MODELING THE NEW TECHNOLOGY RAW SUGAR FACTORY/REFINERY USING SUGARS™ FOR WINDOWS®

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ABSTRACT

New technology using ultrafiltration, juice softening and chromatographic separation jointly developed by Amalgamated Research Inc. and Sugar Cane Growers Cooperative of Florida offers the potential to improve the yield of sugar from existing raw cane sugar factories and produce a high quality refined sugar. The Sugars™ computer program is used extensively for sugar process modeling and simulation. Using Sugars, a model was constructed of the Cooperative's raw cane sugar factory and then the new technology was added to the model to evaluate the operation of the new factory. The model was designed to produce both raw sugar using the traditional process and refined sugar from a portion of the clarified juice diverted to the new process. Simulations of the new factory with 21% of the clarified juice used to produce 454 tonnes (500 US tons) per day of refined sugar show an increase in process revenues that are directly related to the higher sucrose yield and the price difference between refined and raw sugars. Steam requirements for the new factory are only about 5% higher than they were before the new process was added. Other alternatives for the new process along with their simulation results are discussed in the paper.

KEYWORDS: Simulation, Modeling, Ultrafiltration, Chromatography, Recovery, Quality.

INTRODUCTION

Technological advancements are challenging the traditional sugar production process. New separation technologies using membrane ultrafiltration and chromatographic desugarization hold the promise to improve the recovery of sucrose and the quality of sugar[1]. Modeling and simulation are changing the way existing and new processes are evaluated and improved[2]. This paper shows the application of modeling and simulation using the Sugars for Windows computer program to model a new process using ultrafiltration and chromatographic separation being developed jointly by Amalgamated Research Inc. (ARi) and Sugar Cane Growers Cooperative (SCGC) of Florida for cane sugar factories to increase sucrose recovery and produce refined white sugar.

SCGC of Florida operates a cane raw sugar factory with a grinding rate of 21,780 tonnes (24,000 US tons) per day. In April of 1999, the Cooperative purchased a license to use the Sugars computer program to model their factory and make simulations of different alternatives for expansion of the factory and to evaluate a new process for producing refined sugar under development by ARi and the Cooperative. After SCGC of Florida received the program, a model was built of the existing factory. This model was completed in 1999 and results from simulations of the model showed excellent agreement with actual factory results. Next, modifications were made to the model to evaluate the expansion of the plant to a capacity of 23,600 tonnes (26,000 US tons) per day of cane and to add the new process consisting of ultrafiltration, juice softening by ion exchange, ion exclusion chromatographic separation and crystallization to produce 454 tonnes (500 US tons) per day of refined sugar. The model of the proposed new factory was completed in 2000 using data from tests performed on pilot equipment at the factory.

A model is built in Sugars by drawing the process flow diagram using stations that are selected from the available stations in the program and connecting the stations together using flow streams. Flow streams between stations, and flows that leave the model, are called *internal flows*. Flows that go into the model from outside sources (e.g., cane, steam, water, lime, etc.) are called *external flows*. All external flows must be specified before doing a balance. Internal flows are calculated by Sugars during the balance calculations. Each station in the model has a data input screen for entering properties that control the performance of the station. The SCGC of Florida model uses 10 pages containing more than 750 flows and over 400 stations.

PROCESS OVERVIEW

An overview of the processing sections of the new factory Sugars model is shown in Figure 1. Each block in the diagram represents one drawing page in the model. The existing factory consists of the Milling, Purification and Evaporation, West ‘A’ Sugar Station, East ‘A’ Sugar Station, ‘B’ & ‘C’ Sugar Boilings, and the Steam Generation/Distribution and Water Distribution pages. These pages and the Refined Sugar Production page are not shown in this paper because of space limitations. The Ultrafiltration, Juice Softening and Concentration, Chromatographic Separation & Evaporation and Refined Sugar Production pages represent the new process. The first three of these four pages are shown in subsequent sections of this paper.

