# Real Time Process Control - Management Systems for the Sugar Industry

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# 1 Introduction

Sugar factories use different kinds of process control systems. Often these systems have been added to as new software became available resulting in many graphic configurations and formats. Because all the necessary parameters such as pump start/stop stations to the PID control loops are shown on the screen it often appears as a tangled assemblage of figures and numbers to the untrained personnel. Even with the most intuitive system, the operators have to have thorough training before being able to operate the control screen without close supervision. This makes it difficult to switch operator positions during the running campaign.

Analytical data, measured and supplied by the factory laboratory is still essential to operate the entire sugar factory. These laboratory supplied results such as purities, dry substance content, colors, etc. are mostly filed in separate computer programs which can be reached, viewed and printed from the factory computer network. Additionally, most of today's sugar factories possess integrated computer management systems that show overall balance values like sugar production, lime stone usage, molasses production, primary energy demands, etc. Only authorized personnel have access to this data.

During the last 20 years, the development of factory process equipment and process control software has made the sugar process more efficient and economic. But labor costs are still a significant factor during production of granular sugar. Also energy costs, which may be equal to or higher than labor cost has an important role in maintaining a competitive edge in converting a beet into sugar.

Consequently, a system is desirable that combines all available information in the sugar factory and gives concentrated and extracted information to operators and engineers during the daily operation of the process. This system should have the flexibity to adjust (automatically) parameters and outputs just as the factory operation must do during the campaign. It should monitor the process and detect parameters that are out of range.

Since most of the information is already available that will identify the reason for an out of range parameter, the software should be structured to systemically check these variables for the root cause of the upset. As examples, it could be a thermodynamic variable like pressure or temperature, or a mechanical parameter like tower amps or a technological value like brix or color.

A lot of research was done by the sugar industry and the concerning suppliers, but there was still no market-oriented software available that meets these described demands.

The goal of ESCON was to develop a software program that gathers all the information filed in different software systems, and presents it in a format that is easy and adaptable for factory operators to utilize. It should assist in identifying opportunities and problems in a single system that is continuously monitoring the process and laboratory results. As a result of such a software system, the operators will act faster on identifying and correcting process bottlenecks. It also will give the operators a better insight into the different process steps and their interactions. Costs for primary energy and additives like cleaning chemicals could be decreased by knowing the exact thermodynamic performance values of heat exchangers and evaporators.

This paper introduces a new development in integrated computer software that meets the forementioned requirements.

## 2 Architecture

The architecture of this recently introduced ESCON Energy-Management-System is shown in Figure 1. It is designed as a "stand alone system" which gathers information from software systems which are available in the sugar factory.

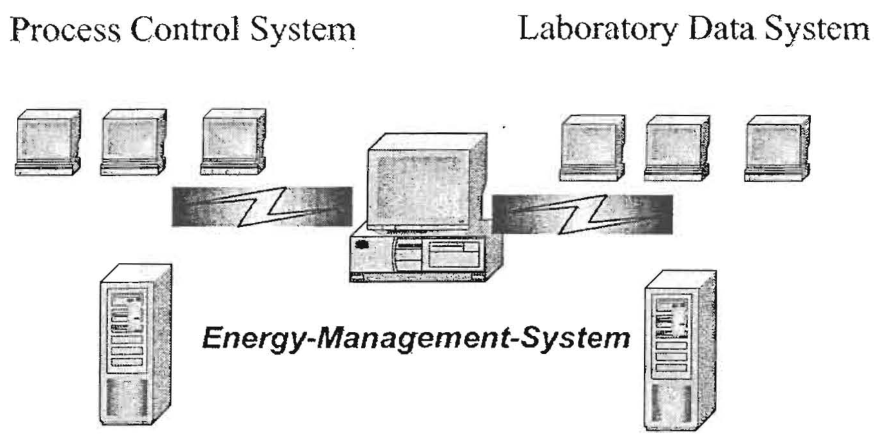


Figure 1: Architecture of the ESCON Energy-Management-System

The Energy-Management-System conducts an online balance of the factory process and informs the personnel about defined occurrences. A data base is fed with certain parameters from the surrounding software systems in 5-minute steps. A chain of calculations is performed to compare present process data with the allowed range. If a value leaves this range, defined by the operating personnel, the Energy-Management-System follows a line of influences on this particular parameter. Every possibility that could cause the parameter to leave the range will be checked. After identifying the influence(s) affecting this parameter, the operator is informed about the parameter that is out of range, the direction (too high / too low) and the reason. For example, the temperature of the thin juice is too low. There are several possible reasons for this parameter to be low and out of range. The follow description highlights the functionality of the system to help solve this problem:

Possible reasons are the thin juice heat exchanger: The surface could be scaled or the condensate traps are not working properly - this reason can be described in the overall heat transfer coefficient of the heat exchanger. The heating medium also could be the reason: a vapor pressure could be too low. This leads to the question what causes the vapor pressure to be too low - thus the evaporator will be checked. If the vapor for the thin juice heater would be from the $4^{th}$ effect, the evaporator #4 has to be checked. But evaporator number 4 is not independent of the inlet pressure to the first effect thus all the evaporators must be systematically checked to aid in identifying a low vapor pressure supply to the thin juice heater. Of course, there are many more possibilities for a low temperature for the described thin juice heater (juice flow rate, venting, etc. - see Figure 2) but the Energy-Management-System will check every possible reason and inform the operator about the reason (or mutiple reasons, if necessary).

