MODELLING A CONTINUOUS PAN INSTALLATION USING SUGARS™ FOR WINDOWS®

By

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Abstract

The installation of a continuous pan for the Sugar Cane Growers Cooperative of Florida factory was modelled using the Sugars™ computer program to evaluate changes in the process and potential changes in revenues. A model was constructed of the existing factory, and factory data were used to define the performance of equipment in the model and to estimate the solubility characteristics of the syrup by determining the coefficients for the Vavrinecz solubility function. Balance calculations from the model were then compared to the actual operation to verify the model. Next, the model was modified to use a continuous pan for 50% of the 'B' boiling and reduced sucrose supersaturation for the 'A' and 'C' boilings to compensate for the reduced loadings in these boilings from the installation of the continuous pan. The reduced loading in the 'A' boiling would occur because an existing 'B' batch pan would be moved to the 'A' boiling when it is replaced by the new continuous pan, and the 'C' boiling would be reduced because of a load reduction. Results from the simulation showed that the factory could expect an increase in process revenues with decreases in the final molasses purity and the bagasse consumed by the boilers. 'B' centrifugal performance was then increased to see if the effect of more consistent crystal size variation in the 'B' massecuite from the continuous pan would improve factory performance. It was found that improvements in 'B' centrifugal performance were not as significant as the performance improvements from the lower supersaturation values used in the 'A' and 'C' boilings.

Introduction

The Sugar Cane Growers Cooperative of Florida was considering the installation of a new continuous 'B' pan to increase crystallization capacity, improve sugar recovery and improve raw sugar quality. The factory is a good candidate for installation of a continuous vacuum pan. It uses the "Double Einwurf" three-stage crystallization scheme and, as reported by Van der Poel, *et al*. (1998), magma from 'C' crystallization can be used as seed magma for the continuous pan to produce 'B' massecuite. It was decided to evaluate the feasibility of this change by using the Sugars for Windows computer program to construct a model of the factory and then modify the model to use a continuous pan in place of one of the 'B' batch pans.

Continuous vacuum pans have had good success replacing batch pans in both beet and cane sugar processes. Reported or claimed advantages include: reduced variation in evaporator vapour bleeds and pan vapours to the condenser, steady flow of feed syrup and massecuite out-put, lower massecuite boiling temperature, improved crystal size distribution, ability to operate with lower calandria vapour pressure and better massecuite exhaustion. Of these potential advantages, the Sugars program is capable of evaluating the possible benefits to the factory of the process performance issues that affect crystallization, steam consumption and separation of sucrose crystals from the massecuite. Also, it can give a prediction of the change in process net revenues as a result of the installation.

The purpose of this paper is to show the results of modelling the installation of a continuous pan and the effects of the installation on the performance of the factory and to provide information to help evaluate the value of the investment.

Factory process and Sugars model

Sugar Cane Growers Cooperative of Florida has a large raw sugar factory located in Belle Glade, Florida with a normal campaign that runs from the end of October through to the end of March. Cane supplied to the factory has about 13% sucrose, 10.5% fibre and 74.5% water. The normal grind is around 980 tonnes per hour (23 500 tonnes per day). Bagasse is used for steam generation and approximately 14 to 15 megawatts of electricity is produced.

Two steam turbine driven mill tandems (East tandem and West tandem) are used with about 52% of the cane going to the East tandem that has seven 4-roller mills and 48% of cane going to the West tandem having six 4-roller mills. The cane passes though two sets of steam driven knives before the mills, and compound imbibition is used with about 2.1 to 2.2 imbibition water on fibre. Final bagasse has about 1.75 Pol with 50-51% moisture. Exhaust steam from all the knives and mill turbines is combined with the turbo generator and boiler induced draft fan turbine exhaust steam for use in juice heating and evaporation.

Mixed juice from the mills goes through a traditional raw sugar purification process using milk-of-lime to give 0.05% CaO content on juice. Spiral, plate, and tube and shell heat exchanges are used to heat the juice after liming and floc (polymer) is added after the flash tank and before the clarifier. Mud from the clarifier has bagasse added to it and then it goes to a vacuum filter where the high and low vacuum takeoffs are recycled to the mixed juice liming tank. Clarified juice is heated in plate heat exchangers before going to evaporation and crystallization.

