Cane Factory Process Modeling using Sugars™ for Windows®

L. Warner Weiss
Sugars International LLC
30 Glenmoor Drive
Englewood, Colorado 80110 USA
Phone: (303) 761-8442
Fax: (303) 761-8048
Email: sugars@sugarsintl.com
Web Site: www.sugarsintl.com/sugars

ABSTRACT

The Sugars™ computer program is used extensively for sugar process modeling and simulation to make improvements to existing factories, or design new factories. The new Windows® version of Sugars features a full graphical interface that uses drag-and-drop techniques to draw the flow diagram and build a model of the process. It is fast, flexible and very user-friendly. Stencils containing shapes of stations are provided with the program and these shapes are used to draw the flow diagram. Connections are made between shapes using a connector tool with automatic line routing and crossovers. Data for each station and flow stream in the model is entered on dialog screens that are displayed by double clicking on the station shape, or flow stream. All of the data for a model is stored in a Microsoft® Access database that can be addressed by other programs. Heat, material and color balances are quickly obtained from simulations of the model to predict the performance results for the process. A revenue screen shows the net process revenues generated by the process to assist with financial decisions. The new Sugars for Windows computer program is a major upgrade to assist cane sugar factory and refinery process engineers and management with decisions for making improvements to their operations.
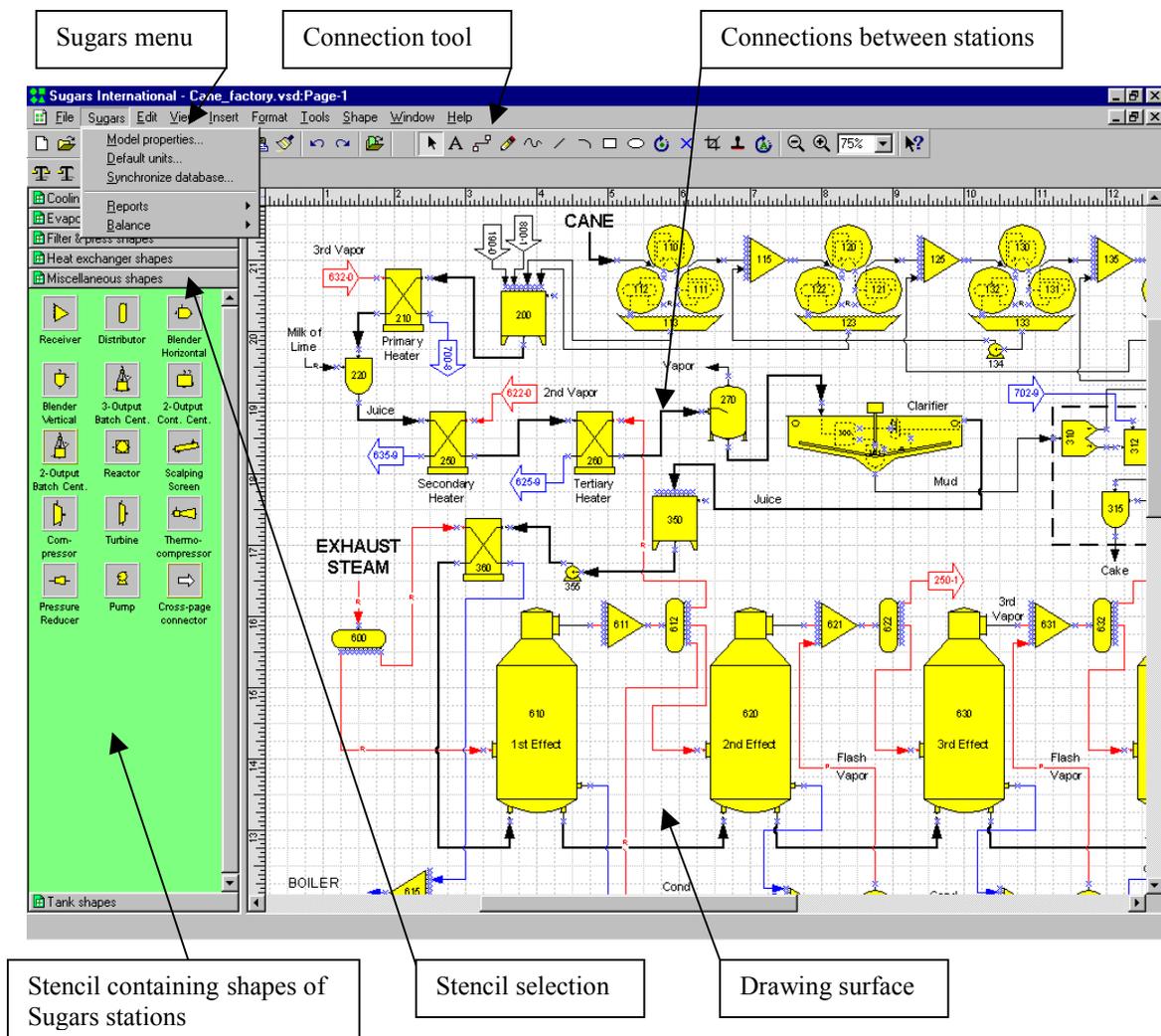
INTRODUCTION

The Sugars™ Computer Program is used to model sugar factories and refineries, and it has successfully modeled thousands of sugar processes since it was first introduced in 1986. It is a reliable program that is used by sugar companies and engineering firms to improve existing factories, or to design new ones. Sugars is the most widely used program in the world for modeling and simulating sugar processes.

Originally, the program was designed with a text-based interface for IBM compatible personal computers using the DOS operating system. A flow diagram was made of the process model for simulation by using a separate CAD, or diagramming program. The flow diagram was used as a reference to build text files with a text editor to describe the model for simulation by Sugars. This method worked well for users that were familiar with personal computers, and simulations from Sugars were found to be an accurate representation of the process. However, modern Windows® based software provides opportunities for dramatic improvements in the user interface and tools were developed that made it possible to integrate the drawing and model building steps.

In August of 1997, Visio Corporation released version 5.0 of their diagramming software. The Visio® program was known to be an excellent program for making process flow diagrams; however, it lacked some of the necessary features for integration with Sugars until the release of version 5. Once it was determined that this new release had the necessary functionality, development work was directed to a new Windows version of Sugars that would use Visio to give Sugars a robust graphical interface. Early versions of the integrated programs were shown last year at the SIT meeting in Marseille, France and at the ICUMSA meeting in Berlin, Germany. A beta test version of the new program was released in December 1998 to some sugar companies in the USA and the first showing of the complete program was made at the ASSBT meeting on February 11, 1999 in Orlando, Florida. The new Sugars for Windows program is an exciting change. Now, using Sugars, it is a simple procedure to build a model and obtain material, energy and color balances that can be used to evaluate a process.

NEW USER INTERFACE

The new graphical interface for Sugars makes model building a simple matter of dragging pre-drawn shapes from a Shapes Stencil to the drawing surface. The shapes are designed to represent stations for modeling the process by Sugars. Connections between the shapes are drawn using a connection tool that automatically routes connections between associated stations. Data entry dialogs for controlling the performance of each station are displayed by double clicking on the station shape. Flow stream properties are entered and displayed on a dialog screen by double clicking on the flow stream. Sugars for Windows is now a fully functioning Windows 95/98/NT program that gives all of the benefits to a user that are available in the Windows environment; such as, drop-down menus, online help, print preview, scrolling, object design and database storage. It is a dramatic change for users of Sugars and it makes the program much easier to learn and use while still providing all of the flexibility needed for modeling sugar processes.

