

Refinery Simulation

Using

SUGARS™

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ABSTRACT

The SUGARS Computer Program is used to make static simulations of a model cane sugar refinery. Simulation results are shown for the refinery when normal pol (98.7) raw sugar is processed. Results from the simulation are used to evaluate the efficiency of the refinery when processing normal pol raw sugar. Next, modifications are made to the refinery model for it to process low pol (97.9) raw sugar. Simulation results are then shown for the refinery when low pol (97.9) raw sugar is processed.

A discussion is given of the changes that occur in the refinery when the two different raw sugars are processed. Total sugar production and steam and water consumption values are predicted by the simulations, and the production and consumption values are used to calculate the revenue margins for each raw sugar. Management can use the revenue margins to help make raw sugar purchasing decisions.

Examples are given of changes in the performance of some equipment in the refinery when processing normal pol sugar. The changes in equipment performance are used by SUGARS to predict their impact on the efficiency of the refinery. Also, mention is made of the use of simulation to help with Complete and Rigorous Model based Reconciliation (CRMR) for data analysis and inference of data values for flows, temperatures, pressures, and compositions that often cannot be measured.

INTRODUCTION

The SUGARS Computer Program was first used in 1985 to simulate a beet sugar factory. Copies of the program were licensed to other sugar companies beginning in 1986. The program was called PC-SUGARS at the time. The earliest versions of the program did not include integration of the evaporator balance into a model. With the release of version 2.20 on July 1, 1988, a completely integrated model of a sugar factory was possible, and the first models of complete beet sugar factories were built in July of 1988. The name of the program was simplified to SUGARS when version 2.22 was released in November of 1988. Continual improvements have added many new features to expand its versatility since then. Today, SUGARS can model cane, or beet, sugar

factories and refineries of almost any configuration. It is used by sugar companies, in thirteen (13) countries, to predict how changes in the process and/or equipment will affect the performance of their factories and refineries. The information from these predictions is used to make investment and process decisions. SUGARS has modeled thousands of process variations covering both beet and cane and its results have been verified independently by actual factory data.

This paper describes an example model of a cane sugar refinery. The model shown in this paper is only for illustration purposes. SUGARS can easily model other refineries - it is not limited to the model shown. This example merely shows how predictions from SUGARS are used to make decisions and to calculate the gain, or loss, in revenues that will result from those decisions. These predictions may not reflect those that will actually occur in a particular refinery because of the unique characteristics of each refinery and its raw sugar supply.

EXAMPLE MODEL

A model of a refinery is constructed by first drawing a flow diagram showing all of the equipment and process flow streams. The flow diagram shows all *external flows* that go into the process from outside sources (e.g., raw sugar, steam, water, etc.) and all individual *station modules* with interconnecting flows called *internal flows*. Individual station modules used in the diagram are selected from different station types available in SUGARS, and they are used to simulate actual stations in the refinery being modeled. SUGARS is completely flexible in the type of refinery that it can analyze because the station modules can be arranged in any order. Sometimes, SUGARS station modules are combined to simulate actual stations used in the refinery.

Figure 1 shows the flow diagram of an example cane sugar refinery. Numbers on the process stations refer to station numbers used by SUGARS. Not all of the flow streams in the refinery are shown on this diagram for the sake of clarity; for example, steam flows to each pan from the steam distributors nos. 1200 and 1201 and condensate flows to condensate receivers nos. 890 and 690. However, these flow streams are included in the SUGARS model. Stations on the diagram with more

than one number are cases where more than one SUGARS station module is used to model the actual station in the refinery.

