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**ON-LINE MONITORING OF FACTORY PROCESSES**

By

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**Abstract**

The knowledge of mass and energy flows in a cane sugar factory is a crucial aspect in order to enhance the plant performance and detect process deficiencies. The development of the Advanced Monitoring System (AMS) based on the Sugars software allows nowadays visualising the sugar process by connecting the software to the process and laboratory information system. The AMS was first introduced in 2004 to the sugar industry. Experience gained over the last few years is reported in this paper. Besides the creation of the mass and energy balance, the system can be used for data reconciliation with special regard to measured flows, temperatures and pressures as well as laboratory analytical data. Calculated and measured data are compared to facilitate improvements to process performance and reliability. The AMS requires approximately 100–150 data points (cane mass flow, analytical data, pressures and temperatures) to characterise and display the actual process operations with high accuracy. The AMS is a process monitoring tool allowing the sugar engineer to validate the operation and performance of the process. By defining benchmark values (key performance indices), it is possible to monitor and subsequently improve the performance of process equipment and the processes.

**Introduction**

The Advanced Monitoring System (AMS) is a software package which was specifically developed for the sugar industry (Morgenroth and Pfau, 2004). The AMS package consists of the Microsoft® Visio® program and the Sugars™ program combined with a data exchange add-on that allows the importing and exporting of various types of process information. Microsoft Visio is used for the graphical and operating data display of the sugar processing stations, for example, extraction, purification, evaporation and crystallisation. The Microsoft Visio program is linked with the Sugars program to calculate mass flows, temperatures, purities, etc. Approximately 100–150 data points from the laboratory and process control system (e.g. dry substances, purities, temperatures, pressures and flows) are imported via an Extensible Markup Language (XML) file. The XML file is created on demand by the Management Execution System (MES) of the factory and subsequently imported to the AMS.

Following the import of data, the AMS calculates a closed mass and energy balance of the factory. It is possible to do balances for daily, weekly or monthly production overviews. The AMS helps process engineers and operators to analyse the operation and performance of each processing station as well as the entire factory.

## Applicability

The AMS is flexible regarding the type of factory to be analysed because it uses individual station modules that can be arranged to suit the process being simulated. Typical applications are cane sugar factories, beet sugar factories and sugar refineries. The distillery process can also be displayed with regard to simulated mass balances. Some parameters that are usually fixed (like heating surface areas) can either be integrated as constants into the model, or imported in accordance with the requirements. For example, the area of active heating surface could be imported. Figure 1 shows an open model property window for a heat exchanger. The outlet temperature and the operating heating surface are imported into the model by the AMS from the MES data base. As a result, the calculated heat transfer coefficient (k-value) is shown in correlation to the optimum k-value.

