SIMULATION OF THE MALELANE AND KOMATI MILLS WITH *SUGARS*™ SIMULATION SOFTWARE

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Abstract

The Malelane and Komati mills were modelled using the *Sugars*™ simulation software package. Application of the program is illustrated by comparison of predicted outputs with actual mill performance. A process modification at the Komati mill was first simulated with the program and the actual performance after implementation compared favourably with the simulation. Material and energy balance outputs obtained from all the simulations closely match the observed performances of the mills. The *Sugars*™ software has proven to be a suitable program to achieve modelling goals within reliable limits. Implementation of the process economics facility of the program in the near future will further enhance the evaluation of envisaged plant modifications.

Keywords: simulation, process modelling, Malelane, Komati

Introduction

Numerous models to simulate the sugar manufacturing process are in existence. Most of these are empirically based, usually on the developer's own experience and rules of thumb. Rather than acquiring or developing yet another empirical spreadsheet model, TSB's Research and Development department decided to invest in a commercial model specific to the sugar industry. TSB required a model having a sound theoretical base and centralised, continuous updating and development using inputs and the needs of many users. The *Sugars*™ software package met these requirements.

Sugars™ was implemented at the TSB mills with the purpose of simulating the existing sugar manufacturing process. It can now serve as an analytical tool to evaluate the effect of different process modifications on the performance of the mills. Implementation of the economics module will further enhance the use of the program.

A model can be described as an idealised representation of a real system that is used to analyse and explain the essential relationships within the system. The use of a model for an experimental investigation results in design and operational decisions in less time and at less cost than direct manipulation of the system (Blanchard and Fabrycky, 1990). It is therefore obvious that simulation and modelling are useful tools in the evaluation of a concept or system.

Mass and energy flow balances in the sugar factory typically occur in an *open system*. In such a system material (or energy) is transferred across system boundaries, i.e. it enters and leaves the system (Himmelblau, 1982). In a simulation environment nearly all the models operate in *steady state*. This implies that there is no internal holdup or release of mass or energy in the system.

Sugars™ simulation software

Computer programs available for flow-sheeting can be divided into two basic types: full simulation and simple material balance (Sinnot, 1993). *Sugars*™ is a PC based simulation program of the first type, and is specific to the sugar industry. It models both beet and cane sugar mills or sections thereof. It is used in 16 different countries of the world, among them the United States, Australia, Germany and Taiwan. The program has been used extensively to evaluate major decisions on process modifications. A US pollution control agency accepted results from *Sugars*™ for use in applications for boiler permits.

A model is constructed from a flowsheet of the plant. The actual plant flowsheet is translated into a sequence of virtual stations that are similar in performance to the actual stations. Virtual station models that are included in the program are: centrifugal (batch and continuous), heater, melter, pan, distributor, dryer, crystalliser, evaporator (single or multiple effect), tank, receiver, flash tank, cooler, separator/filter, blender, reactor and compressor/pump. Each of these stations have parameters that control the performance of the station. These parameters can be adjusted to allow the simulation to agree with data from the factory. Several virtual stations must sometimes be combined to be able to model a physical unit. A simple example to demonstrate this is a system with two feed and three outlet streams, typically a tank, as is shown in Figure 1 (Sugars International, 1996).

Virtually any process can be modelled provided the stations in *Sugars*™ can be used to simulate the actual unit operations. For a new model to be simulated only the sequence of stations needs to be specified in a single file, with the remaining data being supplied from within the simulation environment. A flow diagram of the Malelane refinery model is presented in Figure 2, which illustrates how complex a model can become.