The next generation of the Energy-Management-System is a software tool that interacts with the factory network. Parameters can be changed by personnel that are authorized to do so on their network stations (office, process control room or even at home). These screens can be displayed on any authorized network machine improving the management system versatility. It is no longer a stand alone machine. This system is called the General Management System (see Figure 3).

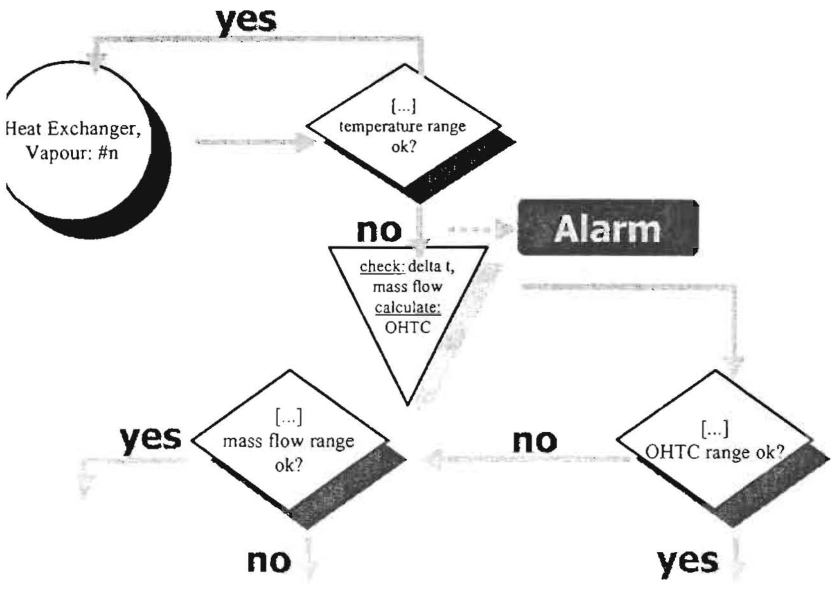


Figure 2: internal procedures of the Energy-Management-System

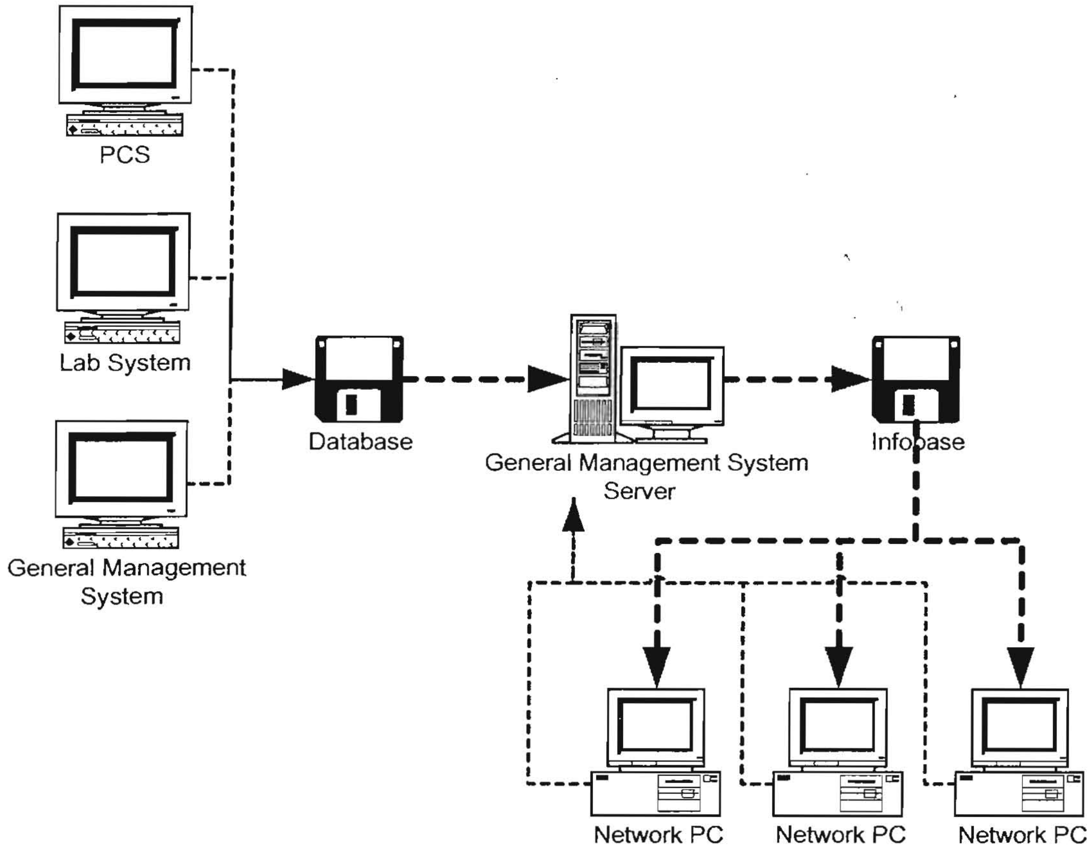


Figure 3: network integrated Management System

# 3 Parameter Input Mask

The parameter input mask is the heart of the system. Information for temperature ranges, pressures, flow rates, dry substance contents, colors, heat exchanger and evaporator surfaces, overall heat transfer coefficients, etc. are listed. These values can be defined only by personnel that have authorization. The parameter input mask is pass word protected.