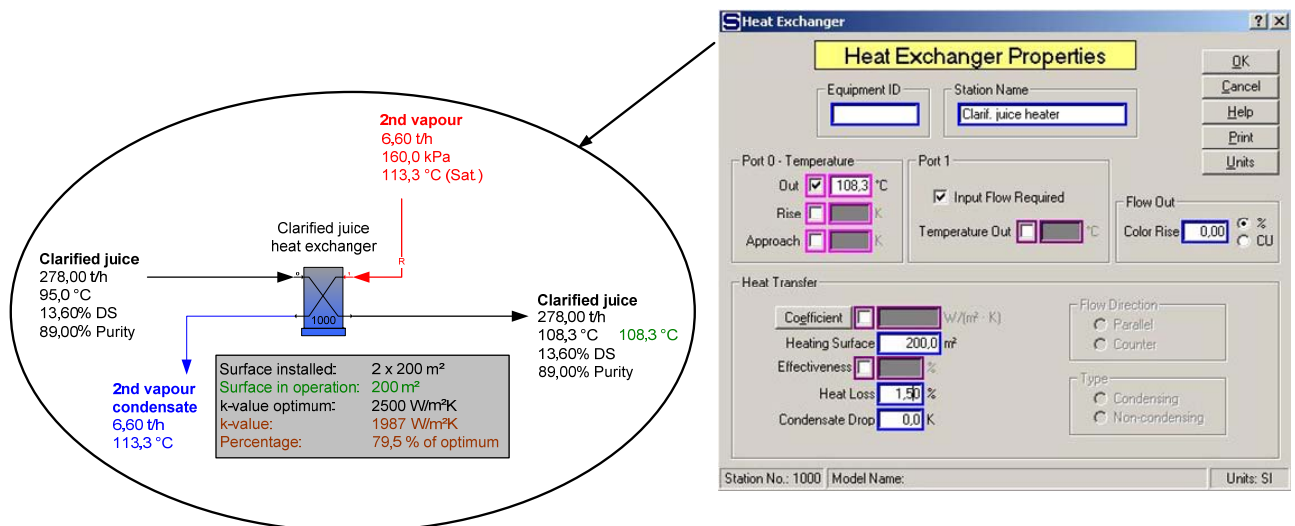


Fig. 1 – Heat exchanger with open model property window

## Description of on-line monitoring performance steps

Approximately 100–150 measured analytical, temperature, pressure and flow data values from the sugar process of the factory are required in order to perform a consistently balanced model of the complete sugar manufacturing process. It is important that the quality of imported or measured process variables and analytical data is high, meaning sensors need to be checked regularly for accuracy and process samples need to be treated in accordance with modern laboratory routines and analytical methods. In some countries, gravimetric brix measurements are still common and they cannot be used as a basis for the mass and energy balances. In such cases, the laboratory needs to switch to internationally recognised analytical methods.

A MES integrating the process control and the laboratory system provides the basis for data handling and transfer. The appropriate monitoring intervals need to be determined and this aspect is managed in the MES as the availability of different data types can vary. While

process variables such as flows, pressures and temperatures are usually available instantly, averaged values can be easily created.

Analytical data are more difficult to collect as this information is usually not provided on-line, but instead by the laboratory once each analysis has been completed. The measurement intervals depend on the importance of the measured values for general factory control as well as the available man power and laboratory policy. Time intervals for analytical data usually vary between two hours and one week.

The task of the MES is to gather all the required data on demand for a selected time frame. The MES creates an XML data file that is subsequently imported to the AMS and processed in order to calculate a mass and energy balance. In the case where no analytical data have been measured within the selected time frame, it is necessary to decide if typical values will be used for the calculations or if the last available data should be used. The last available data are usually used in such cases.

To achieve a highly accurate mass and energy balance of the sugar process, a relatively constant operation of the factory is required. This is usually not a problem in modern beet sugar factories or refineries, but stoppages are much more common in cane sugar factories. Therefore, it is required to choose a time interval that is long enough to gather adequate data, but short enough to exclude longer stops or low capacity periods. Short stops of less than 20 minutes and flow fluctuations do not impact on the mass and energy balances if calculated averages of process variables are used to smooth out short term variations.

Typically once a day, fresh data from the previous day are imported and then used for the process display and analysis.

Other data like heating surfaces can be fixed in the model but also can be imported to reflect actual heating surfaces in use for cases where individual heaters or evaporators are taken off-line for cleaning or complete evaporation trains are stopped, e.g. for cleaning.

Other available process data (especially flows) not required for the mass and energy balance itself can be imported to verify the calculated data. For example, usually only the cane processing rate is imported as a mass flow measured by a weighing scale to the program. All other flows are calculated in order not to rely on data such as volumetric flow measurements. The AMS helps to compare calculated and measured data and allows data reconciliation. Experiences have shown that often more than 50% of the process flow measurements as well as many temperature and pressure sensors are in error. The reasons for these errors are typically scaling on probes and instrument sensors and incorrect installation of instruments. By comparing the AMS results with process data from instruments and sensors, significant variations can trigger the need for recalibration.

The AMS model also can be used to examine different operating scenarios and the impact of these changes to the process. For example, the impact of using different process values on the steam demand can be easily examined by shifting the vapour extraction to a different effect. Also, a colour balance can be performed by the program. This feature can be used to predict the final sugar colour or it can be used to model different operating scenarios.

The detailed view of the process and its performance allows quick detection of weak points like underperforming equipment or process units as well as inaccurate process values. This allows correction or adjustments to the operation of the process to achieve improved

processing results. By on-line access of the XML data exchange file, the monitoring of processes can be done over the internet at any time.

