FELIXTON - A NEW SUGAR MILL IN ZULULAND

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Abstract

The design and project implementation philosophies are outlined for the new Felixton mill situated in Zululand which was designed with a crushing capacity of 3,3 million tons cane per annum. The main features resulting from these philosophies are described and their effectiveness after the first season of operation reviewed.

Introduction

The decision by Tongaat-Hulett Sugar to invest some R180-million in a new sugar mill at Felixton was the culmination of ten years of investigations and feasibility studies into the problems and opportunities of the cane sugar industry in Zululand. It clearly constitutes a vote of long-term confidence in the Natal sugar industry.

The permutations and combinations of alternative strategies to cater for changing sugar production economics in the area were evaluated again and again as different perspectives were fed into the thinking. Alternative sites, expansions of existing mills in numerous phases to accommodate expected growth in cane supplies and by-product opportunities, were all carefully evaluated and compared, as well as leaving the status quo, viz. the operation of two small ageing mills within 12 kilometres of each other. The decision to proceed came close on a number of occasions, but was delayed while further strategies were evaluated. Every evaluation came back to the desirability of closing down the two old mills and concentrating all cane crushing capacity in a new and efficient mill.

Design Philosophies

The design of the new mill was conducted in-house, using outside consultants only for specialist areas such as civil, structural and electrical design. The main advantages of designing a plant for one's own operation and long-term use is that it affords the opportunity of reviewing what is the most economic solution to the opposing requirements of:

- minimum capital cost
- lowest operating and maintenance costs
- highest sucrose recovery
- highest labour productivity
- least operational downtime

The opportunity of evaluating these factors under operating conditions makes the difference between a good design and an over-expensive, or cheap and nasty alternative.

Design philosophies which would guide decisions on present versus future needs had to be established at the outset. It was decided that layouts should enable maximum productivity — output per man — to be realised in the future, but that investment in automation should follow current evaluations. Provision also needed to be made for a future expansion of capacity by 50% where the layout would be affected, but expenditure to this end was to be minimised and limited to vital areas only. With these guidelines it was possible to aim at optimising return on investment in all decisions on the design of plant.

The general principles of the plant requirements were fairly easy to establish: cane handling should be minimised; extraction should be as high as economically justified; boilers must burn whole bagasse, bagasse pith and coal; the process plant must be steam efficient to minimise requirements as export bagasse potential existed; it must be possible to make high grade export sugar from the relatively poor quality cane available in the area; and overall sugar recoveries should be good, but again only as high as was economically justifiable.

The size of the plant was dictated by the present and predicted cane supply available within the next five years and established a required crushing capacity of 3,3 million tons of cane per annum.

The exercises into optimising the opportunities presented in a "green field" situation have resulted in some radical departures from accepted practice and design. Innovation for its own sake does not make money, but when based on soundly evaluated operating experience, it affords the opportunity for a step change in plant profitability.

Innovative Features

Identifiable areas where there were opportunities to improve on current performance norms were in cane handling and preparation, in bagasse dewatering, bagasse depithing, in clarification, pan boiling and crystallisation, obviously in the overall energy balance, and in the control and automation of the plant. In some of these areas, developments were in the process of research and this had to be accelerated, while in-depth investigation had to be launched where the best solutions to a number of options were required.

A general description of the solutions decided upon and some of the more significant features incorporated into the new mill which are unusual in the cane sugar industry are dealt with, in order of process flow. A more general description of the mill appears in the S A Sugar Year Book[1] and the S A Sugar Journal[2].

Cane Handling

One of the most labour-intensive areas in most Southern African sugar mills is in cane receipt and handling. This is generally due to the variety of modes of transport, the delivery of whole stick cane and the necessity for adequate sampling of identifiable consignments from individual cane growers. A requirement for stock-piling cane in the mill yard to bridge times of undersupply also usually leads to cumbersome double-handling arrangements.

The original Felixton cane supply pattern was roughly one-third of the cane on heavy road vehicles, one-third on mainline rail trucks and one-third on existing tramline systems at Felixton and Empangeni. The option of linking the Empangeni tramline system to the new mill was investigated and discarded as a possibility, due to the move away from tramline systems as a result of their higher cost structure. The remaining delivery modes had to be combined into a cane receipt and handling system which was able to feed the two extraction lines at full rate and embody sufficient surge capacity, as well as provide a system which could be expanded to a third extraction line in the future. The provision of mainline rail delivery facilities was essential and this led to the solution to feed each extraction line with a rail truck tippler as well as a road spiller table. The simplest solution for the remaining tramline cane local to Felixton was to tranship this into mill-owned rail trucks designated "carousel" trucks, as they merely formed a container system rotated between the transhipment facility and the mill rail truck tipplers. The system led to a simple yard layout with automatic truck handling which was reasonably flexible in terms of expansion and used the minimum of operating staff. Surge capacity was provided by the cane stored on wheels in the mainline trucks, tram trucks and carousel trucks in the yard and consequently double handling of cane was avoided.