A bagasse-fired boiler is used to produce 27 bar (400 psig) steam and five turbo-generators produce electricity and steam for the factory. One of the turbo-generators uses a condensing turbine. Also, not shown on this overview drawing for simplicity purposes is the distribution of condensate, city and cooling water throughout the model. The complete water balance for the factory is given by Sugars along with the heat, material and color balances.

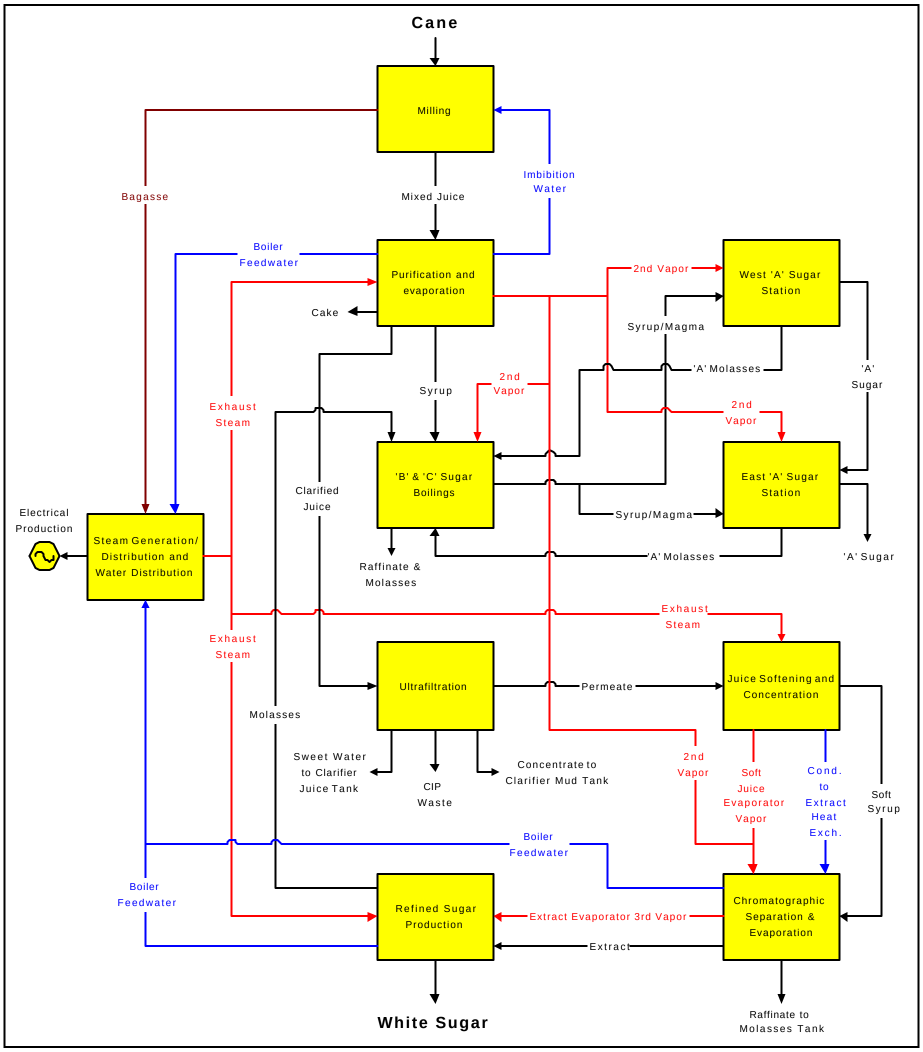

Figure 1. SCGC of Florida New Factory/Refinery Sugars Model Overview.

Exhaust steam is used for: (1) the clarified juice evaporators, (2) soft juice heat exchanger before evaporation, (3) soft juice evaporators, and (3) the refined sugar dryer. Vapor from the intermediate evaporator (2nd vapor) is used for West 'A' sugar boiling, East 'A' sugar boiling, 'B' & 'C' sugar boilings, and the raffinate evaporators in chromatographic separation. Last effect vapor from the triple effect soft juice evaporator is used for: (1) the extract evaporator and concentrator, (2) the raffinate heat exchanger before evaporation, and (3) the raffinate evaporator along with vapor from the intermediate evaporator. Last effect vapor from the triple effect extract 1 evaporator is used in refined sugar production for the white pans and the sugar melter. Total steam demand only increases by 5%, or less, for the new factory when compared to the original factory before installation of the new process.

