A DECADE OF REFINING AT NOODSBERG

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Abstract

The newest and most modern refinery in South Africa completed its 10th year of operation in 1991. In this period it has produced just on 1,4 million tons of high quality refined sugar and has been at the forefront of modern developments in the technology of sugar refining. A review of the past 10 years is presented and describes how the overall refinery performance has been improved. Details are also given of equipment changes and process innovations introduced during this time, as well as practical experience gained in operating a refinery of this type.

Introduction

CG Smith Sugar's decision to erect a new refinery at Noodsberg (NB) was taken against the background of a developing South African domestic market and the fact that its refinery at Sezela was old, inefficient and producing poor quality product. The Sezela refinery also had capacity limitations and so it became apparent that a completely new and much larger refinery was required. It was decided to build the new refinery at Noodsberg because Sezela already used part of its bagasse for a byproduct plant and the industry would benefit from considerable savings in transporting the white sugar to Reef markets.

After studying various refining processes used locally and overseas a phosphatation/ion exchange process was chosen. The motivation behind this was to secure the very best quality sugar and, although it was recognised that this process scheme would involve slightly higher operating costs, there were compensatory savings in capital outlay. Modern, centralised process control philosophy was used in the design which included the most advanced instrumentation available at the time.

The refinery was designed by Tate & Lyle Technical Services in conjunction with the Technical Services Division of CG Smith Sugar Limited, as a back-end refinery which would directly receive the total raw sugar output from the adjacent mill, at a target colour of 1000 ICUMSA units. The design capacity was 35 tons refined sugar per hour at an average colour of 50 ICUMSA units. The capital cost of the refinery amounted to 10 million Rand with a further 5,5 million Rand being spent in the raw house, mainly for the provision of steam to the refinery.

The full original process began with the melting of A-sugar produced by the raw house, followed by clarification by means of phosphatation in a Talo-clarifier and single stage polish filtration in Suchar pressure filters. The clarifier scums and pressure filter sluicings were desweetened in a single-stage operation using a small Talo-clarifier. Decolourisation was carried out, partially by the use of Talofloc during clarification, and partially by means of ion exchange of the filtered liquor. Thereafter double-effect evaporation prepared the liquor for crystallisation which was performed according to a straight four-boiling system. Initially all the sugar, following drying in a fluidised-bed type dryer, was packed in 25 kg bags by means of three Richard Simons valve-pack machines.

Although the basic process has not been changed over the past ten years a number of major changes and improvements have taken place. The most notable of these are the erection of a conditioning plant and the installation of pan stirrers in 1985, the installation of deep-bed filters in 1986, and an expansion to increase the output from 35 to 45 tons refined sugar per hour in 1987. Simultaneously with the refinery expansion the decolourising facilities were boosted to enable production of sugar at an average colour of around 40 ICUMSA units.

Refinery commissioning and initial teething troubles

The commissioning of NB's refinery began in early July 1982 but due to numerous problems very little sugar was bagged before the end of August. Altogether 42 000 tons of refined sugar were produced in the 1982 season against a budgeted amount of 60 000 tons. Although there were numerous mechanical problems, the major production problems occurred in the packing station. Performance was also hampered by process difficulties, the most serious of which were with colour build-up across the melter and poor performance of the ion exchange plant which only achieved a 47% removal of colour. The nett result of all the problems was that the average sugar colour for the season was 82 ICUMSA units with brix recoveries of between 85 and 90 being somewhat below the design figure of 92. The centralised Provox control system however performed very well.

By the second season most of the initial problems were resolved but reasonably serious problems were still experienced with colour removal in general and filterability. How these problems were tackled and resolved is discussed in detail in the following sections.

Controlling colour and decolourisation

Colour increase across melter

One of the advantages of a back-end refinery over a stand-alone one is the better control of raw sugar colour that it affords. When the refinery first started, there was an increase in colour of up to 20% across the melter which served to negate partially the benefit of the high quality raws it was receiving. The cause of this problem was found to be the highly coloured sweetwater used for the melting. The main offenders were found to be pan steamings and pressure filter sluicings. The former were removed from the sweetwater stream by discharging them into the strike receivers with no noticeable affect on pan yields. The filter sluicings were eliminated by diverting them directly to the rawhouse filter station rather than through the desweetening clarifier. The combined effects of these and other minor changes have meant that colour increase across the melter is now contained to less than 6%. During the 1987 and 1988 seasons, with the aim of reducing the quantity of returns to the rawhouse, attempts at treating the filter sluicings in the refinery were made. However colour increase across the melter once again became unacceptably high and the refiltering system that had been introduced was abandoned.