Evaporation is accomplished using six bodies for pre-evaporation, six bodies for inter-evaporation and a triple effect to produce syrup at a little over 68% Brix. Pre-evaporator vapour is used for the second limed juice tube and shell and clarified juice plate heat exchangers. Inter-evaporator vapour is used for the first lime juice tube and shell heat exchanger. Vapour from the 2nd effect of the triple effect is used for the limed juice plate heat exchanger. Exhaust steam is used for the final clarified juice plate heat exchanger before the clarified juice goes to evaporation to raise the temperature of the juice to close to 120°C. Inter-evaporator vapour is used for all boilings in crystallization. No condensate flashing is used between any of the effects.

The factory uses the “Double Einwurf” three-boiling scheme to produce raw sugar. ‘A’ massecuite is produced using ‘B’ sugar for seed magma and ‘C’ sugar is used as seed magma for ‘B’ sugar. Excess ‘B’ and ‘C’ sugar is dissolved with clarified and thick juice to make standard liquor for the ‘A’ pan. ‘A’ molasses is combined with ‘C’ sugar magma as feed for the ‘B’ pan, and ‘B’ molasses is combined with some ‘A’ molasses and standard liquor as feed for the ‘C’ pan.

Condensate from all heat exchangers, pans and evaporator bodies is collected and used for boiler feedwater, limed juice heating in a spiral heat exchanger, vacuum filters, centrifugal wash water, imbibition water, magma preparation, etc. Cooling water to the condensers for all pans and evaporation is circulated in a cooling water loop with a cooling tower.

Steam from the boilers is used as motive power for the knives, mills, induced draft fans and feedwater pumps and then combined with exhaust steam from four turbo generators to provide process steam for the factory. One turbo generator is a condensing turbine that produces about 6.0 megawatts. The other four turbo non-condensing generators produce in excess of 8.0 megawatts.

The Sugars model of the factory covers all areas of the process starting with the cane knives and proceeding through sugar production along with steam and electrical generation. The complete model covers ten drawing pages and each page covers a section of the factory. For example, the East milling tandem covering cane knives and seven 4-roller mills is shown on one page and additional pages cover the West tandem, purification, ‘A’ boiling, ‘B’ boiling, ‘C’ boiling, evaporation, condensate recovery, water distribution, and steam generation and distribution with electrical generation. Only the ‘B’ boiling page is shown in this paper because of space limitations.

’B’ boiling page

Figure 1 shows the ‘B’ boiling with both a batch pan and a continuous pan. The arrangement of the model is such that all of the crystallization can be done in the batch pan, in the continuous pan, or it can be split between the batch and continuous pans by using a distributor station to adjust the amount of ‘A’ molasses going to each pan. A supplier of continuous pans estimated that the pan could produce a massecuite with 94% Brix and 1.30 sucrose supersaturation at a pressure of 13 kPa. These data were entered into the properties for the continuous pan and the computer program used these performance data to process the syrup coming to the pan to determine the crystallization. The massecuite discharged from the pan is held in a mixer where additional crystal growth occurs and then it is sent to the centrifugals for separation of the mother liquor from the crystals. Performance values for the centrifugal were determined from actual factory measurements of the feed to the centrifugal and the sugar and molasses flows leaving. The performance values include crystal loss, mother liquor purge and wash water purge. When the continuous pan is installed, the performance of the centrifugal may change due to different characteristics of the massecuite from the continuous pan.

