Process Modeling Using Sugars™ - Cane Factory

L. Warner Weiss, Sugars International LLC, Denver, Colorado USA

Abstract

The Sugars™ for Windows® program has been used since 1986 by sugar companies, engineering firms and equipment suppliers in more than 40 countries to model sugar processes to improve and designing factories and to evaluate equipment. Thousands of processes have been modeled with Sugars. It does the complete mass, energy and color balance for sugar processes of almost any configuration. Development of the program began in 1984 and the first versions were sold in 1986 to two beet sugar companies operating in the United States. The earliest version was a DOS program that required users to create text files to describe their models. Since that time, it has evolved into a full Windows program with a graphical interface provided by Microsoft Visio®. Now, Sugars includes ethanol as a component property and XML data import and export can be added as an option. The model of a cane factory is illustrated using the latest version of the program.

Introduction

All sugar factories use process variations and modifications to achieve their final products. Modifications to the process occur from new technological developments in process design or equipment. Also, the processes used by cane and beet factories and refineries are different. Because of this, a process modeling program for sucrose production must have flexibility to accommodate the variations in existing factories and allow for future developments. The Sugars program meets this challenge by its modular architecture. Equipment can be freely place on the diagram and connections can be made between the equipment to mimic the actual process used in the factory or for proposed changes. In addition, unit modules (stations) in the model talk to each other to communicate their needs to other stations. For example, flash tanks that need a

pressure for flashing, pans that need vapor for boiling, filters that need wash water, and many other intercommunications that are necessary for a unified model. Once the model is built and verified, modifications to equipment performance or process routings can be made to quickly evaluate the economics. Also, with the latest version of Sugars, data can be imported directly into the model to provide on demand mass, energy and color balances along with the net process revenues for economic evaluations.

Cane Factory Model

The cane factory model used for this paper consists of nine pages: Milling, Purification, Evaporation, 'A' Boiling, 'B' Boiling, 'C' Boiling, Condensate Recovery, Water Distribution and Steam Distribution. The Milling page is shown in the diagram below.
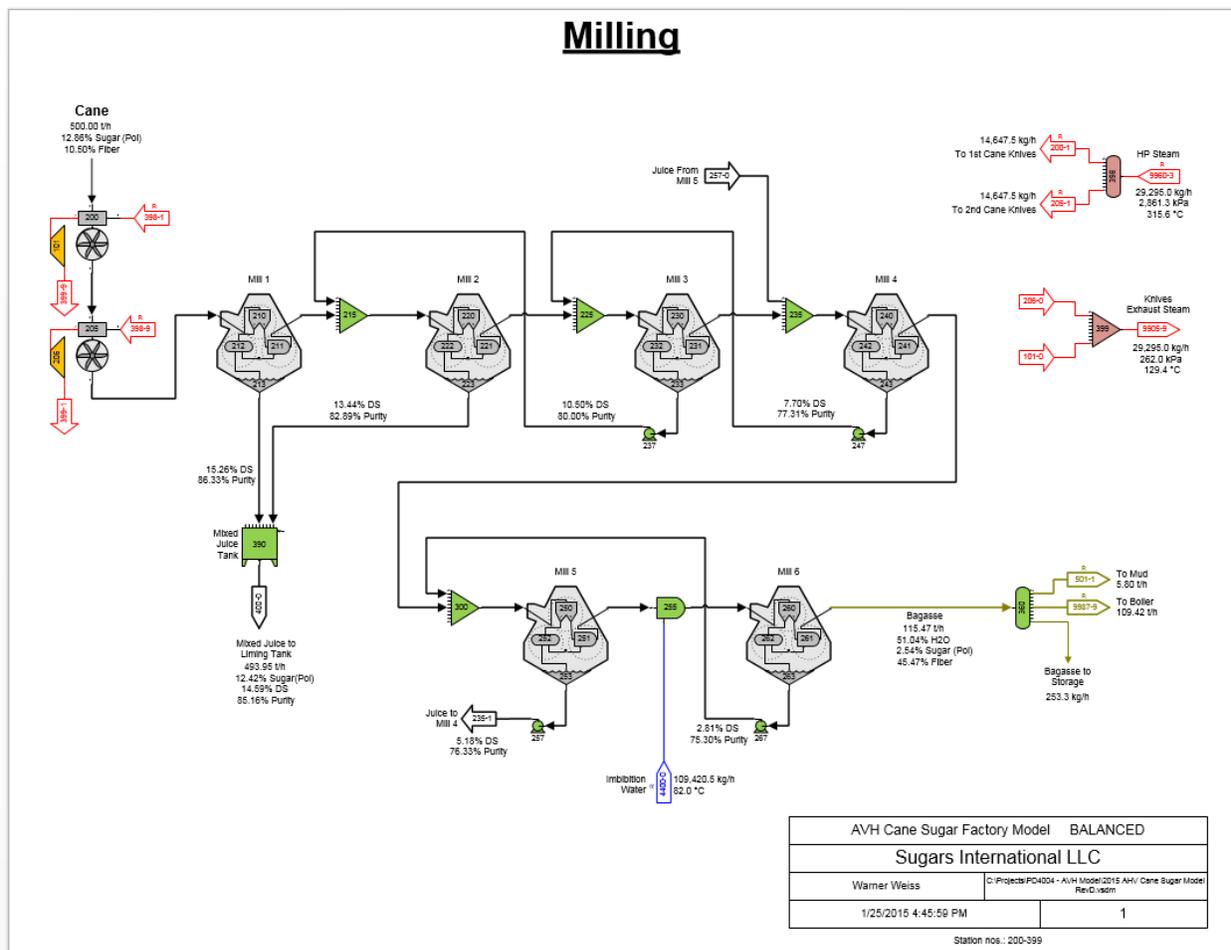
Compound imbibition is used with six mills to process 500 t/h of cane. This diagram shows some of the intercommunication that occurs between station modules within a model. For example, imbibition is added to the bagasse from the penultimate mill using blender 255 as shown in the diagram below.
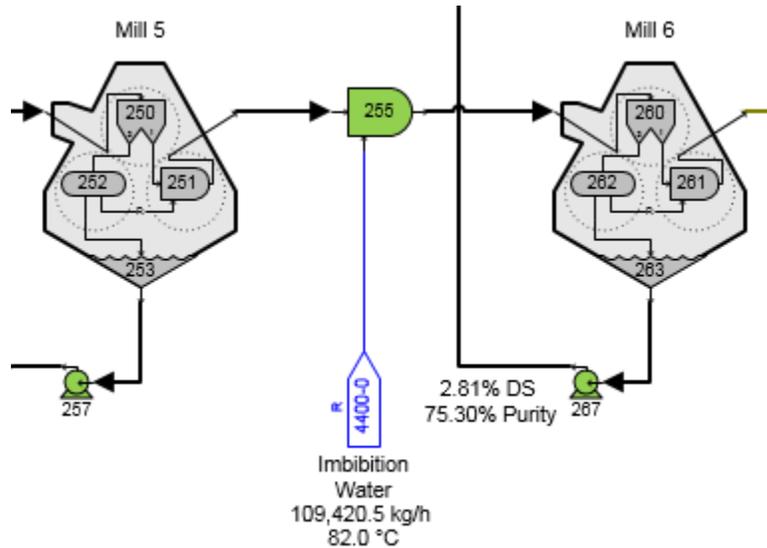
The quantity of imbibition water (109,420.5 kg/h) is controlled by the blender, and it is being taken from output port 0 of the condensate tank 4400 on the Condensate Recovery page. The quantity of imbibition water is set in the blender as a ratio to the fiber in the bagasse. If the fiber rate changes by either the grinding rate or the percent fiber in cane, the amount of imbibition water will automatically change and the quantity of condensate being taken from the condensate tank 4400 will be changed by Sugars to satisfy the amount needed by the blender. This occurs without any user intervention. Similar communications occur between other stations in the milling section of the model.