## Examples

The following examples are provided to give an understanding of how the AMS works. Selected examples are displayed here for processing stations (and single processes). Table 1 details the legend for the subsequently displayed figures.

**Table 1** - Legend for Figures 2, 3, 4 and 5

<b>Black lines / values:</b>	<b>Juice</b>
<b>Red lines / values:</b>	<b>Steam</b>
<b>Blue lines / values:</b>	<b>Condensate or water</b>
<b>Green values:</b>	<b>Imported values by process and laboratory</b>
<b>Brown values:</b>	<b>Key Performance Index (KPI)</b>
<b>Violet values:</b>	<b>Measured process values for comparison</b>

Figure 2 shows a five effect evaporation station operating with falling film plate evaporators in a cane sugar factory. Similar evaporation set ups are already employed in a couple of cane sugar factories. Clarified juice enters the 1<sup>st</sup> effect with a brix of 13.6 and a temperature of 116°C and leaves the evaporation station with a brix of 65 and 97.2°C. The properties of the clarified juice including purity, brix and mass flow (black values) are calculated by the simulation model. The violet values show the measured values imported from the laboratory and process for comparison purposes. It is possible to compare the measured values (temperatures, brix, mass flows) with the calculated values (black). Normally the difference between the calculated and measured values should not be more than 1-3%. This comparison enables the process or instrument engineer to check for defective flow meters or temperature transmitters. The green values are imported values from the process and the laboratory.

In the example shown in Figure 2, the vapour pressures and operating heating surfaces for each effect and the syrup brix are necessary to do the mass and energy balance and display selected values of the evaporation station. As a further feature of the AMS, key performance indices (KPI) are shown (brown values). For the evaporation station, effective temperature differences and k-values for each effect are calculated. These KPIs enable the process engineer to check the performance of the evaporators and to determine the amount or severity of fouling. The actual k-values calculated from the measured process variables can be compared with theoretical benchmark values and the resulting actual/optimum ratio is displayed (as a percentage). This KPI can be used to trigger the cleaning process.