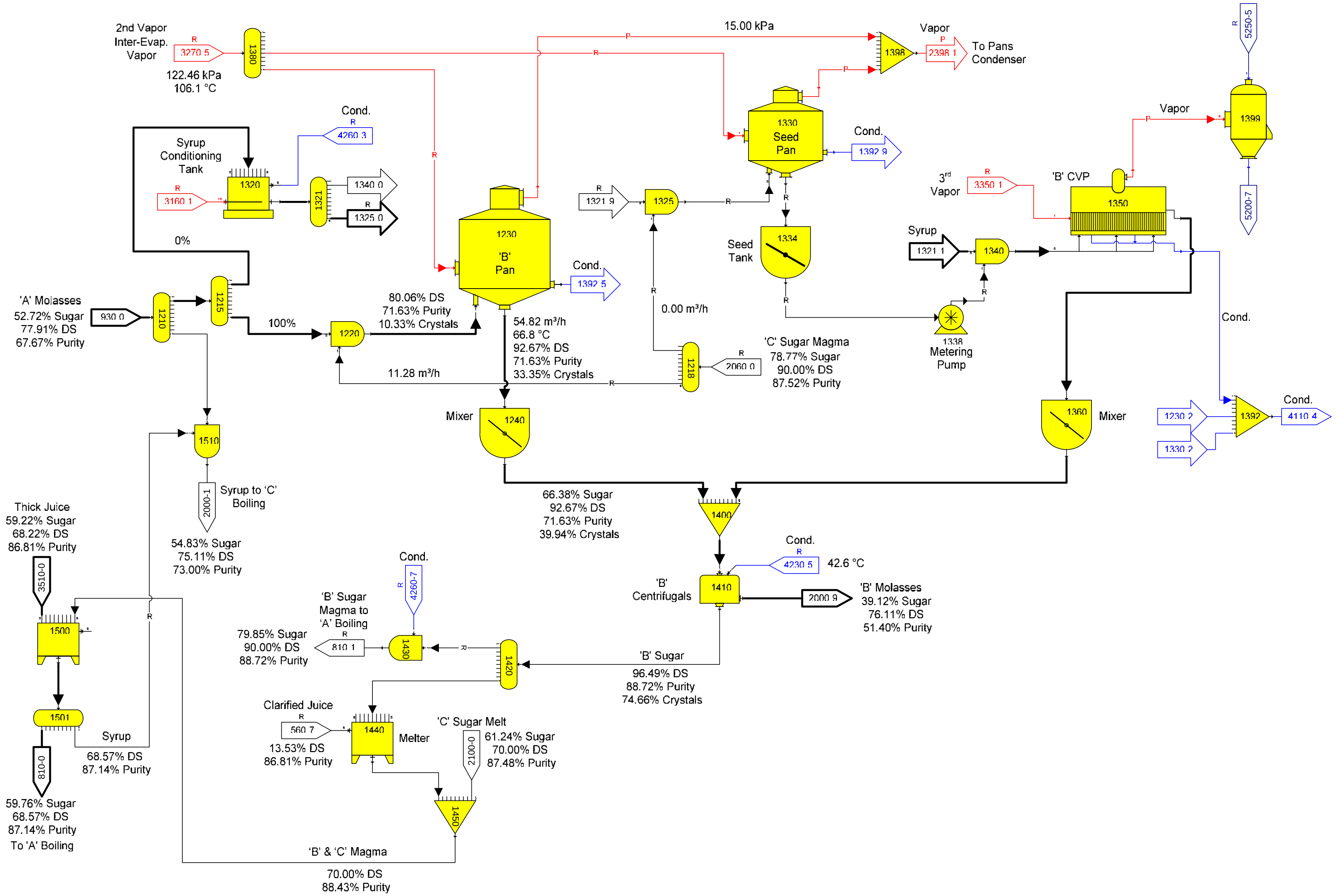


Fig. 1 - 'B' crystallization page of model

Blender stations from Sugars are used to blend ‘C’ sugar magma with the ‘A’ molasses in a ratio that is set by the data. Hence, simply changing the amount of ‘A’ molasses going to either the batch pan or the continuous pan will cause the model to automatically blend ‘C’ magma as pan footing into the ‘A’ molasses. The addition of a continuous pan to the model required the addition of two distributor stations, a syrup conditioning tank, a seed pan and tank, a metering pump, the continuous pan, a massecuite mixer and a condenser. Also, the continuous pan is supplied with 3rd vapour instead of the 2nd vapour used for the ‘B’ batch pan.

Large arrows with internal text represent connections between shapes on the flow diagram. Arrows without an arrowhead are for flows that are connected to stations on another drawing page; whereas, arrows with an arrowhead are for flows that have a connection on this page. The text within the arrow identifies the station number and port where the connection either originates or where it terminates. For example, condensate flow from the ‘B’ batch pan goes to receiver station number 1392 into port number 5 (shown as “1392-5” on the diagram inside the large arrow connected to the condensate port of the pan).

Figure 1 shows the results (data on the drawing) from the simulation with all of the crystallization done only in the batch pans (shown as one pan); that is, the continuous pan is not active.

Factory and model data

Data from the operation of the existing factory were used to control the performance of the stations in the model to give the simulated results. In some cases, inference was used to determine flow stream and station characteristics when actual data were not available.

