cone assists with the conditioning of the feed to ensure that massecuite flows freely into the machine. It was found that operating with excessively high water rates on the Silvortex (>150 L/h) caused streaking on the working screen of the basket. For normal operation the Silvortex water rate is restricted to or below 120 L/h.

Once a colour setpoint is determined using the procedure described previously, the operator places a target setpoint into the DCS colour algorithm. A visual display (see Figure 11 below) is provided to allow the operator to make a quick check on the performance of the No 4 fugal and the whole fugal station magma output with respect to magma colour. The algorithm sets a range of +/- 100 colour units on the display alert for the No.4 fugal Neltec device and +/- 200 colour units for the screw Neltec device.

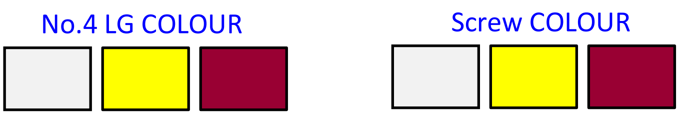

Figure 11 **Visual indication of algorithm for optimising magma purity control using colour**

The yellow box indicates that the colour is in the desired range. Should the instrument fall outside the set range, it will alarm the operator that the magma is either too light or too dark.

Because of the rapid response of the Neltec device to variations in fugalling conditions, e.g. water pressure or motor load, the control strategy for No 4 fugal was changed to adjust the spray water rate to respond to the Neltec signal. The Silvortex rate was fixed at 100 to 120 L/h and the spray water flow ranged to vary between 0 to 700 L/h. The machine load was routinely set at 150 Amps. This control system worked exceptionally well. In previous seasons Isis staff relied on a manually set spray water flow for a given motor load with visual inspection of magma quality. Some operators even relied on taste to set magma purity targets.

For the magma in the screw the water rate for magma preparation was ranged between 12 to 14 L/min and adjusted according to the magma pump speed output.

6.4. Outline of the test program on No 4 low grade fugal

The test program had the following objectives:

- Determine the accuracy and repeatability of the Neltec device to measure the colour of C sugar produced by No 4 fugal
- Demonstrate how the Neltec device can be utilised to optimise the sugar and molasses purities of the continuous fugal in real time by:
    - Adjusting the distribution of water between the centrifugal feed system and the spray water onto the basket (for use of the same total water rate)
    - Altering the spray water rate and using a fixed Silvortex water rate.

The fugalling conditions that were monitored and controlled during the trials were:

- Fugal load (amps)
- Massecuite temperature
- Feed/wash water temperature
- Feed water (Silvortex) rate
- Spray water rate
- Neltec ColourQ signal

Magma mixing is undertaken within No 4 fugal by the addition of melter water within the monitor casing. During the trials, once steady conditions were established, composite samples of C magma and C molasses were obtained directly from the discharge of the fugal.

The process products were analysed as detailed in Table 1 and purities were calculated. There was a minor deviation from the official ICUMSA colour method for some of the initial laboratory colour analyses. A GF/F 0.7 µm filter was used early in the season for filtering the colour solution rather than the 0.45 µm filter nominated in the method. This resulted in the ICUMSA colour being overstated by around 4%; this was considered to be within the experimental error of the system and it would not significantly affect the Neltec on-line signal correlation to the full results of laboratory colour. The correct filter was used for later tests once this error was determined.

Table 1 Methods used for C sugar and molasses analyses

Process product	Analysis	Method
C sugar magma	Colour	ICUMSA Method GS 1/3-7 (2011)
	Brix	BSES Method 16
	Pol	BSES Method 15
C molasses	Brix	BSES Method 16
	Pol	BSES Method 15

6.5. Test results for routine sampling and analyses across the season

At regular times through the season Isis staff collected a sample of magma from No 4 fugal for conditions of high, normal and low spray water addition rates and noted the Neltec signal. Figure 12 compares the Neltec colour with the ICUMSA colour. There is a quite large deviation from the linear relationship at very low colour values (very high C sugar purities). Overall the data across the season are fairly widely scattered.

For normal production conditions the target magma purity was around 89 to 91, depending on whether changes to the C sugar magma purity may assist compliance with the sugar specification for the factory.