Purification is shown in the next diagram. Mixed juice from milling goes to the liming tank 400 and then to blender 410 where milk of lime is added to give 0.05% CaO content on juice. A spiral heat exchanger 430 is used to heat the juice to 58°C using condensate from distributor 4120 on the condensate recovery page. The spiral heat exchanger (HE) controls the amount of condensate taken from distributor 4120 by the temperature setting for the juice flow leaving the HE. After the juice leaves the spiral HE, it is further heated in limed juice heat exchangers 440, 450 and 460. Heat ex-

changer 440 uses 4th vapor, 450 uses 2nd vapor and 460 uses 1st vapor. Each of these heat exchangers controls the amount of steam needed to achieve the temperature of the juice leaving the HE by the temperature setting entered by the user.
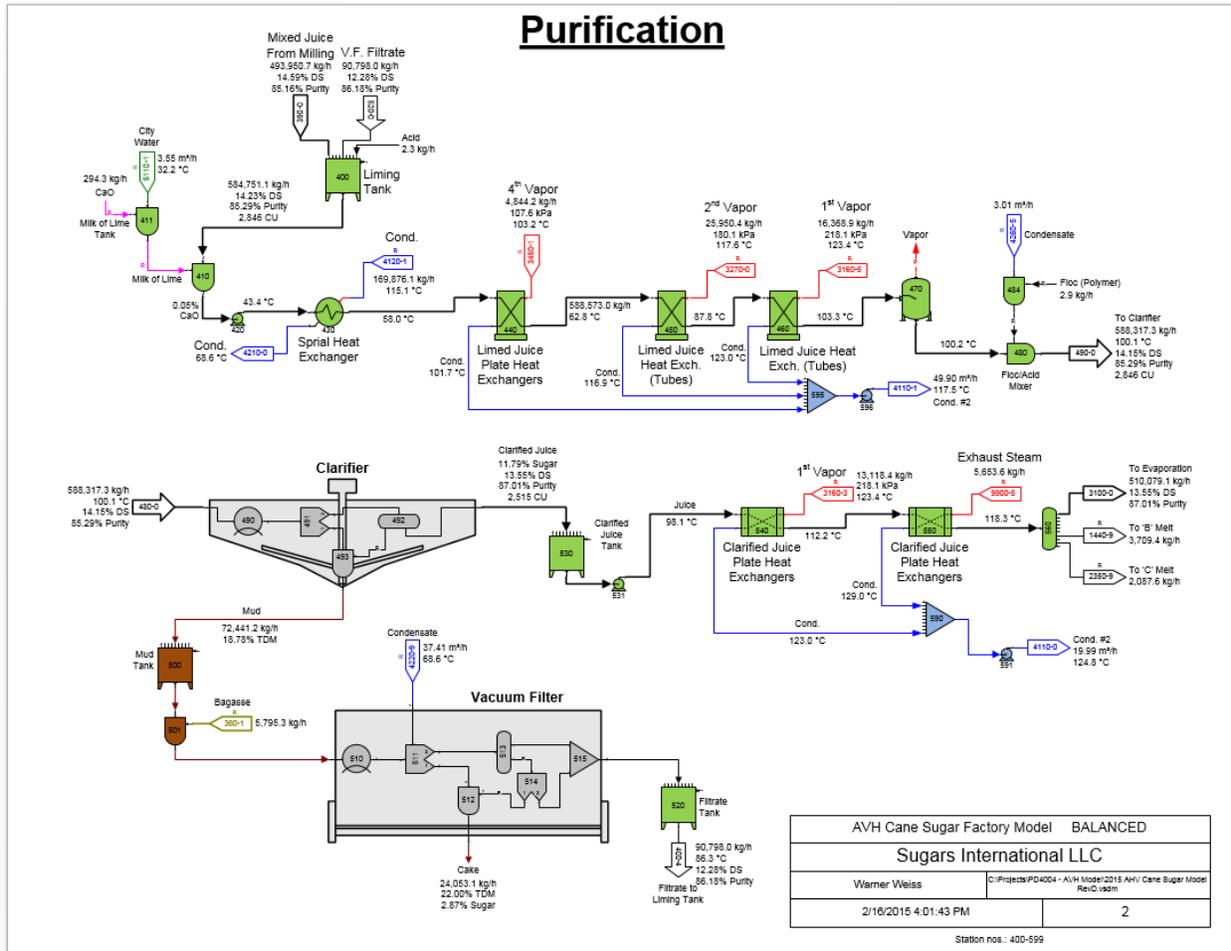

After the clarifier, there are two plate heat exchangers 540 and 550. Heat exchanger 540 is on 1st vapor and 550 is on exhaust steam and the quantity of steam to these heat exchangers is controlled by the conditions set in these heat exchanges by the user. The vapor for each of these heat exchangers is automatically taken from the multiple effect evaporator which then causes a rebalance of the evaporator and a change in the exhaust steam to the evaporator. All of this occurs automatically without any input from the user.