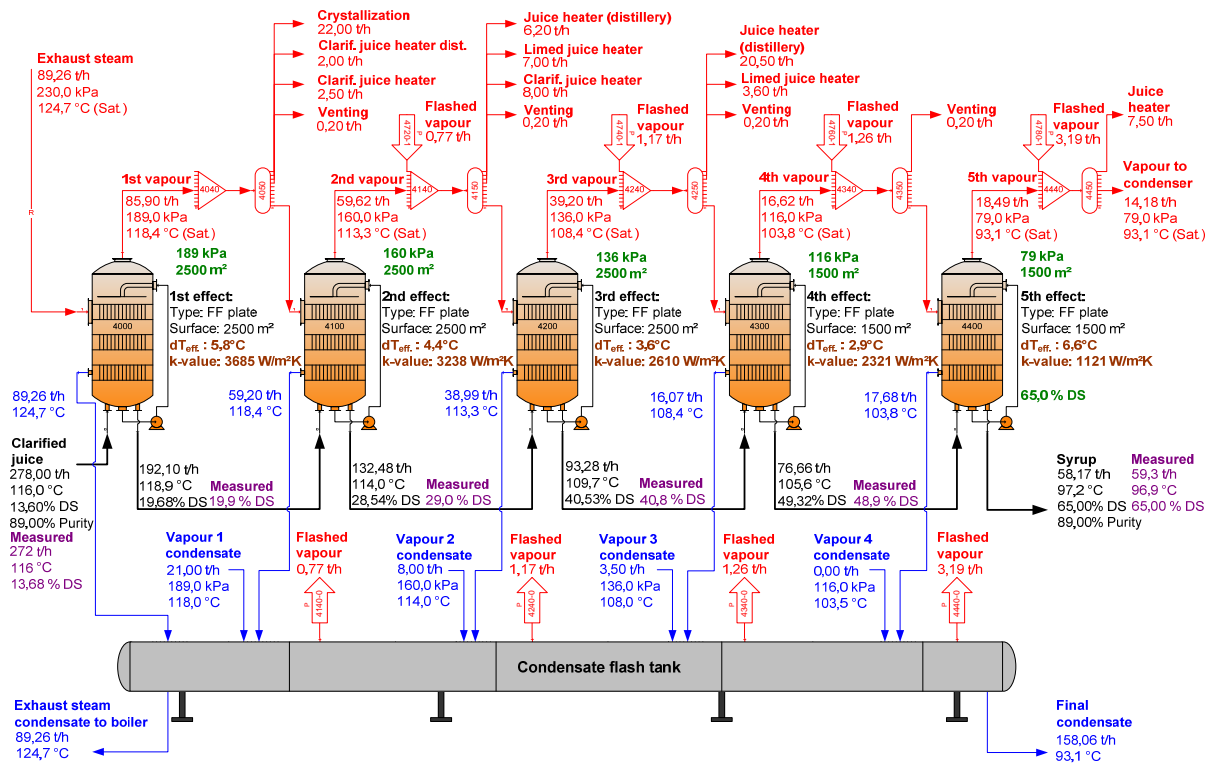


Fig. 2 - Evaporation station simulation

Figure 3 shows the performance of an A centrifugal station in a cane sugar factory. The input values for purity, temperature and mass flow of A massecuite to the centrifugals are calculated by the AMS (black values). Analytical data including purities and dry substances for the A Molasses and A Sugar are imported to the simulation model (green values) from the MES. The simulation model calculates the flows for A Sugar, A Molasses and the wash water amount to the centrifugals. These calculated values can be compared with measured values (violet) from the process and differences like the wash water amount in the example can be detected. The wash water amount to the centrifugals (5.8% on massecuite) and the crystal losses (20.0%) are calculated to provide KPIs and give the process engineer in the factory the ability to easily and quickly check the performance of installed equipment. Large crystal losses without an increase in wash water can indicate the need to change the centrifugal screens.