ULTRAFILTRATION

Figure 2 shows the Ultrafiltration page of the new factory model. The model allows for clarified juice (approximately 21% of the total) going to ultrafiltration from either the clarified juice tank before evaporation, or after the clarified juice pre-evaporator. The pre-evaporator raises the concentration of the juice from a little over 13% to about 19%, which reduces the capacity requirements of ultrafiltration and juice softening by about 30%.

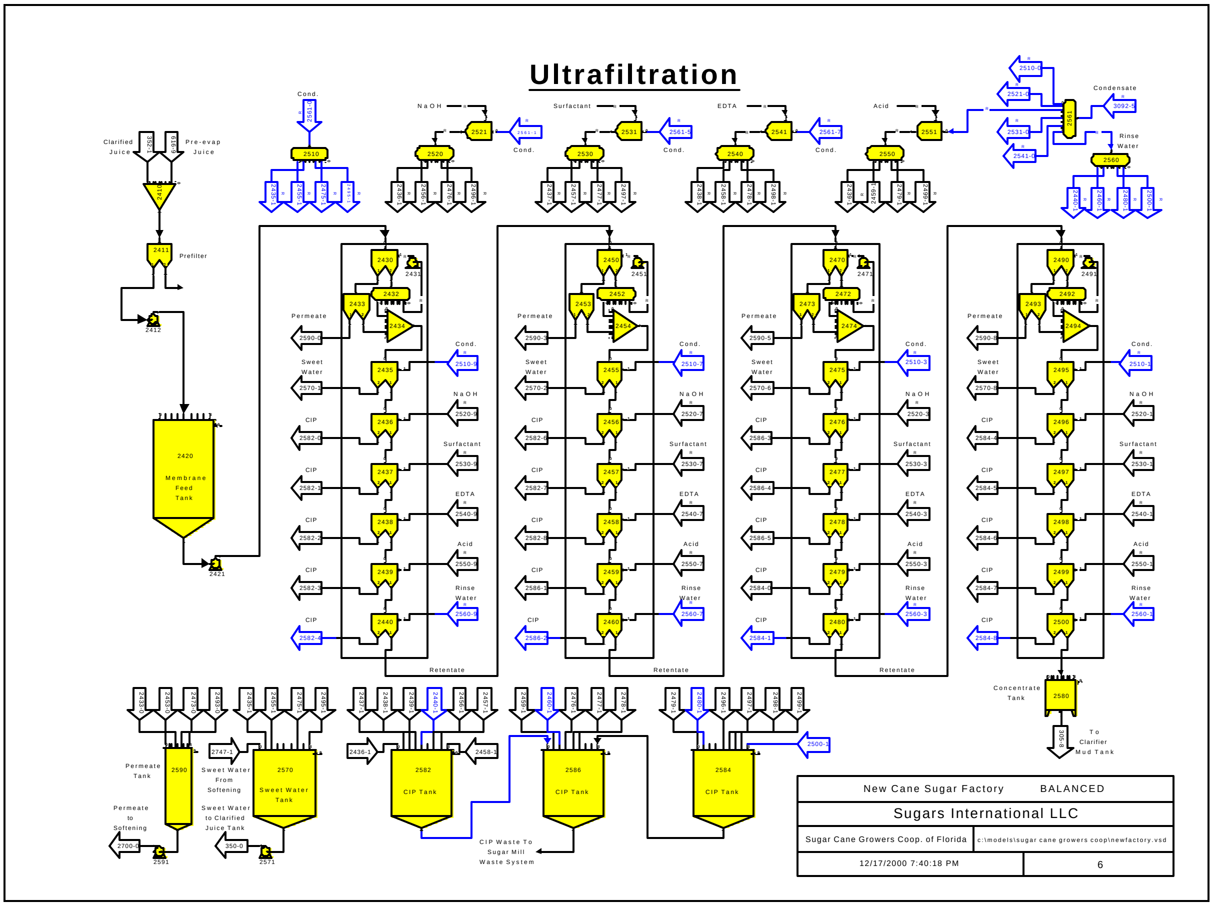

Figure 2. Ultrafiltration page of model.