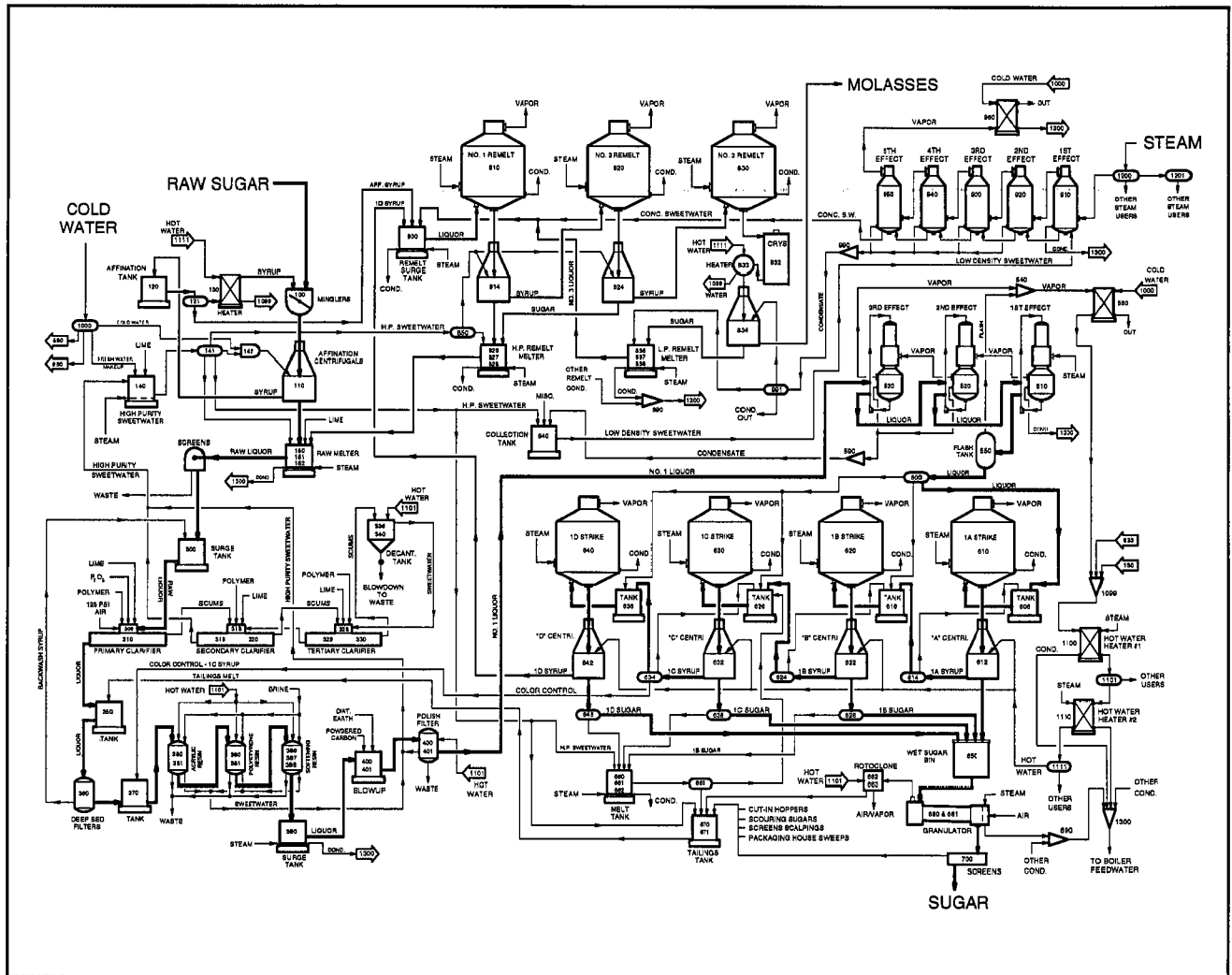


Figure 1. Cane sugar refinery example model flow diagram.

As shown in Figure 1, there are external flows for raw sugar, steam, cold water (all shown in large type as flows into the process) and lime. Other external flows such as polymer, air, brine, diatomaceous earth and phosphoric acid are not considered in the model because of their very small effect on the material and heat balance. All other flows are internal flows that go from station-to-station, or leave the flow diagram (e.g., vapors, condensates, molasses and sugar). Each block with a station number is a station module from SUGARS that has been assigned a specific purpose. For example: station no. 610 is a pan

module used to process liquor into 1A massecuite; station no. 1000 is a distributor module used to split a flow stream into two, or more, output flows (four output flows in this case); station no. 1099 is a receiver module used to combine several input flows (three in this case) into one output flow.

The example refinery model, shown in Figure 1, starts with raw sugar going to the minglers (station no. 100) and then to affination centrifugals (station no. 110) that use wash provided by high purity sweetwater and cold makeup water (station nos. 140, 141 and 142). Clarification of the raw liquor to remove color and turbidity after screening is done by flotation clarification using phosphoric acid (station nos. 309 through 340). The clear effluent goes to deep bed filters (station no. 360), and the scum is desweetened by a countercurrent desweetening operation (secondary, tertiary and decanting). Lime is used to maintain the proper pH (pH control is not considered in SUGARS; however, lime is considered in the model). After the deep bed filters, the liquor is sent to ion exchange for further color removal (station nos. 380 and 381) and ash removal in the softening resin (station nos. 386, 387 and 388). Liquor from ion exchange goes to the blowup tank where powdered carbon and diatomaceous earth are added before the polish filter (station nos. 400 and 401). Powdered carbon and diatomaceous earth are not considered by SUGARS; however, sweetwater from the polish filter is considered along with sweetwater from ion exchange and clarification. The final filtered no. 1 liquor is sent to a triple effect countercurrent falling film evaporation station (station nos. 510, 520 and 530) for concentration to 73% dry substance. No. 1 liquor is flashed in a flash tank (station no. 550) to cool it to about 80°C after it leaves the three effect evaporator station. The flash tank further concentrates the liquor to about 75% dry substance. Vapors from the evaporator and flash tank are condensed by heating cold water (station no. 580) which is used for centrifugal wash water, sugar dryer rotoclone, and boiler feedwater after going through hot water heaters (station nos. 1100 and 1110). A four strike boiling arrangement (station nos. 606 through 648) is used to produce refined sugar. Provisions are made in the model to allow for in boiling, backboiling and remelting of off-specification sugar (see melt tank station nos. 660, 661 and 662) and tailings recover (station nos. 670 and 671). Wet sugar from the wet sugar bin (station no. 650) is dried and cooled in the granulator (station nos. 680 and 681), screened (station no. 700) and sent out of the model. Scalping screen losses of 2.5% and sugar losses in the granulators, that are recovered in the rotoclone (station nos. 682 and 683), are considered in the model. 1D syrup from the 1D centrifugal

(station no. 642) is sent to the remelt surge tank (station no. 800) for further sugar extraction in the remelt pans. Also, affination syrup from affination and concentrated sweetwater from the sweetwater evaporators (station nos. 910 through 950) are sent to the remelt surge tank. The remelt section consists of three pans (station nos. 810, 820 and 830) and centrifugals (station nos. 814, 824 and 834). Massecuite from the no. 3 remelt pan (station no. 830) is sent to a vertical crystallizer (station no. 832) for cooling and additional crystal growth. Then it is heated in a massecuite heater (station no. 833) using hot water to reduce the viscosity of the massecuite before it is spun in the no. 3 remelt centrifugal (station no. 834). Hot water for the massecuite heater is in a closed loop that goes through the massecuite heater and hot water heaters #1 (station no. 1100) and #2 (station no. 1110). Condensate from the triple effect no. 1 liquor evaporator is combined with excess high purity sweetwater (that isn't used in affination, remelt centrifugal wash, and the melt and tailings tanks) and concentrated in a five effect evaporator station (station nos. 910 through 950). Fifth vapor from the sweetwater evaporators is used to preheat cold water in a heater station (no. 960) as additional boiler feedwater to make up for steam lost in the process. The concentrated sweetwater is sent to the remelt surge tank (station no. 800). Low pressure steam is provided to all steam users (evaporators, pans, heaters and tanks) by two steam distributor stations (nos. 1200 and 1201). All condensates from steam users are collected in receiver stations and combined in a condensate receiver (station no. 1300) for boiler feedwater. Output flows from the process consist of white sugar, molasses, condensate, vapors and various waste streams.

After the flow diagram is completed, the SUGARS model is constructed and all of the data for each external flow and the performance of each station is entered using entry screens in SUGARS. The complete SUGARS model for this refinery process consists of 232 internal flow streams, 14 external flow streams into the process and 107 stations. SUGARS can handle up to 500 internal flow streams, 50 external flow streams and 400 stations (limitations only because of DOS's maximum of 640kb RAM).