Sugars menu

Connection tool

Connections between stations

Stencil containing shapes of Sugars stations

Stencil selection

Drawing surface

The new interface is shown in the figure above. Stencils on the left contain shapes of stations that are used to build a model. Different stencils are selected by clicking on the gray bar with the name of the stencil. Shapes on a stencil are dragged from the stencil to the drawing surface and dropped in place. Drawing tools are available to design shapes of factory equipment and add them to the stencils as needed. Connections between stations are drawn using a connection tool that features automatic routing around shapes and crossovers (line jumps) for crossing connection lines. Drawings can be composed of different layers and pages. Full zoom-in, zoom-out and panning features are provided in the interface. The menu selections at the top of the window include a Sugars menu entry that gives a drop-down menu containing selections for:

|	
Model properties	- overall properties of the model such as molecular weights for flow stream components, colors, iteration accuracy and atmospheric pressure are set on this screen,
Default units	- units used for all entries and when a model is saved,
Synchronize database	- check/correct synchronization between drawing and database,
Reports	- selection of reports for print preview and printout,
Balance	- model iteration balance calculations (single, or full).
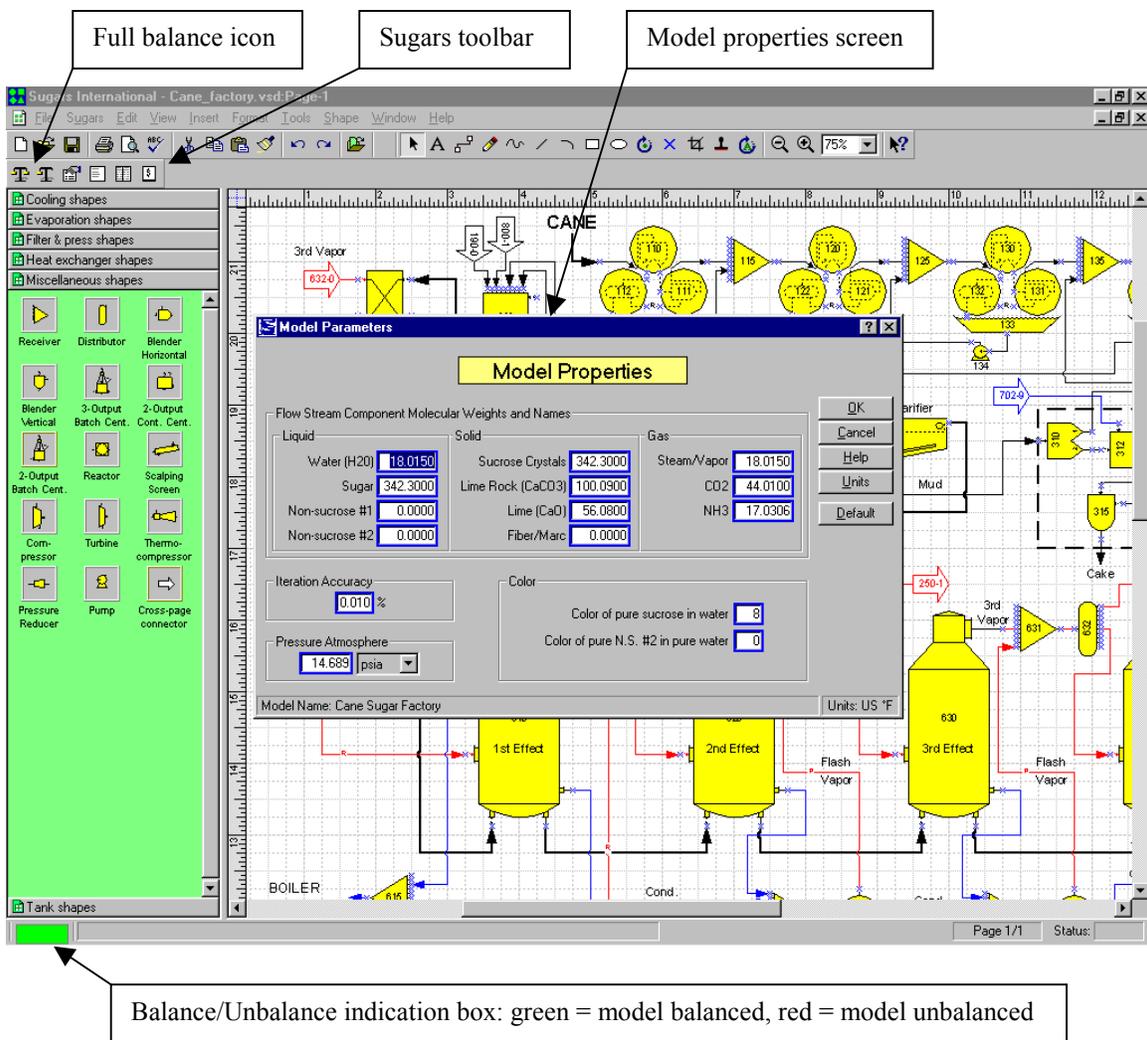
The figure above shows the Model Properties screen when it is selected from the Sugars drop-down menu.

Also, shown on the figure above is the Sugars toolbar. The Sugars toolbar provides icons for (numbered from left-to-right): (1) Balance - full, (2) Balance - single step, (3) Display last error or warning messages, (4) Summary report, (5) Detail report and (6) Revenues report. The tool bar icons provide a quick method for selecting items that appear on the Sugars menu without having to go to the menu to make the selections. Item (1) Balance - full, gives a full iteration balance of the model. If any errors occur during the balance calculations, they will be displayed on an error, or warning, message screen. Sometimes revisions to the design of the model, or data controlling the performance of stations in the model, may be needed to bring the model into balance. The last error, or warning, message screen can be referenced as corrections are made to the model. Item (2) Balance - single step, can be used to see how the model changes between iterations.

At the bottom of the screen, in the lower left-hand corner, a small box indicates whether the model is in, or out of, balance. When the box is green (as shown in the figure above), the model

is in balance. When the box is red, the model is unbalanced.   Any changes to a model will cause the balance indicator box to change to red for a model that was in balance (box was green).

Default Units Selection screen

Stencil with shapes of Sugars stations
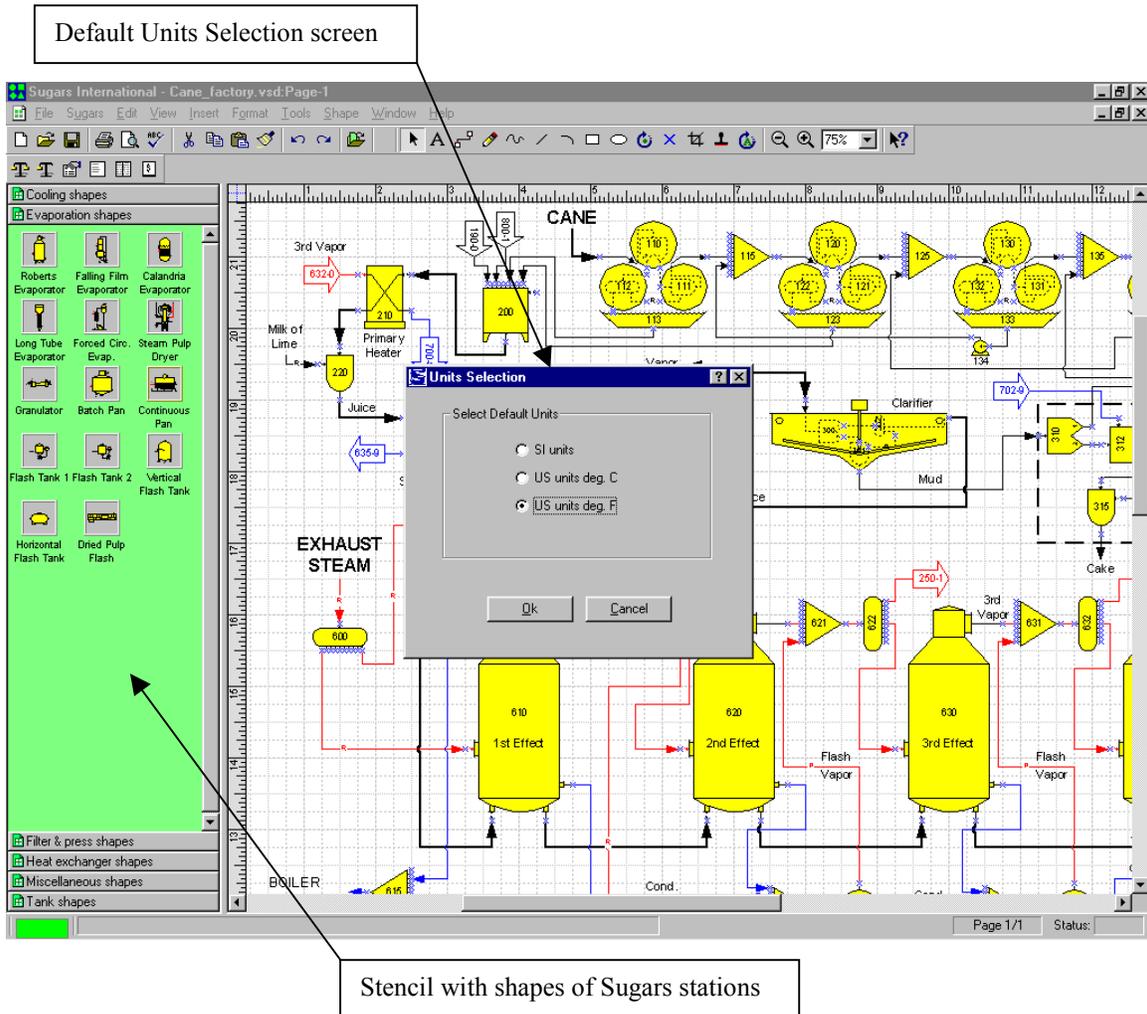
The figure above shows the Units Selection screen for selecting the system of units to be used with Sugars for entering data and displaying the results from the balance calculations. The default system of units is used when a model is saved, even if the displayed units are different. Units are available for SI, US with temperature in °C and US with temperature in °F systems.