Four membranes are shown. Each membrane model allows for cycling to give permeate production, rinsing with condensate to give sweet water, and then rinsing with sodium hydroxide, surfactant, EDTA (or bleach), acid and condensate with the discharge from each of these rinses going to the CIP waste tank. The CIP waste is sent to the mill waste system. The final retentate (concentrate) from the last membrane goes to a tank and from there it is sent to the clarifier mud tank for vacuum filtration with the clarifier mud before it is discharge from the factory with the filter cake.

Permeate from ultrafiltration is pumped to juice softening and concentration before it goes to chromatographic separation for desugarization.

JUICE SOFTENING AND CONCENTRATION

The Juice Softening and Concentration page is shown in Figure 3. Permeate from ultrafiltration is sent to the softening columns. The model is designed for three columns simply for illustrative purposes. Cycles are modeled for sweeten off, regeneration with sodium hydroxide, rinse and sweeten on. Sweeten off flow goes to the soft juice tank, and sweeten on flow goes to the sweet water tank on the Ultrafiltration page. Regenerate waste from softening goes into the sugar mill waste system.

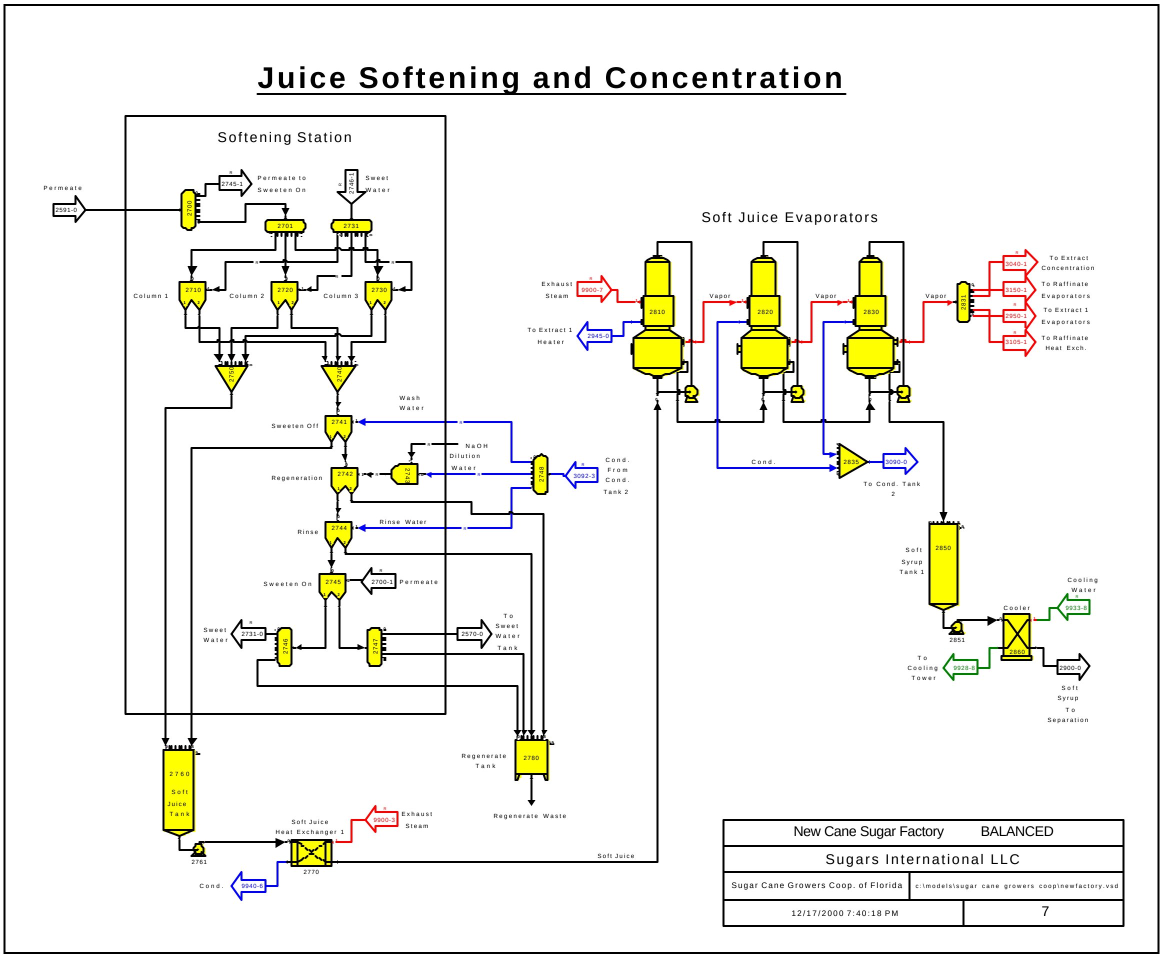

Figure 3. Juice softening and concentration page of model.

Softened juice goes into the soft juice tank and is then pumped through a heat exchanger on exhaust steam to the soft juice evaporators where the juice is concentrated to a syrup of approximately 66%DS. The syrup is then sent to a tank and pumped through a cooler to cool it to 85°C before it is sent to chromatographic separation. Cooling water for the syrup cooler is from the cooling tower water loop for the factory.

Last effect vapor from the soft juice evaporators is used to concentrate the extract and to heat and concentrate the raffinate from separation.

CHROMATOGRAPHIC SEPARATION & EVAPORATION

Chromatographic Separation and Evaporation is shown on the page given in Figure 4. Two separator systems are included in the model. Extract 1 from the first system leaves the separator at about 30%DS and 87.5 Purity. After heating in a condensate heat exchanger to about 99°C using exhaust steam condensate, extract 1 is fed to a triple effect evaporator for concentration to about 66.5%DS. The extract leaves the evaporator at 84-85°C.