The actual performance of the factory process is always compared with the definitions, specified in the parameter input mask. Thus it is necessary to maintain this list during campaign, because technological parameters vary during campaign, due to several circumstances (beet quality, ambient temperature, etc.)

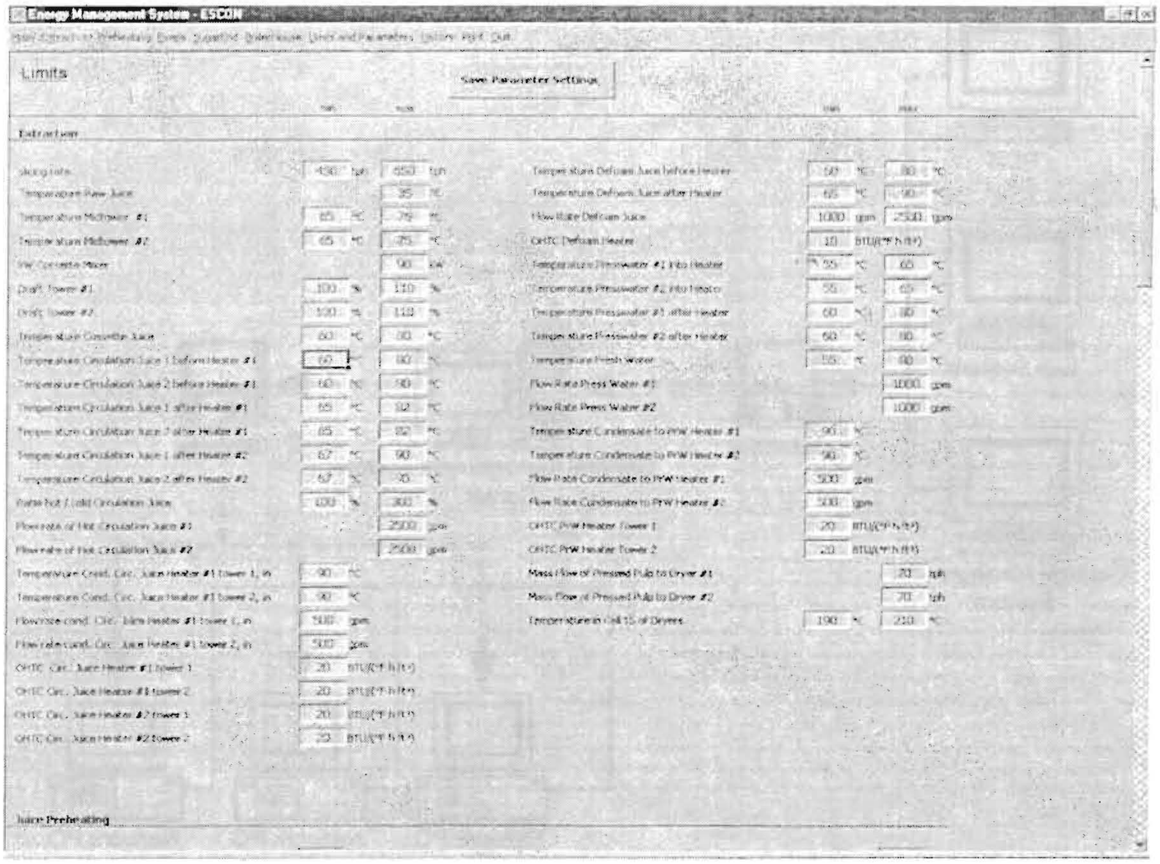

Figure 4: Limits and Parameters input mask

It is also possible, that a parameter considered constant changes during the campaign. I.e. the surface of a heat exchanger can be increased by adding plates to a plate and frame heat exchanger. This value can be typed into the input mask and the system will recognize the changed heat exchanger area (see Figure 5).

All internal calculations are based on the information, defined in the parameter input mask "Limits and Parameters".