The external flows data entry screen for normal pol raw sugar is shown in Figure 2. Fields shown in light gray are entry fields for defining the characteristics of raw sugar into the model. Two non-sucrose liquid components are shown: N.S. #1 and N.S. #2. N.S. #1 is for all miscellaneous non-sucrose components and N.S. #2 is for ash. Raw sugar color is 3,500 IU and the cost (value) is \$0.4850 per

kilogram (\$0.22 per pound). Similar entries are made for steam, cold water and lime.

```

Esc=Cancel F1=Help F3=Liquid %DS & Purity          F10=Accept
-----
EXTERNAL INPUT FLOW
"FLOWIN" File: FLOWIN.RFN      Flow Stream No.: 1      Flow Type: 0
Flow Stream Name: RAW SUGAR-Normal Pol Goes To Station No.: 100
-----
Pressure (kPa): 101.4      Temp. (°C): 15.0      Flow (kgs/hr): 75,000.0
FLOW STREAM SUMMARY
-----
Tons/hr | %TDM | %Sugar | %DS | Purity | %Crys. | %ISMS | %Gas
75.00 | 99.73 | 98.70 | 99.73 | 98.97 | 98.00 | 0.00 | 0.00
-----
FLOW STREAM COMPONENT FRACTIONS (%)
-----
Liquid                               Solid                               Gas
(1) Water = 0.27      (5) Sacr. Crystals = 98.00      (9) Steam = 0.00
(2) Sucrose = 0.70   (6) Lime rki(CaCO3) = 0.00     (10) CO2 = 0.00
(3) N.S. #1 = 0.72   (7) Lime (CaO) = 0.00         (11) NH3 = 0.00
(4) N.S. #2 = 0.31   (8) Other = 0.00
-----
COLOR: 3.500      SOLUBILITY COEFFICIENTS: a: 0.0375 b: 0.7070 c: 2.050      VALUE: 0.4550
-----
29.04.94      CANE SUGAR REFINERY (1000 TPD) - NORMAL POL      SI units
Enter name of flow stream.
  
```

Figure 2. Raw sugar external flow input screen.

Performance data for each station in the model is entered along with the characteristics of each external flow. Figure 3 shows the input data screen for blender station no. 100 (mingler in model). Affination syrup is blended with raw sugar until the magma has 92% dry substance (8% water - component no. 1).

```

Esc=Cancel F1=Help          F8=Name F9=Units F10=Accept
-----
BLENDER INPUT PARAMETERS
-----
Ratio flow
-----
Ratio to Comp. # [ 1 ]
-----
Blend Quantity [ 0 ] kgs/hr
-----
Blend to specified value
-----
Value to Comp. # [ 92 ]
Total Purity [ 0 ]
-----
Non-sugar/water Ratio [ 0 ]
Temperature Deg. C [ 0 ]
-----
Blend flow comes from Station number: [ 100 ]
-----
27.04.94 | Station no.: 100 | MINGLERS | STATIONS.RFN | SI units
Enter output flow value (total, or %) to be held by blend flow
  
```

Figure 3. Blender station (mingler) input parameters screen.

SUGARS shows each station in the model and the input and output flows for the station with flow stream information. Figure 4 below shows the 1C Strike pan as an example. You can move to any station in the model to see all input and output flows for that station. Performance parameters for the

station, such as those shown in Figure 3 for the blender (mingler) station, can be reviewed by simply double clicking on the station number with the left mouse button, or by pressing the enter key. After the model is balanced by SUGARS, the details of any flow stream into, or out of a station, are displayed by

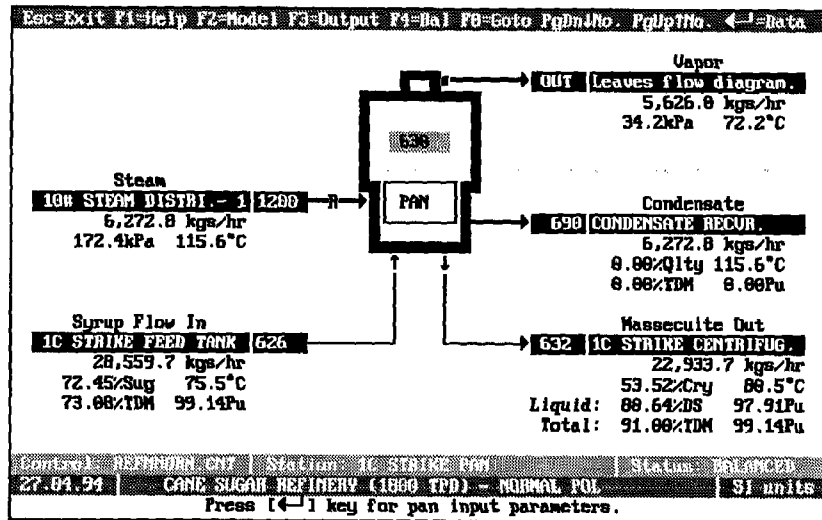


Figure 4. 1C Strike pan with input and output flows.

double clicking the left mouse button on the flow stream. Figure 5 below shows the details of the maseccuite leaving the 1C strike pan. All external and internal flow streams in a flow diagram carry

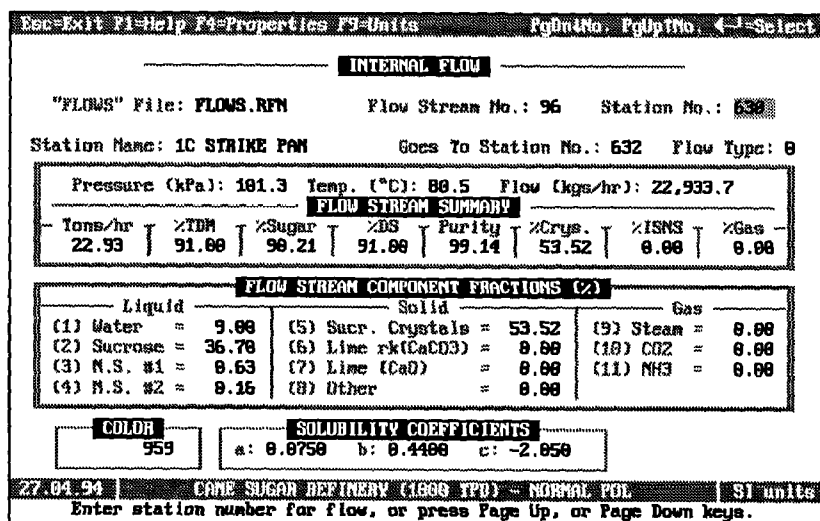


Figure 5. Details of maseccuite flow from 1C strike pan.

values for pressure, temperature, weight flow, eleven (11) flow components, color and three (3) coefficients for the solubility coefficient equation. The eleven (11) flow stream components consist of

four liquid components (water, sucrose and two non-sugars), four solid components (sucrose crystals, CaCO₃, CaO and other) and three gas components (water vapor, CO₂ and NH₃). All of this data, for each flow stream, is shown on the details screen as illustrated by Figure 5. Also, a value can be entered for the cost, or value, of all external input flows and each internal flow that leaves the model.