As shown on the figure above, the stencils on the left contain shapes of stations that can be used to build a model of a sugar factory, or refinery. Each of the station types in Sugars is represented on the stencils and many of the stations have more than one shape that can be used for the process flow diagram of a model. Also, other unique shapes can be drawn and added to the stencils, if needed. There is no limit to the number of different shapes that can be used to represent the Sugars station types.

Complete online help systems are available from the main menu for both Visio and Sugars (see figure below). Help for Visio describes all of the drawing features available in Visio, and help for Sugars describes each of the stations, input properties, examples and features of each station.

Also, the Sugars help system describes how to design shapes so that they will work with Sugars and other features of the program. The help system includes features such as a table of contents, index and full search for key words.
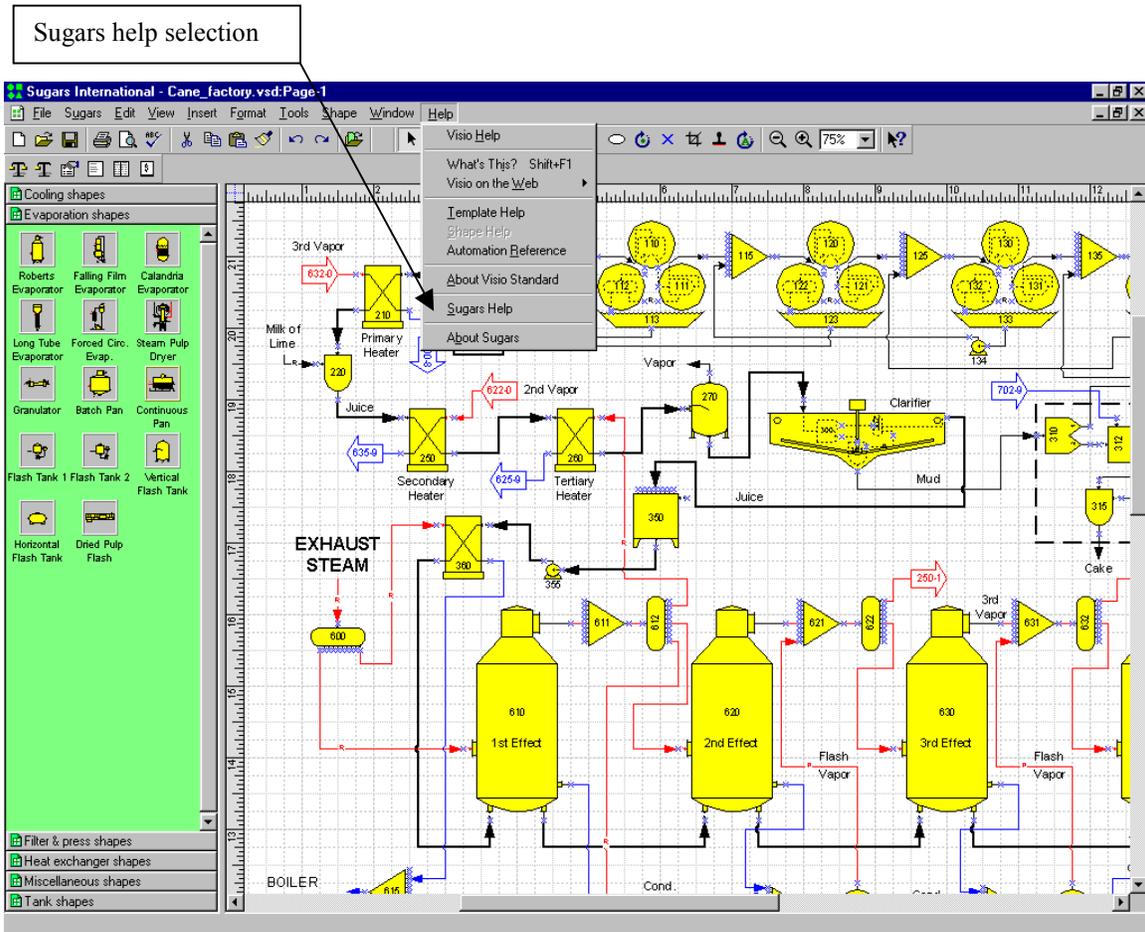

The input and output connections for the shapes stay glued to the shapes even when the shapes are moved, or the flow streams are rerouted. Stations can be copied from one part of the flow diagram and pasted into another part with the data for the station repeated in the copied station. Also, groups of stations may be combined and placed on the drawing as a group instead of having to add each station individually (station numbers for each station are entered when the group is dropped on the drawing).

MODEL BUILDING

Every model of a factory, refinery, or portion of a process is built by selecting stations from the available station modules in Sugars and connecting the stations together using flow streams. Flow streams between stations, and flow streams that leave a model, are called *internal flows*. Flow streams that go into the model from outside sources (e.g., beets, steam, water, milk of lime, etc.) are called *external flows*. All external flows must be fully specified before a balance can be done. Internal flows are calculated by Sugars during the balance calculations.