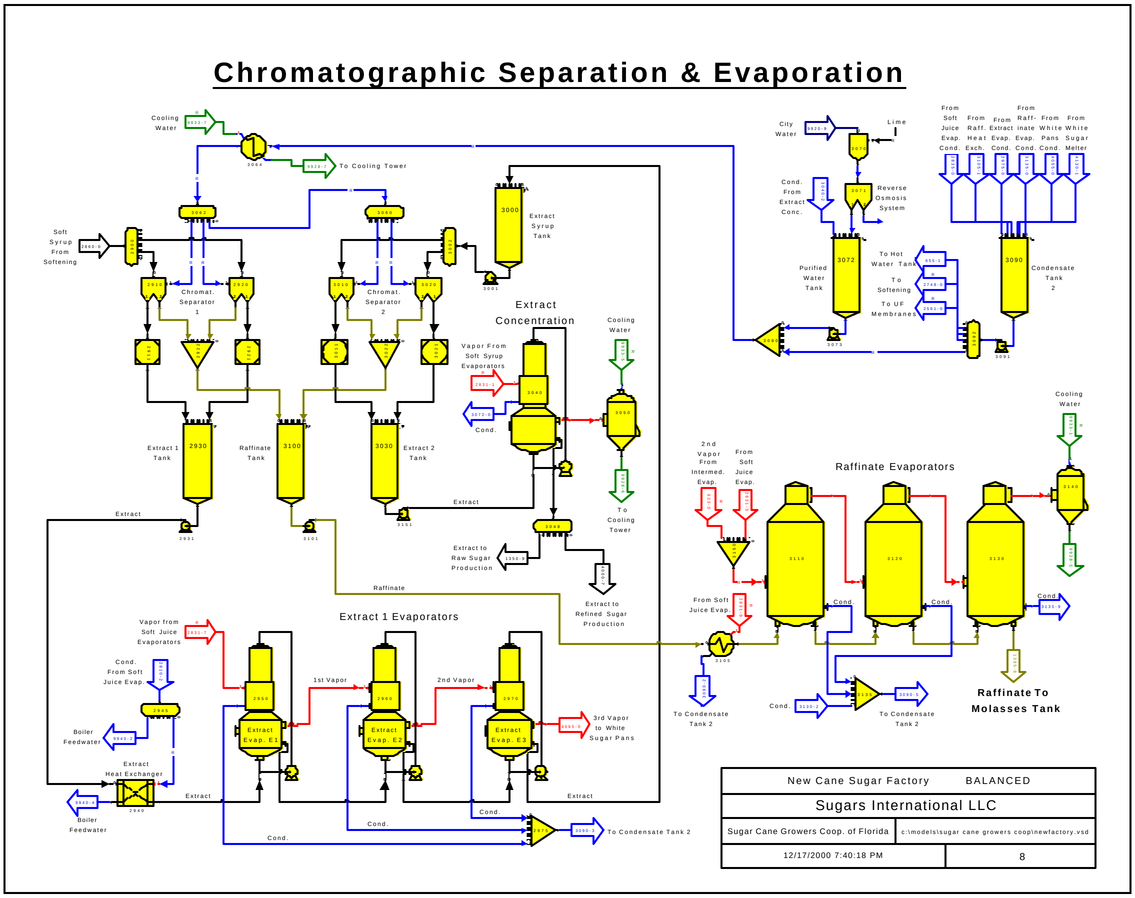

Figure 4. Chromatographic Separation & Evaporation Page of Model.

Extract 1, from the evaporator, is fed to the second separator and concentrated to 70%DS in a single effect evaporator before going to refined sugar production. Provisions are made in the model to allow for the change in solubility of the extract due to the change in melassigenic compounds from the separation. Eluant water for the separation is provided first by condensate and supplemented, if necessary, with city water after treatment with lime and reverse osmosis.

Raffinate from both separators is combined in a raffinate tank and then pumped through a heat exchanger that is heated with vapor from the soft juice evaporators. After the heat exchanger, the raffinate is concentrated in a triple effect evaporator to a concentration of 80%DS before it is sent to the molasses tank.

RESULTS

Simulations were made of the new factory model: (1) without any clarified juice going to ultrafiltration (i.e., the existing factory); (2) with 454 tonnes (500 US tons) per day of refined sugar production using clarified juice before concentration in the pre-evaporator; (3) with 454 tonnes per day of refined sugar production using clarified juice after concentration in the pre-evaporator; and, (4) with all of the extract sent back to 'B' and 'C' sugar boilings for raw sugar production. Producing 454 tonnes per day of refined sugar gives the best financial results (i.e., the largest increase in revenues). Obviously, the financial advantage depends on the difference between the price of refined sugar and raw sugar. Using 23,600 tonnes (26,000 US tons) per day as the grinding rate for the factory and with 21% of the clarified juice going to ultrafiltration to