Other properties of every flow stream are available by selecting "F4=Properties" from the details screen (see Figure 5). Figure 6 shows the properties of the 1C strike pan massecuite. Properties displayed are volume flow, specific weight, enthalpy, specific heat capacity, supersaturation and boiling point elevation. The characteristics of all internal flows are calculated by SUGARS using the data entered for

INTERNAL FLOW									
"FLOWS" File: FLOWS.RFN		Flow Stream No.: 96		Station No.: 632					
Station Name: 1C STRIKE PAN				Goes To Station No.: 632		Flow Type: 0			
Pressure (kPa): 181.3		Temp. (°C): 88.5		Flow (kgs/hr): 22,933.7					
FLOW STREAM SUMMARY									
Tons/hr	%TDM	%Sugar	%BS	Purity	%Crys.	%ISMS	%Gas		
22.93	91.88	98.21	91.88	99.14	53.52	8.88	8.88		
FLOW STREAM PROPERTIES									
Property	Total	Liquid	Gas						
Volume flow (m3/hr)	15.51	7.72							
Specific weight (kgs/m3)	1,478.39	1,388.18							
Enthalpy (kJ/kg)	146.35	193.84							
Specific heat (kJ/kg/°K)	2.848	2.643							
Supersaturation (Van Hook)	1.288	1.288							
Boiling point elevation (C)	18.8	18.8							
27.04.94 CANE SUGAR REFINERY (1880 TPD) - NORMAL POL ST units									
Enter a station number for flow, or press Page Up, or Page Down keys.									

Figure 6. Properties of 1C strike pan massecuite.

each external input flow and the performance parameters for each station module. Hence, changing the data for any external flow, or the performance of any station module will result in new balance results for the refinery. Also, changing the routing of any flow stream will give new balance results.

Results from the balance calculations can be displayed on the monitor, or printed out. In addition, a net process revenues screen can be displayed showing the cost of all external input flows and the revenues that can be realized from the output flows. Figure 7 shows the screen giving the net process revenues for the example model refinery processing normal pol raw sugar. Flows out of the model with a negative

value are flows, such as waste streams, that have a cost associated with their disposal. Values and costs can be expressed in any currency units. Using the revenues screen in SUGARS, it isn't necessary to

PROCESS NET REVENUES				
Revenue From Process Flows out of Model				
Station #	Name	Flow (kgs/hr)	Value	Revenues/hr
700	SUGAR SCREENS	73,151.0	0.5512 =	40,310
834	#3 REVELT CENTRI.	2,099.7	0.0717 =	150
340	DECANTING TANK	12,320.3	-0.0110 =	-23
	Other Output Flows:	431,967.5	-0.0006 =	-242
Total Process Revenues per hour =				40,203
Cost of External Flows Into Process				
Goes To	Description	Flow (kgs/hr)	Cost	Costs/hr
100	RAW SUGAR	75,000.0	0.4850 =	36,376
1200	STEAM	60,426.0	0.0077 =	520
1000	COLD WATER	139,592.0	0.0002 =	31
	Other Input Flows:	191.4	0.1000 =	19
Total Process Costs per hour =				36,954
Net Revenues From Process:		3,249 per hour	77,968 per day	
Press [Alt-H]=help, or any key to continue.				

Figure 7. Net process revenues with normal pol raw sugars.

review individual flow stream quantities to determine the advantages of different process alternatives. However, SUGARS provides full detailed printouts for all flow streams in a model.

SUCROSE SOLUBILITY

Solubility of sucrose in every process flow stream is calculated by SUGARS using the Vavrincz Solubility Function and the Vavrincz Equation for pure sucrose in water as a function of temperature. The Vavrincz Solubility Function is:

$$S_c = a \cdot NSW + b + (1-b) \cdot e^{c \cdot NSW}$$

Where: S_c = sucrose solubility coefficient
 NSW = non-sucrose to water ratio
 e = Log base 2.71828...

The sucrose solubility coefficient (S_c) is used to modify the solubility of pure sucrose in water to account

for impurities in a flow stream¹. Laboratory analysis is used to determine the 'a', 'b' and 'c' coefficients that account for melassigenic substances in the raw sugar. Cane sugar solubility is dependent on reducing sugars and ash in addition to other impurities². To consider the influence of reducing sugars (RS) and ash, the 'a' and 'b' coefficients are modified as follows:

$$a = B_2 \cdot (RS/Ash)$$

and,

$$b = B_0 + B_1 \cdot (RS/Ash)$$

The value of 'c' for different raw sugars can be determined using an exponential curve fit to the line given by the 'a' and 'b' values. Values for B_0 , B_1 and B_2 are determined by laboratory analysis. Figure 8 shows a comparison of solubility coefficient curves between normal pol raw cane juice at