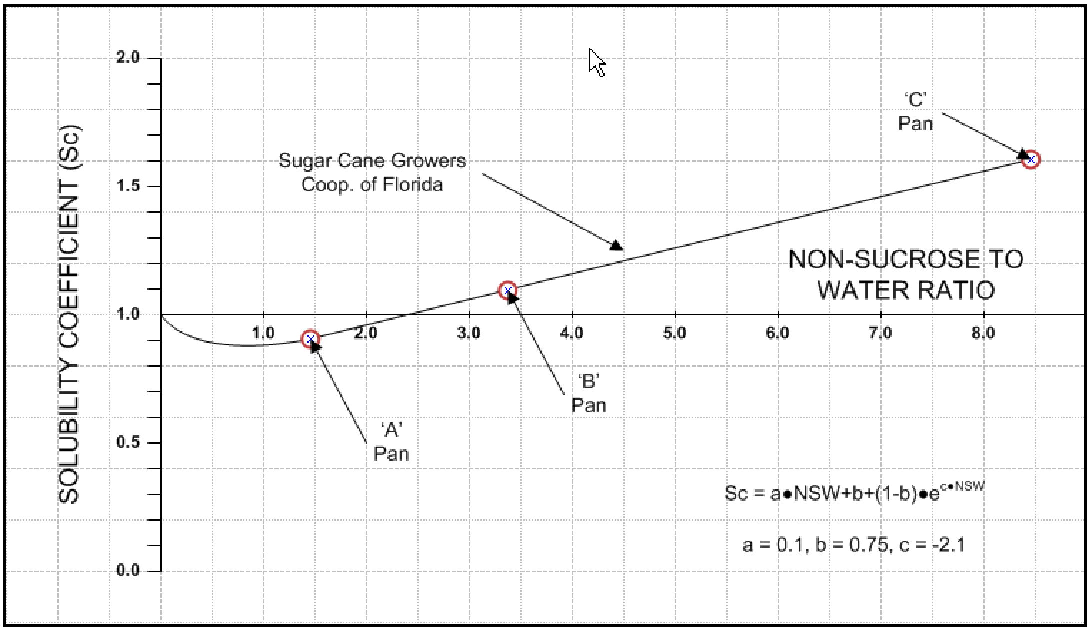
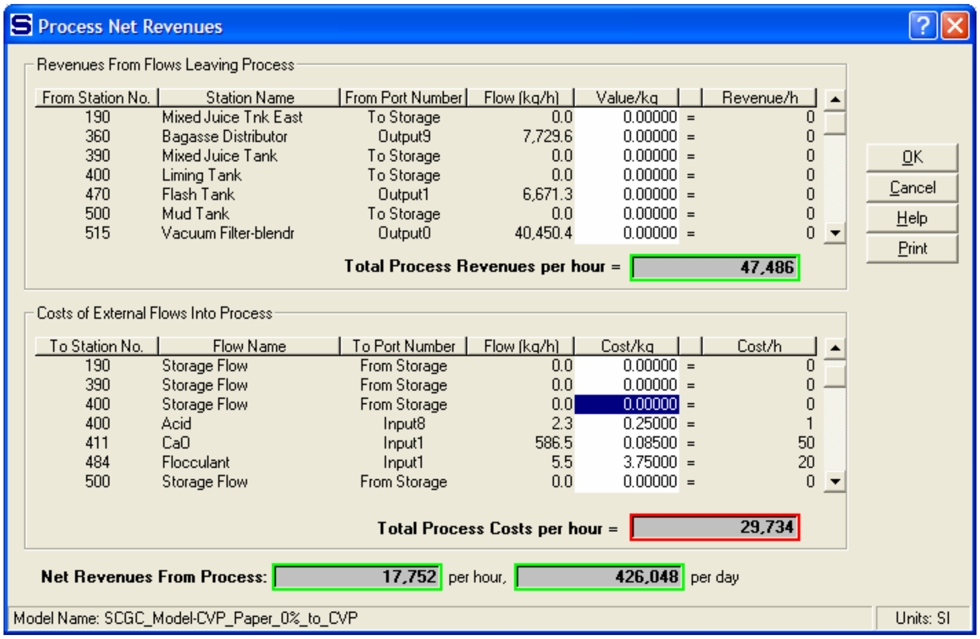


Fig. 2 - Solubility coefficient vs. non-sucrose to water ratio

For example, Sugars uses the Vavrinecz solubility function to determine the crystal content of flow streams containing sugar. The constants for the solubility function are dependent on the melassigenic substances in the flow. These constants were estimated by looking at the operating data from the factory and estimating the sucrose supersaturation from pans and crystallizers. Figure 2 shows the solubility function curve and the constants that were used in the model. The ‘A’, ‘B’ and ‘C’ pan crystallization conditions for the factory are shown on the curve. The curve is based on data from the factory that is for measured Brix and apparent purity. Hence, it reflects the same measurement inaccuracy as the other data that are used in the model.