Multiple effect evaporation is shown on the Evaporation page below. Five effects are used with condensate flashing between the 2nd and 3rd effects and between the 3rd and 4th effects. Bleed vapors are provided to heat exchangers, tanks and pans on other pages of the model. These bleed vapors are taken from the vapor flows between effects as needed by the vapor consuming stations.
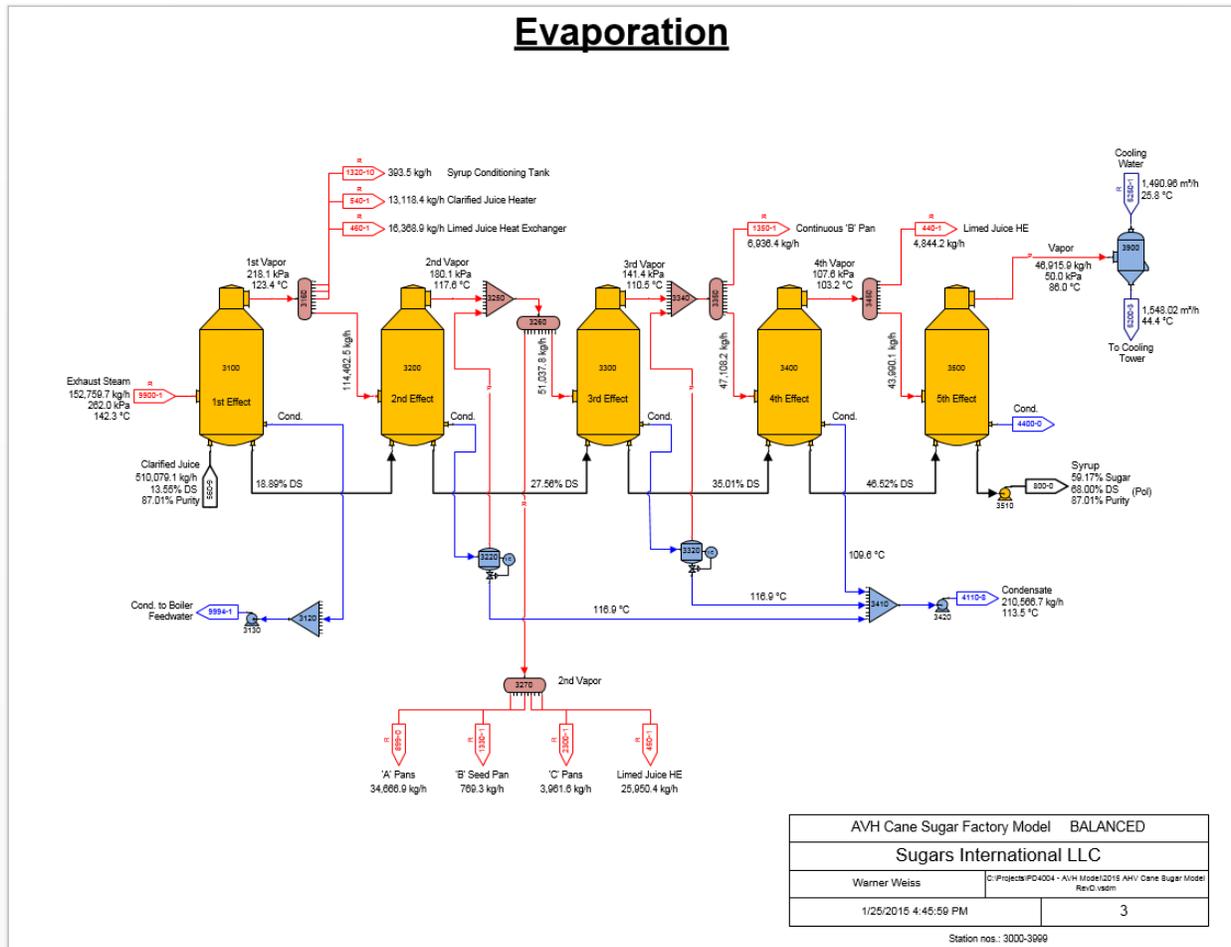
Flash tanks 3220 and 3320 are used to flash the condensate to 2nd and 3rd vapors, respectively. Vapor from flash tank 3220 goes to receiver 3250 and vapor from flash tank 3320 goes to receiver 3350. The flash pressure for these two flash tanks are communicated to the flash tanks from their respective vapor receivers so that the flash tanks flash to the same pressure as the vapor leaving the 2nd and 3rd effects. The next diagram shows the two flash tanks and their connections in the model.
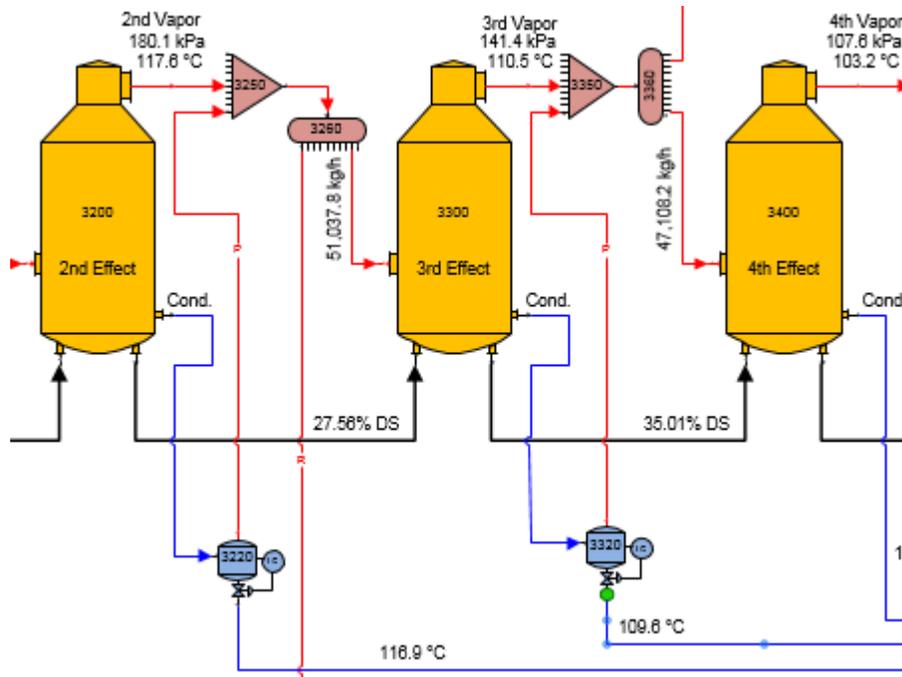
Also, the vapor pressure for the 5th effect 3500 is provided by the internal vacuum pressure in the contact condenser. This pressure is communicated to the 5th effect by the contact condenser (see diagram below).
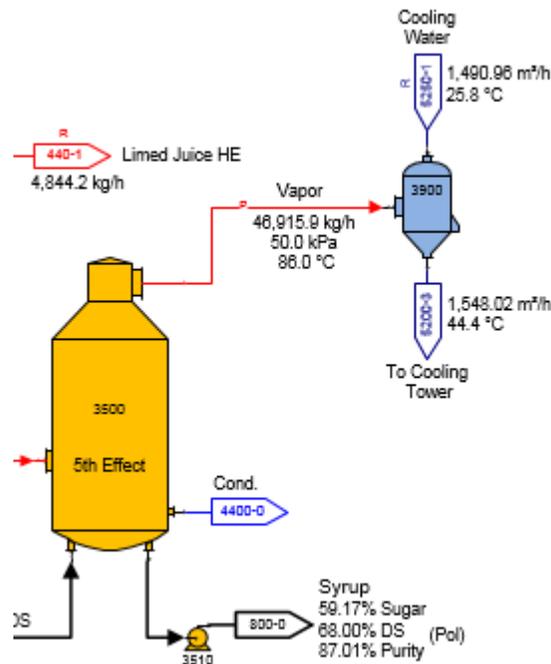
Sugars automatically provides these pressures to the appropriate stations during the balance calculations.