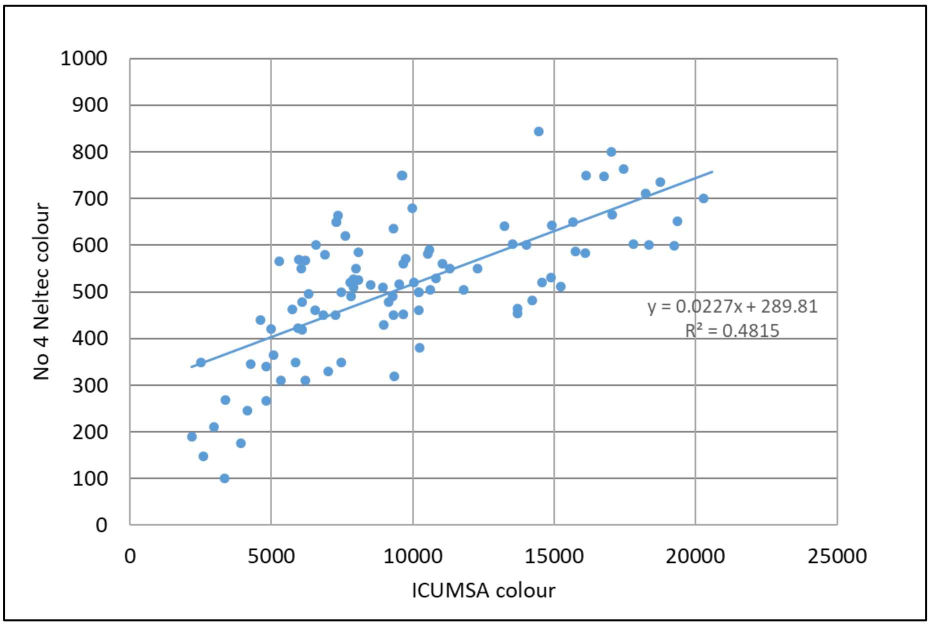

Figure 12 Comparison of Neltec colour and ICUMSA colour of magma from No 4 fugal across the season.

Figure 13 shows the magma purity versus the Neltec colour value. Again there is a fairly wide scatter of results which indicates that control of a fugal across the season to a single Neltec signal is likely to result in magma having a wide range of purity values. It is seen that at a Neltec signal of 600 (average for 90 purity magma) the range of purity values was ± 5 units about the mean. The plot shows the linear regression to the whole data set and also to data for magma purities between 85 and 95 purity. The data shows that a 100 units change in Neltec colour equates to approximately 2 unit change in magma purity.

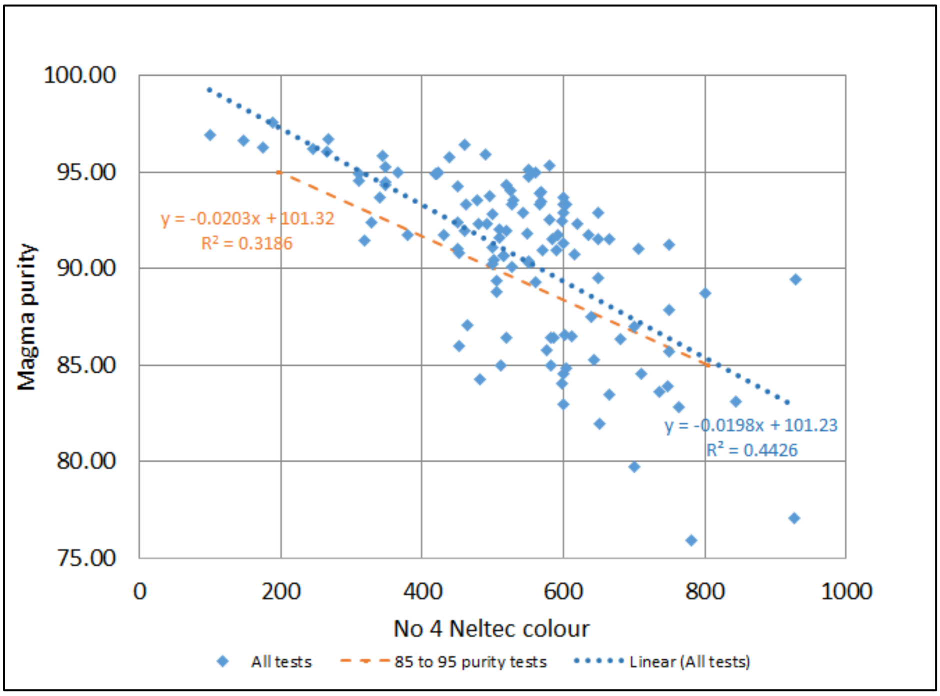

Figure 13 Relationship between magma purity and Neltec colour for No 4 fugal across the season.

It is noted that these data include the influence of many factors that may affect the colour of the molasses layer retained on the crystal surface, including changes in the colour/impurity relationship attributable to variations in impurities in the cane supply or variations in colour generated in process (such as during a maintenance stop or wet weather). Other factors that may influence the colour value for a constant magma purity or the way in which the image is reflected include the aeration of massecuite in the crystallisers and massecuite properties such crystal size distribution.

Figure 14 shows the relationship between magma purity and ICUMSA colour across the season. This relationship is much stronger than shown for the relationship with Neltec colour and is linear across the full range of values for the season.