produce 454 tonnes per day of refined sugar, the financial advantage for refined sugar at the same price as raw sugar is less than US$10,000 per day. This increase is due to the additional sugar produced with the new process. Each US$0.01 (penny) increase in the selling price of refined sugar increases the financial advantage by US$10,000 per day; hence, with a US$0.06 higher selling price for refined sugar, the financial advantage is close to US$70,000 per day.

Using clarified juice after concentration to about 19%DS in the pre-evaporator, showed a problem with the heat balance for the existing design. The soft juice evaporators did not have sufficient vapor to drive the "extract 1" evaporator and condensate (exhaust steam condensate) from the first effect of the soft juice evaporator was not sufficient to heat the extract in the "extract 1" heat exchanger before evaporation. Revisions to the design were made to use intermediate evaporator vapor (2nd vapor) for the extract 1 evaporator and condensate from the pre-evaporator for heating the extract before the extract 1 evaporator. Using clarified juice after concentration gives about a 30% reduction in the size of the ultrafiltration and softening equipment; and hence, a reduction in the capital cost of this equipment. However, using this approach causes the steam consumption to increase to about 5% more than used by the original factory instead of the 3% increase that occurs when clarified juice before evaporation is used. Also, the quantity of clarified juice had to be increased slightly to 21.1% (instead of 21%) to maintain the 454 tonnes per day of refined sugar production.

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ACKNOWLEGEMENTS

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