The Sugars model is a reflection of the data provided by the operating results. Sugars provides absolute dry substance and purity values; whereas, data from the factory (e.g., Brix and pol) are not absolute and contain errors. Hence, using factory data to define the constants for the solubility function and supersaturation gives simulation results that compare to the factory data, but introduce inaccuracies in the model and the simulation. This gives sugar and molasses production results that do not agree with actual measurements. In the Sugar Cane Growers Coop. of Florida model, the simulation predicts about 3.8% less sugar and 5.7% more molasses than is actually produced because of these measurement errors.

Simulation



Revenues From Flows Leaving Process

From Station No.	Station Name	From Port Number	Flow (kg/h)	Value/kg		Revenue/h
190	Mixed Juice Tnk East	To Storage	0.0	0.00000	=	0
360	Bagasse Distributor	Output9	7,729.6	0.00000	=	0
390	Mixed Juice Tank	To Storage	0.0	0.00000	=	0
400	Liming Tank	To Storage	0.0	0.00000	=	0
470	Flash Tank	Output1	6,671.3	0.00000	=	0
500	Mud Tank	To Storage	0.0	0.00000	=	0
515	Vacuum Filter-blendr	Output0	40,450.4	0.00000	=	0

Total Process Revenues per hour = 47,486

Costs of External Flows Into Process

To Station No.	Flow Name	To Port Number	Flow (kg/h)	Cost/kg		Cost/h
190	Storage Flow	From Storage	0.0	0.00000	=	0
390	Storage Flow	From Storage	0.0	0.00000	=	0
400	Storage Flow	From Storage	0.0	0.00000	=	0
400	Acid	Input8	2.3	0.25000	=	1
411	CaO	Input1	586.5	0.08500	=	50
484	Flocculant	Input1	5.5	3.75000	=	20
500	Storage Flow	From Storage	0.0	0.00000	=	0

Total Process Costs per hour = 29,734

Net Revenues From Process: 17,752 per hour, 426,048 per day

Model Name: SCGC_Model-CVP_Paper_0%_to_CVP

Units: SI

Fig. 3 - Process Net Revenues with ‘B’ batch pan

Figure 3 shows the process revenues for the model using fictitious value and cost data for the flow streams using the existing batch pans for ‘B’ crystallization. The amount of US$426 048 per day is shown only to evaluate the relative change in revenues that can occur from the installation of a continuous vacuum pan. The actual US dollar amounts for the Sugar Cane Growers Coop. of Florida’s factory are not given in this paper.