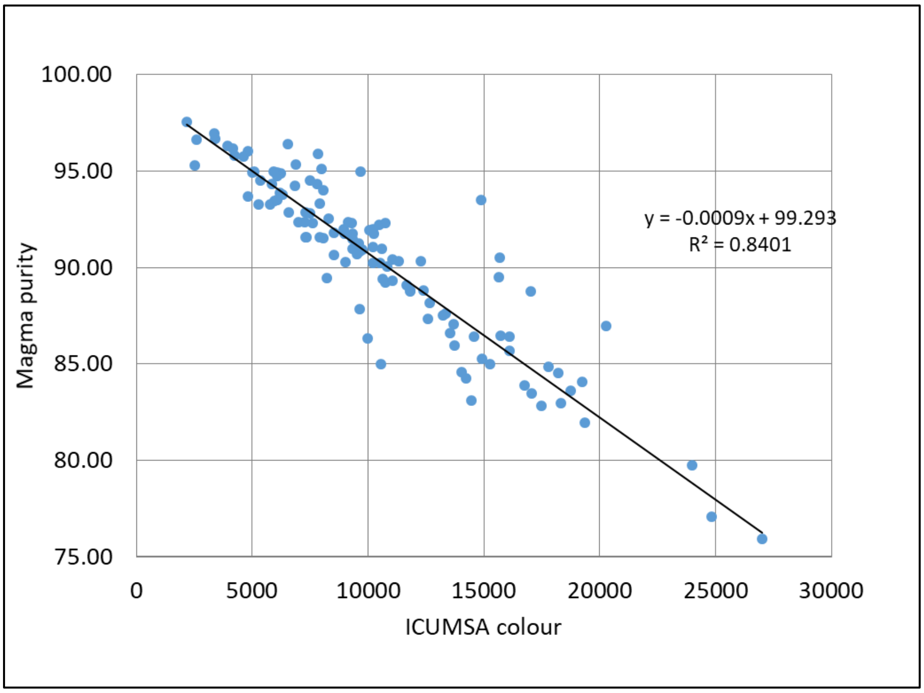

Figure 14 **Relationship between magma purity and ICUMSA colour for No 4 fugal across the season.**

6.6. Test results on a single crystalliser

The data in Figure 12, Figure 13 and Figure 14 are across the season and include the effects of varying massecuite conditions. Trials were also undertaken on massecuite from a single crystalliser (i.e. massecuite from a single pan strike) in order to limit the variation that may be caused by varying C massecuite properties.

The data in Figure 15 show the typical relationship between Neltec colour and ICUMSA colour when processing massecuite from a single crystalliser. A very strong correlation exists between the Neltec colour and ICUMSA colour when processing massecuite of consistent characteristics.

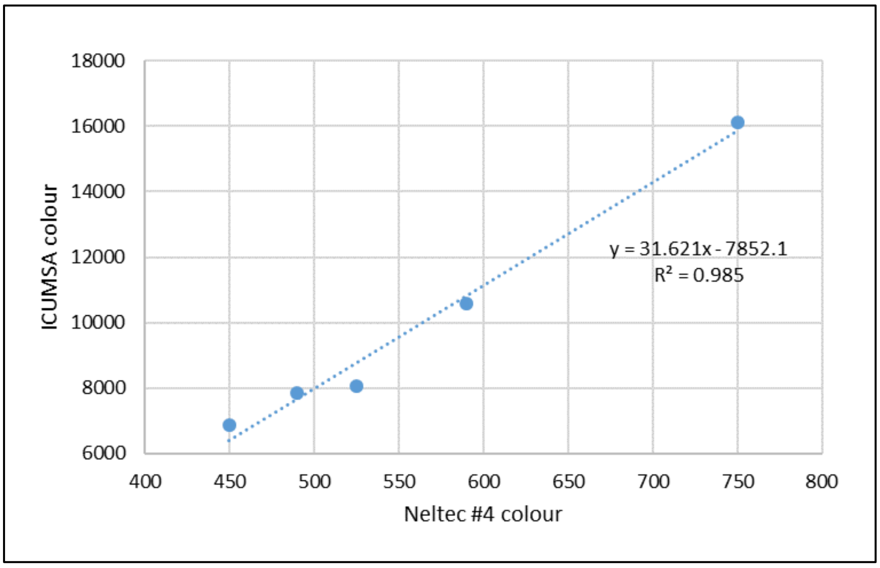

Figure 15 Neltec and ICUMSA colour correlation when fugalling massecuite of consistent composition

6.7. Effect of the distribution of the same total water

A trial was undertaken to determine the optimum distribution of water between the Silvortex water and the spray water. A constant total water flow of 600 L/h was selected for the trial. Figure 16 shows the Neltec colour signal and the purity of the molasses collected for each combination of water use. As the Silvortex water rate increased from zero the C molasses purity increased linearly. Being a centre feed centrifugal with a well-designed massecuite conditioning pot and bell it is apparent that increased dissolution of sucrose occurred with increased Silvortex water rate. The Neltec colour response decreased initially, indicating a higher magma purity, but then increased. Isis staff investigated the cause and discovered that the massecuite feed became unstable at the high Silvortex water rates, with significant streaking of massecuite/crystal up the screen. As a result a Silvortex water rate of 100 to 120 L/h was identified as the optimum for massecuite feed stability and low sucrose loss in molasses.