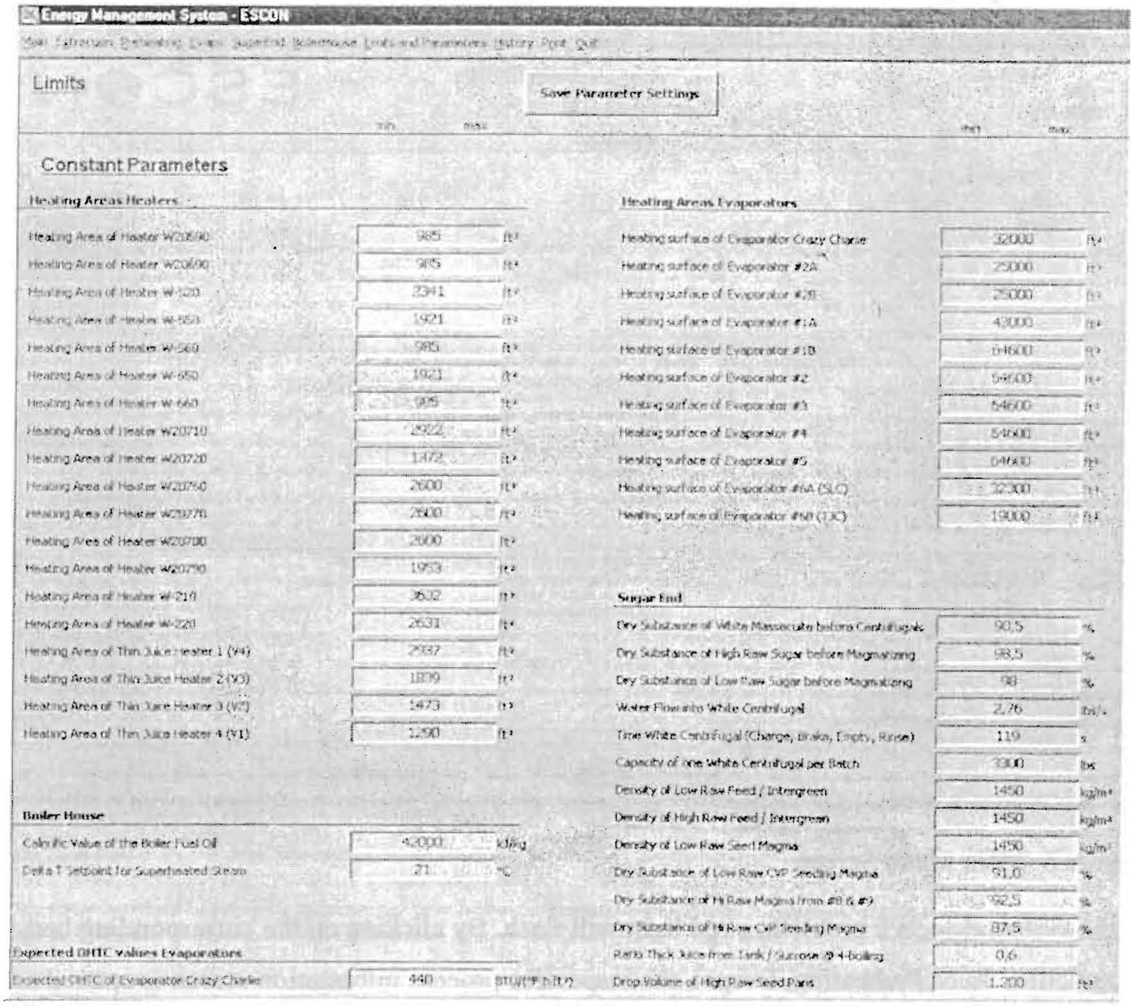


Figure 5: definition of constant parameters

# 4 Main Screen

The Main Screen is designed for the users of the Energy-Management-System. Here, a quick warning is displayed if the system detects an error in the factory and the error, as well as the reason is shown.

The system is also started and shut down in this screen. All information that is shown in the warning windows can be reviewed in the corresponding process information screens (see below).

The warnings are filed in the history sheet. This sheet can be viewed and printed. At the end of a year, a new history file is generated automatically.