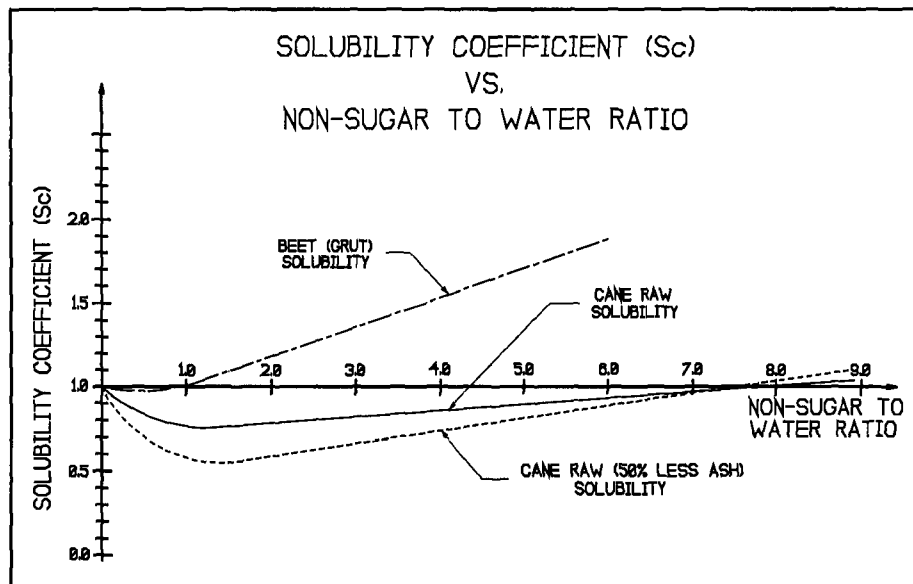


Figure 8. Solubility coefficient curves for beet and cane juice.

full and 50% ash (0.29% reducing sugars) and beet juice with Grut solubility. The large difference in solubility coefficient between cane and beet is the reason crystallizers are more effective in cane factories than in beet factories. Most of the ash removal occurs during purification (clarification and ion

exchange), and the reducing sugar-to-ash ratio stays relative constant during boiling; hence, 'a', 'b' and 'c' values will remain constant during crystallization. SUGARS uses the 'a', 'b' and 'c' coefficients to determine the solubility in all flow streams. During affination, coefficients for full ash are used, and after purification, coefficients for 50% ash are used. The coefficients are set to new values in a reactor station module (station no. 388) following the softening resins. Figure 9 shows the reactor station

REACTOR INPUT PARAMETERS

Reactants	INPUT FLOW		OUTPUT FLOW		% Reaction Efficiency	Solubility Coefficients
	Comp. No.	Mole (%)	Comp. No.	Mole (%)		
1st						a = 0.0750
2nd						b = 0.4400
3rd						c = 2.850

Heat of Reaction
kJ/kg

Color Out

Input flow components react together to produce new output flow components.

01.05.94 Station no.: 388 SOLUBILITY CONTROL STATIONS: RPN SI units
Enter value for 'a' coefficient of sucrose solubility equation

Figure 9. Reactor to set solubility coefficients for 50% less ash.

performance parameters where solubility coefficients are set for 50% less ash following softening of normal pol raw sugar. Also, if desired, pan station modules in SUGARS can be used to set the solubility coefficients for crystal content calculations of massecuites leaving pans.

LOW POL RAW SUGAR

The refinery model can be changed to predict operation of the refinery using low pol raw sugar by simply changing the characteristics of the raw sugar into the refinery and changing the solubility following purification due to ash removal. Figure 2 shows the characteristics of normal pol raw sugar into the refinery, and Figure 9 shows the new solubility coefficients that are entered into the reactor station module following the softening resin. Changing the input data on these two screens, as shown in figures 2 and 9, is all that is required to change the refinery from processing normal pol

to low pol raw sugar. Figure 10, below, shows the new entries for low pol raw sugar (reducing sugars for low pol sugar are 0.76%). With low pol sugar, the color increases to 6,000 IU whereas normal pol sugar had a color of 3,500 IU.

```

Esc=Cancel F1=Help F3=Liquid ZDS & Purity F10=Accept
-----
EXTERNAL INPUT FLOW
-----
"FLOWIN" File: FLOWIN.RFL Flow Stream No.: 1 Flow Type: 0
Flow Stream Name: RAW SUGAR - Low Pol Goes To Station No.: 100
Pressure (kPa): 101.3 Temp. (°C): 25.0 Flow (kg/hr): 75000.0
FLOW STREAM SUMMARY
-----
Tons/hr | %TDM | %Sugar | %DS | Purity | %Crys. | %IMS | %Gas
75.00 | 99.67 | 97.90 | 99.67 | 98.22 | 96.00 | 0.00 | 0.00
-----
FLOW STREAM COMPONENT FRACTIONS (%)
-----
Liquid Solid Gas
(1) Water = 0.33 (5) Sacc. Crystals = 96.00 (9) Steam = 0.00
(2) Sucrose = 1.90 (6) Lime rk(CaCO3) = 0.00 (10) CO2 = 0.00
(3) N.S. #1 = 1.10 (7) Lime (CaO) = 0.00 (11) NH3 = 0.00
(4) N.S. #2 = 0.59 (8) Other = 0.00
-----
COLOR SOLUBILITY COEFFICIENTS VALUE
0.000 a: 0.0000 b: 0.5000 c: -1.500 0.4050
01.05.94 CANE SUGAR REFINERY (1000 TPD) - LOW POL SI units
Enter flow rate of external flow (max. = 9,000,000)
  
```

Figure 10. Low pol raw sugar entry.

Entries are made in the reactor station module (station no. 388) for the solubility of sucrose after softening. Figure 11 shows the entries in reactor station no. 388 for 50% less ash with low pol sugar.

```

Esc=Cancel F1=Help FB=Name F9=Units F10=Accept
-----
REACTOR INPUT PARAMETERS
-----
INPUT FLOW OUTPUT FLOW % Reaction Solubility
Efficiency Coefficients
-----
Reac- Comp. Mole Comp. Mole % Reaction Solubility
tants No. (%) No. (%) Efficiency Coefficients
-----
1st [ ] [ ] [ ] [ ] [ ] a = 0.1600
2nd [ ] [ ] [ ] [ ] [ ] b = -0.1700
3rd [ ] [ ] [ ] [ ] [ ] c = -1.600
-----
Heat of Reaction
kJ/kg
Color Out
-----
Input flow components react together to produce new output flow components.
01.05.94 Station no. 388 SOLUBILITY CONTROL STATIONS.RFL SI units
Enter value for 'a' coefficient of sucrose solubility equation
  
```

Figure 11. Low pol raw sugar solubility coefficients at 50% less ash.