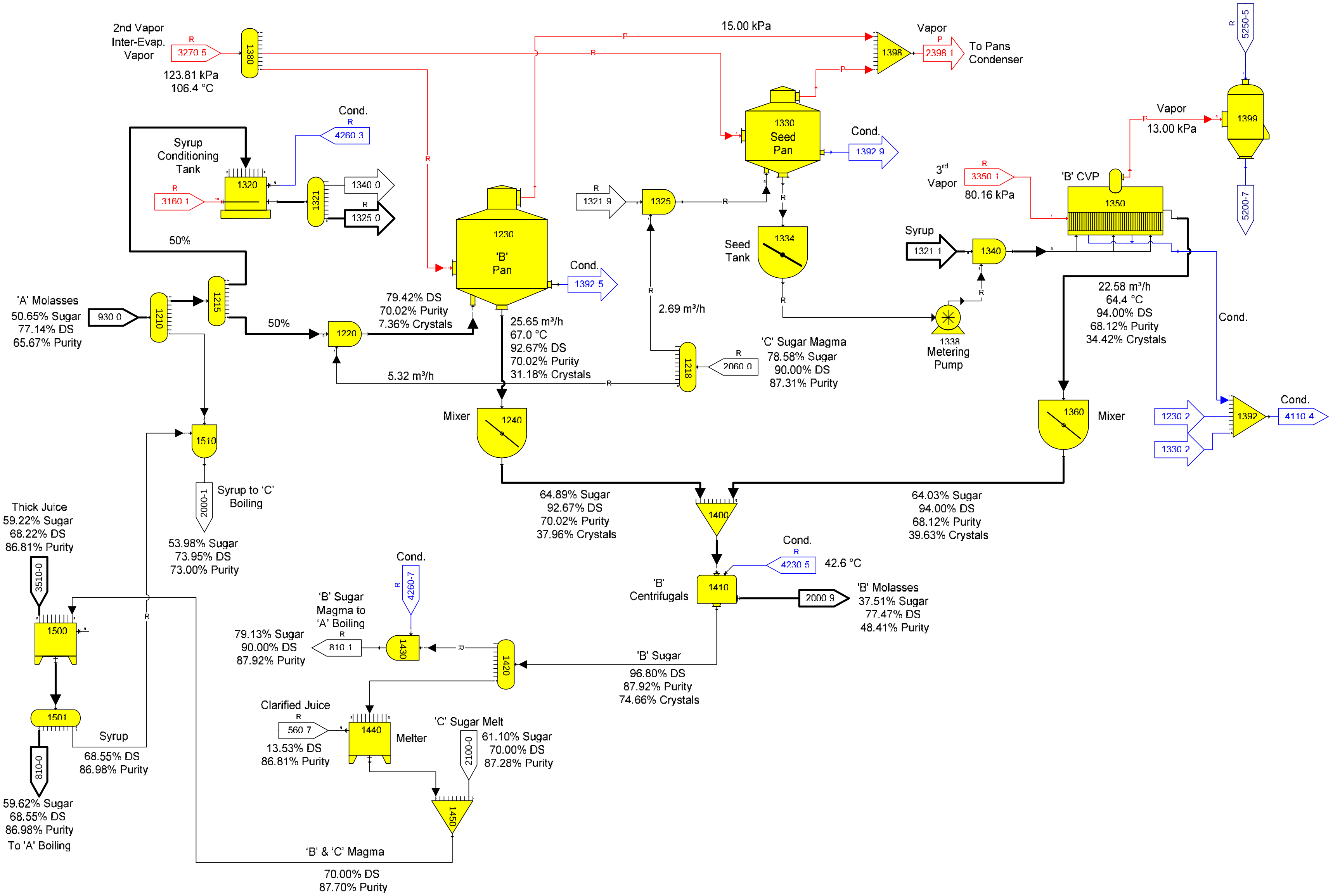
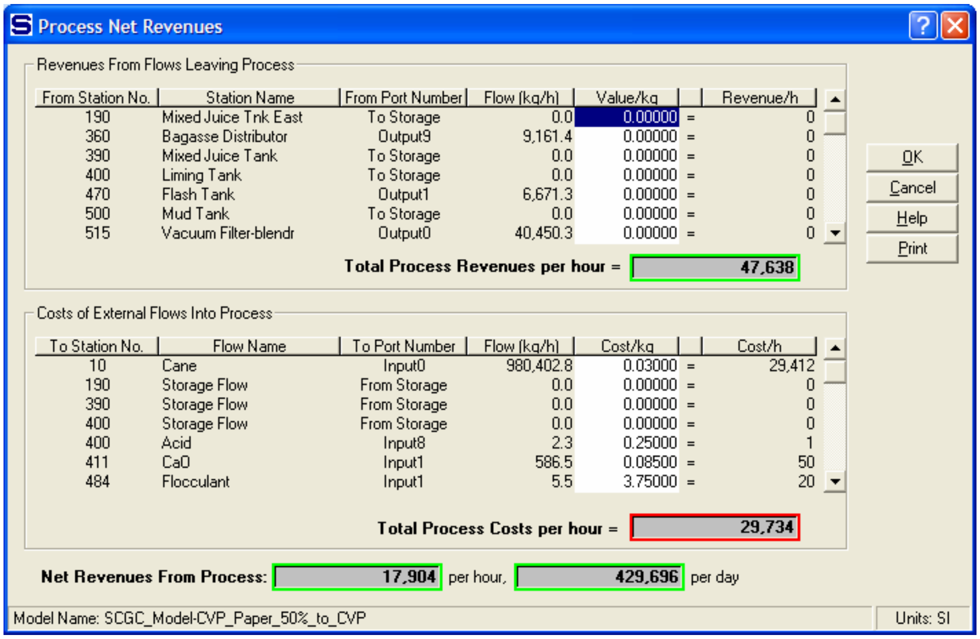


Fig. 4 - Continuous pan operating results

Installing a continuous pan will free up one of the existing ‘B’ batch pans that can then be moved to the ‘A’ boiling. Sending 50% of the ‘A’ molasses to the continuous vacuum pan and reducing the supersaturation of the ‘A’ massecuite by 0.1 and the ‘C’ massecuite by 0.03 because of the additional ‘A’ pan capacity and the reduced loading in the ‘C’ pan respectively gives the results shown in Figure 4 and the process revenues as shown in Figure 5.