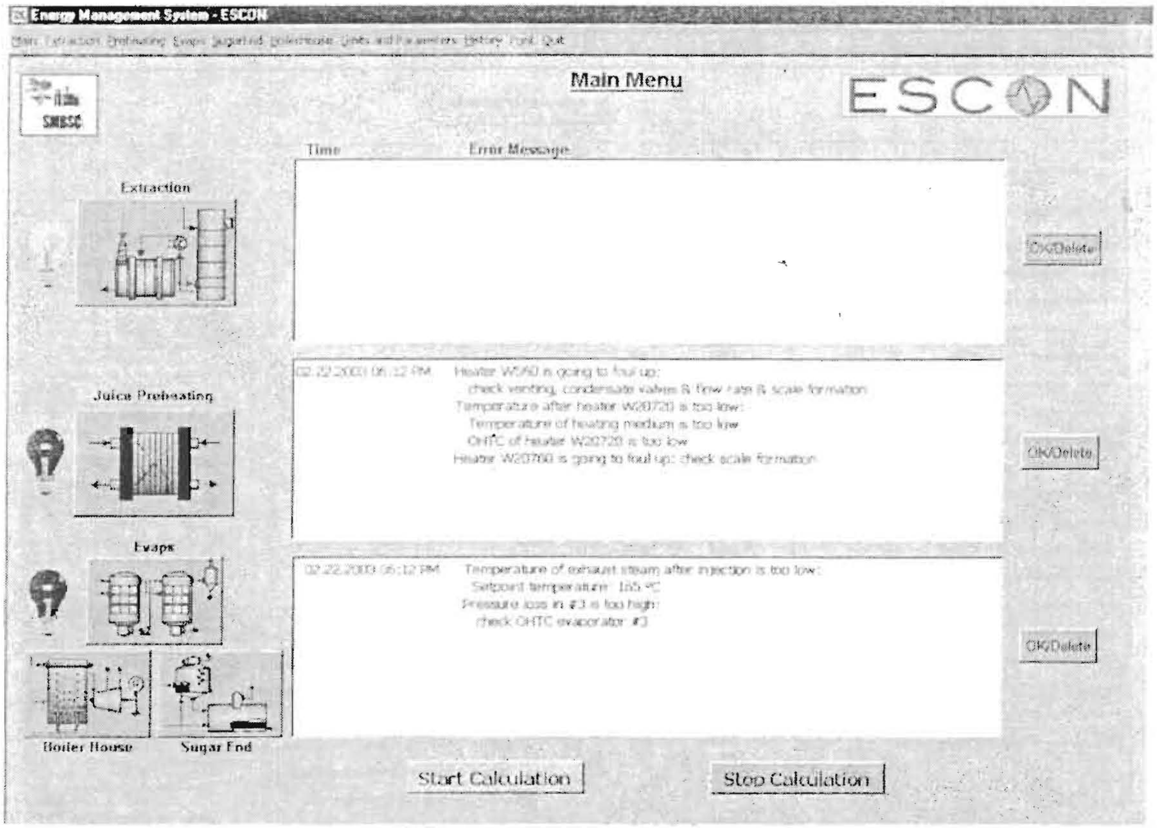


Figure 6: Main Menu Screen

If the system detects a problem, a red light will flash. By clicking on the corresponding button (Extraction, Juice Preheating, Evaps), the respective process information screen is opened and further information is displayed.

## 5 Process Information Screens

The process information screens are subdivided into the different process steps. This is always customer oriented, because every factory has different demands on the system. In this example, the process information screens are subdivided into the parts:

1. extraction,
2. juice pre-heating,
3. evaporation,
4. boiler house and
5. sugar end.

## 5.1 Extraction

The extraction part shows the cossette mixer, the tower diffusers, pulp presses and the pulp dryers.

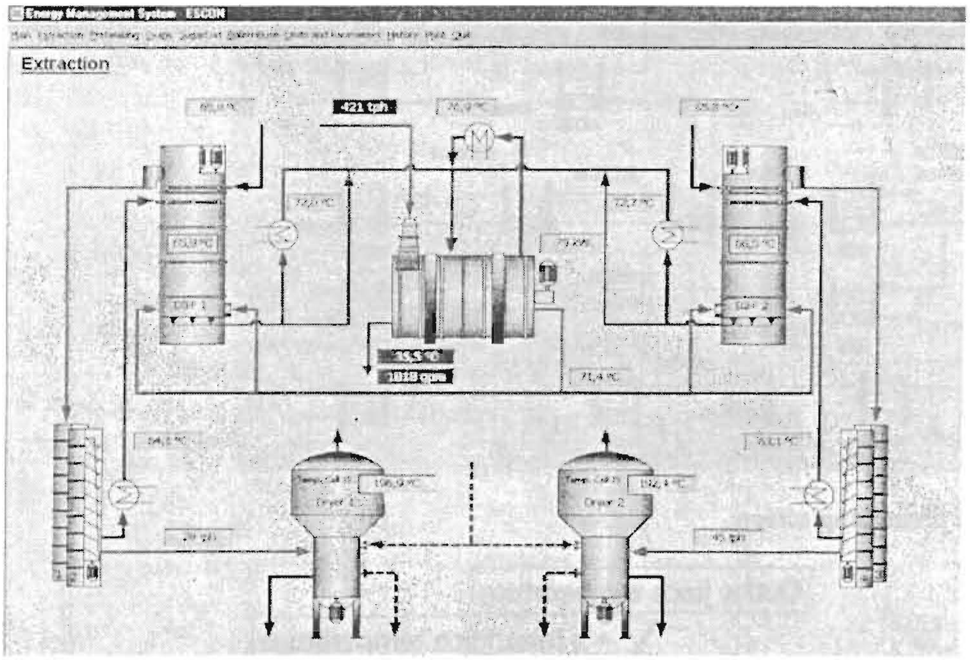


Figure 7: Extraction area

The most important values are displayed on the screen. If one or more of these parameters leave the given range, they are marked blue (value too low) or red (value too high).

## 5.2 Juice Preheating

The juice preheating screen is a very powerful tool of the Energy-Management-System. During every calculation cycle, all heat exchangers are balanced and the overall heat transfer coefficient (OHTC) is displayed. In the case of a low OHTC, the value will show up with a brown color, and will indicate that this particular heater has to be cleaned. In praxis, this result leads to a decrease of cleaning chemicals, since heat exchangers will be cleaned only when it is necessary, eliminating the need for cleaning on a regular schedule. The energy management system determines the cleaning schedule.

The Energy-Management-System separates between vapor heated heat exchangers and those that use condensate. The thermodynamic energy balance will calculate the amount of condensate flowing through the heater.