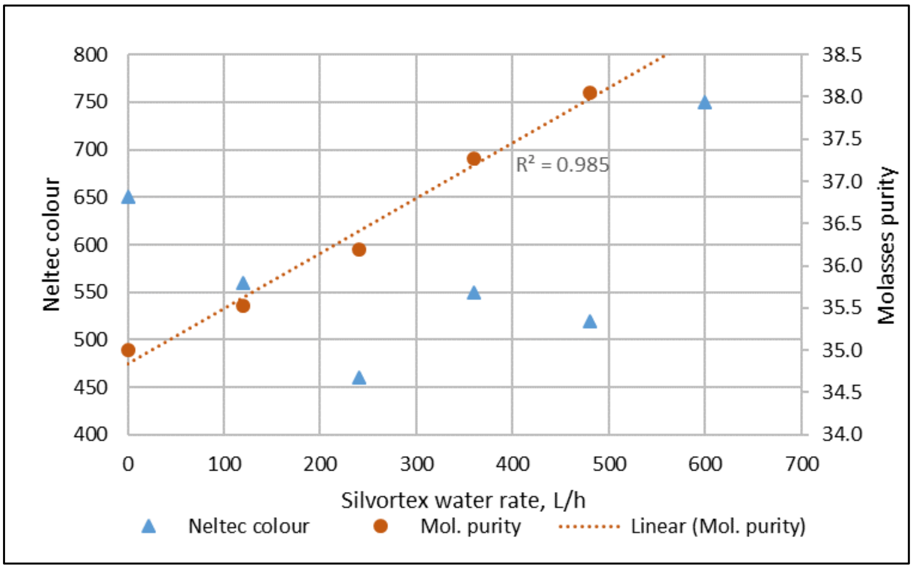

Figure 16 **Effect of water distribution on Neltec colour and molasses purity.**

6.8. Effect of grain size in the C massecuite on the Neltec signal

The grain size of the C sugar was found to not significantly affect the Neltec signal. Consecutive C massecuites were boiled with one having a grain size of 0.34 mm and the other 0.25 mm. This range of sizes covers the typical range for C massecuite in the industry. The centrifugal parameters were controlled to achieve a similar Neltec signal for each massecuite. The difference in the laboratory magma colour and purity of the C sugar of the large and small grain size was less than 2% (Figure 17).

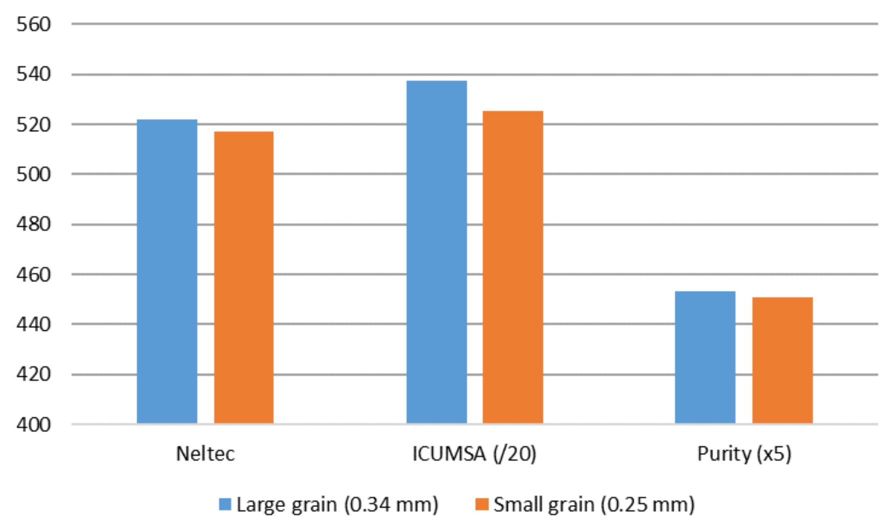

Figure 17 **The response of the Neltec colour signal to grain size.**

6.9. Effect of molasses lubrication quantity to the crystallisers on the Neltec signal

A trial was undertaken where a pan drop C massecuite (80 m^3) was split between two crystallisers and different quantities of lubrication molasses (viz. at the rate of 1 and 5% on massecuite) were used prior to centrifugalling. The massecuites in the two crystallisers were fugalled successively in automatic control with the Neltec signal manipulating the spray water flow. The Neltec set point was 650 for fugalling both crystallisers. Table 2 shows the results for the magma purity and ICUMSA colour based on three samples taken during each test.