Sugars has sixteen different stations that can be used to simulate a process. The sixteen stations are: centrifugal (batch and continuous), heater (or heat exchanger), melter, pan, distributor, dryer, crystallizer, evaporator body, tank, receiver, flash tank, cooler, separator/filter, blender (also used to model a contact condenser), reactor, and compressor/pump. When a shape is dragged from a stencil to the drawing surface, a dialog screen appears to assign a number to the station (see figure below).
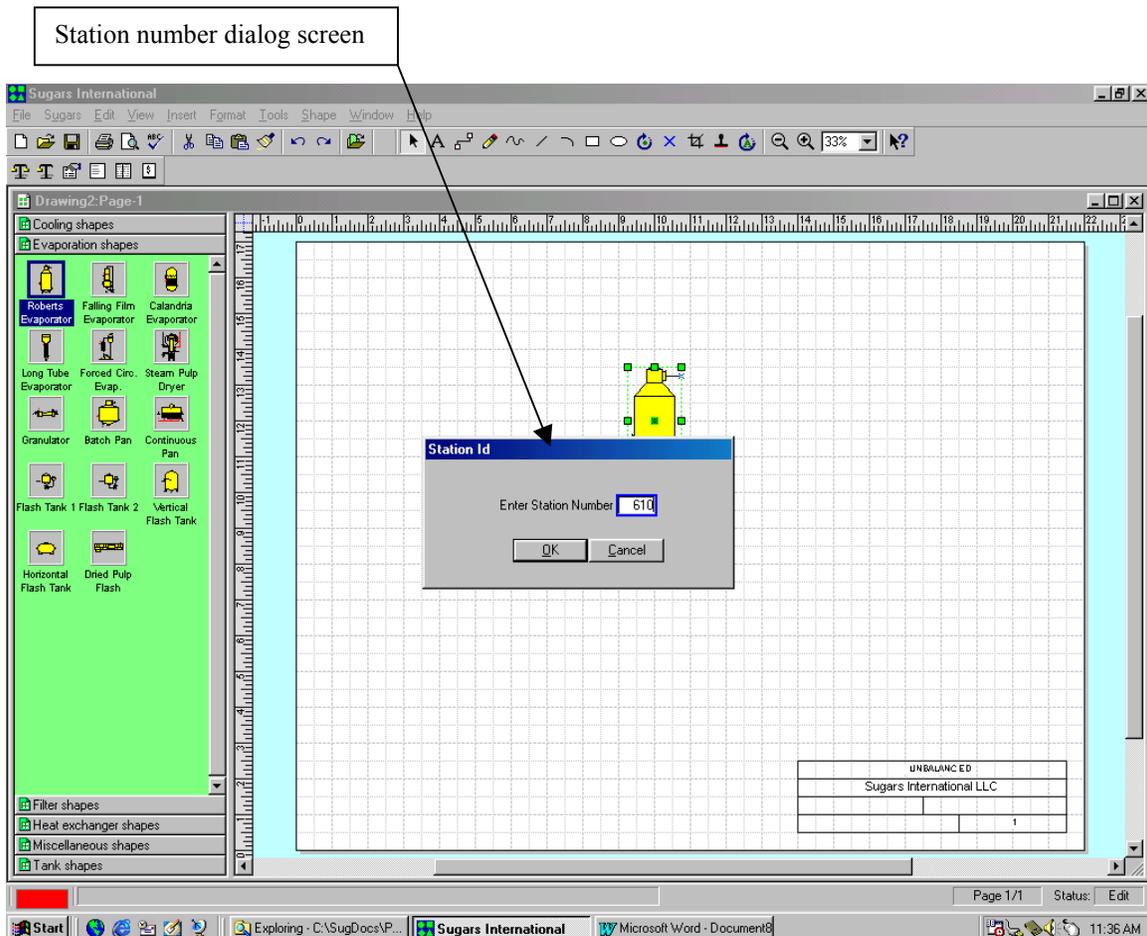

The station number for each station in a model must be unique. Sugars will automatically index the station numbers by 10 as each new one is added to the flow diagram; however, the number may be changed on the dialog screen to any unused number in the model.

Each Sugars station type has a data input screen (dialog) that is associated with the shapes for that type of station. The data input screen defines the properties of each station (object) in a model. Drawing the process flow diagram defines the model. The output flows emitted from a station are a result of the properties of the station. Changing the properties of a station will control how the station processes flows coming into the station. For example, an evaporator station, with juice and steam input flows, will process the juice flow to evaporate water while

using steam, or vapor, to boil the juice. Thus, the properties of the stations in a model and the characteristics of the external flows into the model control all of the internal flows between stations, and the flows leaving the model. Each station type has a properties dialog screen for entering the appropriate data, and a dialog screen is provided for entering the data to define external flows into the model.

Shapes on the stencils are associated with their respective Sugars stations by naming the shapes in Visio with station names from Sugars and identifying the input and output ports for the stations. The Sugars help system provides full details on how to make shapes that can be identified by Sugars.
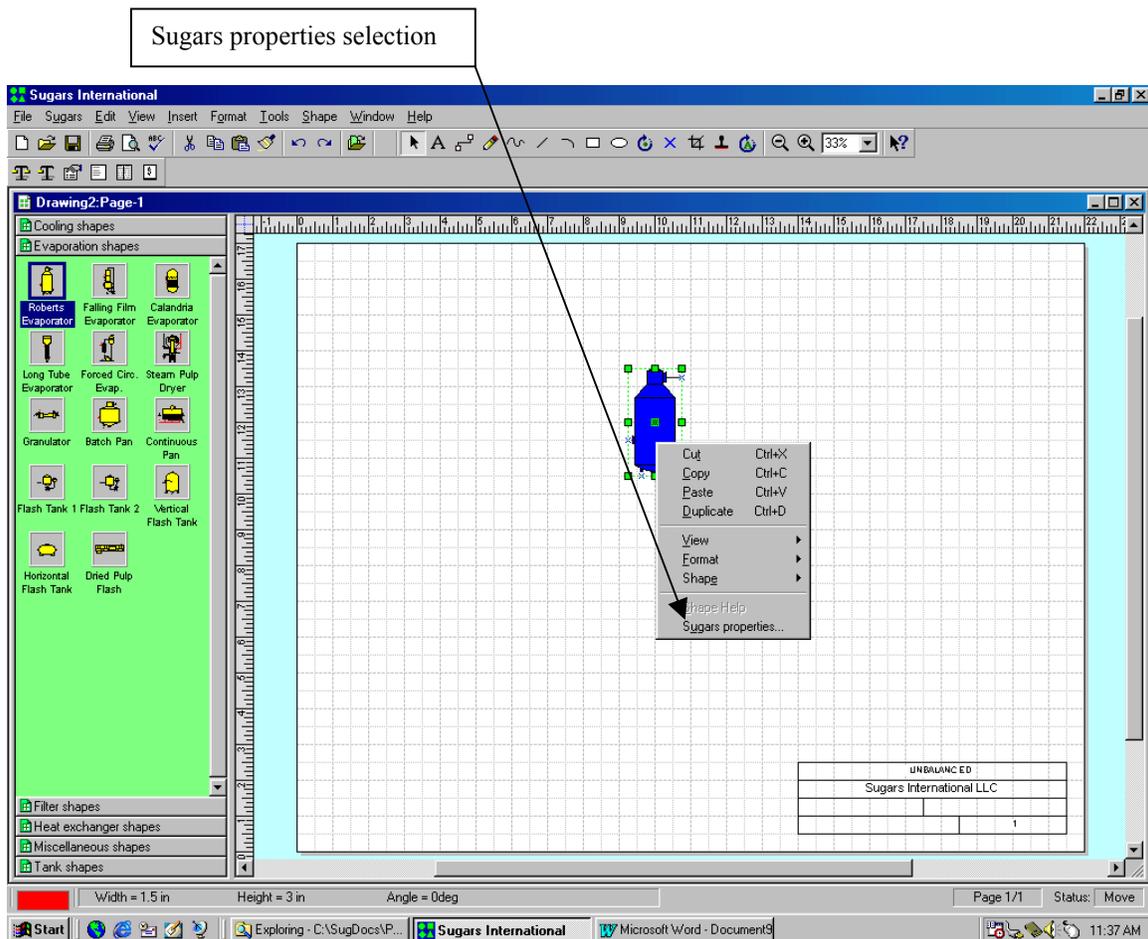
The shape color turns to blue after the station number is entered. Double click the shape (or right click and select "Sugars properties" from the drop-down menu - see figure above) to get the data entry screen (Evaporator Properties screen in the figure below).

All of the necessary data to describe the performance of the station is entered on the Properties screen. The station turns yellow to indicate that data for the station was entered after the Properties screen is closed by clicking on the OK button. Shapes are added to the drawing until

all of the stations for the model are on the drawing and data is entered for each station until all of the stations on the drawing are yellow.