Keeping all other conditions the same (i.e., all other external flows with the same characteristics and all

other station modules with the same performance parameters), the massecuite leaving the 1C pan (station no. 630) is shown in Figure 12. Comparing the crystal content of 1C strike massecuite for low pol sugar

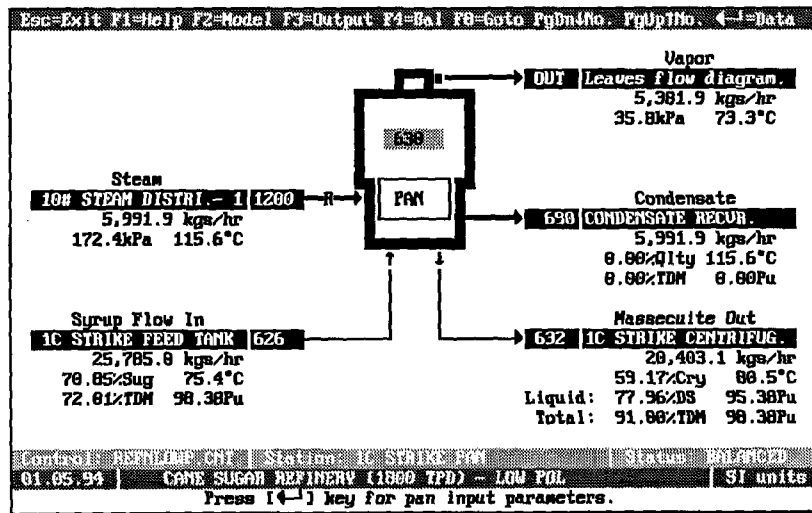


Figure 12. 1C strike pan input and output flows with low pol raw.

with the crystal content for normal pol sugar shows that the low pol sugar gives a higher crystal content in the massecuite. This occurs because the non-sucrose components in low pol sugar give a lower sucrose solubility than for normal pol (for the raw sugars being used in this example).

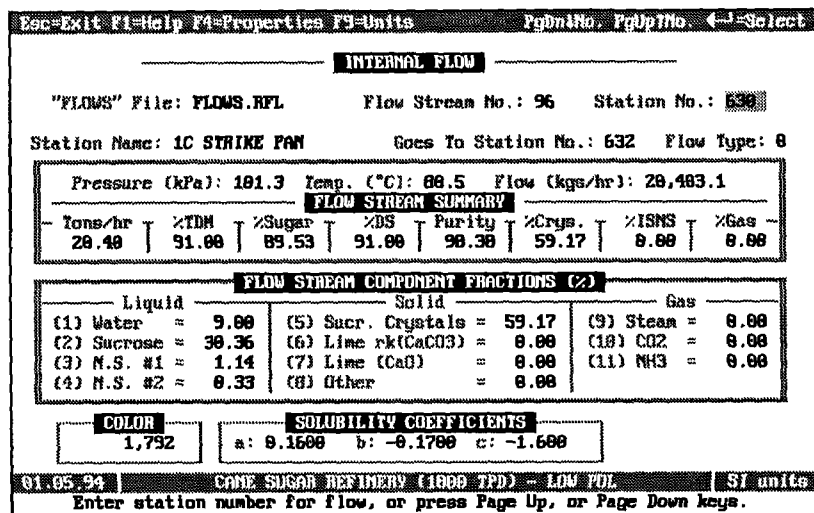


Figure 13. 1C strike massecuite details.

Further details about the massecuite are shown in Figure 13 which shows the increase in color that occurs with low pol when compared to normal pol raw sugar. Net process revenues for the refinery with

low pol sugar are shown in Figure 14. The net process revenues are less with low pol when compared to normal pol; however, figure 14 shows the net process revenues with the cost of low pol raw the same

elp		PROCESS NET REVENUES				continue
Revenue From Process Flows out of Model						
Station #	Name	Flow (kgs/hr)	Value		Revenues/hr	
700	SUGAR SCREENS	72,572.1	0.5512 =		39,999	
034	#3 REMELT CENTRI.	2,569.8	0.0717 =		184	
340	DECANTING TANK	12,372.8	-0.0110 =		-28	
	Other Output Flows:	420,695.8	-0.0006 =		-235	
Total Process Revenues per hour =					39,919	
Cost of External Flows Into Process						
Goes To	Description	Flow (kgs/hr)	Cost		Costs/hr	
100	RAW SUGAR - low Pol	75,000.0	0.4850 =		36,375	
1200	STEAM	66,136.3	0.0077 =		510	
1000	COLD WATER	137,062.5	0.0002 =		30	
	Other Input Flows:	309.6	0.1000 =		31	
Total Process Costs per hour =					36,946	
Net Revenues From Process: 2,973 per hour , 71,342 per day						
Press [Alt-H]=help, or any key to continue.						

Figure 14. Net process revenues with low pol sugar.

as normal pol raw. Figure 15 shows the net process revenues for low pol with the cost of raw at a slightly reduce price of \$0.480 per kilogram (\$0.2177 per pound). Reducing the price of low pol gives an increase of \$2,374 in daily net process revenues when compared to normal pol raw sugar. Also,

help		PROCESS NET REVENUES				continue
Revenue From Process Flows out of Model						
Station #	Name	Flow (kgs/hr)	Value		Revenues/hr	
700	SUGAR SCREENS	72,572.1	0.5512 =		39,999	
034	#3 REMELT CENTRI.	2,569.8	0.0717 =		184	
340	DECANTING TANK	12,372.8	-0.0110 =		-28	
	Other Output Flows:	420,695.8	-0.0006 =		-235	
Total Process Revenues per hour =					39,919	
Cost of External Flows Into Process						
Goes To	Description	Flow (kgs/hr)	Cost		Costs/hr	
100	RAW SUGAR - low Pol	75,000.0	0.4800 =		36,000	
1200	STEAM	66,136.3	0.0077 =		510	
1000	COLD WATER	137,062.5	0.0002 =		30	
	Other Input Flows:	309.6	0.1000 =		31	
Total Process Costs per hour =					36,572	
Net Revenues From Process: 3,346 per hour , 80,342 per day						
Press [Alt-H]=help, or any key to continue.						