Table 2. Results for trials using different quantities of molasses lubrication

Massecuite	Magma purity	Magma ICUMSA colour
With 5% molasses	89.9 ± 1.0	10500 ± 400
With 1% molasses	89.9 ± 0.5	11100 ± 400

The conclusions drawn from this one-off test were that the changes in molasses lubrication quantity did not confound the Neltec signal; possibly because it was located near the top of the rim of the fugal. A consistent magma purity was able to be produced within the usual scatter of results when processing massecuites of similar properties other than having a change in lubrication quantity.

6.10. Effect of magma brix on the Neltec signal

Isis staff observed that the signal from the Neltec device located above the magma screw was affected by the brix of the magma. Tests where the melter water rate was varied demonstrated the change in Neltec signal. This result is expected as visually magma is of darker colour when the brix is reduced. Isis staff use the speed of the magma pump as a guide to the operators to select the appropriate melter water rate.

6.11. Other observations

Figure 18 shows practically instantaneous response of the Neltec signal to incremental changes to the spray water rate in the region circled. The changes are marked by a positive "blip" on the chart which was introduced by opening the top inspection hatch on the centrifugal monitor case. The subsequent windage created a disturbance of steam and water that was registered by the Neltec transducer. Each major division on the horizontal scale of Figure 18 is 10 minutes and each point a 1:06 minute average. The vertical scale major divisions are 50 units which is equivalent to around 1 unit of purity and 2000 IU. The changes in the bracketed region were created by decreasing the spray water rate by the equivalent of 0.3% massecuite in each step, i.e. 50 L/h.

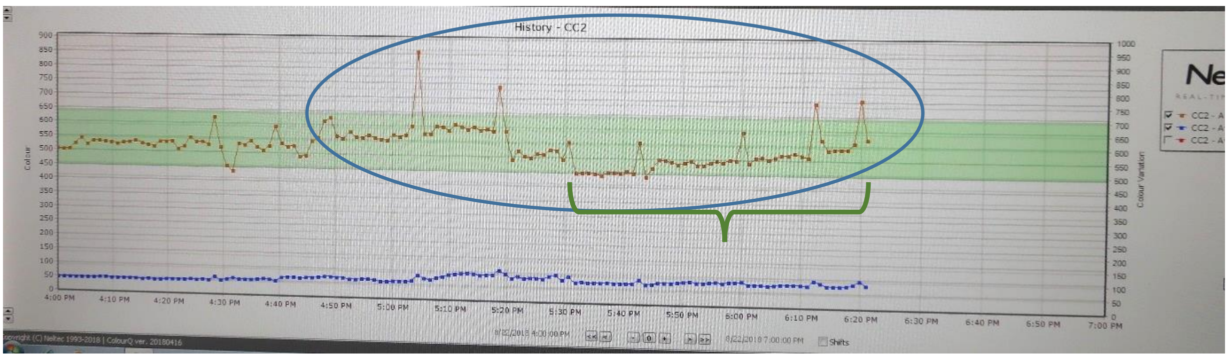

Figure 18. Neltec ColourQ display demonstrating the response to changes in spray water rate.

6.12. Use of the Neltec ColourQ 1700CC to optimise fugal performance

Because of the rapid response of the Neltec transducer, the tight relationship between magma purity and ICUMSA colour and the strong relationship between Neltec colour and ICUMSA colour for massecuite of consistent properties, the instrument enables optimisation of the low-grade fugal performance in terms of C magma purity and molasses purity. The optimisation of the fugal is a trade-off between the recirculation of impurities to the high-grade pans and the sucrose loss in molasses. The recirculation of impurities impacts shipment sugar quality, production loadings on the high grade pans and the loading on the low grade stations - pans, crystallisers, and fugals. The loss of sucrose in molasses, measured by the molasses purity and molasses loss, impacts the overall economics of the factory in terms of the raw sugar make as measured by overall recovery of sucrose and PSI (Pool Sugar Index). The test data described below demonstrate the interactions and selection of the appropriate Neltec colour set point.

The test data for a trial on a single crystalliser to optimise fugal performance are shown in Figure 19 and Figure 20. For this trial the Silvortex water rate was held constant at 100 L/h and spray water rates varied to effect changes in magma and molasses composition. Both the magma purity and molasses purity increase with decreasing Neltec colour (Figure 19) as a result of increasing total water flow (Figure 20). The total water flow consists of the sum of the Silvortex water and the spray water. Data from this trial indicated that a Neltec signal range of 600 to 650 would be an appropriate set point for automatic control of the magma purity to within the target range of 89 to 91 purity and achievement of a relatively low molasses loss. Control at these conditions would ensure that high grade massecuite production suited premium shipment sugar quality and the low-grade pan, crystalliser and fugal station loading was appropriate for good exhaustion performance.