Data entry (properties) screen
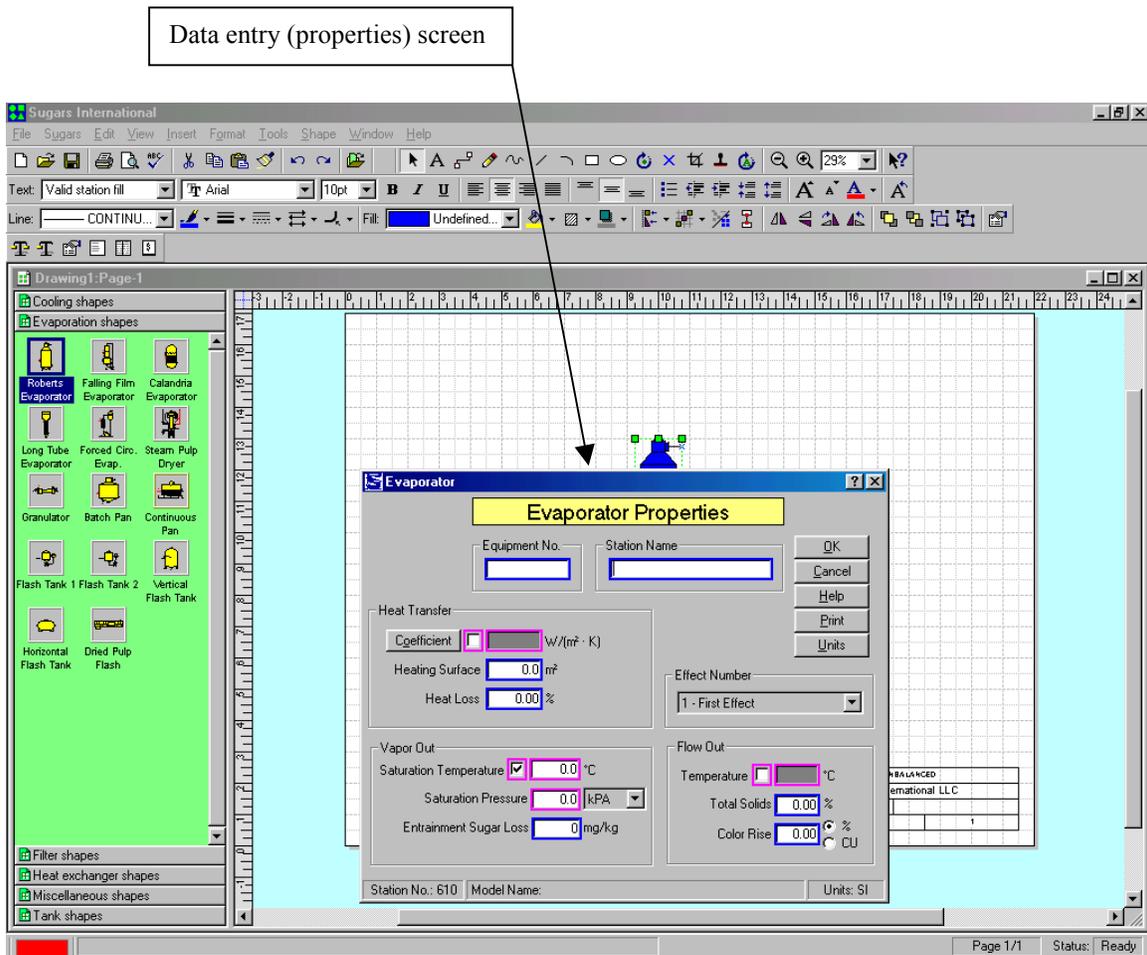
Connections are made between input and output ports on each station using the connection tool until all of the ports on the stations have connecting flows. Some stations, such as distributors, melters, tanks and receivers, do not need to have all of their ports connected (extra ports are provided), but these stations must have at least one input and output flow.

Data for external flows into the model is entered on the External Flow Properties screen. The External Flows Properties screen (see figure below) is accessed by double clicking on the external flow, or right clicking and selecting "Sugars properties" from the drop-down menu. Every external flow stream going into the model must be specified with pressure, temperature and flow stream components. If the flow stream contains dissolved non-sucrose components, the solubility coefficients must be defined. And, if the flow is not a required flow, the quantity of the flow stream must be specified. *Required* flows are flows that have their quantity determined by the properties of a station. For example, the vapor flow into a pan is a required flow because the quantity of the vapor needed by the pan is determined by the properties of the pan. A flow

9

stream color entry must be made for the external flow if the color balance is being done. And, a currency value is entered if the net process revenues are being calculated for the model.

External flow

External flow properties screen
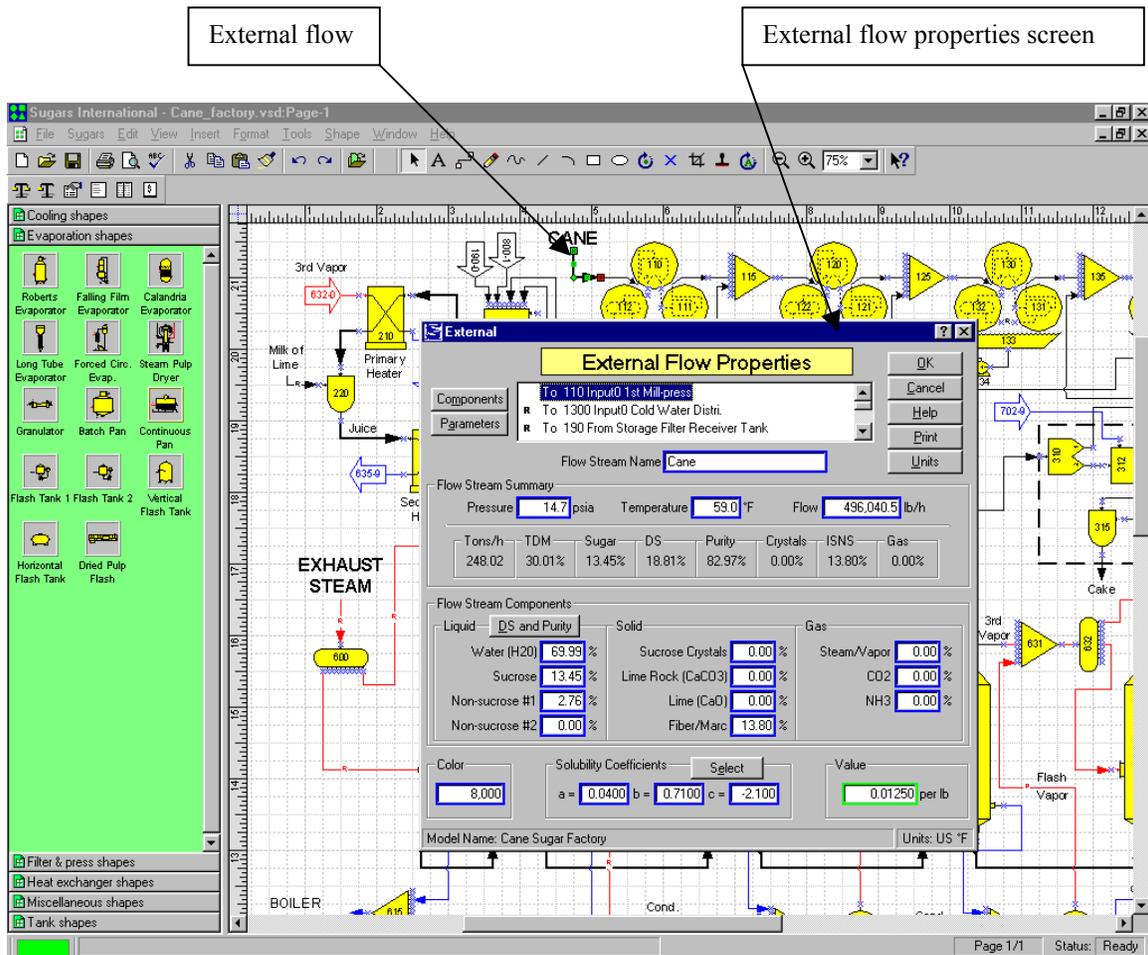
SIMULATION

The model is ready for balancing once the data for every station in the model and every external flow stream into the model is entered. The balance calculations give a simulation of the process and provide all of the details of the internal flow streams in the model.

