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The results of using an inline color analyzer directly after the white centrifugal station

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ABSTRACT

Color is an important parameter in the supply of sugar. In the past no rapid method or application existed to directly obtain the color of granular sugar as it is produced. The past methods used indirect measurement references or grab samples of the sugar just produced to confirm compliance to internal and external specifications. This often resulted in too large of time lags to avoid off specifications sugar from reaching the storage bins. The use of the Neltec color monitor directly after the white centrifugal station has prevented this problem as well as allowing an optimization of the overall station and individual batch machines. The relationship of the mixer level, start and end of individual strikes of sugar can be monitored and evaluated. Process changes are able to be monitored immediately for benefits. Results of varying process parameters and being able to monitor the results over extended periods of time have confirmed or altered relationships allowing a better understanding of the white sugar side of the process.

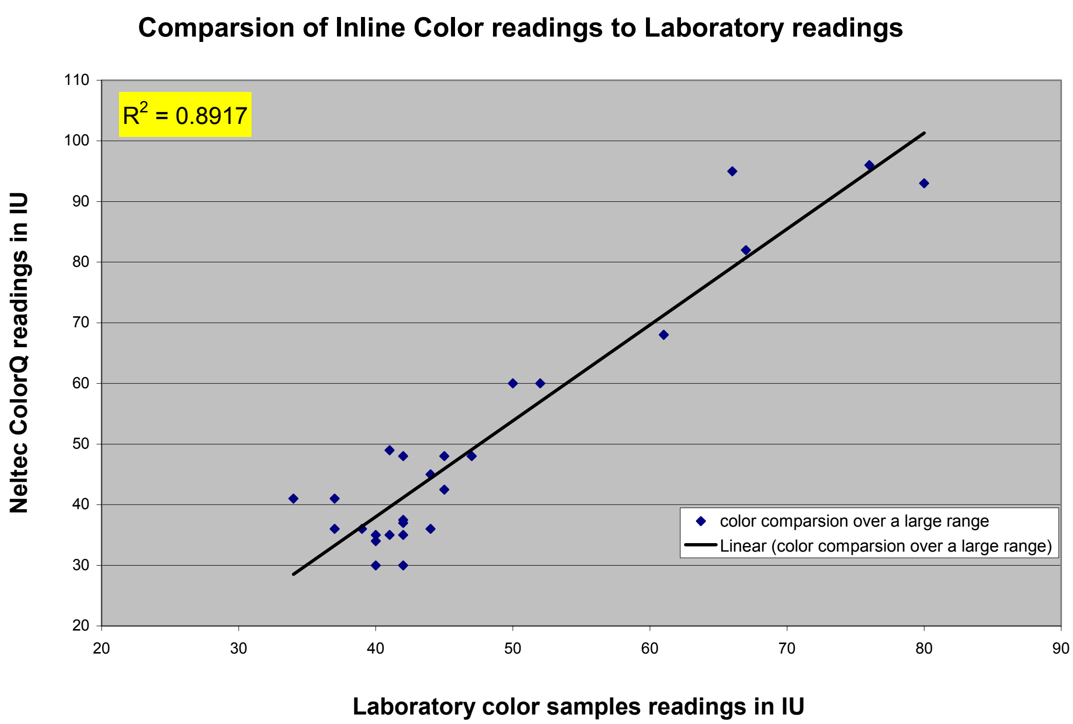
Introduction

The Neltec ColourQ 2100 for white sugar measurement at SMBSC has been in use since the 2000-2001 beet campaign. It measures the wet sugar as it is discharged from each centrifuge in the screw conveyor directly below the machines. The measurement point is near the discharge of that conveyor. This is accomplished by the color sensor control unit receiving input from each centrifuge confirming it is discharging sugar (plow in) and properly timing the discharge and screw conveyor speed to match color reading to the sugar from each particular machine. In addition because the sensor is able to take 15 to 40 measurements per second and presents a new color value every three seconds, it is able to give information about the color in relation to position of the sugar discharging from the machine.

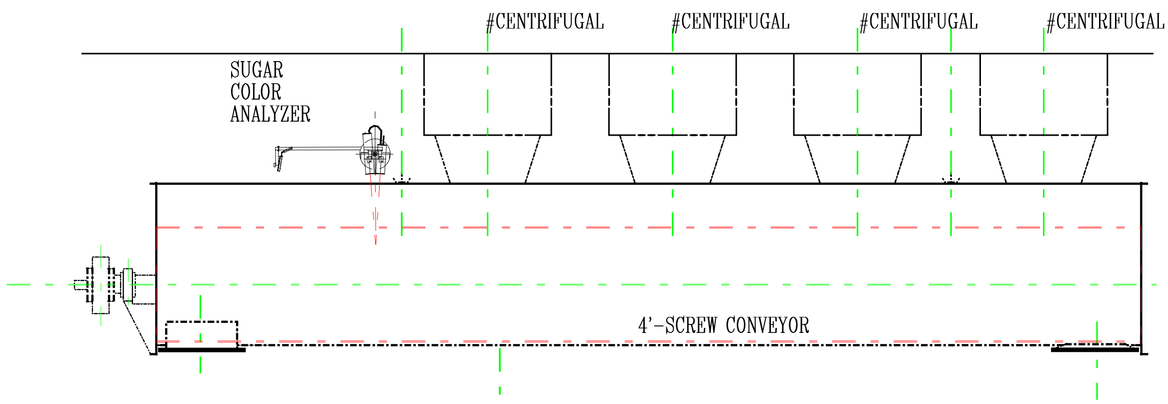
There have been several papers covering the principles of operation[1]. In short review, the in-line measurement is an indirect method. The unit requires a calibration curve to be developed to relate the measurement of the sensor to the analytical result produced by the laboratory. The ColourQ 2100 measures reflected light from crystallized sugar on a conveyor, in our case a screw conveyor. The ColourQ 2100 provides its own illumination with stroboscopic light and a detection unit to sense both wavelength and intensity. The light source and detector are located approximately three feet from the sugar. The pulsing of the light source allows the ambient background light to be filtered out as this light is not stable in intensity or color due to uncontrollable variables such as temperature. The detection unit is measuring a portion of the reflected lights wavelengths and intensities and this raw data is manipulated with the calibration data previously gathered to produce an output in ICUMSA ‘color units.’ The instrument has shown a high level of accuracy and repeatability. The literature reports values between 1.5 and 4 ICUMSA ‘color units’ for a standard error of prediction or the standard deviation between the two measurements. The sample comparison tests of laboratory color values to the ColourQ 2100 values recorded by the unit at SMBSC have had excellent results. Field verification, with potential timing and sample coordination issues still resulted in average differences of less than 1.0 ICUMSA ‘color units’ to as high as 5 ICUMSA ‘color units’. The larger difference of 5 ‘color units’ appeared to be due to several individual samples. One individual sample difference was 23 ‘color units.’ This sample had no explanation or field change note to eliminate it, so it was included in the data. The color of the sugar was varying over a large range during this period which made the sampling coordination between the laboratory sample and the Neltec ColourQ 2100 unit much more difficult. Even with the more difficult timing and coordination problems we were still only an average difference of 5 ICUMSA ‘color units.’ A summary of 4 verification tests is:

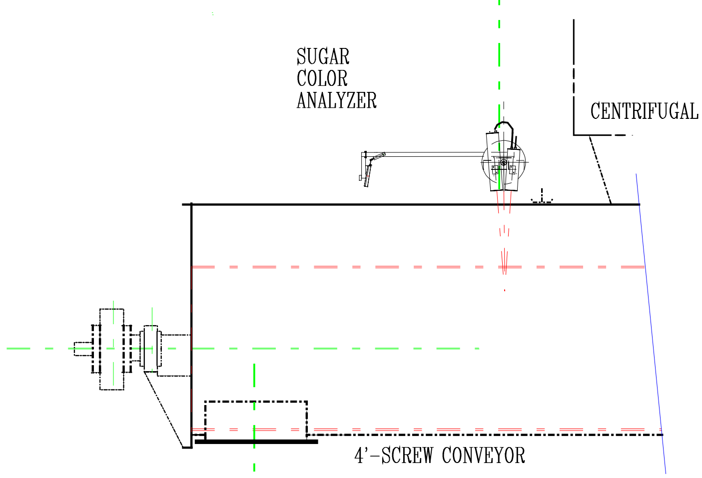
Color verification test	Number of laboratory samples taken during the test	Laboratory average color value (IU)	Neltec ColourQ 2100 Color value (IU)	Difference
1	58	41.5	40.5	.95
2	53	41.4	39.5	1.85
3	90	44.9	41.5	3.39
4	46	42.5	37.4	5.08

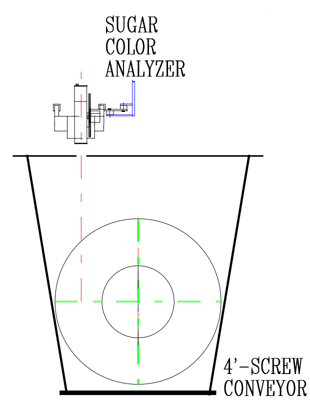
A comparison graph of laboratory to ColourQ 2100 readings with a large range is shown:



The installation is relatively simple. The environment for the instrument is not particularly demanding, however an enclosure to ensure the calibration tile is not readily compromised with debris and air borne materials that may create offsets is recommended. The installation was completed using a support steel directly above the discharge end of the wet sugar scroll. Less than 40 hours was charged to installation.







The unit was purchased during a period of high and widely varying juice colors. The ability to turn the wash sprays on for longer periods of time with less fill per batch on the centrifuges demonstrated salable sugar could be made during this time period. The difficulty was the color variation in the standard liquor was causing color variation in the white sugar of over 10 ICUMSA 'color units' from batch pan to batch pan. The decision for purchasing the Neltec ColourQ 21000 was to improve the operator's ability to make adjustment at a higher frequency with immediate feedback that the changes were justified. The laboratory was limited to the speed they could sample and the ability to relate the potential processes changes made to the sample collected. Without the ColourQ 2100 analyzer and with the large process variations the ability of the operators to optimize the operation was being compromised.

The installation of the color analyzer was initially accepted with reservations. The decisions to reduce or increase the centrifuge fill and/or wash times were immediately captured and this data clearly demonstrated that less basket fill and more wash times were often necessary to meet the maximum allowable color. This is never a pleasant situation in any operation and there was reluctance to accept the data as accurate especially since the grab sample could be significantly different than the current output from the in-line sensor.

This required additional service time from Neltec and the laboratory to check the calibration curve again and to track the lab samples back to the time the ColourQ 2100 unit was recording values to demonstrate reliability to the operators. Operators became interested, especially due to the efforts of the laboratory and Neltec to perform additional samples and to continually answer all their questions and concerns. The operators in turn worked hard to determine if they 'could count on the readings from this instrument.' Operators took it upon themselves to track the sugar from the centrifuge all the way to storage with a large number of samples and timing sequences performed to verify the continuous reading from the ColourQ 2100 were reliable.

The result was that the instrument was indeed accurate and reliable. The operators were now convinced they had good information in real time and could control the sugar color and increase production when the opportunities were available.

The step of acceptance was completed and the benefits of the Neltec ColourQ 2100 could now be utilized and quantified. The software developed to interface with the operator is visual and intuitive.

Using the Neltec ColourQ 2100, we attempted to enhance the economic operation of the four BMA G2100 discontinuous white centrifuges by optimising the use of wash water and the cake thickness as well as increase the capacity.