It is interesting that the data in Figure 20 show that at high total water rates (> 400 L/h) the magma purity did not increase. Similarly, increased dissolution of sucrose into final molasses did not occur. Closer inspection of Figure 19 shows that there could be a flattening in the Neltec response at lower than 500 Neltec colour but there are too few data points to be conclusive. It is surmised that at a high spray water rate (>400 L/h) the crystal bed may be disturbed (perhaps with streaking of the massecuite flow over the basket) and the spray water is then less effective in removing the molasses layer from the outside of the crystals.

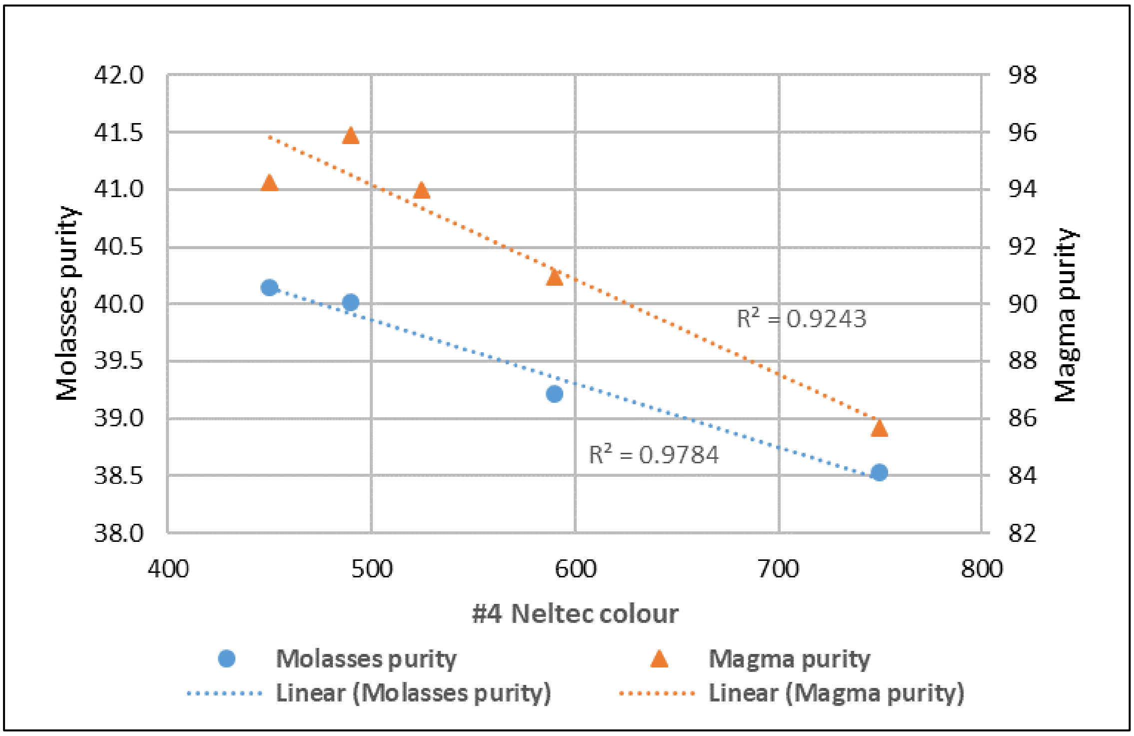

Figure 19 C magma and molasses purities versus Neltec colour for trials on a single crystalliser using different water rates.