Figure 15. Net process revenues at \$0.48 per kilogram.

processing low pol requires about 3.3% less steam than normal pol raw sugar because of the higher crystallization that occurs with the low pol raws used for this example. Maseccuite supersaturation and

temperature for all pans were maintained at the same values for low pol and normal pol. In actual practice, these values could change somewhat because of the higher invert in the low pol sugar. This would have an effect on the crystallization and steam consumption for each pan. Higher invert reduces the solubility of the sucrose (hence, assisting crystallization), but also reduces crystallization during a given boiling time³. This can be reflected in the SUGARS model by changing the supersaturation of the massecuite leaving a pan.

Cold water consumption is also slightly less with low pol because of lower centrifugal wash and ion exchange (clarified liquor flow is lower) water needs. However, the color of no. 1 liquor (350 IU for low pol and 206 IU for normal pol) is almost 70% higher for low pol raw and additional color removal may be required to produce satisfactory sugar. Additional color removal can be simulated by adjusting the performance parameters for ion exchange (station nos. 380 and 381 - SUGARS separator station modules) which were set to 60% removal of removable color and/or in clarification which were set for 25% removal of removable color in the example model for both low pol and normal pol raws. Removable color is the color that can be taken out of a flow stream; that is, the color of pure sucrose in pure water can't be removed from a flow stream without removing the sucrose. The color of pure sucrose in pure water can be set in SUGARS. Normally, this color is less than 10 IU.

No change in invert was considered in this example model; however, inversion could be considered by adjusting the solubility coefficients and even transferring material from sucrose to non-sucrose component fractions to allow for the inversion of sucrose in appropriate stations.

STATION PERFORMANCE

The performance of individual stations in the model will affect the overall efficiency of the refinery. Questions about the impact of a change in performance of a station can be evaluated easily by entering the new performance value for the station and then rebalancing the model. For example, what will be the effect on the refinery from lowering pan dropping temperatures of the 1A through 1D strikes when processing normal pol raw sugar? Figure 16 shows the initial performance entries for

the 1A strike pan station. The output temperature is 80.5°C for massecuite leaving the pan. This performance parameter is changed to 75°C, along with the massecuite output temperatures for the

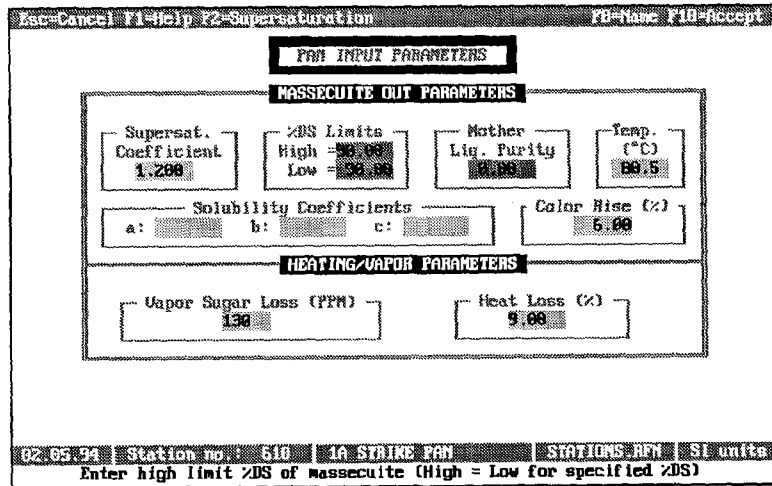


Figure 16. 1A strike pan performance parameters.

other three strikes (no other parameters are changed), and the model is rebalanced. Figure 17 shows the new input and output flows for the 1C strike pan. Comparing it with Figure 4 shows the change in

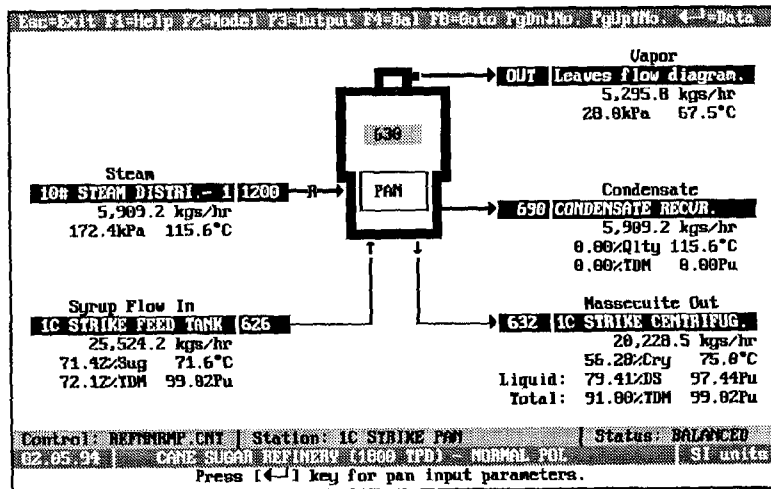


Figure 17. 1C strike pan input and output flows.

massecuite output temperature to 75°C, increase in crystallization and reduction in steam consumption for the 1C strike pan. Also, the quantity, sugar content and temperature of syrup into the pan are all reduced. Figure 18 shows the change in net process revenues due to the lower pan output temperatures.

Comparing Figure 18 with Figure 7 (normal pol raw sugar with original 1A through 1D massecuite temperatures) shows an increase in net process revenues of \$817 (= 78,785 minus 77,968) per day.

Station #		Revenue From Process Flows out of Model	Flow (kgs/hr)	Value	Revenues/hr
700	SUGAR SCREENS		73,194.6	0.5512 =	40,342
834	#3 REHEAT CENTRI.		2,028.7	0.0717 =	145
340	DECANTING TANK		12,319.7	-0.0110 =	-22
Other Output Flows:			425,259.2	-0.0006 =	-239
Total Process Revenues per hour =					40,225

Goes To		Cost of External Flows Into Process	Flow (kgs/hr)	Cost	Costs/hr
100	RAW SUGAR		75,000.0	0.4850 =	36,376
1200	STEAM		66,968.5	0.0077 =	517
1000	COLD WATER		138,392.0	0.0002 =	31
Other Input Flows:			191.1	0.1000 =	19
Total Process Costs per hour =					36,943

Net Revenue from Process:	3,283 per hour	78,785 per day
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Press [Alt-H]=help, or any key to continue.

Figure 18. Net process revenues at reduced pan temperatures.

These additional revenues are due to a slight increase in sugar production less a decrease in molasses production and more than 1.45 metric tons per hour of steam savings.