"Double Einwurf" crystallization is used to produce 'A' sugar. The 'A' Boiling page is shown below.
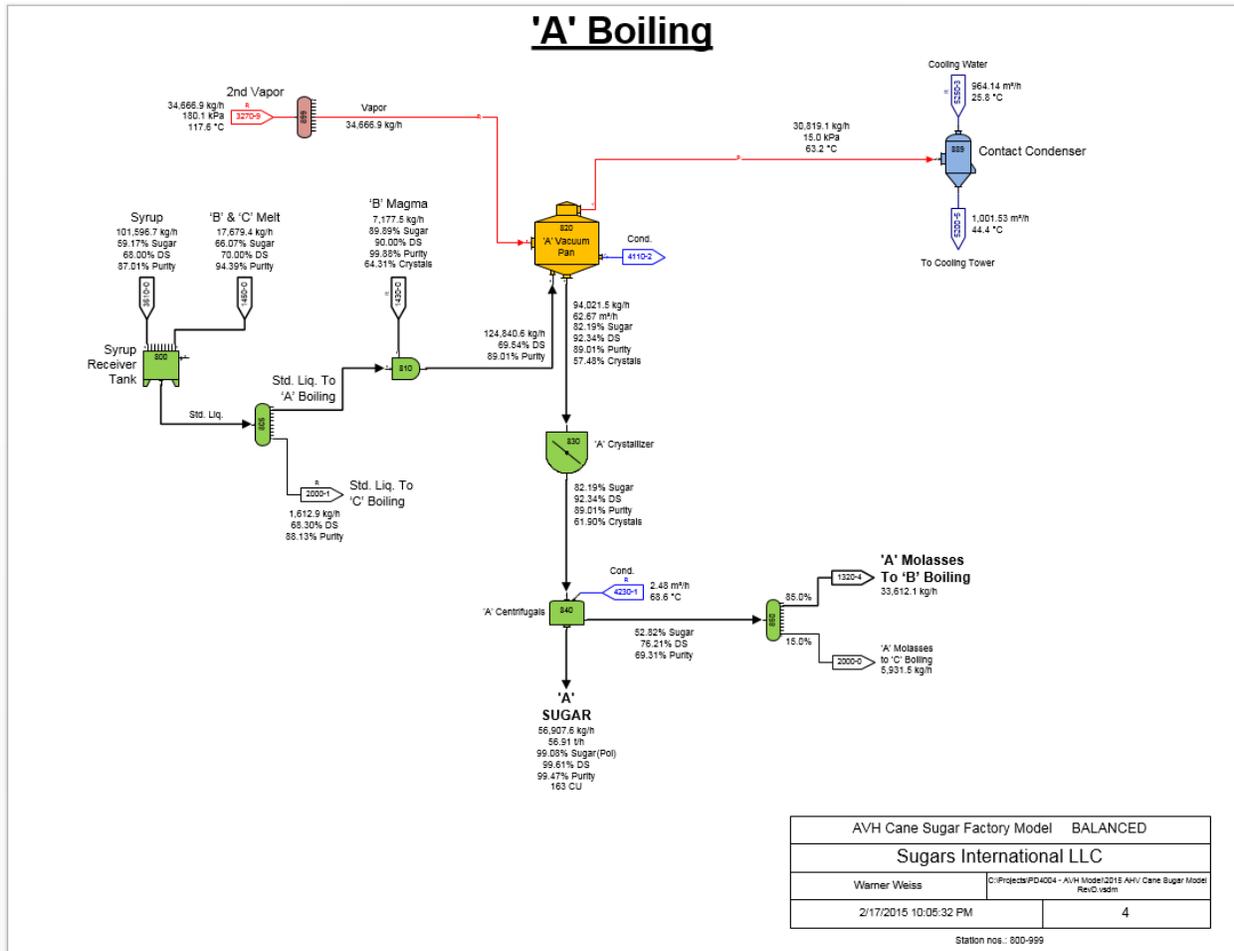
Syrup from evaporation goes to a syrup receiver tank where 'B' and 'C' melt are added to produce standard liquor. A majority of the standard liquor goes to the 'A' pan and a small amount of it goes to the 'C' pan. 'B' magma is blended into the standard liquor before it enters the 'A' pan. The quantity of the 'B' magma is controlled by the blender station 810 and it is automatically taken from the 'B' sugar mingler 1430 as shown on the 'B' Boiling diagram below.