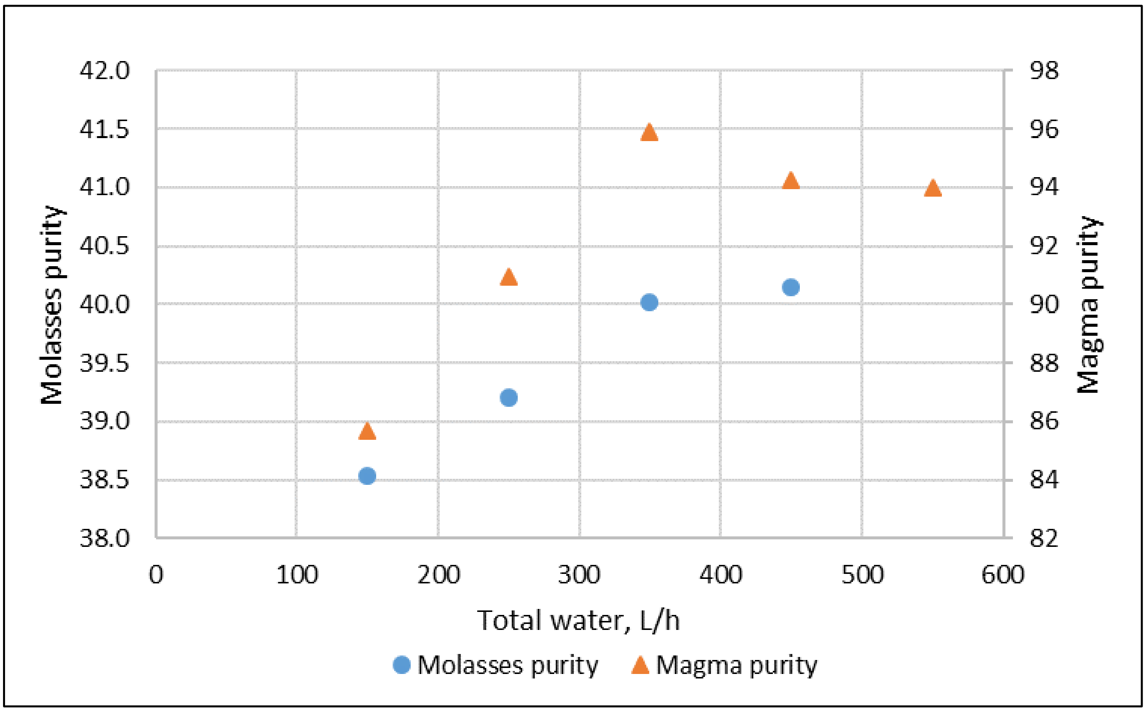

Figure 20 C magma and molasses purities versus total water rate for trials on a single crystalliser.

6.13. Application of the Neltec ColourQ 1700CC transducer

Currently in Australian factories C sugar purity is not measured in real time and so is not controlled as a process variable. Feedback of C magma and molasses purities from the laboratory generally takes several hours and, in the ensuing time, there is the potential for substantial losses of sucrose to final molasses or recycle of an excessive quantity of impurities to the pan stage. The magma purity reported is often not representative, being only a snap or short-term composite and is of historical value e.g. for the previous shift.

The Neltec colour transducer provides real time, continuous monitoring of C sugar colour which allows for automation, objective decision making by operators and supervisors, and continuous monitoring of the performance of continuous low grade fugals.

The Neltec device provides for the first time the necessary real-time process feedback signal on individual continuous centrifugals to manipulate the spray water to automatically control C sugar purity. Many factories do not use spray water on the basket but use a combination of steam rate to the basket, water rate to the feed probe and motor load (least favoured process variable to change) to achieve the desired magma purity. The Neltec signal could similarly be used to regulate the C sugar purity for fugals operating in this way.

If the C sugar colour drifts outside a pre-set range the operator can be warned to investigate. Issues that may raise this warning include - mixed or fine grain massecuite; highly viscous massecuite (such as from stale cane or insufficient heating), blocked fugal screens that require cleaning, low crystal content massecuite; unstable fugal feed, loss of water pressure or reduction in water temperature.

The Neltec ColourQ transducer can enable labour saving either on the centrifugal station or at the laboratory by providing continuous indication of C sugar purity. It will free up operators to allow closer attention to other aspects of their responsibility and so improve overall factory performance.

While the Neltec signal provides an excellent correlation to ICUMSA colour and magma purity when processing C massecuite of consistent characteristics, the experience at Isis Mill is that a cross-reference between magma purity and the Neltec signal should be undertaken at the start of each shift, e.g. just following the calibration of the Neltec transducer with the supplied tile. These results will then define an appropriate Neltec set point for the shift to achieve the target C sugar purity. For factories with continuous crystallisers, the variation in massecuite properties may be less than those experienced with batch crystallisers. A tighter correlation between magma purity and Neltec signal across the season could be expected compared with that given in Figure 13. Nevertheless, the cross-check at the start of each shift is still likely to be required to determine the appropriate set point for the control loop using the Neltec signal, in order to take account of variations in massecuite properties.

The Neltec transducer proved to be beneficial for measuring the colour of the magma in the screw but variations in magma brix affect the signal. For an effective indication of magma purity, the brix would need to be controlled e.g. by using conductivity in a feedback loop. However, the experience at Isis Mill is that the transducer is most effective when installed on individual centrifugals and used for automatic C sugar purity control. It is proposed that for the 2019 season the screw Neltec device will be mounted on No 3 fugal.

6.14. Financial analysis for implementation of the Neltec ColourQ 1700 CC transducer into Australian Mills

A financial analysis has been undertaken for the case where a factory installs a single Control Unit and a Read Head onto each of four fugals on the C massecuite fugal stage. The purchase costs, installation costs, maintenance costs and IT costs for installing and maintaining the Neltec transducers are shown in Table 3. Also shown in Table 3 is the costs of upgrading the control systems on the four fugals to provide automatic control of the C sugar purity.