Since the original installation, the Felixton tramline system has been closed and converted to road deliveries and there has been a major move away from mainline rail cane deliveries. This has led to a re-evaluation of the cane handling system and the changes have been accommodated within the original layout by providing additional carousel trucks and a third heavy road vehicle spiller feeding cane into the surge storage capacity provided by carousel trucks. Provided sufficient surge capacity trucks are available, this will enable the total cane supplies to be converted to road deliveries should this be economically desirable.

Cane Preparation

Feeding whole stick cane into cane preparation equipment is a cumbersome and costly operation and one which we very much wished to simplify. The use of rubber belts was an obvious choice but to make it easy to handle cane on them, as well as protecting the main preparation equipment from rock damage and enabling tramp iron to be removed before the intensive preparation, it was thought that billeting cane into short lengths held some promise. In order to check the performance of a cane billeter, a full-scale plant was manufactured and installed on one of the Amatikulu carriers where the design was optimised. Another advantage of billeting cane was that its more free-flowing characteristics enabled the positioning of a surge hopper above the shredder. This arrangement promoted a steady feed into the shredder stand. The shredders themselves were of conventional Tongaat design with close coupled kicker knives as feed devices, the aim being to produce intensely prepared cane of approximately 92 PI (Preparation Index) with the minimum reduction in fibre lengths. Initial problems of recycling cane by means of this close coupled arrangement were overcome with improved baffling and the type of preparation achieved has been ideal for diffusion.

After the first season's operation, problems with damage to billeting knives have still to be overcome, but the main preparation equipment has been relatively free from damage and improvements now in hand to billeting and magnet positioning are expected to improve and optimise the whole operation.

Juice Extraction

The decision to go for diffusion rather than milling was a natural choice, particularly as high fibre and low purity cane from the Empangeni district made good milling performance difficult to achieve. Even without this added incentive, the capital cost of diffusers against milling tandems, capable of reasonably good extractions, is very much in favour of diffusers.

The high fibre cane in the area resulted in rather larger than usual sizing, but economic evaluations still indicated that a target of a 98% extraction was a viable one. This led to diffusers of 700 m^2 screen area which were somewhat larger than had ever been built. The main engineering in diffuser design is involved with the headshaft and conveyor chains and resulted in a simple one-piece headshaft on spherical roller bearings and weighing some 95 tons, driven with the required 4 260 kNm of torque via a shaft-mounted gearbox. The diffusers in their first season of operation have performed extremely well, achieving an average corrected reduced extraction of 98,48 which is the highest achieved by any sugar mill in Southern Africa.

Drying Mills

The problems of drying diffuser bagasse have been well established and probably occur as a result of the partial softening of cane fibres under the action of heat and lime addition in the diffuser. The lack of sufficiently robust mills, available at an economic price, resulted in the development of a new 6-roller mill designed in conjunction with Smith-Mirrlees of Glasgow. These mills are of close-coupled design with short pressure chutes and of extremely heavy construction. This arrangement has led to very satisfactory dewatering of bagasse.

An interesting outcome of the design optimisation was that it was more economic to provide two gear trains and turbines to meet the 100 000 hour rating required for the main mill and pressure-feeder drives. This leads to the possibility of independently variable pressure-feeder speeds to optimise mill performance.

Bagasse System

Bagasse from the drying mills is fed via a depithing plant to the boilers. Depithed bagasse fibre is supplied to the adjacent Mondi Paper mill via an overhead conveyor system. The reject bagasse and pith feeds the boilers via a rubber belt system, the recycle from which is stored in a conventional storage shed of 2 000 tons capacity. The use of rubber belts throughout the bagasse handling system resulted in considerable capital savings, but the ploughing of bagasse from the boiler feed belt into individual boiler feed chutes gave some problems, since the long fibre diffuser bagasse behaved differently from that produced in milling tandems. Further development of the ploughs and feed chutes was necessary before a satisfactory feed to the boilers could be obtained.

Boiler Plant

The sizing of boilers to satisfy the plant steam requirements was of major importance due to the high capital cost of boiler plant. Large units were more economical, but for continuity of operations some standby capacity was required, as well as the ability to burn all bagasse should the supply of fibre to the paper mill cease for any reason. This led to a decision to install three 150 ton/hour units, any two of which would satisfy the process steam requirements with the third having the alternative possibilities of either acting as a standby unit or of being used to burn excess bagasse. Auxiliary fuel was to be supplied by burning coal and the boilers, therefore, had to be capable of accepting whole bagasse, pith or coal.