Similar evaluations can be made for other equipment in the refinery model, or for changes in the routing of process flow streams. For example, centrifugal performance, backboiling, in boiling, seed magma, and many other possibilities can all be quickly evaluate using SUGARS. Also, the influence of different process parameters on the efficiency of the refinery can be simulated and the results from simulation used to help prioritize investments for improving the process.

DATA RECONCILIATION

Modeling provides details about flow streams that many times are difficult to measure. Using measured values for points in the process where accurate measurements are possible, modeling can provide pressures, temperatures, quantities and compositions for other points in the process that can't be measured. In addition, the results from modeling can be used as a cross check on the accuracy of

measured values. The analysis and comparison of measured data with modeling results leads to Complete and Rigorous Model based Reconciliation (CRMR)⁴ for improving data and providing additional details about chemical processes. CRMR for refineries involves using material, energy and color balances along with equipment capacities, chemical equilibriums and phase changes to develop reference points for data measurements. Measured data becomes suspect when it isn't consistent with other data that correlates with the results from modeling. The suspect data can be further investigated as to the cause which may be from instrument calibration errors, or other process changes that haven't been considered.

SUMMARY

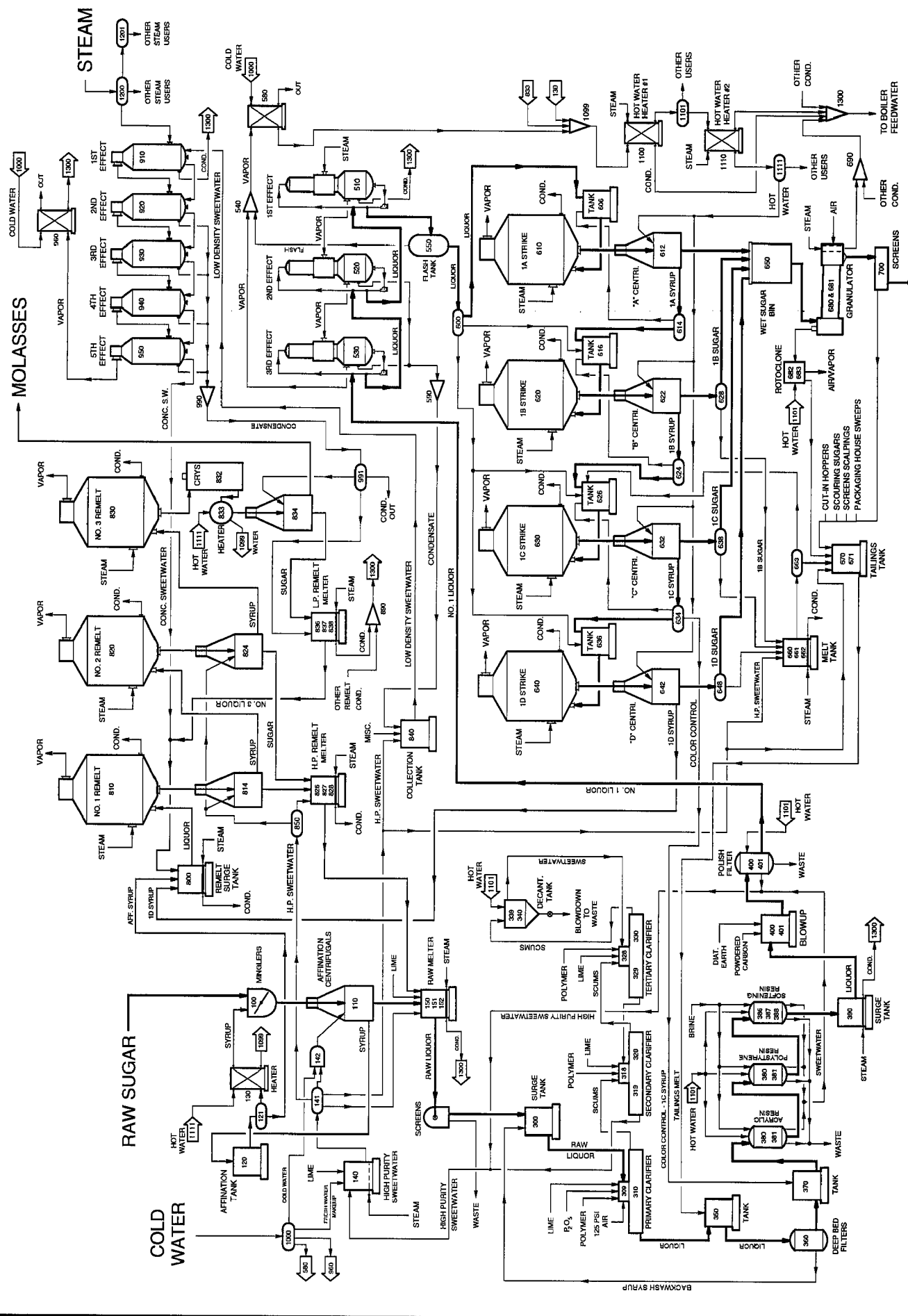
Computer modeling of sugar refining processes using SUGARS enables companies to increase their net process revenues by increasing the efficiency of their refinery. Examples are shown of a refinery model processing normal pol (98.7) and low pol (97.9) raw sugar. Net process revenues are given for both examples and the changes that occur in the refinery when switching from normal pol to low pol raw are discussed. The low pol raw sugar has different impurities (more invert sugar) when compared to normal pol raw; and as such, its solubility coefficient is lower for the same non-sucrose to water ratio. This results in higher massecuite crystal contents and reduced steam consumption for processing low pol in comparison to normal pol raw sugar; however, color of flow streams in the refinery are higher with the low pol raws and may require process changes to produce satisfactory white sugar.

An example is shown of the benefit of reducing pan temperatures (i.e., temperature of massecuite leaving the pan) and the net process revenues that can be obtained if the same supersaturation can be maintained for the discharged massecuite. Reducing the pan discharge temperature results in additional sugar production, a decrease in molasses production and a decrease in steam consumption.

Also, a discussion is given of the use of modeling for data reconciliation and inference of other process variables that may not be measurable.

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SUGAR

MOLASSES

STEAM

RAW SUGAR

COLD WATER

BACKWASH SYRUP