Table 3 Purchase and installation costs for four fugals

Item for the installation	Cost, $
Neltec Control Unit	20,600
Four Read Heads ($32,000 each)	128,000
Software	23,500
Installation of the Control Unit and Read Heads	20,000
Upgrade of control systems on four fugals	23,000
Annual maintenance	5,000

Three main financial benefits are expected to be obtained from effective implementation of the Neltec transducers for automatic control of the colour (purity) on the C sugar. The measurement/control system should provide more consistent control of the C sugar purity about the target value and provide the following financial benefits: -

- a reduction in the final molasses purity through tighter more consistent control of the C fugals, providing increased sugar recovery;
- reductions in costs for pan stage operations resulting from
  - less variation in the extent of breakage of C sugar leading to easier control of washing the magma,
  - more consistent purities of A and B massecuites,
  - greater consistency in the production loading of the B and C massecuites,
  - improved management of sugar quality parameters, e.g. by consistently achieving a higher purity C sugar to reduce ash, colour,
  - possible steam savings and better utilisation of installed plant on the pan, crystalliser and fugal stations,
  - overall improved management of the pan stage;
- savings or increased revenues through freeing up labour previously occupied in managing the C fugals and now able to direct attention to other areas of responsibility, typically high grade fugals, sugar dryer, cooling C massecuite crystallisers and C massecuite conditioning.

The assumptions used for the financial analysis are given in Table 4. The data are based on typical average conditions for Australian factories.

Table 4 Assumptions for the financial analysis

Parameter	Value
Cane crop, t	1,400,000
Molasses%cane	3.3
Final molasses purity before Neltec installation	46.5
Reduction in final molasses purity after Neltec installation and attributable to the improved control of C sugar purity	0.5
Dry substance of final molasses	77
Purity of raw sugar production	99.2
Moisture of raw sugar production	0.3
Sugar price, $	350
Molasses price, $	120
Reductions in costs and savings on the pan stage, $	15,000
Savings from labour concentrating on other responsibilities, $	10,000
Discount rate,%	12

The results of the financial analysis based on a service life of 10 years are shown in Table 5. The benefits are assumed to commence in the same financial year that the installation costs are incurred. The internal rate of return is 64% and the payback period is 3 years based on the value of the discounted benefits to the capital cost.

Table 5 Results of the financial analysis

Parameter	Value
Total purchase and installation cost, $	215,100
Discounted benefits, $	535,000
Internal rate of return, %	64
Discounted benefit/discounted cost ratio	2.49
Payback period based on discounted benefits/capital cost	3 years

7. CONCLUSIONS

The trials at Isis Mill with the Neltec ColourQ 1700CC have shown strong benefit for the operators of the C massecuite centrifugal station for both the measurement of the colour of the total magma stream of the station and to directly control C sugar colour produced by an individual centrifugal. The signal from the colour transducer is highly responsive to changes in processing conditions, e.g. changes in spray water rates to the basket, and so is suitable for feedback control of magma colour. Alarms should be used to define upper and lower limits for the colour signal to warn the operator if a closer inspection is required. It is recommended that the appropriate set point for the control of the colour of the magma is determined at the start of each shift by cross-checking the signal to a sample of magma analysed in the laboratory.

A financial analysis based on the installation of a single Control Unit and four Read Heads for the control of the C sugar purity in four fugals for a typical Australian factory has shown a payback period of 3 years. The main assumption in this analysis is that the improved control results in a reduction in final molasses purity of 0.5 unit.

8. RECOMMENDATIONS FOR FURTHER RD&A

No additional research is required before other factories can install and use the Neltec colour transducer for monitoring the colour of the C sugar in their C fugals. The circumstances at Isis Mill on the C fugal station are slightly different from most other factories viz., use of batch crystallisers compared with the more common crystallisers and use of water spray (no steam) on the basket for control of C sugar purity.

Factories with continuous crystallisers are likely to find a better correlation between Neltec colour and C sugar purity than determined at Isis Mill.

For those factories that use steam, probe water and motor load for control of the C sugar purity, a slightly more complex control algorithm may be required than the simple feedback control used by Isis Mill whereby the Neltec signal manipulated the spray water to the basket. The development of this algorithm may require a small amount of experimentation.

9. PUBLICATIONS

A paper titled "Evaluation of the Neltec ColourQ 1700CC for measuring the purity of magma from C centrifugals" has been prepared for presentation at the 2019 ASSCT Conference.

Seminars to report the results and application into the industry will also be presented to mill staff in all the cane growing regions in the Research Seminar series to be conducted in March/April 2019.

10. ACKNOWLEDGEMENTS

Isis Mill for their support and initial capital funding for the project.

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11. REFERENCES

Neltec website : www.neltec.dk

Pope G, Accatino P, Vidler G, Tack D and Kerchner S (2009). Full automation of a Western States continuous low grade fugal. Proceedings Australian Society Sugar Cane Technologists, 31, 460-469.

12. APPENDIX

12.1. ISIS NELTEC DATA FILE

Table 6 Metadata disclosure 1

Data	ISIS Neltec Data File 2018.xlsx
Stored Location	With Final Report
Access	On Isis Mill server.
Contact	David Pike