Clicking on the full balance icon will initiate the balance calculations and give a small window showing the progress of the iterations (see figure below). Single balance iterations can be done (to observe the progress of the balance) by clicking on the single balance icon. An error message screen will appear if any errors are detected during the iterations. Fatal errors have to be corrected before the calculations can be completed. Sometimes warning, or informative, messages appear giving information about the calculations, or observations about the model.

Full balance icon

Single balance icon

Error message screen icon

Iteration counter

Full Balance In Progress, Iteration: 35
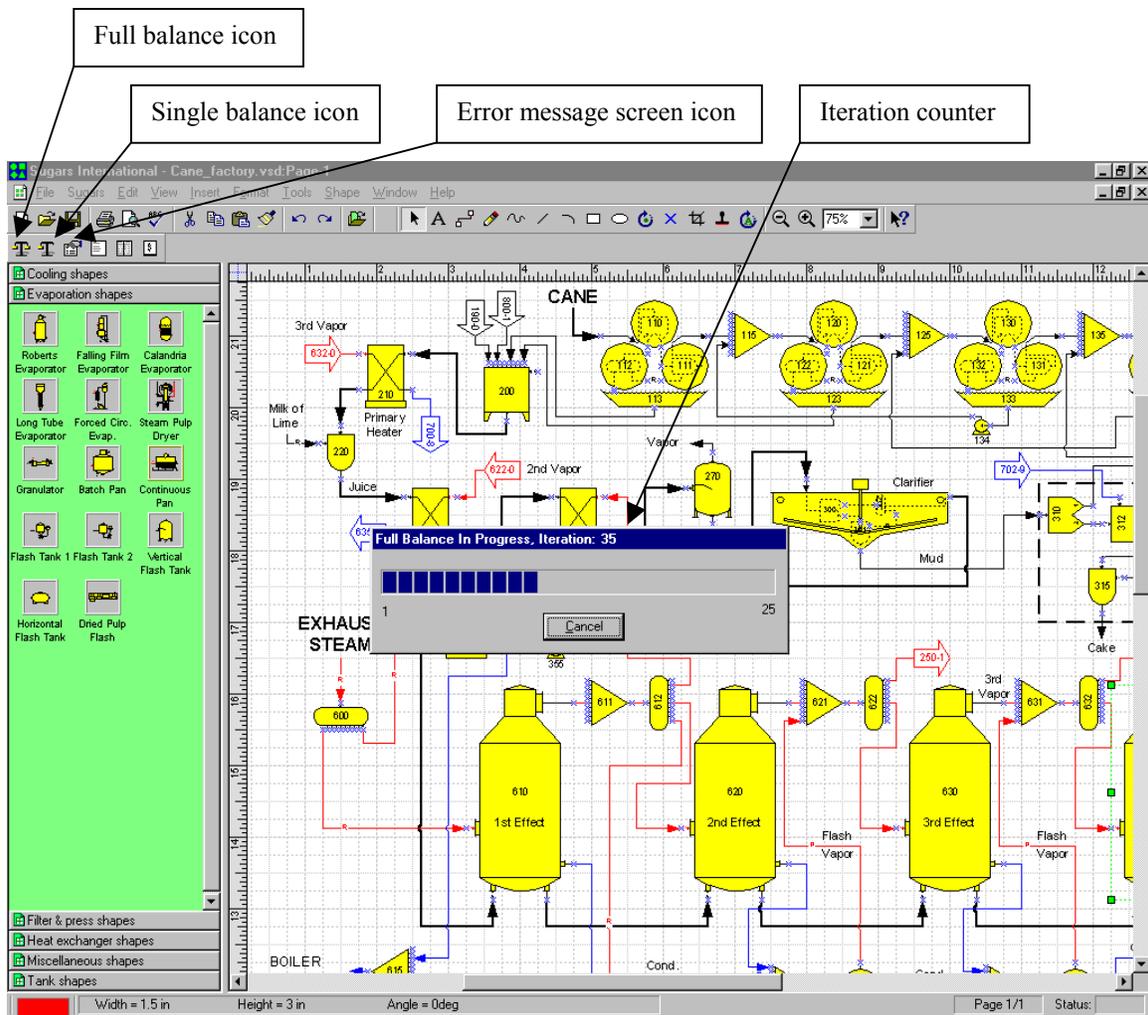
Many of these messages do not require any action by the user, but are merely displayed as information that might be important, or helpful to the user. The error/warning message screen may be recalled at any time after the balance calculations so that it can be referenced as corrections are made to remove any errors that occurred during the balance calculations. Clicking on the error message screen icon will recall the display of the last error messages that occurred during a balance.

RESULTS

The results of the calculations can be displayed after the balance calculations are completed. Sugars provides several different presentations of the results.

The figure below shows the display of the Internal Flow Properties screen after a balance. This screen shows all of the details of an internal flow, such as pressure, temperature, flow quantity, components, color and solubility coefficients. In addition, the % total dry matter (TDM), % sugar, % dry substance (DS), % purity, % crystals, % insoluble solid non-sugars (ISNS) and %

gas are given in the middle of the screen with the quantity of flow in tons per hour. Clicking the DS and Purity button, under the Flow Stream Components, in the Liquid phase section, will give the % dry substance and purity for the liquid portion of the flow. For a massecuite, this would be the mother liquor %DS and % Purity.

Parameters button

Internal Flow Properties Screen

Internal flow stream selected for display
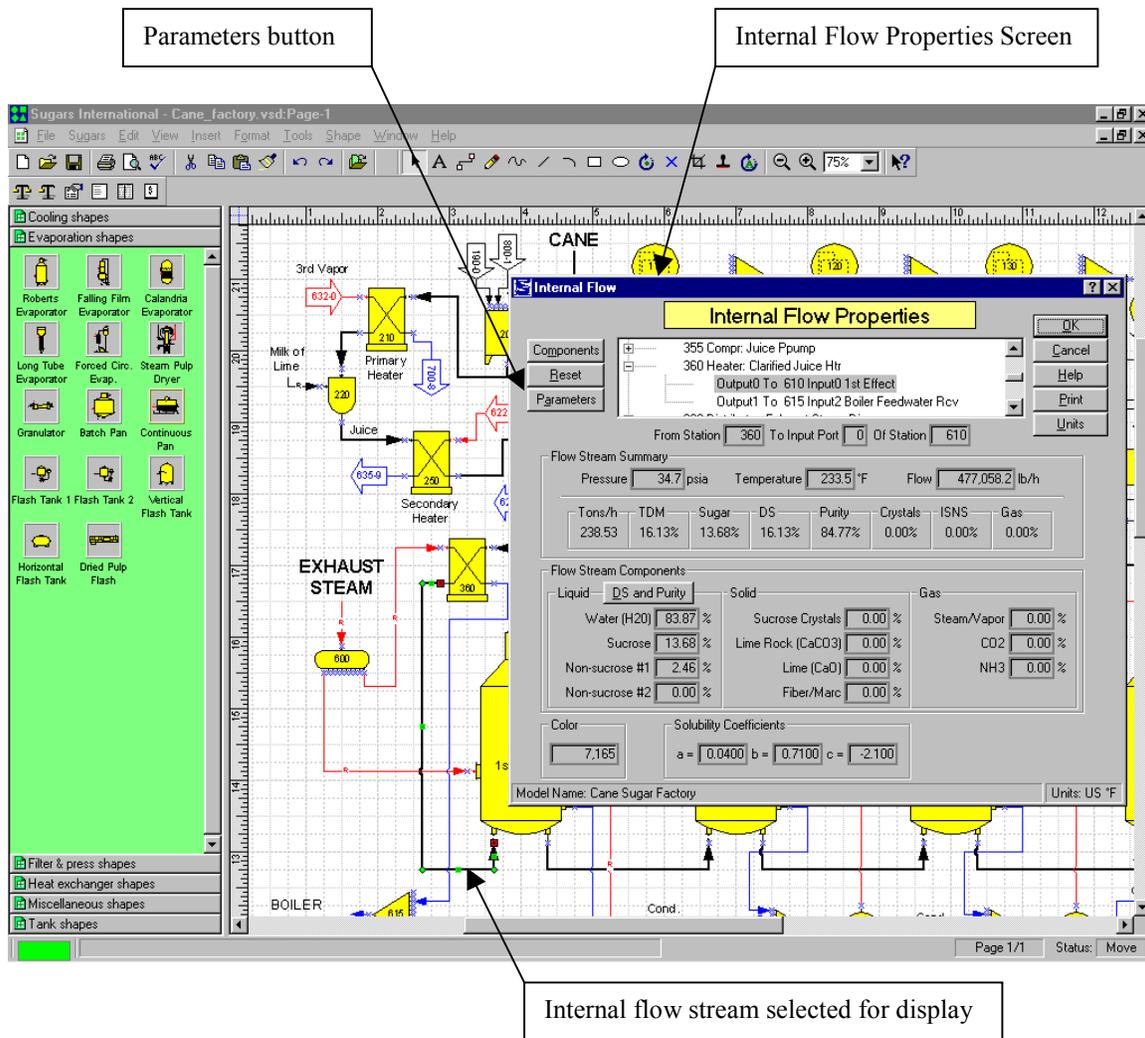
Clicking the Parameters button on the Internal Flow Properties screen gives additional characteristics of the flow, such as: volume flow, specific weight, enthalpy, specific heat capacity, supersaturation and boiling point elevation (see figure below). The Flow Stream Parameters feature is also available for external flows.