Revenues From Flows Leaving Process

From Station No.	Station Name	From Port Number	Flow (kg/h)	Value/kg		Revenue/h
190	Mixed Juice Tnk East	To Storage	0.0	0.00000	=	0
360	Bagasse Distributor	Output9	9,161.4	0.00000	=	0
390	Mixed Juice Tank	To Storage	0.0	0.00000	=	0
400	Liming Tank	To Storage	0.0	0.00000	=	0
470	Flash Tank	Output1	6,671.3	0.00000	=	0
500	Mud Tank	To Storage	0.0	0.00000	=	0
515	Vacuum Filter-blendr	Output0	40,450.3	0.00000	=	0

Total Process Revenues per hour = 47,638

Costs of External Flows Into Process

To Station No.	Flow Name	To Port Number	Flow (kg/h)	Cost/kg		Cost/h
10	Cane	Input0	980,402.8	0.03000	=	29,412
190	Storage Flow	From Storage	0.0	0.00000	=	0
390	Storage Flow	From Storage	0.0	0.00000	=	0
400	Storage Flow	From Storage	0.0	0.00000	=	0
400	Acid	Input8	2.3	0.25000	=	1
411	CaO	Input1	586.5	0.08500	=	50
484	Flocculant	Input1	5.5	3.75000	=	20

Total Process Costs per hour = 29,734

Net Revenues From Process: 17,904 per hour, 429,696 per day

Model Name: SCGC_Model-CVP_Paper_50%_to_CVP

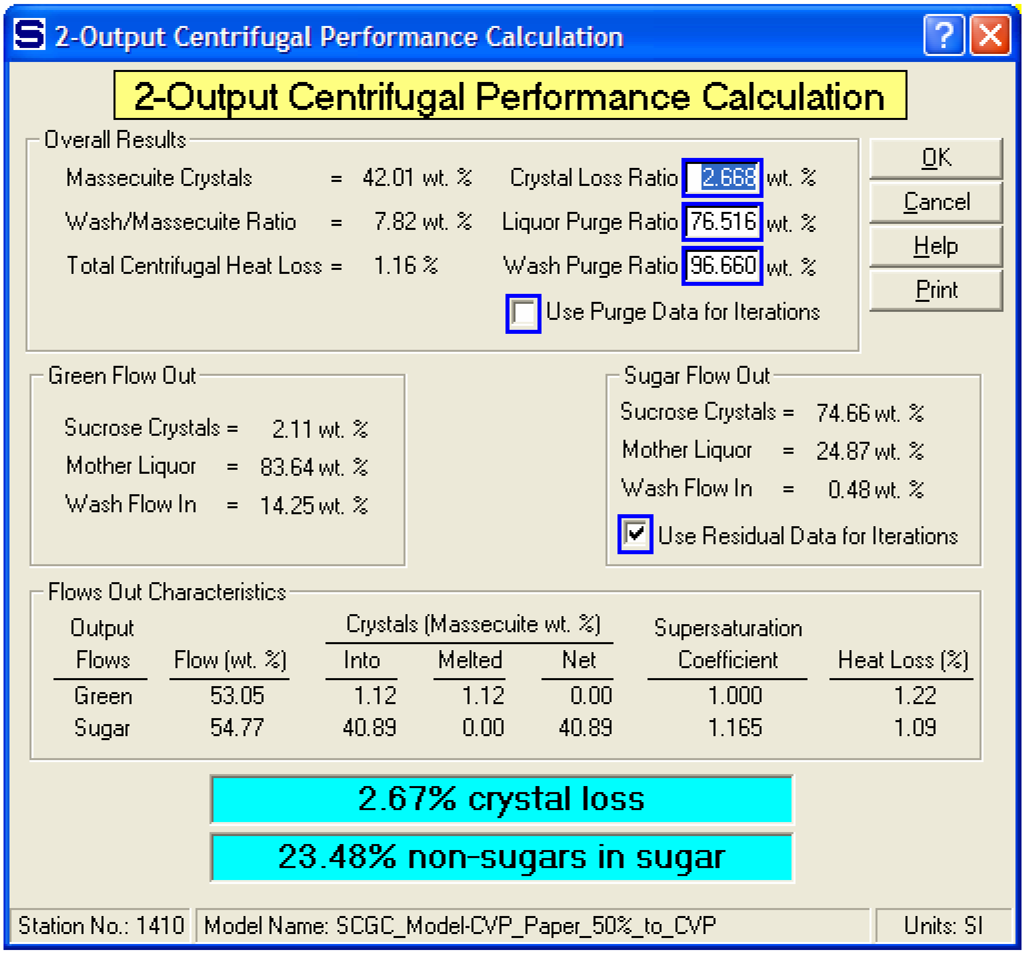
Units: SI

Fig. 5 - Process Net Revenues with the ‘B’ continuous pan

The increase in process net revenues amounts to more than US$3600 per day if the assumed performance improvements in the ‘A’ and ‘C’ boilings are achieved. Additional net revenues will also be realized from the additional bagasse that is produced because of the reduced steam demand. This excess amounts to about 1.5 tonnes per hour of bagasse which would reduce the fuel oil needed by the boilers at various times to supplement the bagasse.