The 'A' pan boiling pressure and the vapor leaving the pan are controlled by the contact condenser 889. The user specifies a vacuum pressure for the internal pressure of the contact condenser and this pressure is automatically communicated back to the 'A' pan.

85% of the 'A' molasses from the 'A' centrifugals 840 is sent to the 'B' Boiling and 15% is sent to the 'C' Boiling. 'A' sugar leaves the 'A' centrifugals as the final product with a color of 163 CU (Color Units: ICUMSA used throughout the model).
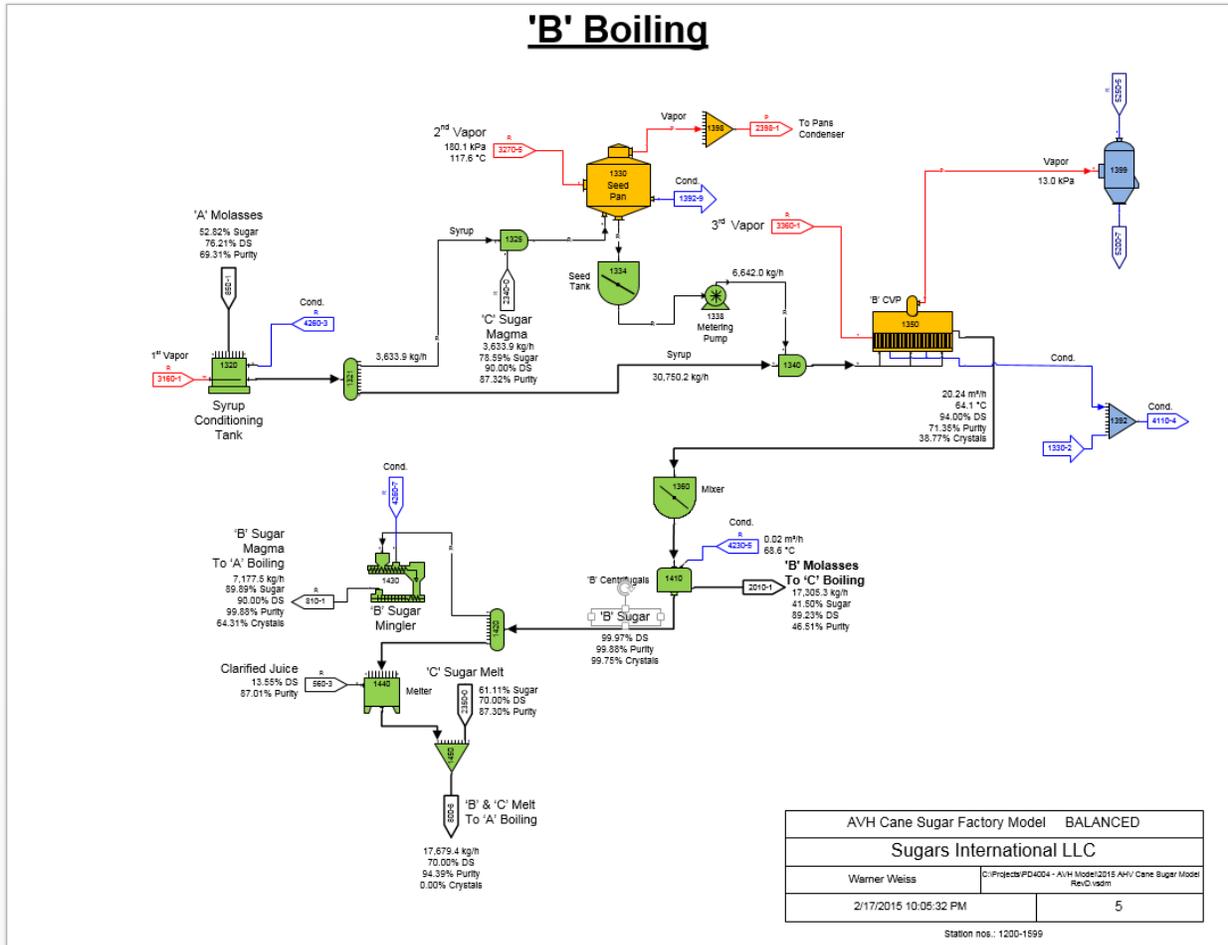
'B' Boiling has a seed pan 1330 using 'C' sugar magma as seed for the continuous vacuum pan 1350. 2nd vapor is used for the seed pan and 3rd vapor is used for the continuous pan. These vapors are automatically taken from the multiple effect based on the needs of the pans. Boiling pressures for the pans are set in their respective condensers and fed back to the pans automatically by Sugars. The seed footing for the continuous pan is controlled by blender 1340 that blends the seed footing with 21.6% of 'A' molasses. The quantity of 'A' molasses to the seed pan 1330 is automatically calculated by Sugars. 'C' sugar magma is mixed with the 'A' molasses for feed to the seed pan. The quantity of 'C' sugar magma is controlled by the blender 1325 and it is calculated by Sugars. All of the quantities are determined during the balance

calculations and the flows to the various stations are adjusted automatically without any need for input from the user. The 'C' Boiling page is shown below.

'B' molasses along with some 'A' molasses blended with standard liquor is sent to the 'C' pan. 'C' centrifugal molasses leaves the model and some of the 'C' sugar is mingled with condensate to make 'C' sugar magma and the rest of the 'C' sugar is goes to a melter where clarified juice is used to make 'C' melt which is then sent to the 'A' Boiling to make standard liquor. Vapor from the 'C' pan is combined with the 'B' seed pan vapor to go to condenser 2399. The condenser sets the vapor pressures for both the 'B' seed pan and the 'C' pan.