Every flow stream in the program output shows weight and volume flow, pressure, temperature, percentage dry substance, purity, percentage crystals, specific weight, enthalpy, specific

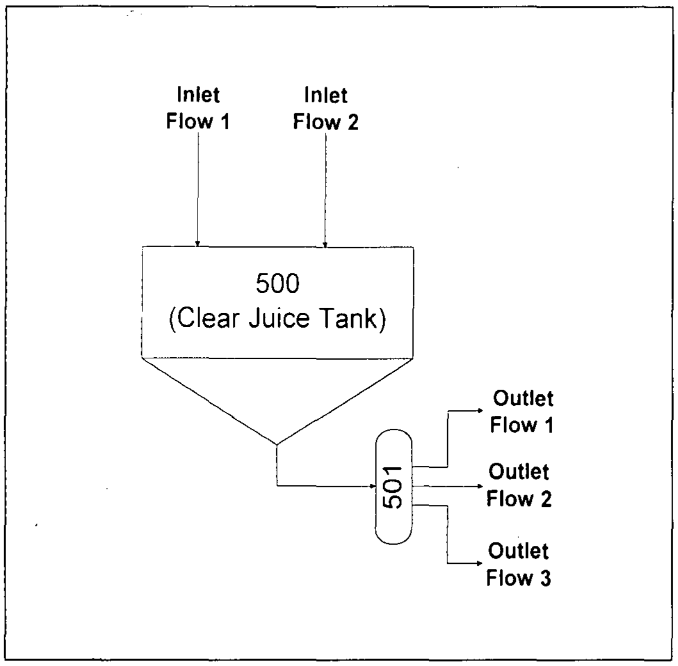

Figure 1. Process tank modelled with *Sugars*™.

heat, supersaturation, boiling point elevation, solubility equation coefficients, colour and flow stream fractions. Streams consist of one or more of the following components: water, sucrose, dissolved non-sucrose compounds, crystal content, lime (as CaO or $CaCO_3$), other solids such as fibre, steam, carbon dioxide and ammonia. Flow streams can be heating or cooling or process. The program calculates the mass balances from true composition and not from pol or brix.

Sugars™ can do complete calculations of energy, mass and colour balances for a model of an existing sugar factory. It is valuable for predicting the sugar yield and steam consumption of a new process, equipment change and/or operating strategy. Data obtained with a simulation do not always correspond exactly with those of the factory because the model is a steady state calculation based on the feed to the model, whereas in a factory the feed is changing continuously and the process streams fluctuate accordingly.

Sugars™ can evaluate the effect of a change in equipment; for example additional or new heat exchangers, crystallisers, pans, evaporators, filters, etc., to justify a capital investment. This was demonstrated in the Komati model with molasses back-blending.