Colour removal during clarification

For the first two-and-a-half seasons Talofloc was used as an aid for improved colour removal. This use was found to be extremely costly and met with strong customer resistance amongst bottlers because they believed that residual Talofloc in the sugar was hindering their operations. Initially it was felt that, by not using Talofloc, difficulty would be experienced in achieving target refined sugar colours. These fears proved groundless as it was found that the resin decolourisation improved dramatically once Talofloc dosing was stopped. This is illustrated graphically in Figure 1 where it can be seen that as the colour removal across the clarifier is reduced (from 1982-1984) the colour removal across ion exchange increases (from 1984 onwards). It is believed that the affinity of Talofloc and resin for the same colourants offers some explanation for this. The cessation of Talofloc usage obviously resulted in a large increase in the colour loading to the resin plant and would therefore also be expected to have a marked effect on resin life. However at the time that Talofloc was being used other problems were being experienced in the resin plant and once Talofloc dosage was stopped no reduction in resin life was observed. It nevertheless seems highly probable that an increased resin life could be expected with Talofloc usage, but the cost of Talofloc under local conditions will certainly be far greater than any marginal reduction in resin life.

Without the use of additional decolourising chemicals (i.e. Talofloc) the amount of colour removal across clarification at NB has varied between 15% and 20%. It has not been found possible to achieve the levels of 30% to 40% colour removal quoted in the literature. This could possibly be attributable to the low melt colours at NB.

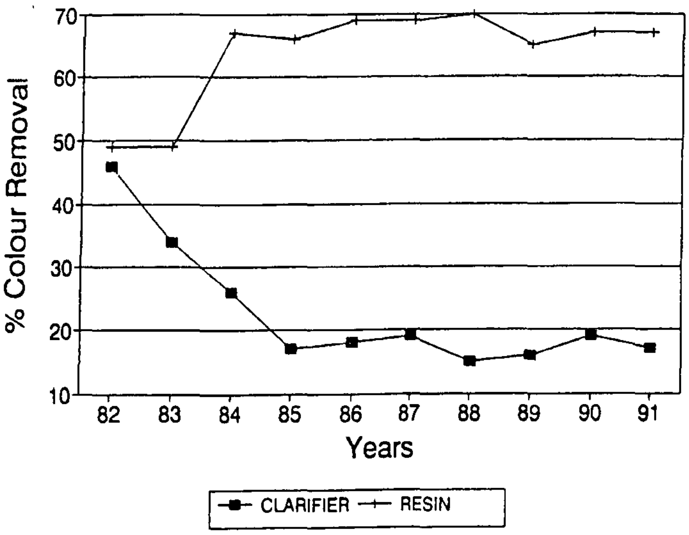

FIGURE 1 Clarification and resin decolourisation.

Resin decolourisation

During the time that Talofloc was being used the level of decolourisation by resin averaged only 47%. This has subsequently increased to an average of 68% for the past eight years. Serious blinding of the resin beds was experienced in the first two years of operation. This was found to be due partially to leakage of pressure filter cake into the filtered liquor on the one hand, and from an aluminium hydroxide precipitate originating from the salt used in the regenerant brine solutions, on the other. Improved performance of the pressure filters and the filtration of regenerants through an in-line 75 micron filter eliminated this problem.

The average resin life at NB has been about 200 cycles. This is somewhat below that achieved at Hulett Refineries, the only other ion exchange decolourising plant in South Africa. It has been found that the shorter resin life at NB is due mainly to the higher colour loading which occurs as a result of the low degree of colour removal achieved during clarification (Getaz, 1978). The resin plant, being fully automated does not require any full-time operating staff and plays a vital role in enabling the cost-effective production of high quality refined sugar at NB.