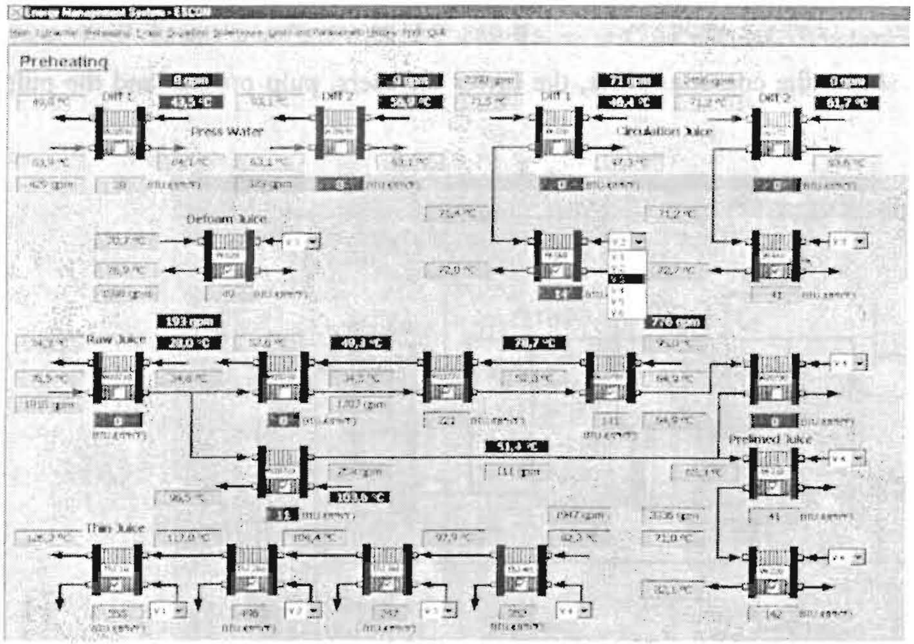


Figure 8: juice preheating screen

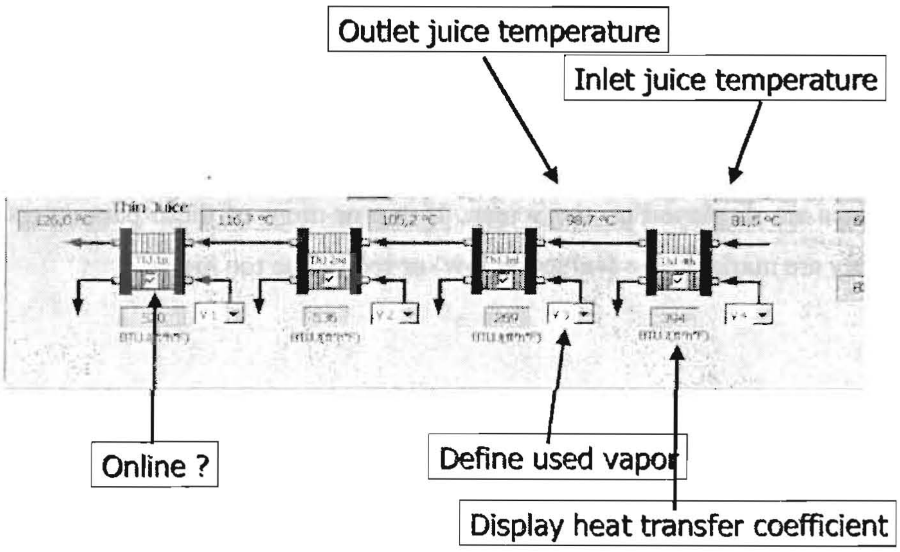


Figure 9: Configuration of heat exchangers

Every heater can be defined on- or offline. For every heater, the connected vapor has to be defined by the corresponding drop down menu. This is necessary, because a lot of heaters are operated with varying vapors during the campaign. The Energy-Management-System will recognize the vapor selected and calculate with the corresponding temperature and pressure of that vapor. The following calculation chains also will take the vapor selected into consideration.

## 5.3 Evaporators

The evaporator screen is configured with regards to the customers needs and desires. In this example, the pressure differences are displayed, since it is not possible to calculate the overall heat transfer coefficients of the evaporators online, due to a lack of brix measuring devices. However, the pressure difference in each evaporator body gives a sufficient idea about the thermodynamic performance.

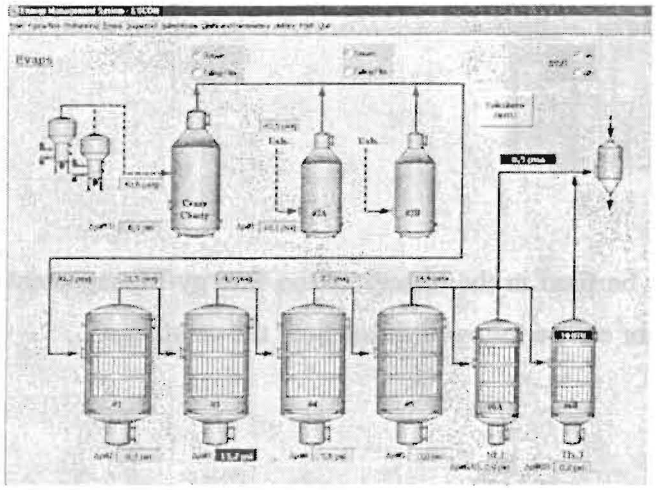

Figure 10: evaporator screen

If several evaporators are in use (i.e. if cleaning occurs and further evaporators can be used) the respective evaporator in use can be defined by mouse click (compare Figure 10 and Figure 11).