The Condensate Recovery and Water Distribution pages of the model are not shown in this paper due to space limitations.

The Steam Distribution page is shown below. Boiler feed water is provided by 1st effect condensate and a boiler storage tank on the Condensate Recovery page.

Steam Distribution
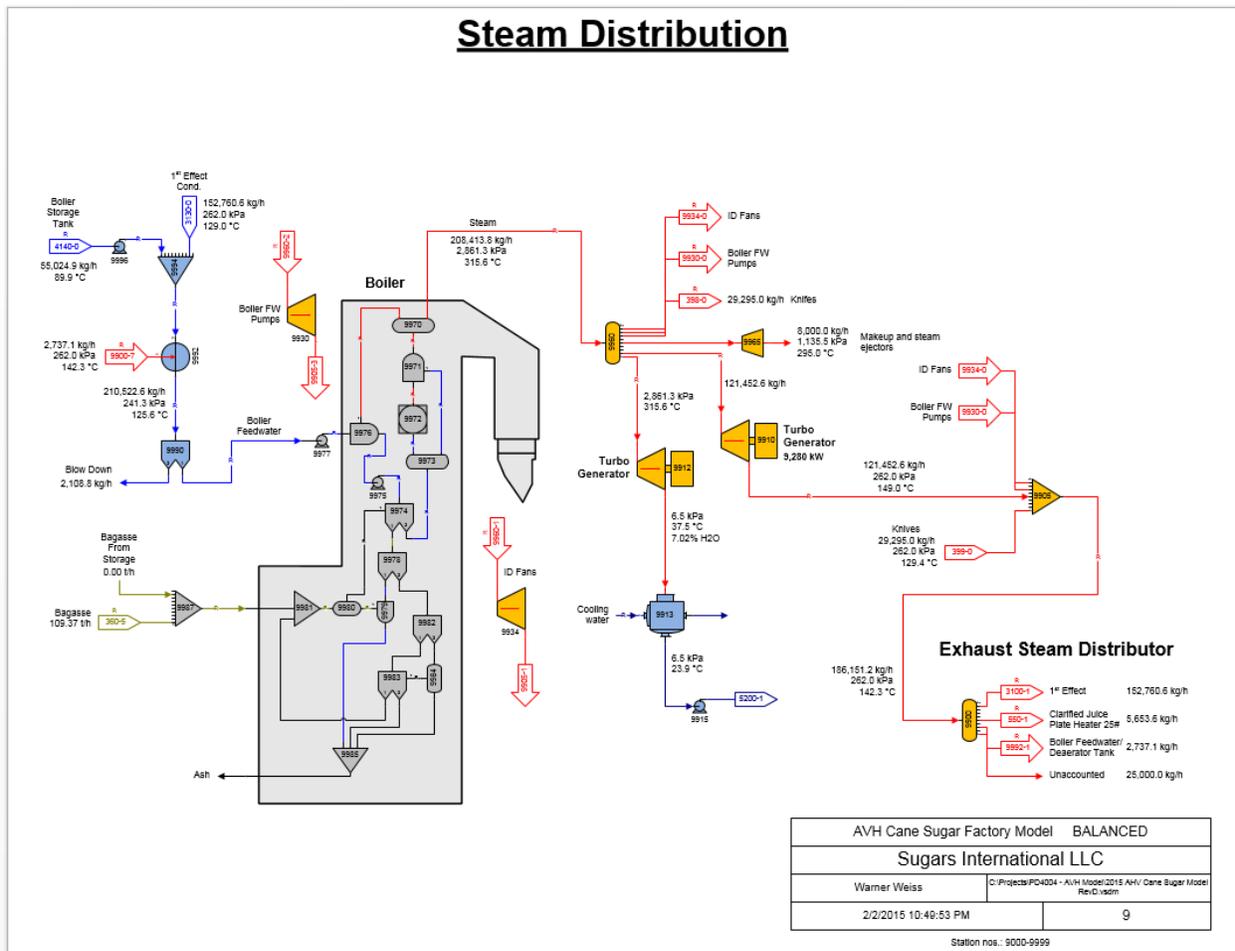
The boiler is a grouping of Sugars stations to convert feed water to steam using bagasse. This grouping is designed to automatically adjust the quantity of bagasse consumed in the boiler by the moisture and sugar content in the bagasse. That is, higher moisture content of the bagasse causes higher bagasse consumption and higher sugar content causes lower bagasse consumption. Two turbo generators provide electrical power for the factory and excess for sale. Turbo generator 9912 has a condenser to condense the exhaust steam from the turbine and return it to the Condensate Recovery page for boiler feed water. The exhaust steam from turbo generator 9910 is combined with exhaust steam from the turbines for the boiler feed water pumps, ID fans and knives to provide exhaust steam for the multiple effect evaporator 1st effect, clarified juice plate heat exchanger, and the boiler feed water deaerator tank. Also, there is an