The reduction in final molasses purity from the continuous pan installation amounts to more than 1 point; that is, 34.38% purity with the two ‘B’ batch pans versus 33.31% purity with the ‘B’ continuous pan and one batch pan. Also, the remaining ‘B’ batch pan has a lower loading which should improve its operation somewhat, but no change was made to the performance of this pan.

Adding a continuous pan could also improve the ‘B’ massecuite crystal size distribution which could result in better centrifugal performance. Data are not available on the change in centrifugal operation when processing massecuite from a continuous pan; however, an estimate can be made just to get an idea of the potential advantage.



2-Output Centrifugal Performance Calculation

Overall Results

Massecuite Crystals = 42.01 wt. %

Wash/Massecuite Ratio = 7.82 wt. %

Total Centrifugal Heat Loss = 1.16 %

Crystal Loss Ratio 2.668 wt. %

Liquor Purge Ratio 76.516 wt. %

Wash Purge Ratio 96.660 wt. %

☐ Use Purge Data for Iterations

Green Flow Out

Sucrose Crystals = 2.11 wt. %

Mother Liquor = 83.64 wt. %

Wash Flow In = 14.25 wt. %

Sugar Flow Out

Sucrose Crystals = 74.66 wt. %

Mother Liquor = 24.87 wt. %

Wash Flow In = 0.48 wt. %

☑ Use Residual Data for Iterations

Flows Out Characteristics

Output Flows	Flow (wt. %)	Crystals (Massecuite wt. %) Into	Melted	Net	Supersaturation Coefficient	Heat Loss (%)
Green	53.05	1.12	1.12	0.00	1.000	1.22
Sugar	54.77	40.89	0.00	40.89	1.165	1.09

2.67% crystal loss

23.48% non-sugars in sugar

Station No.: 1410 | Model Name: SCGC_Model-CVP_Paper_50%_to_CVP | Units: SI

Fig. 6 - ‘B’ centrifugal performance

Figure 6 shows the centrifugal performance evaluation for the continuous centrifugal on ‘B’ massecuite. As shown in the highlighted section at the bottom of the screen, 2.67% of the crystals are lost by melting and 23.48% of the non-sucrose components in the massecuite remain with the sugar out of the centrifugal.

The performance of the centrifugal can be improved by simply decreasing the Crystal Loss Ratio and increasing the Liquor Purge Ratio. Assuming a 10% improvement in both the Crystal Loss Ratio and Liquor Purge Ratio, just for the purpose of illustration, the model was rebalanced to see what the effect would be of improved centrifugal performance. The results show a new final molasses purity of 33.22%, a slightly better ‘A’ sugar (lower colour and higher purity) and an increase in revenues of US$48 per day. Hence, the ‘B’ centrifugal performance improvement is not as significant as the reductions in supersaturation for the ‘A’ and ‘B’ boilings.

The overall drop in final molasses purity from all of the changes is predicted to be 1.16 points with an increase in revenues of close to US$3700 per day without considering the value of the additional bagasse that is not needed by the boilers to produce steam for the process.

Further evaluation and verification of some of the equipment performance and process characteristics will be done during the next campaign.

Summary

A Sugars model was built of the Sugars Cane Growers Cooperative of Florida 23 500 tonne per day cane sugar factory to assess the feasibility of installing a continuous vacuum pan for 'B' crystallization. Additions were made to the model to include the continuous pan and its associated equipment, such as seed pan, seed tank, metering pump and condenser. Simulations were made of the model with the existing batch 'B' pans and then using both the batch and continuous pans to produce 'B' massecuite. Consideration was given to the reduced loading and potential decrease in supersaturation in the 'A' and 'C' massecuite as a result of the installation of the continuous pan. The results from the modelling show that the addition of a continuous pan will reduce the boiler bagasse consumption, increase the process revenues, and reduce the final molasses purity if the potential changes in performance for the 'A' and 'C' boilings are realized. Also, it shows that any improvement in the 'B' centrifugal performance as a result of the installation is not as significant as the potential decrease in sucrose supersaturation that could occur in the 'A' and 'C' boilings.

Acknowledgements

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