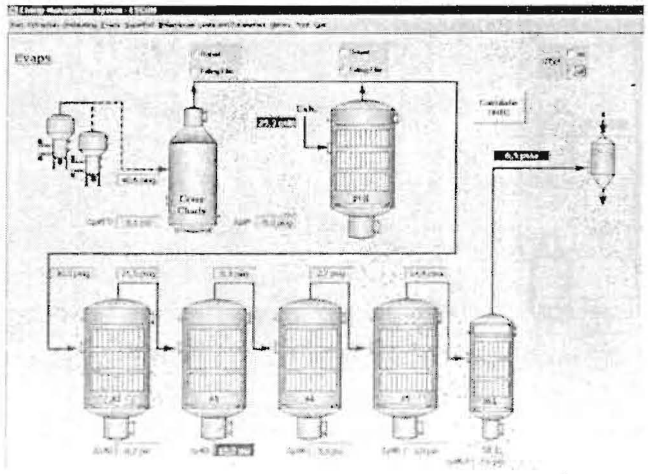

Figure 11: changed evaporator set-up

Given the juice dry substance content for every evaporator, there is sufficient information available to calculate the overall heat transfer coefficient. To obtain the current OHTC, the inlet and outlet brix has to be measured by the laboratory and a special OHTC calculation routine will provide the information (see Figure 12).

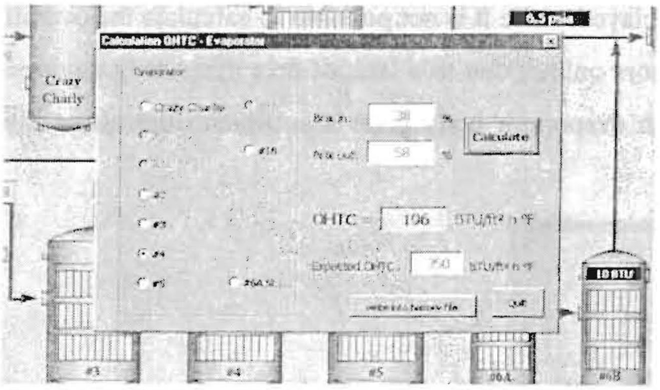


Figure 12: OHTC calculation window

The result of the OHTC calculation can be filed in the history of the Energy-Management-System, thus the behavior of the evaporator can be followed throughout the campaign.

## 5.4 Boiler House

The information of the boiler house is more of less dependent on the installed measuring devices. Superheat of the steam before and after cooling is displayed and the amounts of cooling water are calculated.

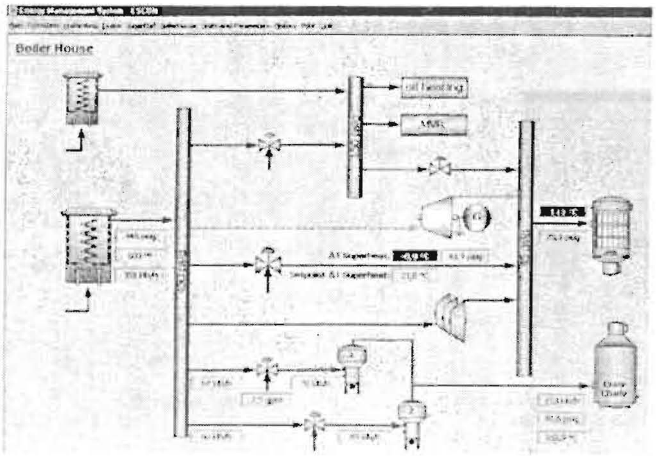


Figure 13: Boiler House screen

## 5.5 Sugar End Screen

The information screen about the sugar end operation also displays the technically necessary information on pans and centrifugals. Again, the number of calculations or the level of troubleshooting and problem identification from the management system is dependent on the installed measuring devices and the amount of samples from the laboratory. Consequently, massecuite flow rates, wash water amounts, crystal contents etc. can be calculated and the corresponding information and recommendations can be given in the "Main Menu" screen.