Every internal flow in the model can be displayed using the Properties screen. Also, flow streams that are required and/or pressure feedback (flow streams that need a pressure value from another station) are identified on the flow diagram by a small 'R' for required and a small 'P' for pressure feedback. Sugars will place these indicators on the flow streams after the balance calculations are completed.

Flow stream parameters

Internal flow stream selected for display

Internal flow selection window
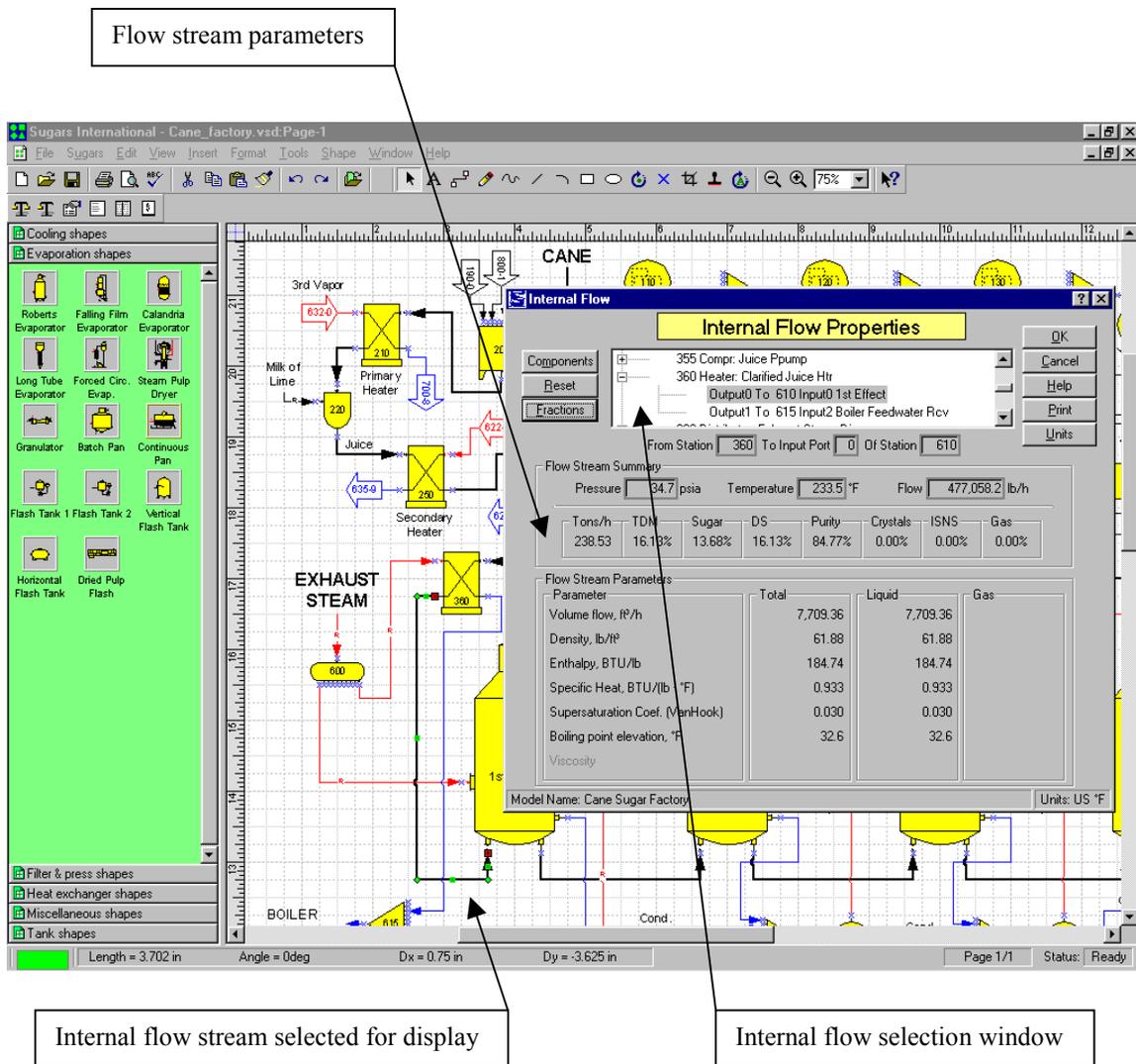
The Internal Flow Properties screen has a small internal flow selection window (scrollable) that shows every internal flow stream in the model. Using this window, individual flow streams can be displayed quickly without having to close the Internal Flow Properties screen and double clicking on another flow stream to display its properties. The External Flow Properties screen also has a similar external flow selection window for viewing external flows.   The internal and external flow properties screens provide valuable information about the process that can be used for engineering design and/or data reconciliation.

Printouts are available for the Revenues report, Summary report and Details report.   These reports provide an overview of the balance calculations. The Details report shows every flow stream in the model with the fraction of each component listed along with the station the flow originates from and the station to which it goes. Also, the pressure, temperature, flow quantity, color, solubility coefficients and currency value is printed for each flow stream. The Details report is a listing of most of the information that is on the Internal Flow Properties and External Flow Properties screens with component fractions displayed instead of percentage values for