A spreader/stoker design of generous furnace volume was specified, with conservative gas velocities to eliminate tube erosion. Moderately high boiler efficiencies of 85% which could be upgraded in the future, appeared to be the best economic solution. The ID (induced draft) fans were positioned downstream of the wet scrubbers, to give protection from erosion. The coal burning requirements necessitated the provision of chain grate stokers. Air pollution requirements indicated the necessity for scrubbing the flue gas; this was undertaken in our own design of irrigated, perforated plate flue gas scrubbers. A problem with corrosion of these scrubbers has been experienced in the commissioning period, when large quantities of coal were burnt, leading to difficulties in controlling pH in the water circuits. This problem has diminished as the incidence of coal burning has reduced, but a solution is still required if extensive coal burning becomes a feature of future operations.

If the mill should be expanded to 900 ton/hour capacity in the future, a further similar boiler would satisfy the increased steam requirements, giving a balanced operation of three boilers with one unit in reserve.

Energy Balance

Extensive investigations were undertaken into the most economic configuration of process steam users, the details of which have been reported elsewhere[4]. The outcome of these investigations resulted in an evaporator with very large 1st and 2nd vessels and a moderately sized tail, giving quintuple effect evaporation with large scale vapour bleeding from the second effect to supply the pan floor and diffuser heating requirements. The configuration was designed for future development by the addition of mechanical vapour recompressors and additional 2nd effect vessels, so that the quantity of surplus bagasse could be increased if it were required by the paper mill. Space was allowed in the layout for these future additions and the power requirements for the vapour recompressors can be accommodated adequately within the present high pressure to exhaust steam let-down quantities, as well as a moderate amount of export power.

Clarification

The poor cane quality from some of the Empangeni supply areas has always resulted in difficulties in producing sugar to export quality specification. This cane was to be crushed at the new mill and something had to be done to ensure good quality sugar at all times.

A research and development project had established the viability of syrup clarification, an additional clarification step after the evaporation of sugar juice to syrup. After laboratory trials, a full-scale clarification plant was installed at the old Empangeni mill and its performance optimised. The process gave excellent results and a new clarification system was designed for the new mill, incorporating the lessons learnt at Empangeni.

The provision of this "back stop" system enabled us to go ahead confidently with the provision of short retention clarifiers despite the local history of very difficult juice clarification at some times. Three SRI type clarifiers and three large Oliver filters were installed as the first clarification step, followed after evaporation with a single syrup clarifier.

Despite extremely difficult conditions, with carryover drought cane and very low juice purities at the end of the season, the clarification systems have worked well, to the extent that it was possible to make VHP sugar, even from an average mixed juice purity of 76 which included many consignments of below 65 purity.

Evaporator

Very large 1st and 2nd evaporator vessels, each of 5 000 m^2 heating surface were required, operating at low temperature differentials to maintain second effect vapour pressure above atmospheric pressure so that it could be used for diffuser heating. These were provided in long tube (7 m) vessels, with quick release tops for easy access for mechanical cleaning and must be rated amongst the largest evaporator vessels built for cane juice. The separators were designed for minimum contamination of condensates and have performed extremely well.

Pan Boiling and Crystallisation

Pan boiling was an area where capital could potentially be saved, but with a commensurate high risk in applying newly developed technology in continuous pan boiling. Continuous boiling of low grade pans had been used in the last few years with success, but the continuous boiling technique had not been applied successfully anywhere in the world to produce an A-sugar which would meet our stringent export specifications.

The required sugar production rate at full throughput was some 80 tons per hour and this would have required five large conventional batch type A-pans; the alternative was two continuous pans, with a single batch pan preparing seed crystals. The potential saving amounted to about R1 million in plant, support steel and buildings. However, by the time the structural design had to be committed, there was insufficient evidence that we would be able to design and operate a continuous A-pan with guaranteed results. It was decided that strenuous efforts must be made to obtain the assurance needed, but that the structural steel would have to be designed to take both options. This unfortunately diluted the potential saving, but the continuous option was still very desirable.

The experimental work necessary to confirm our information was actively pursued at Amatikulu with a converted batch pan and at Maidstone, where the option of converting a Tongaat-Hulett designed continuous B-pan to A-duty was implemented at the end of the 1982/83 season. Difficulties were identified but enough confidence was generated, after the experience gained at Maidstone, to commit ourselves to the design and construction of continuous A-pans. The design, development and performance of the pans has been well reported elsewhere.[3,5,6,7]

Continuous vertical crystallisers were a natural choice for the new mill, but their use on A-massecuite had never been undertaken previously. Here we were not in a position to undertake any full-scale tests, but employed all the collective knowledge available in identifying and solving possible problems before fixing the design.