allowance for unaccounted steam usage. A larger image of the live steam distribution is shown in the diagram below.
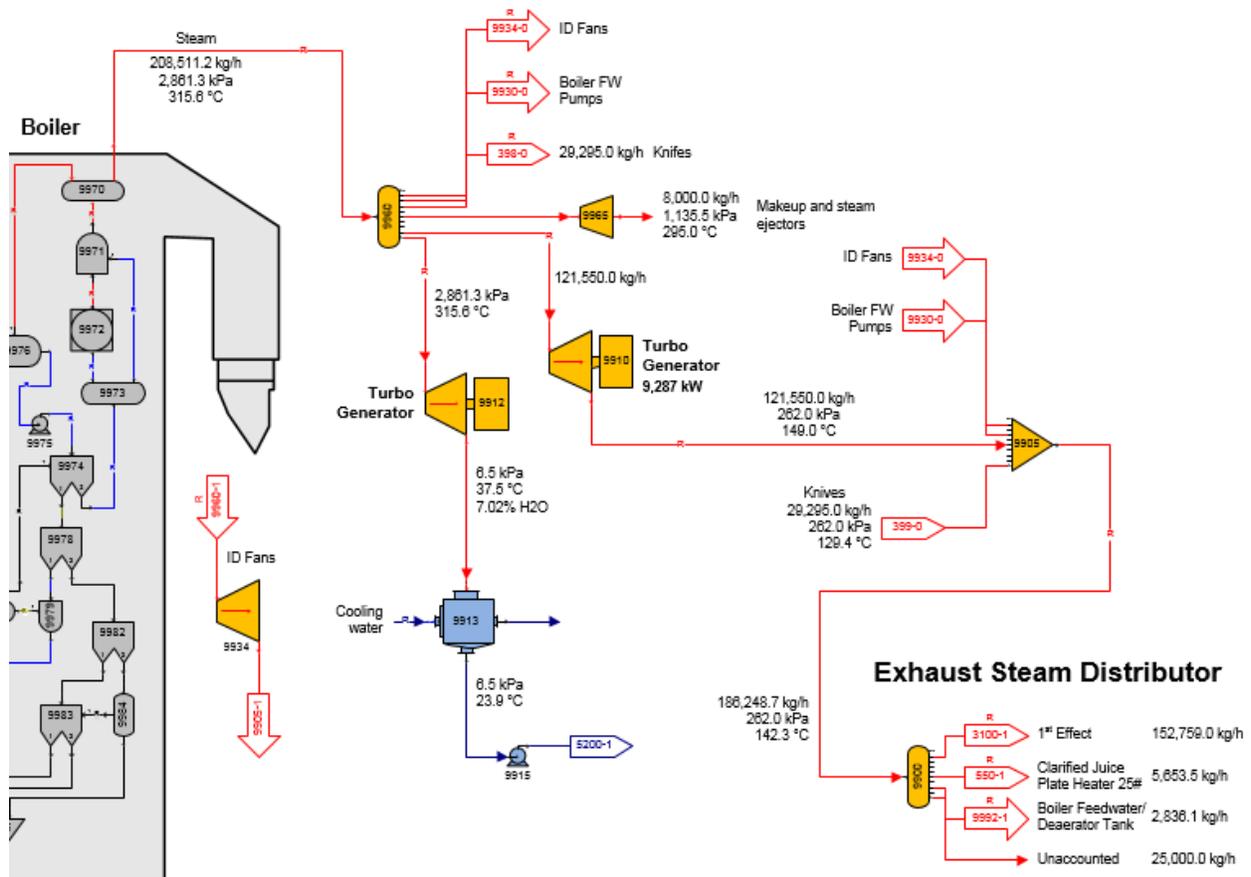
Boiler feed water is supplied by condensates from the 1st effect and the boiler storage tank 4140 on the Condensate Recovery page (not shown).   Condensates going to the boiler storage tank come from heat exchangers in purification, vacuum pans in crystallization and condensates from 2nd through 4th effects in evaporation. More condensate is provided by these other stations than is used for boiler feed water. The excess condensate is used in the spiral heat exchanger 430 in purification and the excess goes to the hot water tank 4251 on the Condensate Recovery page.

If any of the exhaust steam users have a change in their consumption, then the boiler feed water has to change for the model to balance. Hence, changes in the exhaust steam consumers are communicated to the source of boiler feed water to adjust the

quantity until a balance is achieved. This adjustment occurs automatically during the Sugars balance calculations. The diagram below shows the boiler feed water from the 1st effect and from the boiler storage tank 4140 port 0 (4140-0).
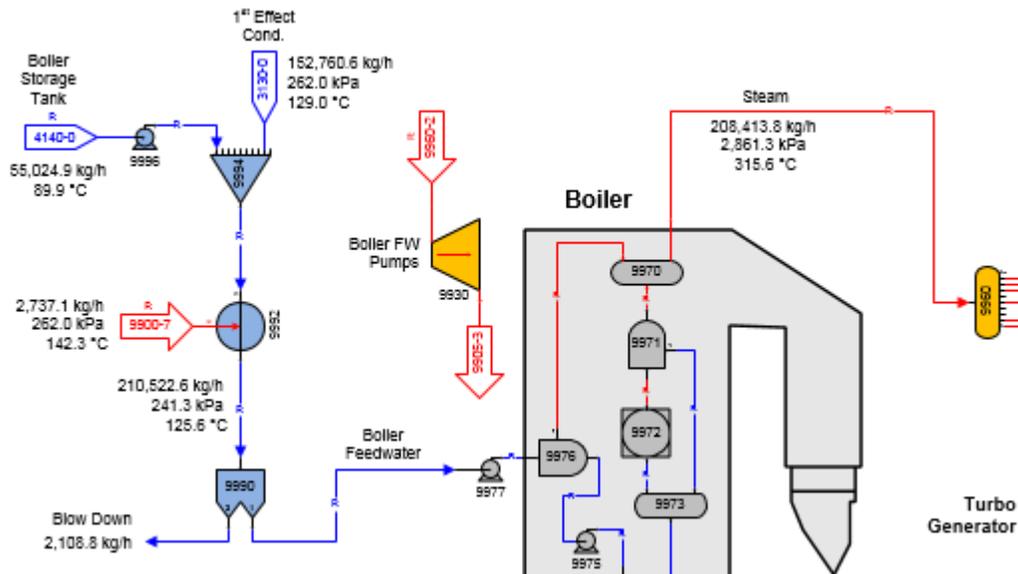

1st effect condensate is a result of the exhaust steam to the 1st effect, but the condensate from the boiler storage tank is adjusted to provide the necessary feed water to the boiler.

The previous examples illustrate some of the intercommunication features between stations as Sugars does the balance calculations. Another benefit of the communication between stations is that it prevents conflicting requirements or data that can't be satisfied. For example, a distributor that supplies steam to a multiple effect evaporator where the evaporator has been specified to produce a syrup with a set percent dry substance. The quantity of steam to the evaporator will be calculated by Sugars and the distributor station providing the steam will not allow the user to enter a steam flow to the evaporator. Or, a turbine with a specified power output will have the steam quantity calculated by Sugars and the distributor supplying the steam will prevent the user from entering a flow rate of steam to the turbine.