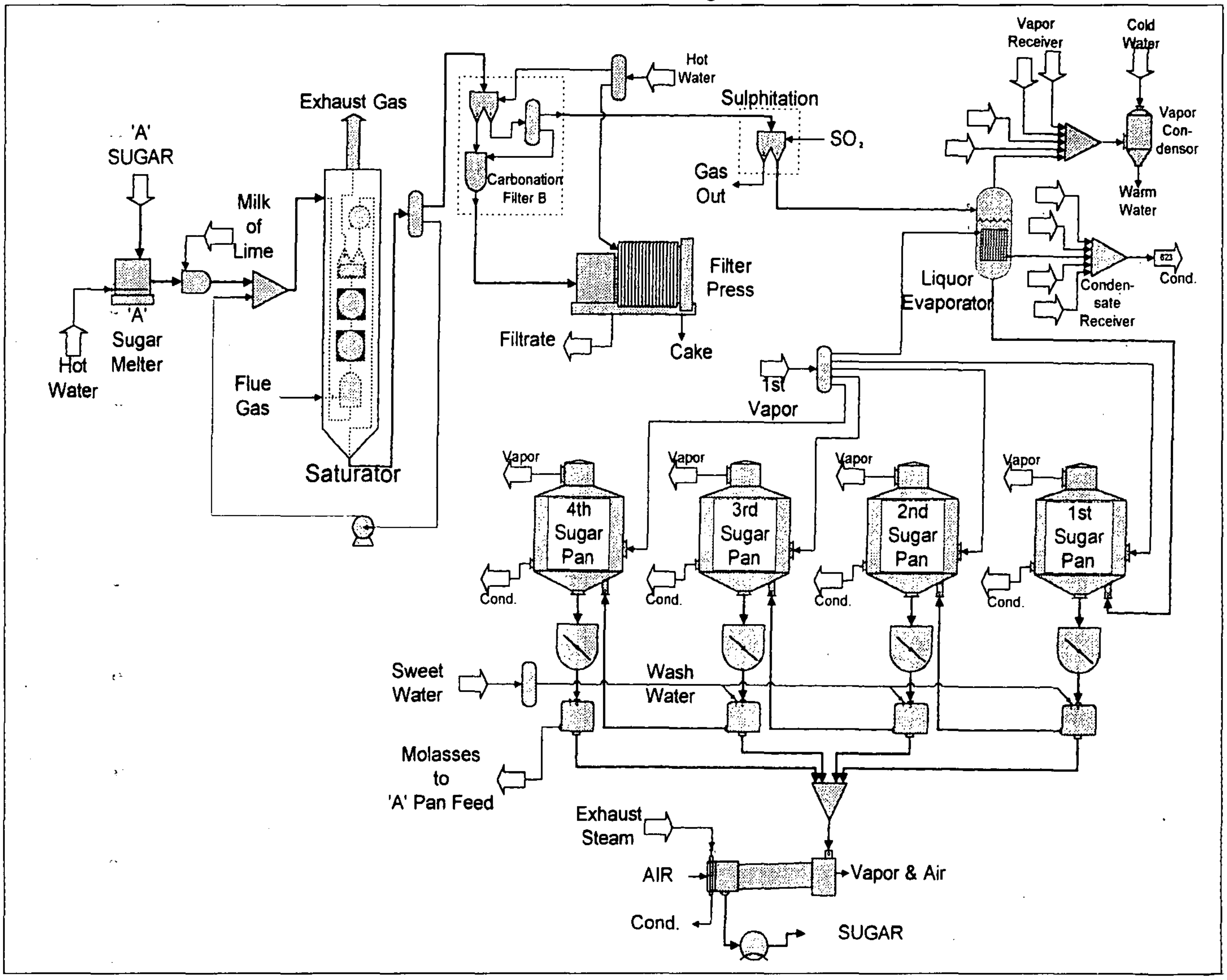

Figure 2. Example of the *Sugars*™ model of the Malelane refinery.

Simulation of the Komati mill

Base case scenario

A model was created for the Komati mill at a crushing rate of 220 tons cane per hour. The Komati mill houses an extraction plant and raw house. Products are A-sugar, final molasses, filtercake and bagasse. The shredder and mills are electrically operated. Extraction is done via a shredder, diffuser and press mills. Mixed juice passes through a clarifier into a quadruple effect evaporator station. Syrup is then boiled in continuous pans with seeds from batch pans. The mill uses a conventional three boiling system. Continuous as well as batch pans were modelled.

Results of the simulation for Komati

Condensed comparative results between the simulation and the mill are presented in Figure 3. Juice and syrup mass flows were not given in the mill report and are therefore not included. It is clear that the actual mill performance is reflected accurately in the simulation. The actual data in the table were obtained from the daily production report of 29 September 1996. Steam usage by the mill was reported as 52% steam on cane for the day. *Sugars*™ calculated a usage of 52,8% steam on cane.

Molasses back-blending at the Komati Mill

Radford (1996a) discussed the potential of molasses back-blending and the Komati process division decided to implement some of the suggestions. Two flow diagrams of the mill were created on *Sugars*™ to simulate blending A-molasses into the continuous A-pan and mixing A-molasses with the A-massecuite before the A-crystallisers. Various simulations were done to determine the effect on product quality by varying the amount of molasses to be fed back. An optimum amount was determined, at present about three tons per hour. This is added to the continuous A-pan. Encouraging results from the simulation justified the modification to be made in the mill.