The following measurements were carried out:

1. Measuring the amount of wash water through each nozzle (non ColourQ study)

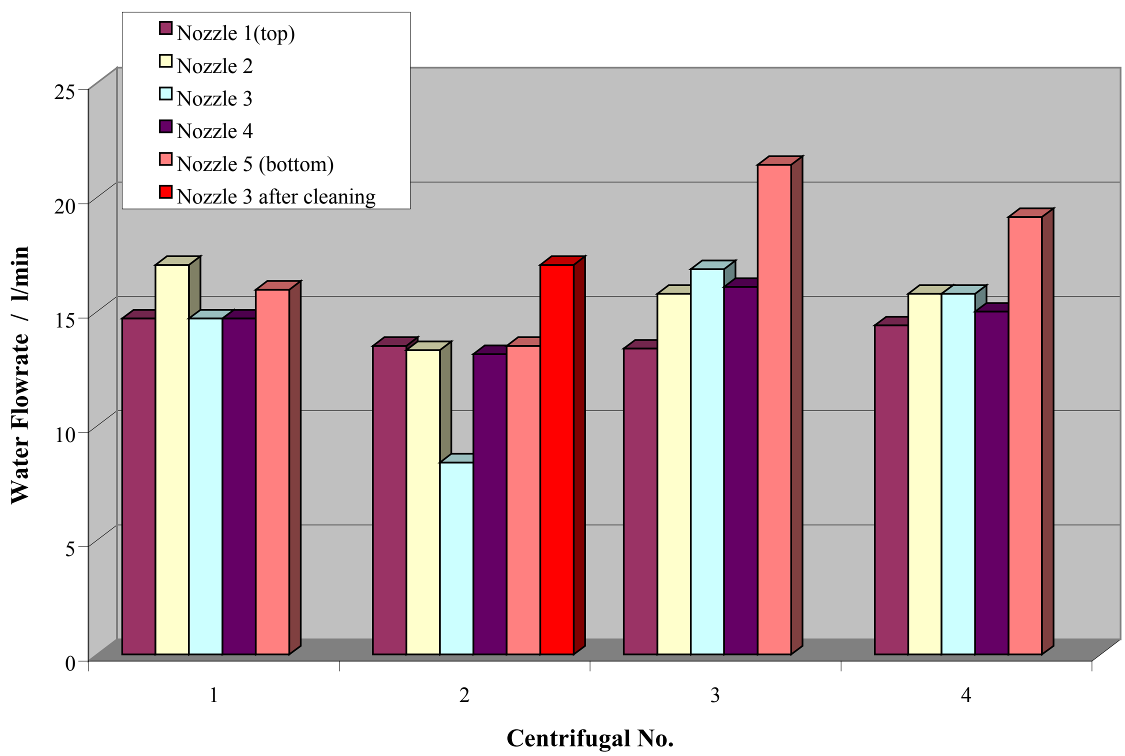
2. Color profile along the centrifugal basket

3. Dependence of the sugar cake thickness on the mixer level

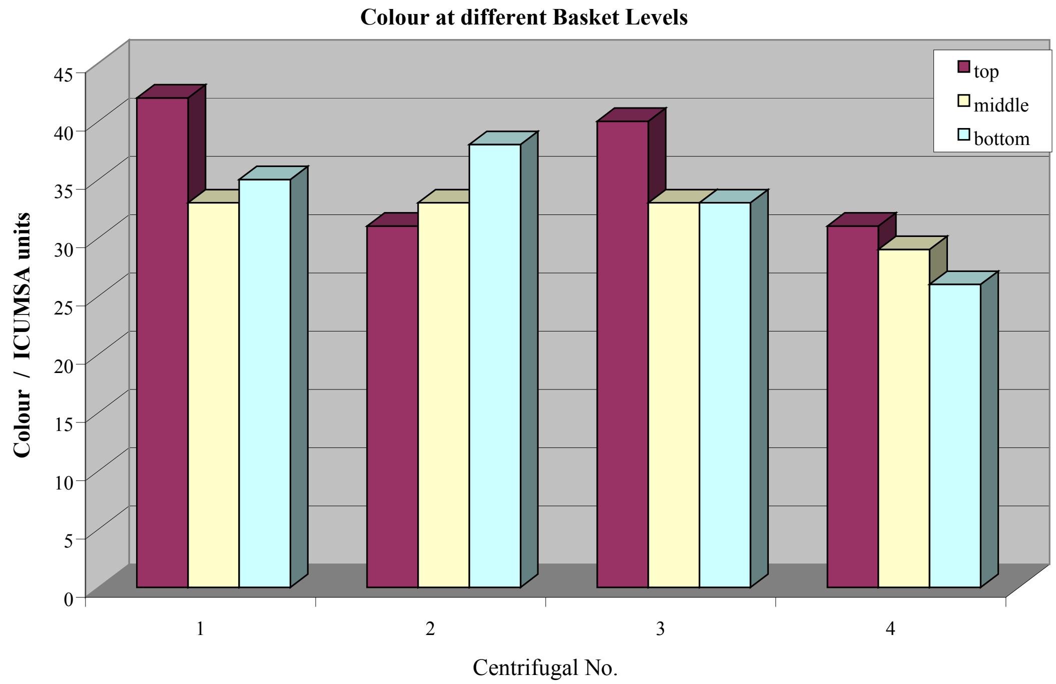
4. Dependence of the color on the sugar cake thickness

5. Reduction of the delay time between the first and second wash and the effect on the sugar color
6. Reduction of the total wash time and the effect on the sugar color