Filterability problems

The phosphatation process has often proved difficult to control (Murray *et al.*, 1976) and since the specific filtration resistance of the phosphatation floc is extremely high (Bennett, 1972) any floc carry-over from clarification will incur upstream processing difficulties. Filtration and filterability problems were certainly a significant feature of the early years of operation of the refinery. Low turbidity removal across the clarifier coupled with filter cake breakthrough in the pressure filters resulted in irreversible fouling of resin, restricted flow and channelling in the resin beds and sugar quality problems (particularly with filterability). High operating (particularly chemical) costs were also being incurred. Several steps have been taken to overcome the problems encountered some of which are described below.

Clarification

The degree of turbidity removal across the clarifier was, over a number of years, raised from an initial level of around 80% to levels (which have been maintained over the past 4 seasons) in excess of 95%.

An early problem with flow and temperature control was caused by blockage of plate heat exchangers used to heat the clarifier feed liquor. The problem was resolved by installing a 60 mesh vibrating screen to remove coarse suspended matter (mainly bagacillo) from the melt. Fluctuating melt brix was another persistent early problem. This was resolved by relocating the controller to the inlet of the clarifier reaction tank rather than at the melter itself.

The original clarifier was replaced, in 1987 during the expansion, with a larger MK4 Talo-clarifier, with a mechanical aerator. This aerator never worked successfully and was subsequently replaced with the original aeration loop, based on a compressed air bleed into a recirculation loop. This change gave significantly improved turbidity removal. Previous experience had shown that the clarifier ran at its best with a scum layer of ± 100 mm. With the initially installed baffles of the new clarifier and a 100 mm scum layer there was excessive turbulence in the scum. Raising the baffles by 40 mm enabled them to extend into the scum layer, thereby reducing the turbulence giving a substantial drop in carry-over from this source.

Polish filtration

The major cause of the leakage of clarifier floc, turbidity and filter-aid into the filtered liquor was determined to be as a result of incorrect grades of filter aid which were also not correctly matched to the type of cloth being used. Following numerous tests and trials acceptable performance was achieved which also improved the sugar quality. However maintenance and filter-aid cost remained problems.

The introduction and use of mono-filament cloths brought another step-change to the filter station performance. Mono-filament cloth, with its more constant aperture size, enabled a more accurate match of the filter-aid/precoat to the cloth and gave immediate improvements in cycle times and therefore reduced filter-aid costs. Mono-filament is also far more robust and less prone to fouling than other cloths and does not require washing. This means that the cloths no longer need to be removed during the season for washing, resulting in lower labour requirements and less mechanical damage to the screens.

Deep bed filters

Prior to the introduction of mono-filament cloth, filter cycle times varied from 1-3 hours. These then improved to a constant average of around 4 hours. Therefore despite the significant improvements that had been achieved filter capacity and operating cost still remained a problem and some customer complaints regarding filterability were still being received. It was thought that a capital expansion to the filter station would be required in order to resolve these problems. At this time Tate & Lyle were about to operate a full size prototype Deep Bed Filter (DBF) and a decision on new equipment was deferred until the performance results of the new filters were known.

Descriptions of the developments that led to the application of DBF's in sugar refining have been published (Alder *et al.*, 1987, Coote *et al.*, 1986). The successful running of the prototype DBF prompted NB to install one unit on trial in 1986. The operation of this unit exceeded expectations and consequently 2 more units were installed in 1987. The DBF's have been positioned in the process stream so as to treat liquor received directly from the clarifier and to pass this treated liquor to the pressure filters for a final "polish" filtration.

The installation of DBF's has had a major impact on process performance, with pressure-filter cycles immediately being increased from 4 to 12 hours. Thereafter further changes were made to the grade of filter-aid being used which better suited the quality of the liquor now being received from the DBF's. These changes further increased the pressure filter cycles to in excess of 24 hours. These changes have given major reductions in the amount of filter-aid consumed and the amount of sweetwater produced. A dramatic improvement in filterability was also obtained following the installation of the DBF's with the complete elimination of all final sugar filterability problems. The changes in filterability of NB's refined sugar over the past six years are illustrated in Figure 2.

The success of the DBF's led to attempts to eliminate completely the final polish filtration step. These trials were conducted during the 1988 season but were not completely successful. As can be seen from Figure 2 the white sugar quality was adversely affected.

Energy management

Another major advantage of back-end refining is the availability of bagasse as a fuel to supply a large part of the energy requirements. Nevertheless the expense of supplementary fuel is an important part of the total refining costs. Sound energy management practices therefore play an important role in cost-efficient refined sugar production. Between 1983 and the present NB's coal usage has dropped by around 90% (Webb and Koster, 1991).