Results with molasses back-blending

Condensed comparative results between the simulation and the modified mill are presented in Figure 4. As in the base case a good comparison was obtained. The expected performance of the process after modification was evaluated in the simulation and proven in the plant. Actual data were obtained from the daily production report of 16 October 1996. The cane composition for this simulation trial was kept constant with the base case to provide a consistent basis for comparison. The deviation in cane composition was small, but is reflected in the lower

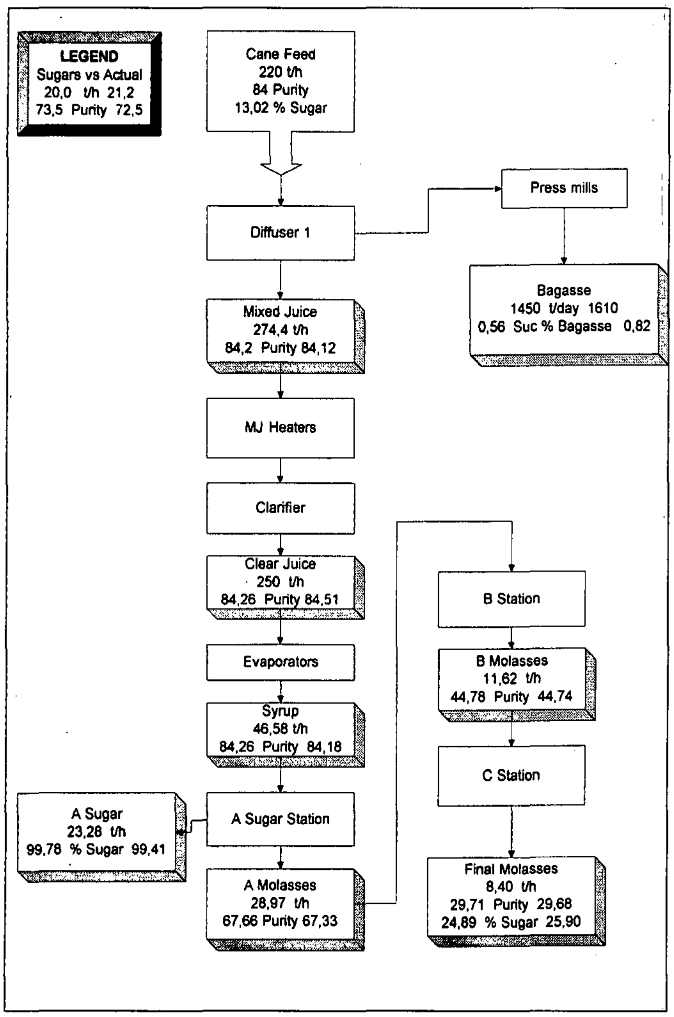

Figure 3. Komati raw house: comparison between actual mill data and *Sugars*™.

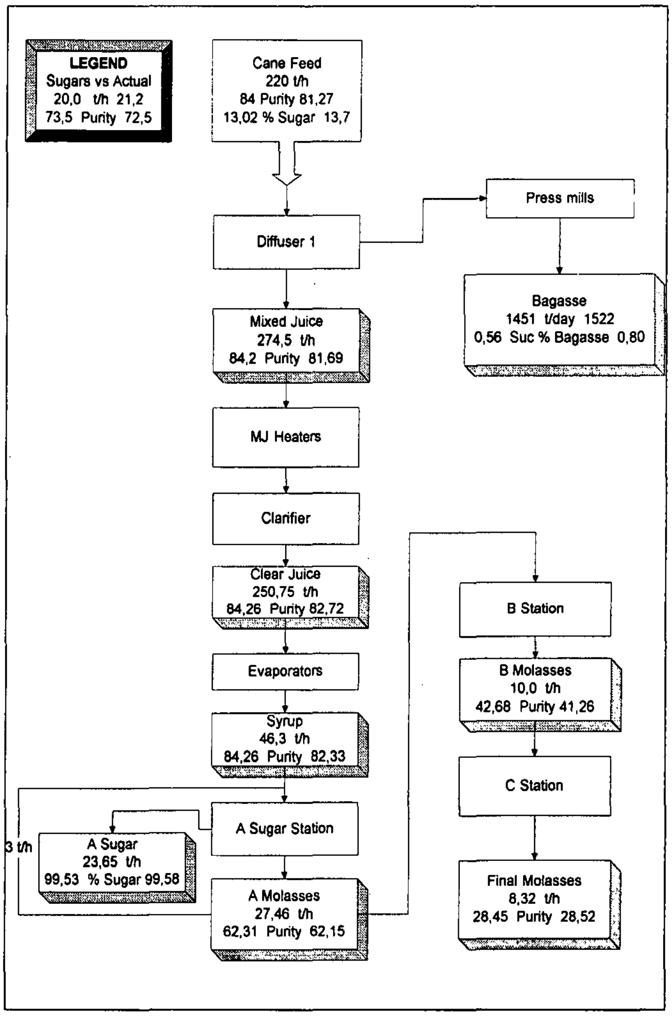

Figure 4. Komati raw house: comparison between actual mill data and *Sugars*™ with molasses back-blending.