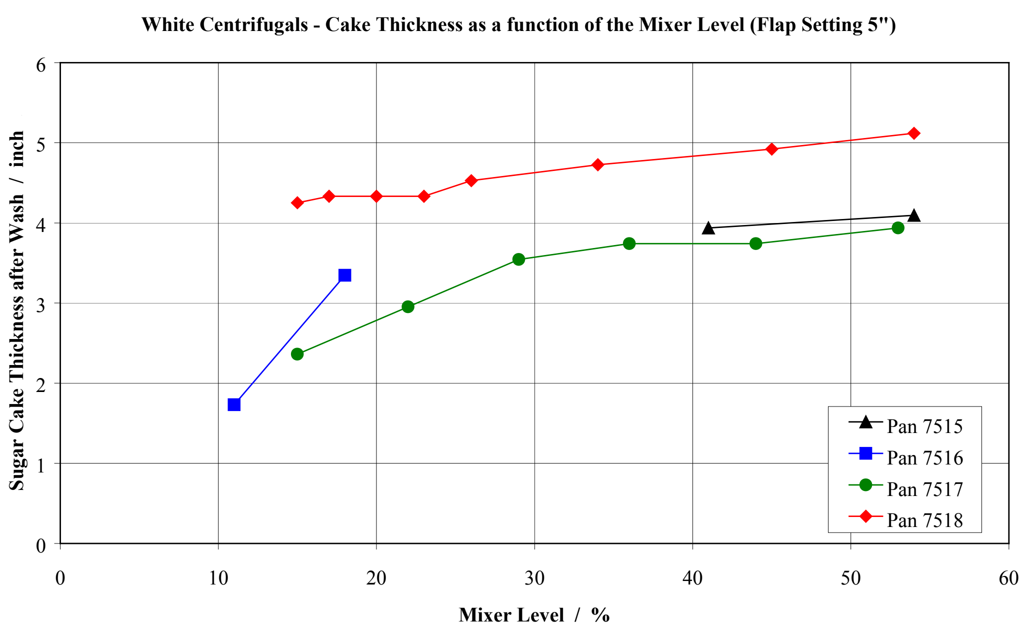
The spray nozzles and wands were examined for capacity. Each wand has five nozzles and the following water delivery rates were measured for each nozzle and graphed. The data surprised us with respect to the variation from nozzle to nozzle and from machine to machine. The higher flow from the lowest nozzle can easy be explained by the drainage of the wand after the water inlet valve is closed. The remaining differences were due to scale formation in the nozzles and wand. After cleaning all the nozzles a more uniform and higher flow rate was found. The fact that significant flow changes were present suggested that washing was less than uniform. The waviness of the sugar in the centrifugal basket just before discharge and the variation of color from the Neltec ColourQ 2100 appeared to confirm this. We were using more wash water than was needed because the spray pattern was not proper and a higher deviation in sugar color within the centrifugal was present.



During this period of less than clean nozzles the color profiles in the centrifuges' basket were examined. The graph demonstrates that each machine behaves differently with respect to color and color appeared to be highest either at the top or bottom of the basket. It is clear that color of the sugar closest to the screen is higher than nearest the wash. There was no definite pattern.

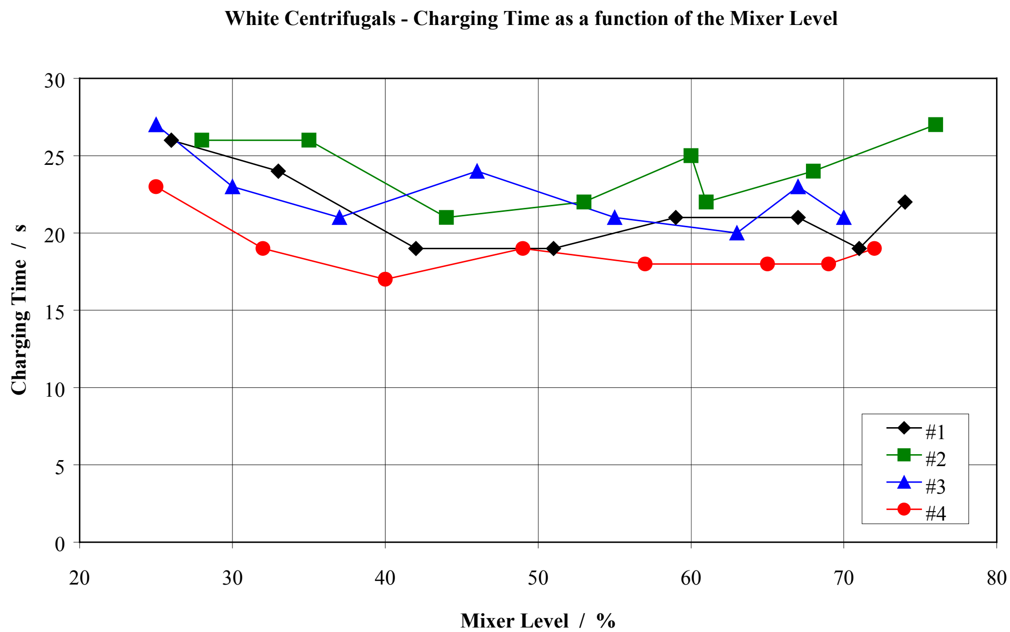


The sugar cake thickness is dependent on the static pressure of the white mixer along with the viscosity of the magma, charging time, and centrifugal inlet valve position. Sugar boiling irregularities have a strong influence on throughput of magma into the centrifuge. The relative cake thickness after washing with the same wash water settings is shown:

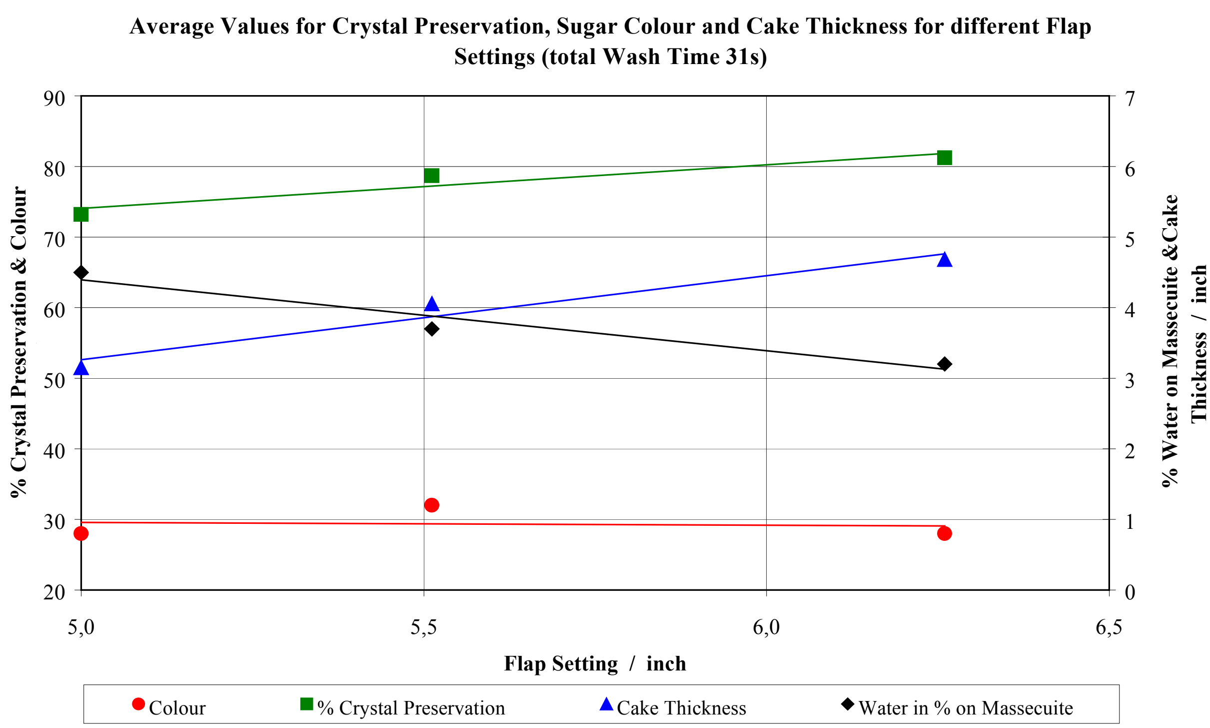


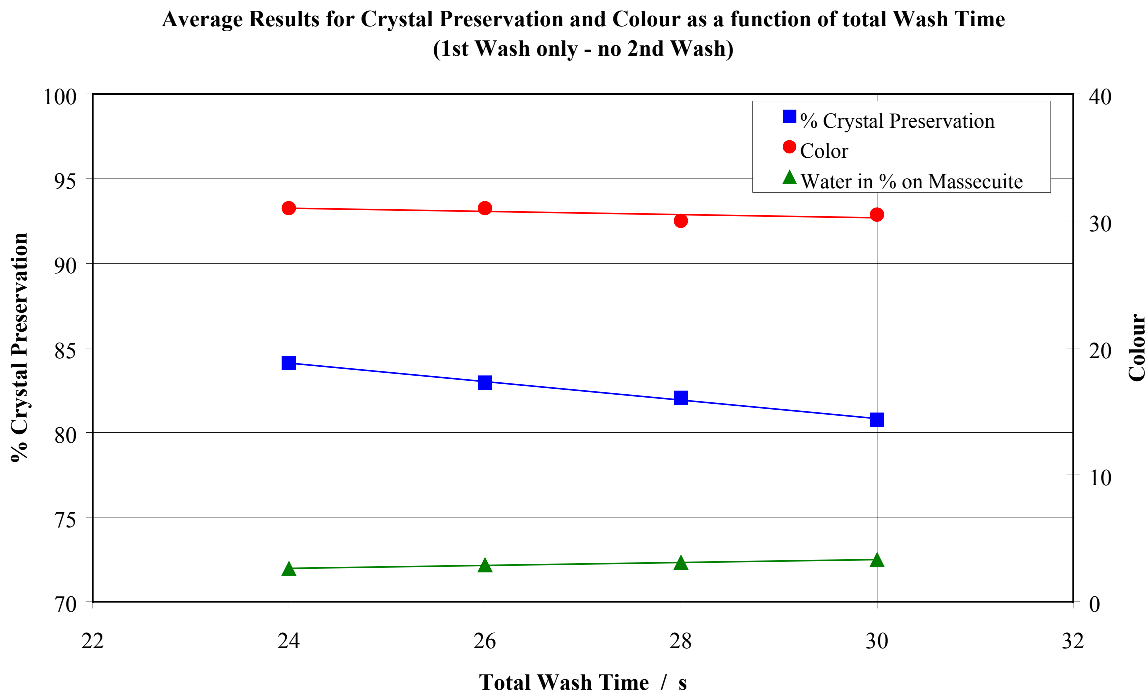
This above graph also helps explain color to water wash ratios that may have been less clear without examining this variation.

Examination of charging time for the same pan strikes is also shown. The time difference is not insignificant at low mixer levels compared to the 40 to 70 per cent mixer levels. Cake thickness after washing significantly improves as well when mixer level is maintained.

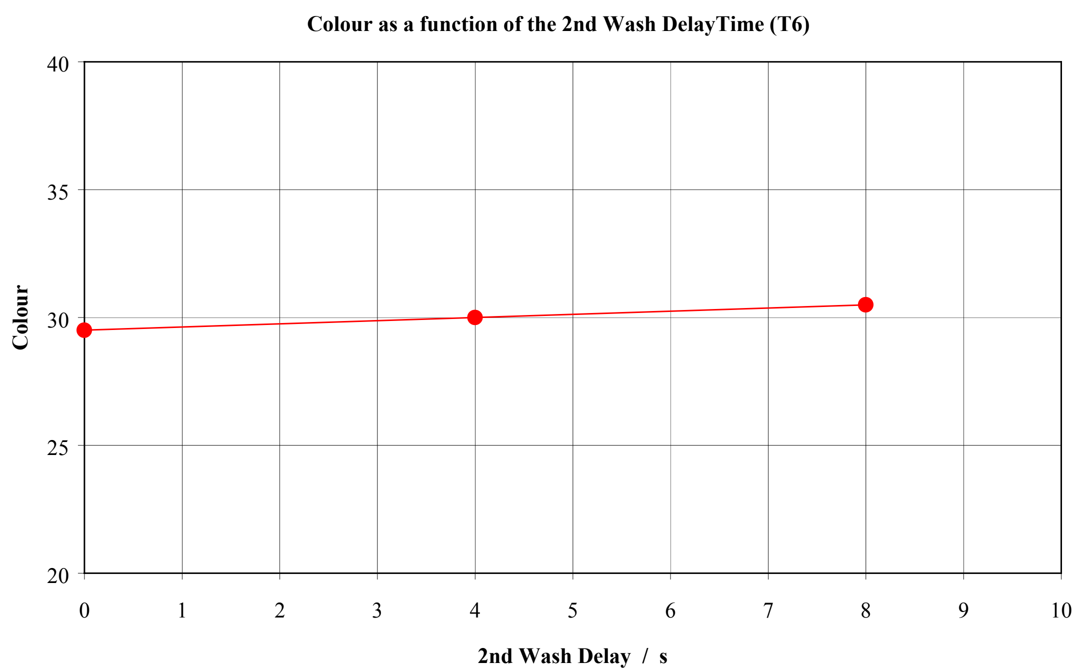


If we maintain the mixer level and keep the sugar cake thickness high what happens to our color? The attached graph demonstrated color change is small but crystal preservation (yield) is substantially improved.