Steps taken to improve the refinery's energy consumption are set out below.

Melt brix increase. Increasing the temperature of the liquor feed to the clarifier from 85°C to 90°C enabled an increase in the melt brix from 65 to 70. This was achieved without any noticeable effect on colour or clarifier turbidity removal.

Pan movement water. The elimination of pan movement water necessitated a change in the boiling techniques employed. The method adopted was to establish the crystal after slurry addition by closing the steam and maintaining circulation with the stirrer only. When the crystal was properly established the steam and feed were once again opened. This method permits the level of saturation to remain constant without the addition of water.

Pan Yields. There has been a major improvement in pan yields over the past 10 years. An indication of how these have been improved, as measured by kg sugar/m3 massecuite, is shown in Figure 3. Factors contributing to this increase include the introduction of pan stirrers (Bachan and Sanders, 1987), the use of a liquor wash during curing (Sanders and Moodley, 1991) and maintaining massecuite brixes in the range 90-91.

Refinery brix recovery. Efficiency improvement throughout the plant has contributed to this. The increase that has been achieved is illustrated in Figure 4.

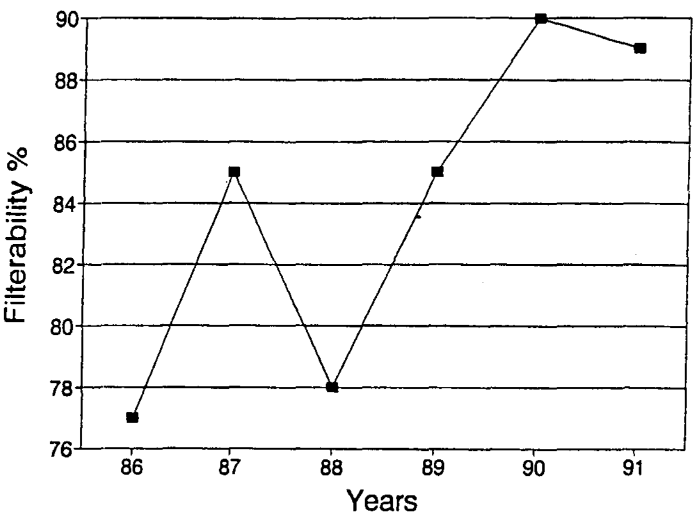

FIGURE 2 Refined sugar filterability.

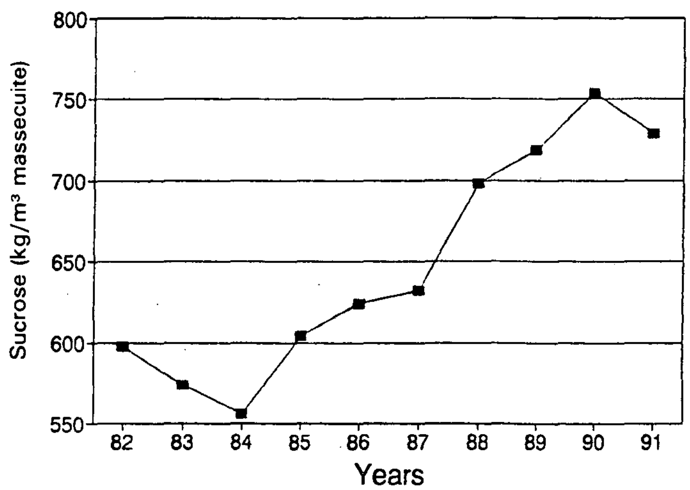

FIGURE 3 Improvement in pan yield.

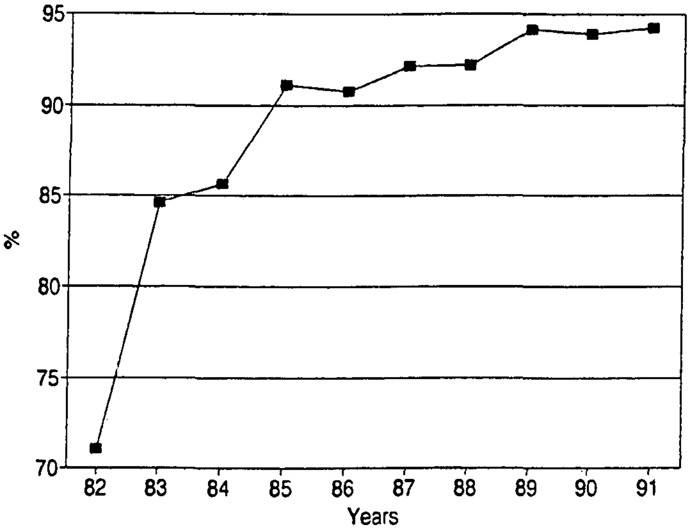

FIGURE 4 Refinery brix recoveries.