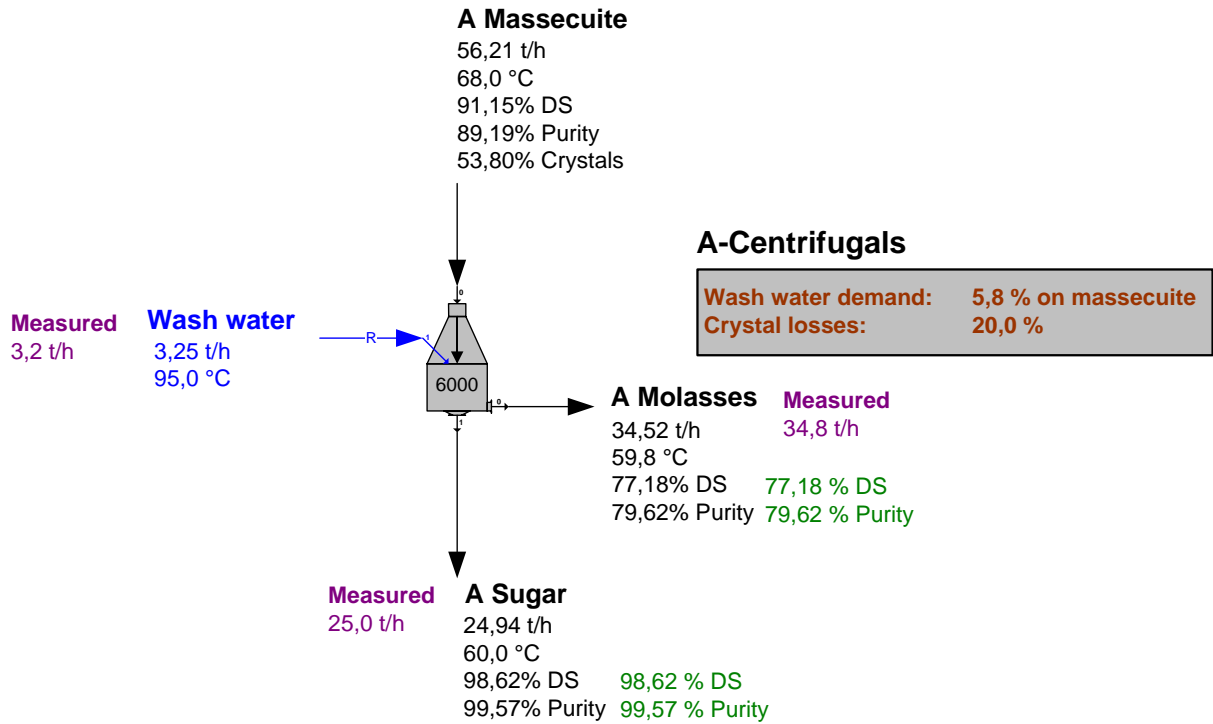


Fig. 3 – Simulation of an A centrifugal station

Figure 4 shows the power station of a cane sugar factory.

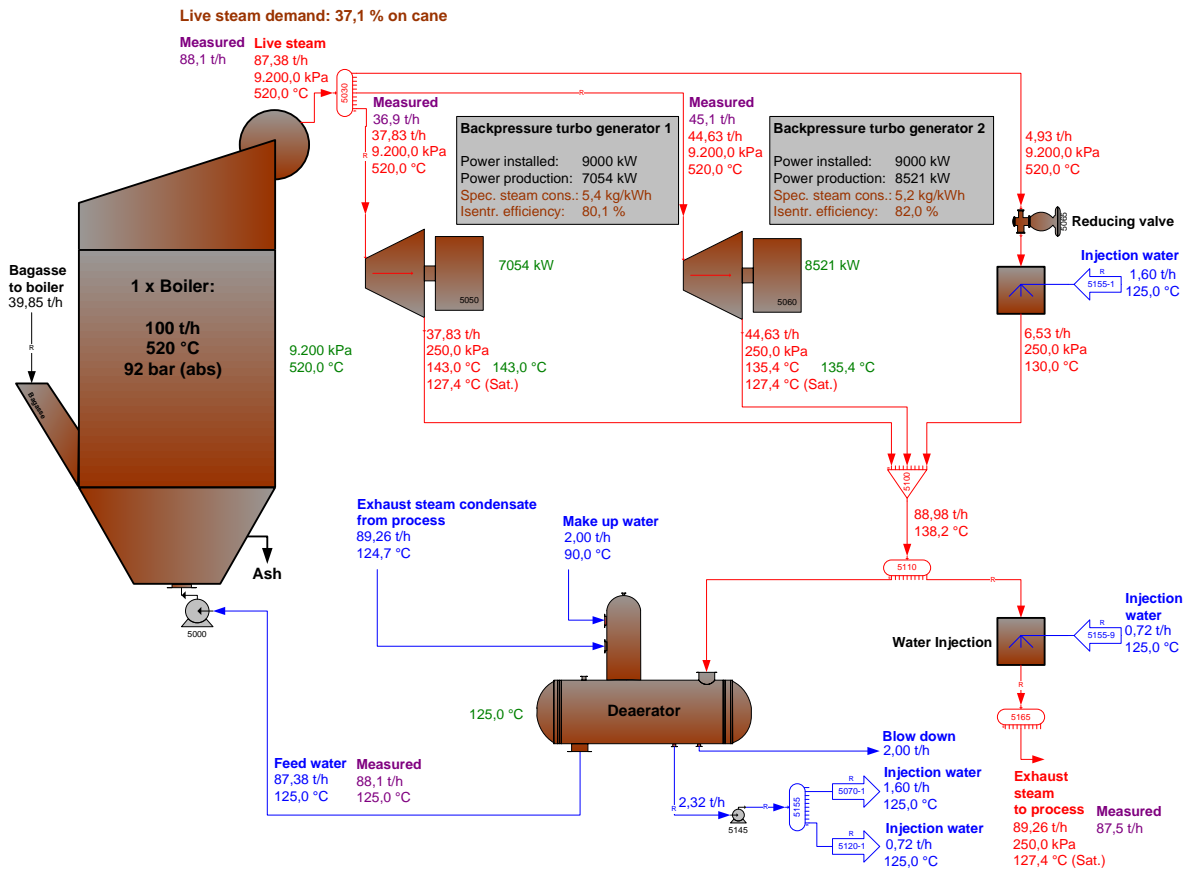


Fig. 4 - Power station simulation

In Figure 4, two 9 MW backpressure turbo generators and a 92 bar (abs), 520°C, 100 t/h boiler are shown. Only seven import values are necessary to simulate this power station (green values). The simulation provides data on the mass flows and properties of live steam from the boiler, exhaust steam to process, steam to turbo generators or feed water amount.