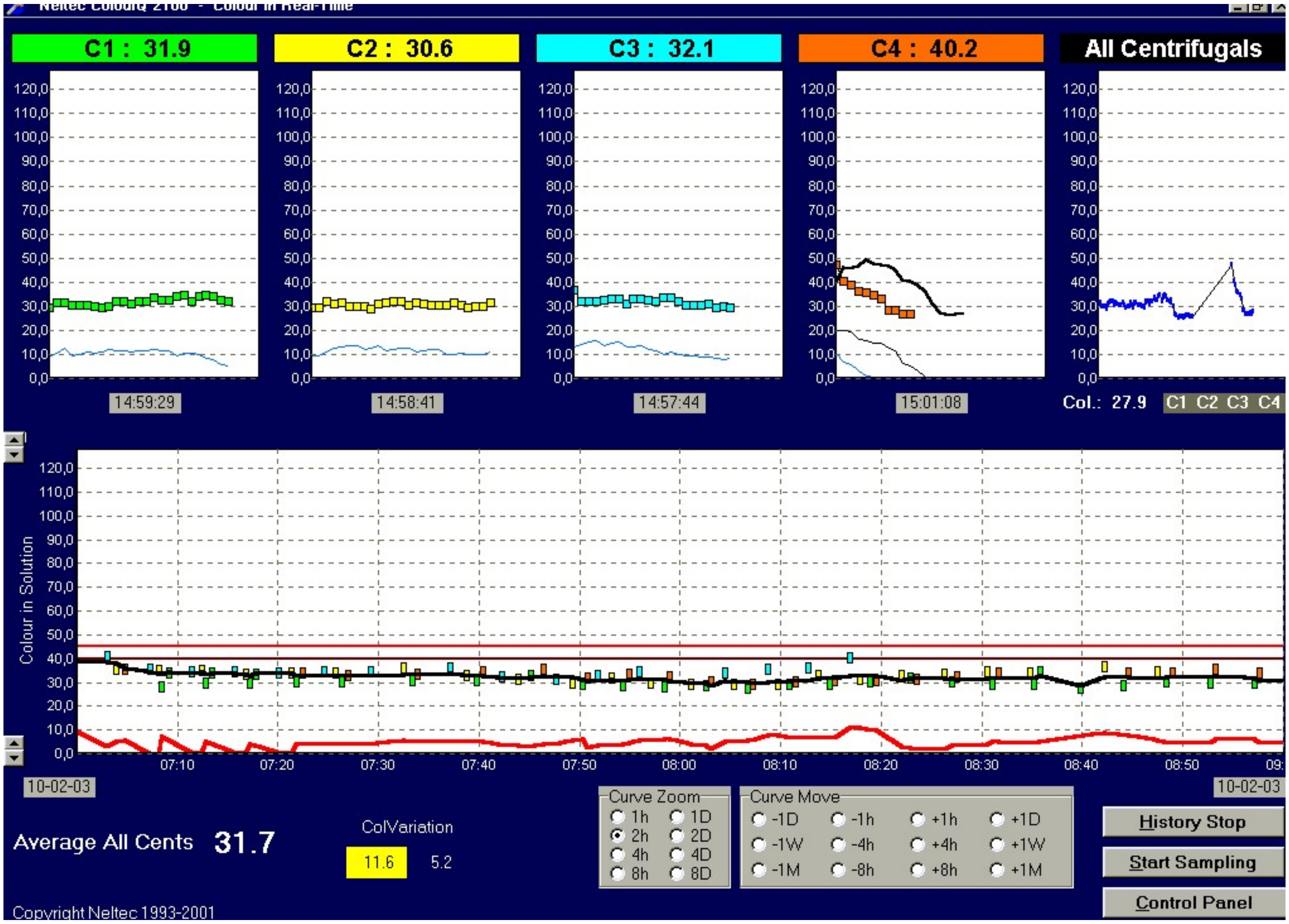
The use of two water washes in the United States is fairly common but in many other countries this was not true. The concept of a single wash is logical but without the Neltec ColourQ 2100 difficult to verify. With the inline color sensor it was confirmed that the longer the delay the more color in the white sugar. This general graph can and has been now confirmed many times at SMBSC:



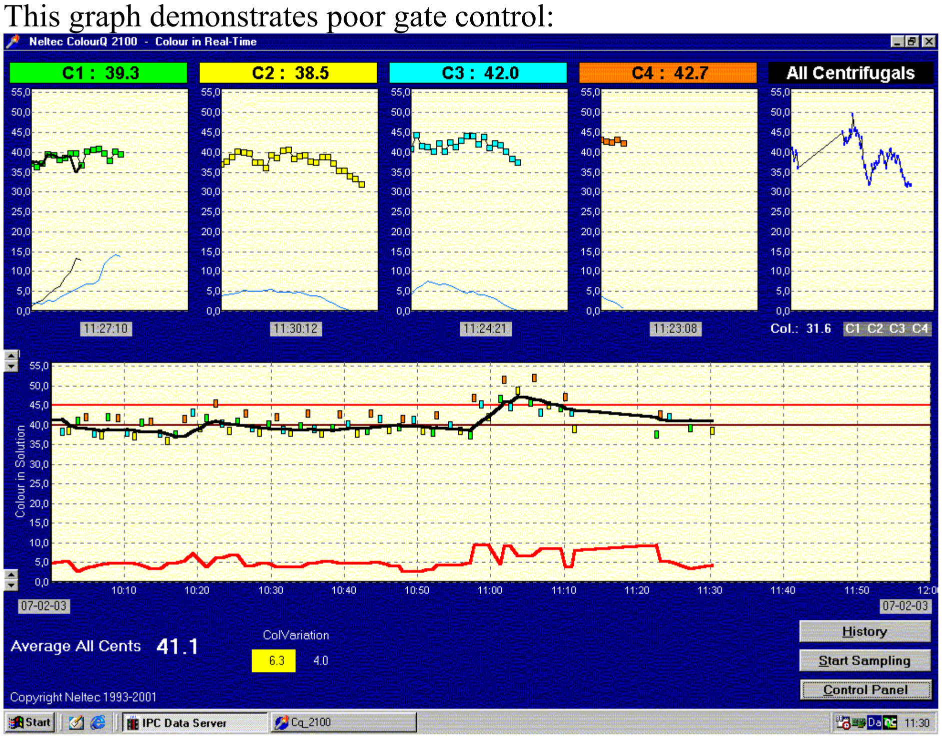
From the use of the inline color sensor we confirmed all centrifuges, even from the same supplier, are not the same in performance. Location of the centrifuge in relation to the mixer has a strong influence on color. The start of a strike gives different results than the end. The color of the sugar from an individual machine varies from the top to the bottom. The setting of the plough to the screen has an impact on color from the machine. The blinding of the screen, smeared pans and improper purge can all be quickly identified by the color analyzer.

The following graphical display from the ColourQ 2100unit shows the many relationships influencing white sugar color due to pan floor or centrifugal operation. The individual centrifugal information on color is quite extensive. It has the current sugar color as it was discharged from the screw conveyor point by point every three seconds. It also has plotted the point by point color of the two previous centrifuges discharges. The thin blue and black lines are indicating the relative amount of sugar in the conveyor. Again the blue line represents the current amount of sugar in the conveyor and the black line represents the average amount of sugar in the conveyor from the previous two centrifuges cycles. Because we often get overlapping sugar from one centrifugal to the next in the conveyor the lines will turn grey to indicate the color and amount of sugar in the screw conveyor is being influenced by more than centrifugal machine. The color of the sugar can be seen for all the machines as individual values and as the total average of all the sugar being conveyed from the centrifuges. It is very easy to note shifts and changes from machine to machine and from batch pan to batch pan. This information being displayed allows the operators to continually work at optimizing the station for color, throughput and yield. The single grab or composite sample from the laboratory on each batch pan requires operators to have to rely heavily on experience and guesses to what changes might need to be done to optimize the station. An old example is color increased. We believed it is because the spoke spray and basket supports needed cleaning. This step is completed and we wait for another sample, possibly another hour. We get the new point color reading that only confirms we are or are not back into an acceptable color range. We never knew for sure that the corrective action was the washing of the spoke sprays or if it was only partially the answer or maybe it was a wrong action. We never knew if cleaning the spoke spray in this example was the controlling variable. Now this cleaning step is confirmed in the first minutes after being preformed and if it was incorrect additional steps can immediately be taken. If it solves the color issue we now know it. The Neltec Colour 2100 is an essential sensor to operating the sugar end of a factory for optimum results.

The first graph show fairly uniform and consistent operation:



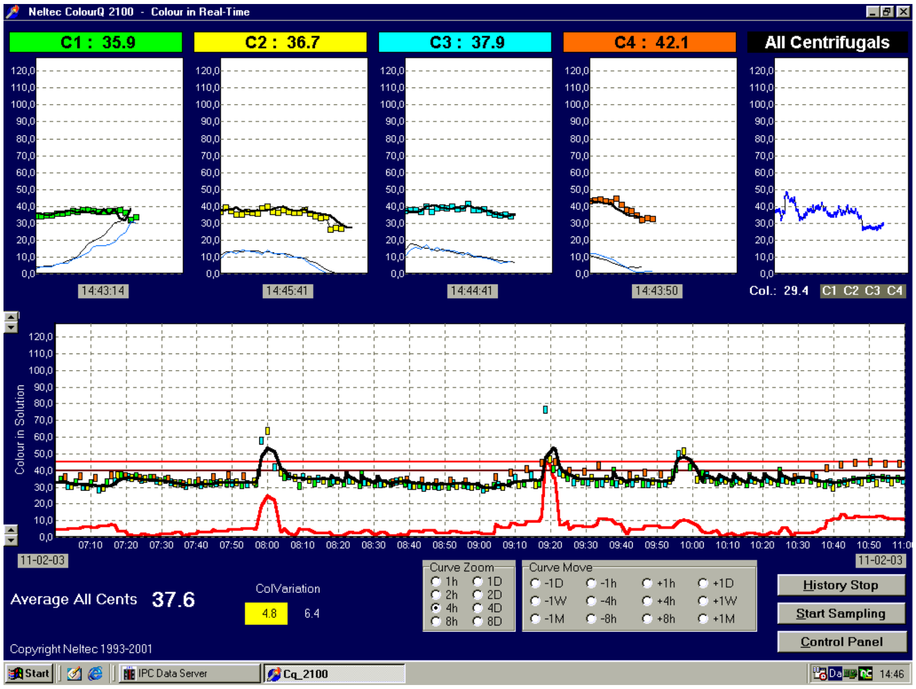
This graph demonstrates poor gate control:



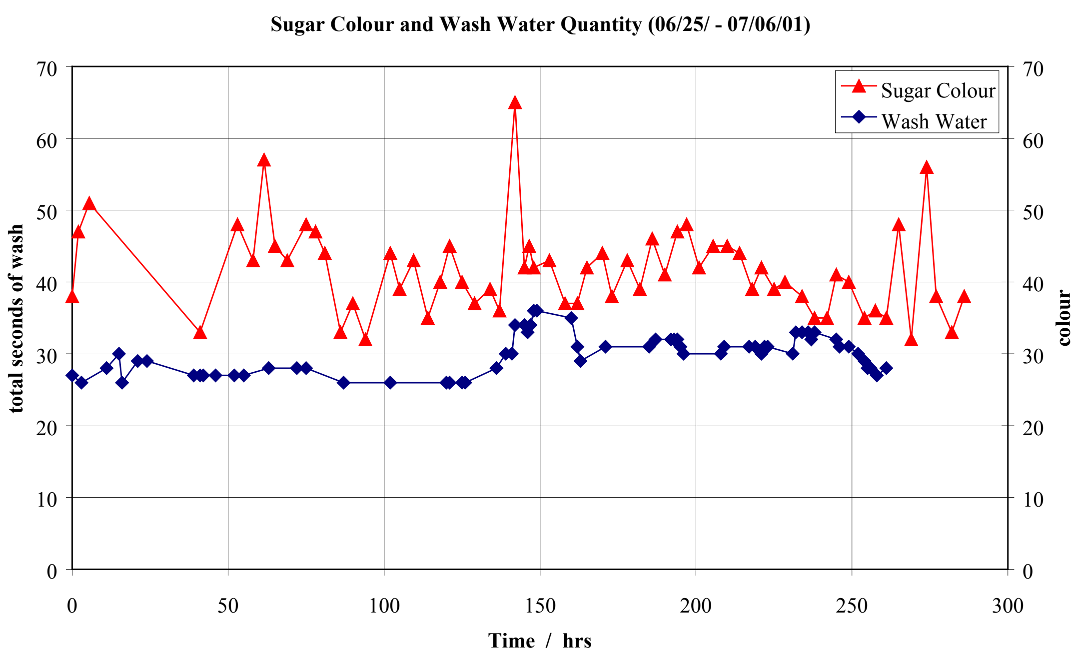
This graph demonstrates a plugged spray:

This graph demonstrates a 60% reduction in water wash on machine #2:

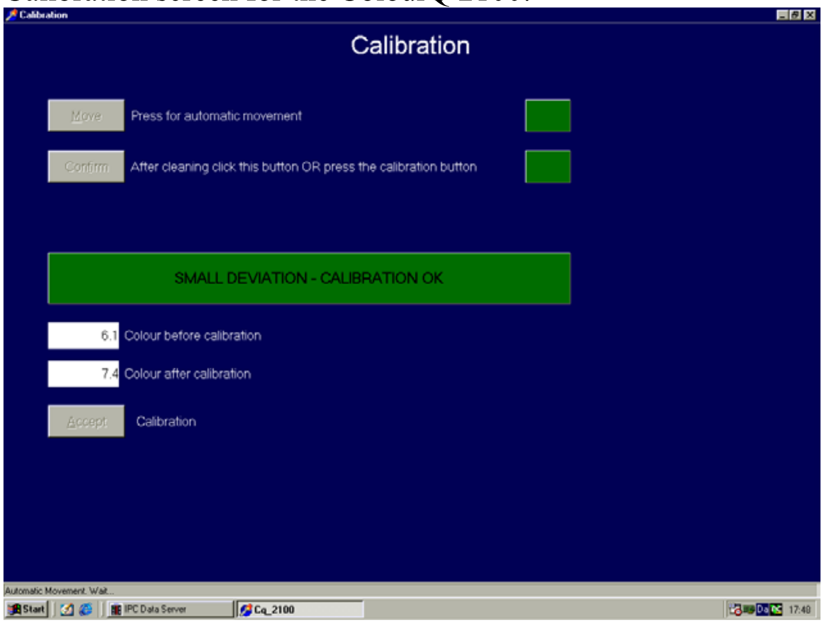
This graph demonstrates a problem on pan floor:



A graph showing water adjustments having little effect on color:



Calibration screen for the ColourQ 2100:



Another trial that we perform regularly at the station by the operator to confirm water wash rates are proper and load setting is as high as possible is summarized in table form:

Centrifuge number	Fill setting (1 to 7)	Wash timer setting for first and second wash in sec.	Delay between first and second wash in sec.	Color change in IU
1 thru 4	Increased from 2 to 3	Maintained	Maintained	Increased 1unit
1 thru 4	Increased from 3 to 4	Maintained	Maintained	Increased 2 units
1 thru 4	Increased from 4 to 6	Maintained	Maintained	Increased 5 units
2	Maintained fill setting	Increased from 23/23 to 25/25	Maintained	Decreased 1.5 units
3	Maintained fill setting	Decreased from 23/23 to 21/21	Maintained	Increased 1.5 units
2	Maintained fill setting	Increased from 25/25 to 28/28	Maintained	Decreased 1.5 units
3	Maintained fill setting	Decreased from 21/21 to 18/18	Maintained	Increased 8 units with high cycle variation
3	Maintained fill setting	Increased from 18/18 to 23/23	Maintained	Returned to same color readings at 23/23 settings
2	Maintained fill setting	Decreased from 28/28 to 23/23	Maintained	Increased 3 IU same 23/23 rd.

The maintenance of the ColourQ 2100 has been relatively simple. The unit has standard “white” calibration tile that it automatically calibrates against every hour. This calibration board is cleaned once per day. It takes approximately 10 minutes to clean. The calibration step takes one minute. The unit in calibration mode:

Savings example:
For the centrifuges used at SMBSC, each spray wand is capable of approximately 85 liters per minute of wash water. There are five nozzles per wand. Therefore if five seconds could be taken off each machine there would be 46 more pounds of sugar in each cycle going to storage. This additional sugar being recycled by not reducing the water to the lowest acceptable level (in this case 5 sec.) will increase energy and sugar loss to molasses. The assumption is 93% recovery in a standard three boil system. For a 20+ cycle, four machine station this calculation could yield economic losses as high as $1100 per day. The installed cost for the Neltec inline ColourQ 2100 analyzer was less than $50,000. If a 70 ton batch pan must be reworked due to high color, at least $1000 is lost in revenue as well as increases in labor and energy. Without the analyzer and a sampling protocol that allows some high color sugar to enter long term storage requires potentially more sugar to be reprocessed than by identifying it at the white centrifugal station. The cost of sugar being shipped to a customer above their specification and being rejected is the most expensive and just not acceptable.

References:

1. In-Line Measurement of Color in Raw and Refined Sugars by Clarke,M.A., Edye, L.A., and Nielsen, B.C.