Data Import/Export

An optional feature of Sugars is to add data import and export. This provides easy communications with other programs to either enter new data into an opened Sugars model or to use its balance results in other programs.
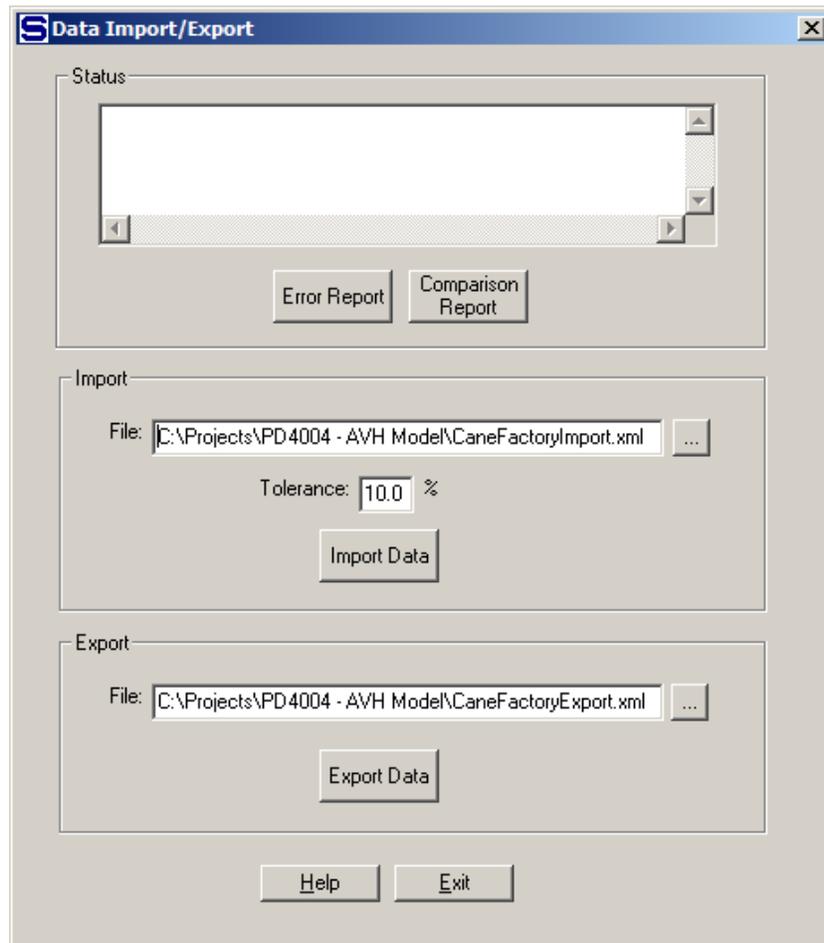
XML data formatted per a schema.is used for the import and export. The imported data is entered into both stations and connecting flows. It isn't necessary to import or export all of the data in a model. Individual stations can be selected for importing data by entering an equipment ID for the stations and then defining new data for those stations. Individual flows can be selected for importing data by using the equipment ID for the station that is the destination port of an external flow or the origination port of an internal flow. Data is exported from all stations that have equipment ID's and their input and

output connecting flows. Data is imported only for stations and flows that have both an equipment ID and an entry in the XML file being imported. An example of an XML file is shown below.

```xml
<?xml version="1.0"?>
<AMSDocument Units="SI" Timestamp="2015-01-26T21:30:23" xsi:schemaLocation="http://sugarsonline.com/AMSSchema.xsd
C:\Program%20Files\Sugars\AMS\AMSSchema.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns="http://sugarsonline.com/AMSSchema.xsd">
  <ExternalFlow>
      <EquipmentID>MS200</EquipmentID>
      <PortNumber>0</PortNumber>
    <Property Name="Temperature">
        <Value> 32.2</Value>
      </Property>
    <Property Name="FlowRate">
        <Value> 500000</Value>
      </Property>
    <Property Name="DrySubstanceLiquid">
        <Value> 17</Value>
      </Property>
    <Property Name="PurityLiquid">
        <Value> 84.5000328623069</Value>
      </Property>
  </ExternalFlow>
  <Station>
      <EquipmentID>MB211</EquipmentID>
    <Property Name="ComponentOutPercent">
        <Value> 57</Value>
      </Property>
  </Station>
  <Station>
      <EquipmentID>PHE430</EquipmentID>
    <Property Name="TemperatureOut0">
        <Value> 59</Value>
      </Property>
    <Property Name="HeatingSurface">
        <Value> 501.0</Value>
      </Property>
  </Station>
  <Station>
      <EquipmentID>PHE450</EquipmentID>
    <Property Name="TemperatureOut0">
        <Value> 88</Value>
      </Property>
  </Station>
  <Station>
      <EquipmentID>PHE460</EquipmentID>
    <Property Name="TemperatureRise">
        <Value> 15.5</Value>
      </Property>
  </Station>
</AMSDocument>
```

The data import and export feature allows quick update of model data from a data acquisition system by importing new data, or to send new set points to controllers. Also, it provides an easy way for Excel and Sugars to talk to each other. For example, data can be exported to an Excel spreadsheet where calculations can be done on the data and then the results of those calculations exported back to Sugars to use in new balance calculations. Currently, this can be done manually on demand, but future releases with a web service interface could make it more automatic and an excellent way to leverage the advantages of each program.

Summary

The Sugars program is a flexible program for modeling and simulating sugar processes. It employs a communication system between unit operations (stations) that allows the program to solve mass and energy transfer between stations in different sections of the process without user intervention during the balance calculations. The interstation communication system is also used to prevent redundant data that can cause conflicting requirements on the parameters within a model. In addition, optional data import and export allows data from other software to be imported directly into the model and the results of a balance can then be exported to other software for further processing. This feature allows external custom calculations that can then be used as input to Sugars.

References

Van der Poel, P.W., Schiweck, H., Schwartz, T. (1998). Sugar Technology, Beet and Cane Sugar Manufacture, Verlag Dr. Albert Bartens KG, 12.4.2.3: 771p.