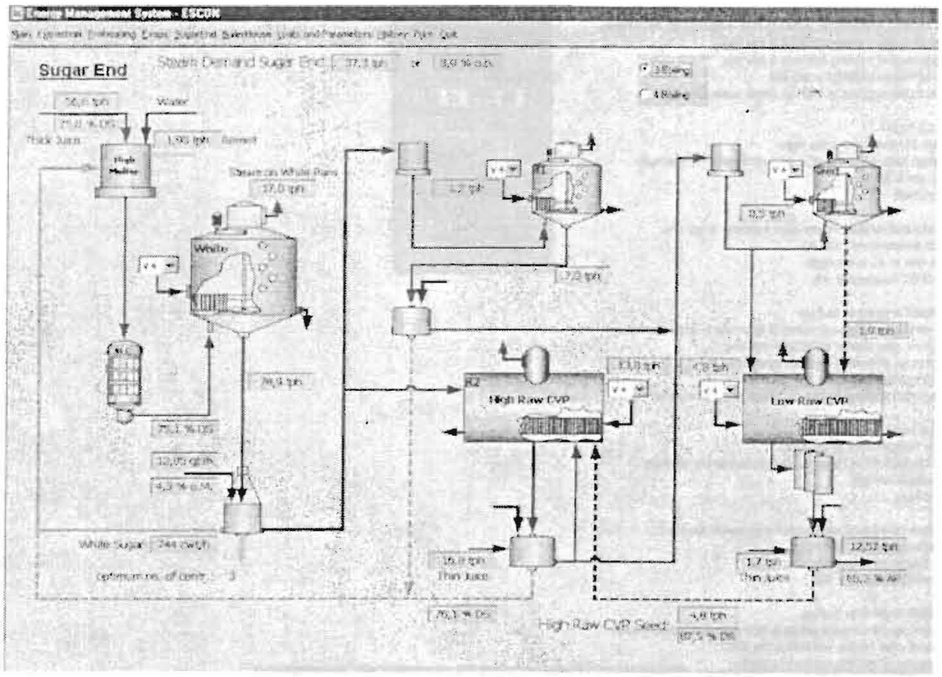


Figure 14: sugar end screen

Different operation scenarios can be recognized by clicking the corresponding buttons (here: 3-boiling or 4-step boiling scheme). The Energy-Management-System will calculate, relative to the respective scenario.

### 5.6 History File

The history file is the collection of all warnings from the Energy-Management-System.

The window is subdivided into 12 ledger cards (one for each month). On the 1st day of a new month, a new ledger card is started and at the beginning of a new year, the history file i.e. 2002/2003 is stored on the hard disk and a new history file (i.e. 2003/2004) is created.

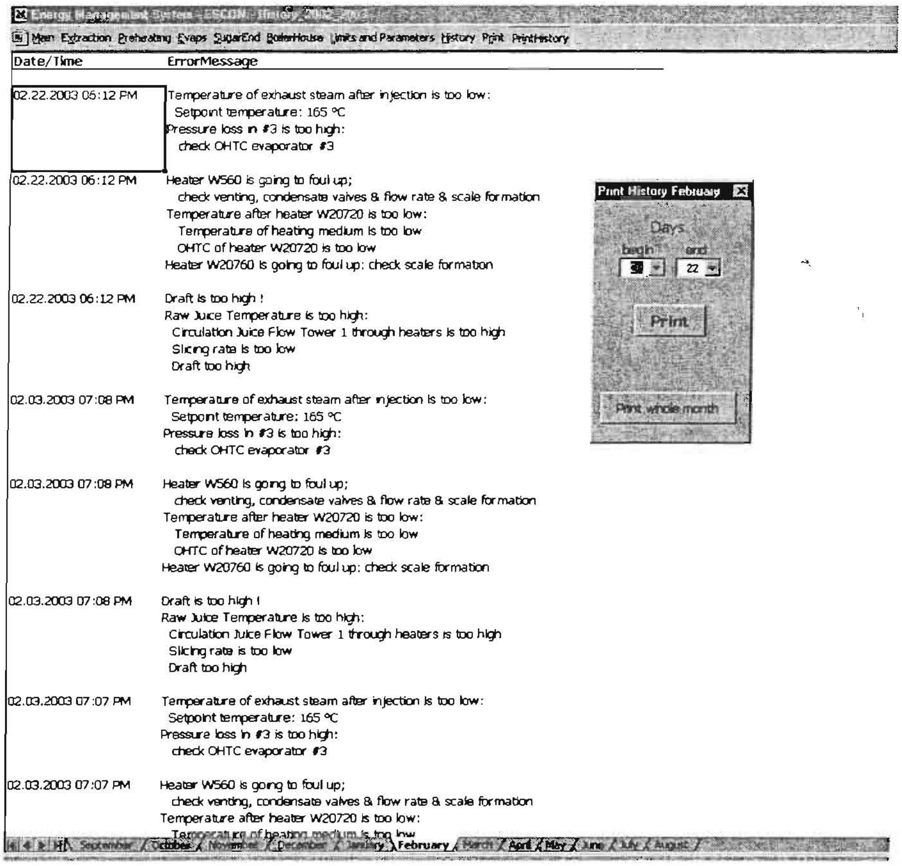


Figure 15: history file

# 6 Summary and Conclusions

The availability of a real-time process control system gives sugar factories further opportunities to increase their profitibity. The goal was to design a software based expert system that is used by both, engineers and operators. Operators can react fast, since the expert system displays warnings and also locates the spot in the factory where the failure occurs. Consequently, operators can react directly to the warning, which saves time and money.

Cleaning costs can be reduced, since the equipment is monitored throughout the entire campaign and cleaning only has to occur when necessary. It will also reduce the risk of higher energy and lower throughput if cleaning steps are not completed when necessary.

Another important result of the presented system is a higher degree of flexibility and interaction by the operators. The system makes it much easier to understand the process and the training phase for operators can be shortened significantly.

The developed expert system is very flexible and runs on different software platforms (Windows NT, XP, Linux, etc.). It is prepared for each factory, based on specific demands and can be used as a stand alone system or can be integrated into the factory network.

The maintenance of the Energy-Management-System can be conducted from every part of the world using the internet. This allows the user to i.e. integrate new heat exchangers and the adjustment of the system will be done from our network computer in our local office. At the start-up of the new heat exchanger, the Energy-Management-System is updated through the internet and the new device will be taken into consideration.

## 7 Acknowledgements

The authors would like to thank the personnel of the sugar companies which were involved in the development of the existing system and have helped to make it run on the present professional standard. These are in particular

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