purity, dry substance, etc. The summary information on the Internal Flow Properties and External Flow Properties screens is basically the same as shown on the Summary report for each flow (see figure below).
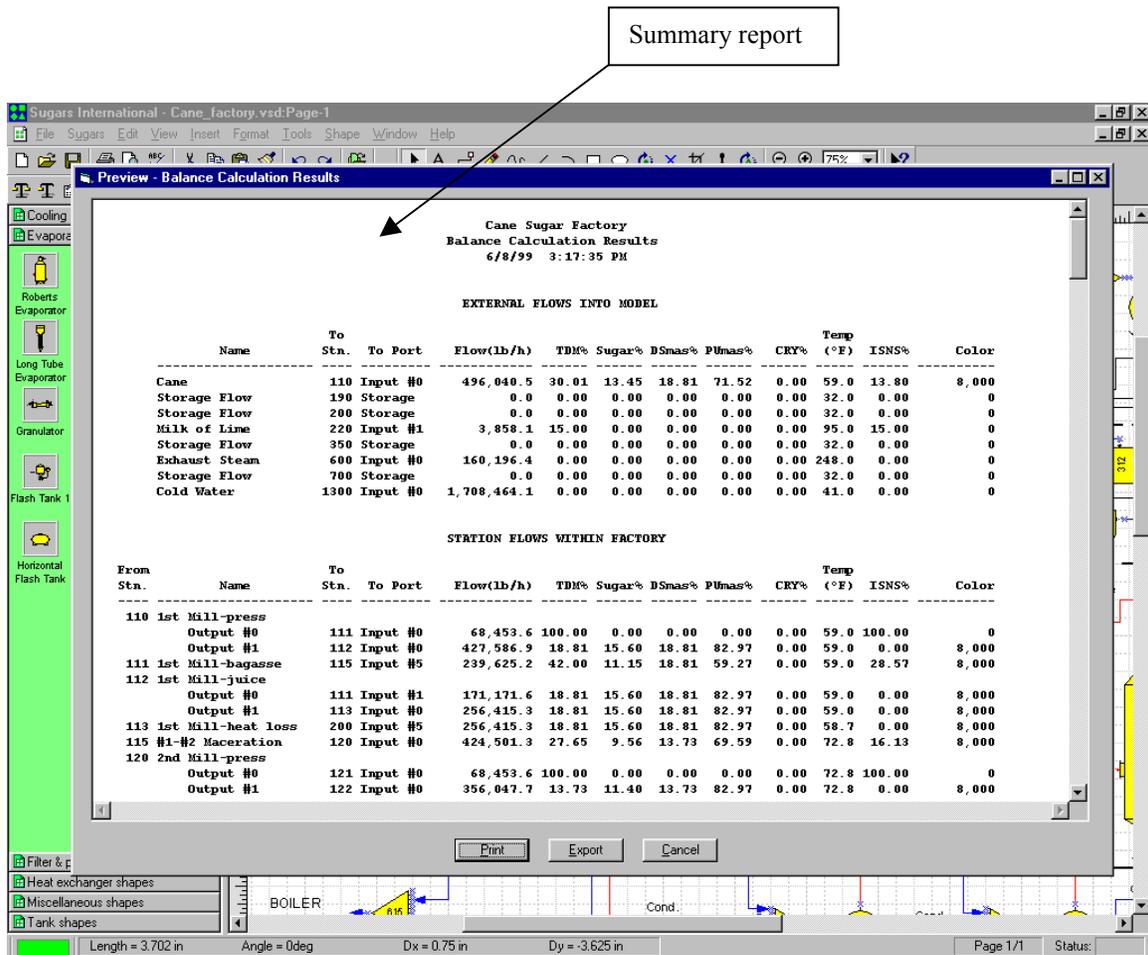
Some of the most useful information from Sugars is given on the Process Net Revenues report (see print preview screen in the figure below). As changes are made to the model, the process net revenues will either increase, or decrease. New process equipment with new station properties, or changes in the process routing, can be evaluated quickly to see now the revenues will change. The Process Net Revenues are calculated from the values for all flows leaving the model (internal flows) minus the cost of all flows into the model (external flows). This information is very useful for making investment decisions. Also, it is the most convenient way to show how changes to the model will affect the operating performance of the process.

The value entries for all external flows into the model and internal flows that leave the model are entered on the External Flow Properties and Internal Flow Properties screens. These values are used to calculate the process net revenues. The entered values can also be changed on the Process Net Revenues screen as shown in the figure below.
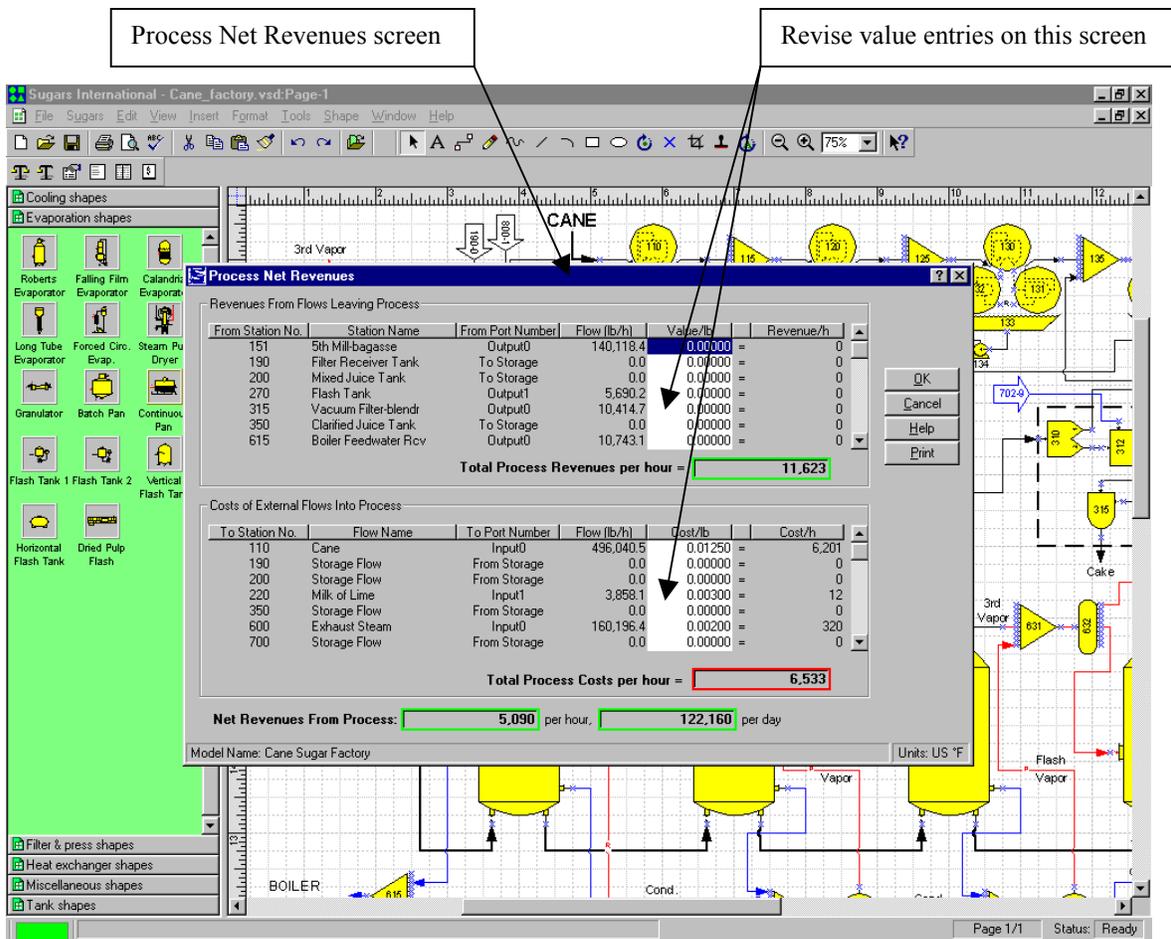
SUMMARY

Sugar companies and engineering firms use the Sugars™ program to make process and investment decisions. They use it to increase the yield and reduce the energy consumption of existing sugar factories and refineries and to design new ones. Also, it is used to evaluate the feasibility of R&D projects, train process engineers, reconcile factory data and give process information that cannot be measured. The new Windows® interface for Sugars greatly enhances the use of the program and makes it much easier to build models for process simulation. A model is built by simply dragging shapes from one of the shape stencils to the drawing surface. The shapes represent actual stations in the factory, or refinery. External flows into a station and flows leaving a station are connected to other stations by using a connector tool with automatic line routing and crossovers. A dialog screen to enter data for controlling the performance of a station, or to describe an external flow, is displayed when the station, or external flow, is double clicked. The model is balanced by clicking on a balance icon after the flow diagram of the model is drawn and the data is entered. The results of the balance calculations provide material, energy and color values for all flows in the model. Also, the overall net revenues generated by the process are calculated. Flow stream values given by the calculations provide information about the process and engineering data (density, enthalpy, boiling point rise, sucrose

supersaturation, etc) that is useful for process design. Process net revenue results are used to make investment decisions for new equipment, or process decisions. All of the data and calculated results for a model are saved in a Microsoft® Access database. The new Sugars for Windows program is a dramatic improvement to the Sugars program that makes it much easier to build models and show the calculated results to assist with decisions to improve the efficiency of a factory, or refinery.

ACKNOWLEGEMENTS