purity of the actual mixed juice obtained. This was the first instance in which a modification was modelled and implemented with *Sugars*™ at TSB.

Simulation of the Malelane mill

Base case scenario

The Malelane mill is larger than the Komati mill, and operates at a crush rate of 350 tons cane per hour. The plant houses an extraction facility, a raw house and a refinery. Products are refined sugar, final molasses, filtercake and bagasse. At Malelane the shredder and mills are steam operated and the relevant turbines are included in the model. The Malelane mill uses two diffusers in parallel followed by mills in parallel in the extraction plant. Juice is clarified and fed into a quadruple effect evaporator station. In the raw house a three boiling system is installed with all the pans operating in batch, except that a continuous C-pan is also installed. All the A-sugar is fed into the refinery for the base case model; this was the case when the model was developed. Development of a new model, in which a section of the A-sugar is exported to the packaging plant, is in progress. The A-sugar is treated in a carbonatation/sulphitation refinery to produce a refined sugar from four boilings. The model incorporates the entire process including the sugar drier. Sulphur dioxide dosing was simulated by incorporating the sulphitation tower and the decolourisation associated with the process in the model.

Results for Malelane

Condensed comparative results between the simulation and the rawhouse are presented in Figure 5. The condensed results for the refinery are presented in Figure 6. The comparison in this case is made between the balance done for TSB by Radford (1996b) and the *Sugars*™ program. The balance from Radford was considered the base case for the energy optimisation program conducted at the mill. Very good comparison was obtained with this model with regard to mass flows. The exhaust steam supplied to the mill is 245,26 t/h according to Radford. *Sugars*™ calculated a steam demand of 201,1 t/h. Steam losses, due to inefficient lagging in the mill, play a large part in the difference between the models and the mill. Assumptions made about heat losses are also influential in causing this difference. For this model the assumption was made that losses of 1% occur in the heat exchangers and evaporators. Losses of between 8 and 10% were assumed for the pans. Radford ([1]personal communication)