Instrumentation and Control

The philosophy used in controlling plant is obviously one of the most vital aspects affecting the success of any operation. Various options up to and including full computer control of the plant were considered. At the same time, the concept of complete centralisation of all control and most supervisory functions was explored. The control system needed to be flexible, reliable, and incorporate manual control options, where appropriate. The advantages of centralising supervisory staff into one control room was obviously helpful in co-ordination of operations and the concept of visual contact with all plant areas was developed. These desirable operating aspects led to the positioning of the control room high up in the plant with good visual contact to operating areas, and with all plant operation supervisory staff and laboratories also located centrally below the control room.

The use of a central computer controlling all the individual control loops was one of our cheapest options, but was rejected on the grounds of not putting all the "eggs in one basket". Eventually a distributed microprocessor-based control system with overall computer monitoring in vital areas was selected. Operator stations were provided for the control loops which could, with advantage, be manually controlled under emergency conditions. The control room then developed into three natural divisions, namely cane input and extraction, boilers and power generation, and process plant from juice input to sugar output.

These three main divisions were developed into control areas within the central control room, from which the plant in each division could be started and stopped, as well as controlled and monitored by one operator in each of the three areas.

The result of this arrangement has proved both effective and practical. The reliability of the automatic controls, the flexibility which microprocessors provide for readily reconfiguring controllers and changing control strategies and the ease of monitoring the total mill operation from one room, have played a vital role in the successful commissioning of the plant.

Project Management

Project management on major projects verges on art rather than science. A survey of available resources revealed that total project implementation costs for projects as large as this one were expensive, in the region of 15% of the basic plant cost.

In addition, we were determined to reduce pre-production interest charges by minimising the implementation time to 26 months from the initial go-ahead to first cane crushed. This meant that design work had to proceed in parallel with construction and a split responsibility for design and project management did not look attractive.

Of the total project cost we believed that, on average, 85% was virtually fixed at the completion of the design phase, a further 10% was fixed during the negotiation and letting of contracts, and the remaining 5% would be affected by the management of the contracts and the construction phase.

We believed the project would be more efficiently and economically managed by controlling it ourselves, the only difficulty being the supply of sufficient and reliable resources. For this reason outside resources were only used on that portion of the project where we could gain most in supplementation of our resources, while making least impact on our management philosophies and on our project costs, namely, in the construction management of contractors. Tate & Lyle Engineering were retained to undertake this portion of the project management, working with our own project engineers. This enabled us to establish a total project implementation cost at 7% of the basic plant cost, which represented a saving of some R12-million.

The implementation of the project was greatly facilitated by the diligent completion of engineering flow diagrams for every aspect of the plant. These gave details of quantities, capacities, power ratings, pipe sizes and instrumentation loops for every section of the plant. Each motor, pump, turbine, pipe, instrument, tank, or plant item, was identified and its size or capacity indicated. These engineering flow diagrams were approved at senior level and no change in any item was permitted without approval at the same senior level. The approval system allowed all concerned to say their piece and be party to the plant design decided on, and then to live with those decisions unless there was an exceptional reason to change. It also played a vital part in the inter-action of different disciplines in the design process.

To control the sequence of events and establish priorities as design and construction proceeded in parallel, a computer-programmed Critical Path Analysis network was utilised. The network was made up of some 3 000 separate activities and played a vital role in establishing priorities.

That the project was completed on time and on budget was a vindication of the decisions made and of great satisfaction to all those involved.

The Outcome

The new mill went into production with a capital cost, excluding interest and finance charges, of R260 000 per ton cane per hour of crushing capacity, or R436 per ton of potential sugar production per annum, which is considerably less than the current costs of providing equivalent capacity in existing mills. In terms of productivity, the new mill has a design output of approximately 1 000 tons sugar per employee per annum, approximately double that produced in the average South African mill, with considerable potential for further improvements in productivity in future years.

The design layout provides for a very easy expansion by the provision of a third extraction line giving a 50% increase in capacity to 900 tons cane per hour, at a present day cost even lower than the above figures. Whether this will ever happen depends on the future of our sugar industry.

There is no doubt that the cane growing potential in Zululand, within economical transport distances of Felixton, could support the additional production, the opportunity for development is there, and cane growing in KwaZulu represents the most viable crop to uplift the rural economy in the area.

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