The KPIs for this example are shown for the specific steam consumption and the different isentropic efficiencies of the turbo generators. Figure 4 shows turbo generator 1 is operating at a lower performance compared to turbo generator 2 (based on isentropic efficiency) because it is running only partially loaded. Also, while not displayed, the live steam demand on cane could be easily calculated as an additional KPI.

In the case where a distillery is attached to the factory, the mass balance of the distillery process can be simulated and displayed (Figure 5) to show the amount of ethanol produced in addition to mass balances of sugar and power for the entire factory.

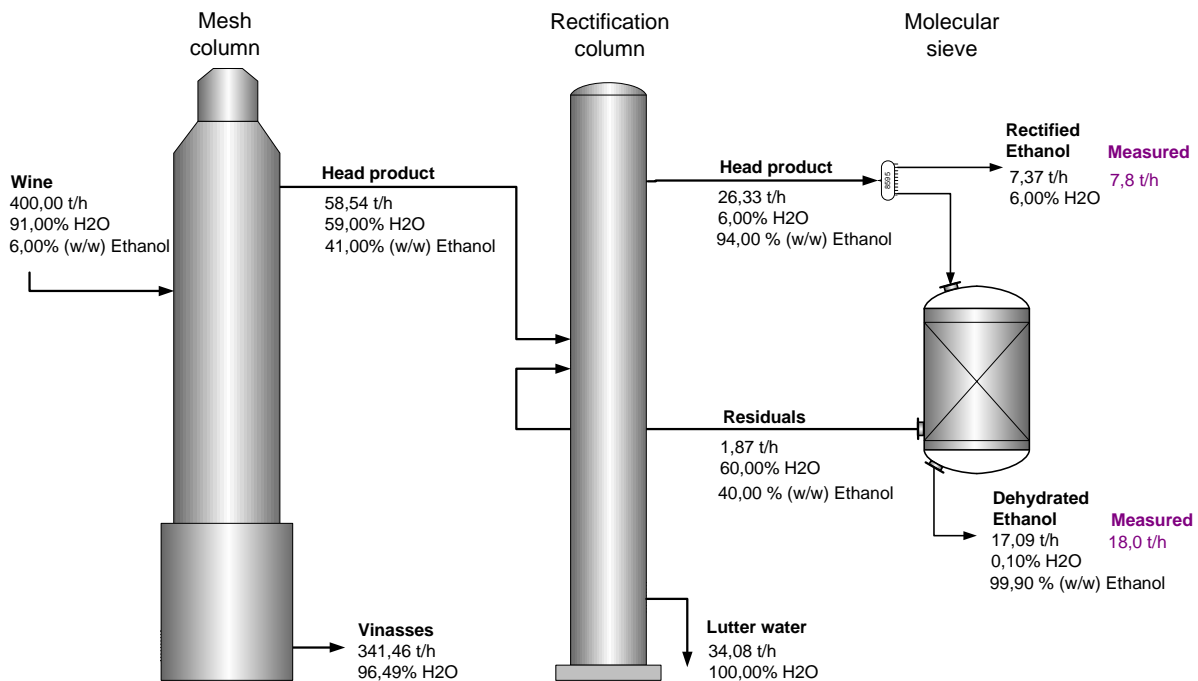


Fig. 5 - Simulation for mass balance of a distillery process

## Conclusions

The installation of AMS in a cane or beet sugar factory or in a sugar refinery offers the possibility to monitor processes closely and provide instant performance data on demand. It is possible to obtain a lot of KPIs for different equipment like centrifugals, heat exchangers, evaporators, turbo generators, etc. The operators or the process engineers are able to visualise the real process in the adapted simulation model for daily, weekly or monthly imported data. The AMS has been operating since 2005 in three cane sugar factories in Brazil and assists the management in analysing and optimising the performance and operation of processing stations and the entire factory.

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## **REFERENCE**

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