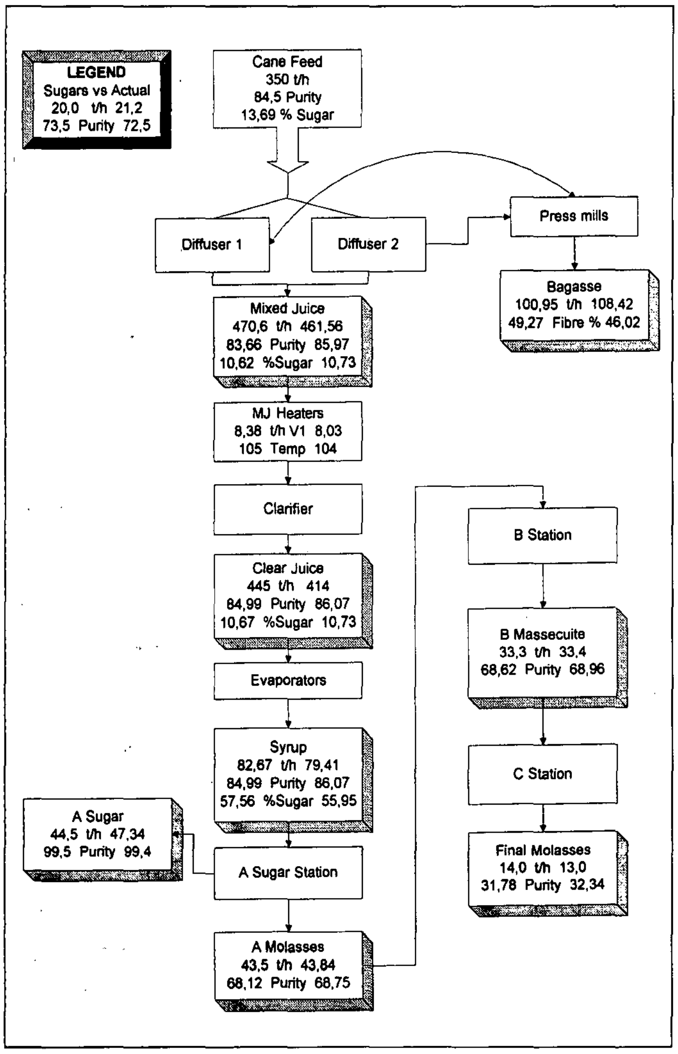

Figure 5. Malelane raw house: comparison between actual mill data and *Sugars*™.

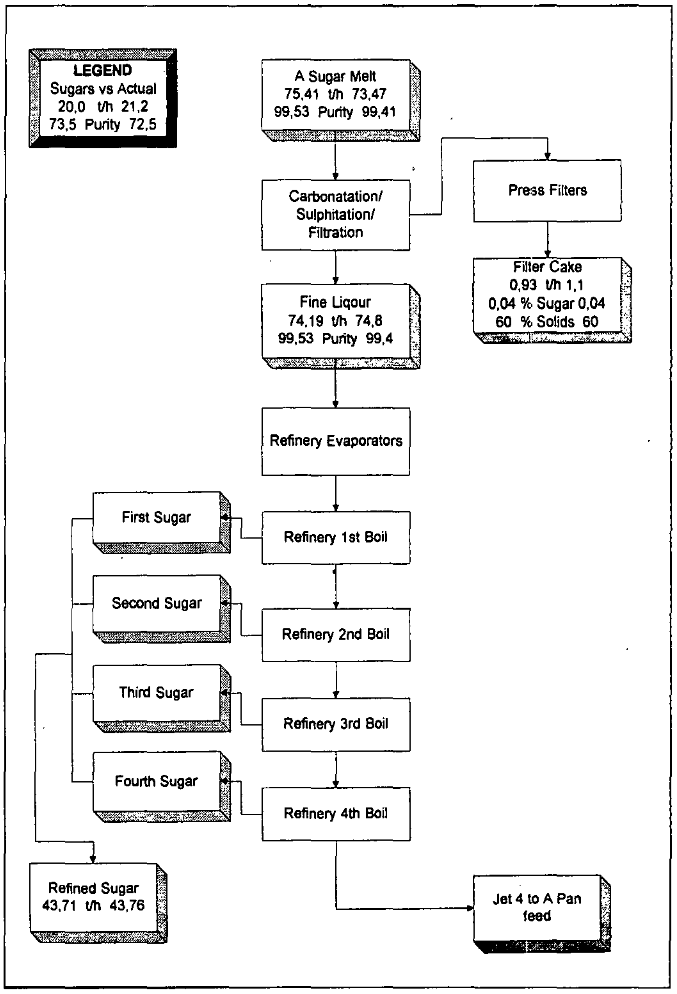

Figure 6. Malelane refinery: comparison between actual mill data and *Sugars*™.

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artificially increased steam losses in an attempt to match the mill performance. It is clear that the steam usage of the Malelane mill can be optimised since the Malelane and Komati mills were based on the same initial flow sheet.

Conclusions

The Komati mill base case simulation proved to be very accurate. The results of molasses back-blending were predicted with good accuracy.

Material balances at Malelane are good, but differences were noted between the steam consumption calculated by *Sugars*™ and the study by Radford (1996b). The steam usage calculated by *Sugars*™ is lower than that estimated by Radford. Actual steam losses are responsible for a major part of the discrepancies since losses in the *Sugars*™ model were assumed on the conservative side, whereas Radford adjusted steam losses to attempt to match actual performance.

Sugars™ proved to be a suitable program to achieve the modelling goals within reliable limits. The process economics section of the program can now be utilised to identify potentially profitable modifications in the factories. This will form part of future investigative work with the program.

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