Sugar conditioning

The conditioning plant at NB was built in 1985 in response to a growing market demand for bulk refined sugar which could not be met by the only producer, Hulett Refineries in Durban, at that time. The venture was financed by the sugar industry and built in conjunction with the expansion of the industry's bulk storage facilities in Germiston. The whole installation consists of two conditioning silos, each able to hold 1 400 tons of sugar, and a 500 ton capacity rail outloading bin. The entire conveying system is controlled by a PLC situated in the refinery control room with all the process controls managed through the centralised Provox system. The design capacity of the conditioning plant was 5 000 tons per week, based on a 60 hour conditioning/residence time. It includes a facility to back-feed sugar to the packing station thereby enabling the total production of NB to be conditioned.

The installation of pan stirrers and consequent reduction in conglomerates in NB's refined sugar together with optimised performance of the dryer has resulted in a reduction in required conditioning time to 48-50 hours. A consequential capacity increase was realised and weekly throughputs in excess of 8 000 tons have now been achieved.

During commissioning of the conditioning plant a freak accident caused one of the silo's to implode. This incident was caused by the dust extraction fans being run during the filling up stage when the conditioning air was not being blown through the silos. In the sealed environment of the silo a vacuum was created by the dust extraction system which led ultimately to the implosion. Subsequently an implosion protection system has been installed.

The availability of conditioned sugar at NB paved the way for another significant development in the local refined sugar market. The packaging of refined sugar in semi-bulk 1 ton bags for manufacturing consumers has proved a success with market demand growing by leaps and bounds. The 1 ton packing machine used at NB was designed and built in-house. It has a maximum packing rate of 38 tons per hour and during the past season produced some 108 695 tons of sugar.

Expansion

As previously noted the refinery was expanded in 1987. The equipment changes included the installation of a new clarifier, increasing the number of resin columns from 3 to 5, an additional centrifugal and uprating of heat exchangers, pumps, some tanks and the dryer. Two-stage clarifier scum desweetening was introduced both to increase the capacity and reduce the pol of the scum returned to the rawhouse. The evaporator station was changed, from a double effect to a triple effect, by the introduction of a third vessel.

An important aspect of this expansion was the fact that importation of sugar from the neighbouring Union Co-operative became a regular and substantial part of the raw sugar feed to the refinery. During the last season this amounted to 25% of the total.

Refinery process control

The centralised (Provox) process control system adopted when the refinery was built has proved extremely successful although, in the rapidly changing world of electronics, the technology can no longer be considered the most advanced. Several improvements have however been made to the process control system over the years. Originally all the clarification controls were locally situated. These have gradually all been moved onto the central Provox controller.

Level control of the evaporators, through D.P. cells, needed constant attention to maintain reliable operation. These have subsequently been changed in favour of capacitance probes which have proved much more reliable.

The centrifugal station consists of 6 BMA machines. The control of the feed system is very complex as there is a common feed trough to all the machines with compartment slides to alter the massecuite grades feed to a combination of machines depending on the load. The controls have been improved through the years and are also now operated from the central control room.

Reliable automation of the pans has only been achieved since radio frequency (RF) probes have been introduced for saturation control. RF probes are also used to control water addition to the run-offs to give a constant brix material to the pans.

Conclusions

The Noodsberg refinery's performance and sugar quality has improved steadily over the decade. Being relatively new and large has meant that many of the recent and innovative developments in refining technology have been readily and easily assimilated into the process. It is impossible, in a review of this nature, to describe fully all the innovations and developments that have taken place in the past 10 years and of necessity many of these have not even been mentioned. It is believed that the Noodsberg refinery has justly earned its place as one of the leading refineries in the South African industry.

Acknowledgements

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