

DEVELOPMENTS IN SUGAR MANUFACTURE IN SOUTH AFRICA FROM 1959 TO 1984: THE SEZELA FACTORY

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Abstract

Developments in sugar technology at the Sezela factory over the past twenty-five years are discussed. During that period Sezela underwent three major expansions and changes at this factory generally mirror those that took place throughout the industry. General trends in cane quality and performance of both Sezela and the industry are compared. Main changes relating to processes and equipment are discussed as well as the influence of a bagasse-based furfural factory on the steam balance and energy requirements. The treatment of effluent, water recycling and smuts disposal are briefly described.

Introduction

Between 1959 and 1984 the South African sugar industry more than doubled its production to a record level of 2 370 040 tons. This was achieved by a process of expansion which started in the 1960's and which included both the building of new factories as well as modernising and expanding existing plants. It has recently involved increasing the capacity of the CG Smith Sugar Limited's Sezela factory to 450 TCH, and the commissioning of the new 600 TCH Felixton factory by Tongaat-Hulett Sugar Ltd. The technical progress of the industry can be followed by studying the evolution of a typical South African sugar factory such as Sezela, within the context of the industry's development. This paper will attempt to show that trends in cane quality and factory performance at Sezela over the period under review are typical of what has been achieved in the sugar industry, generally.

During the period under review, the manufacturing processes used at Sezela have undergone major changes:

- (a) Extraction of juice by straight milling has been replaced by diffusion.
- (b) Clarification by juice sulphitation has been replaced by simple defecation.
- (c) Changes have also been made in evaporator design following the introduction of diffusion and a bagasse-based by-product plant producing furfural and furfuryl alcohol. A refinery which had operated for 24 years has been closed to make room for increasing the capacity of the factory as well as to save bagasse for the furfural plant, which underwent a major expansion in 1981-82.
- (d) The boiling process has been modified to produce very high pol sugar (99,3 Pol) and continuous pans as well as continuous crystallisers and centrifugals have been installed.
- (e) Steam engines were replaced by more efficient high pressure steam driven turbines and electric motors.
- (f) Modern high pressure large capacity steam boilers, both coal and bagasse fired, replaced the small fire-tube units.
- (g) High efficiency turbo-alternator sets were introduced to supply electric power.
- (h) Automation and process control were gradually introduced and are an integral part of plant development.

These changes are highlighted under the appropriate sections, and plant capacities are given in an appendix.

The Sezela Factory

Brief History

Sezela was built in 1914 to cope with increasing land development and cane supply.¹ It is situated on the south coast of Natal and forms part of a group of six sugar factories of CG Smith Sugar Ltd. It achieved a South African record production of 266 740 tons of sugar for the 1984-85 season. Its growth followed the industrial trend and was accomplished in three phases, namely the first expansion (1965-1966) to take advantage of an increasing export market and the lifting of sugar quotas; a second expansion (1975-1976) to cope with cane becoming available after the closure of an adjacent mill, and the final expansion (1981-1984) to meet a projected increase in cane supply. This last project was necessary as an exhaustive study had revealed that the capacity requirements of 365 TCH in 1982/83 would rise to a projected 450 TCH in 1990 or earlier.

Cane Supply

Until the mid 1970's cane was transported from fields to factory by an elaborate tramway/railway system. Sezela had the longest tramline system in the industry, covering 200 km and using 38 locomotives. This was gradually replaced by road transport which was more economical and enabled hilly land to be developed. About 75% of cane delivered to the factory is loose cane transported in Hilo type "spiller" vehicles while the remainder of the cane is delivered in 4-ton bundles by lorry or tractor-drawn road transport. Deliveries are on a continuous basis during the whole week while a constant cane supply is assured by stock-piling in transfer-zones in the fields.

Cane Quality

The quality of the cane processed over the last twenty-five years has gradually deteriorated. Although fibre content has remained fairly unchanged for the industry, it has increased at Sezela; whereas in contrast sucrose content has decreased both for Sezela and the Industry, as shown in Figure 1.

The purity of mixed juice has also declined markedly, resulting in an increase in the amount of non-sucrose entering the boiling house.

The Extraction of Juice

The Evolution of the Extraction Plant

At the beginning of 1959, the extraction plant at Sezela comprised two separate milling tandems, each made up of a shredder, followed by five three-roller mills driven by horizontal steam engines. During the first expansion of 1965-1966 one milling train (McNeil) installed in 1914 was retained and the second was replaced by a new and modern Walkers milling tandem. New steam turbine drives were

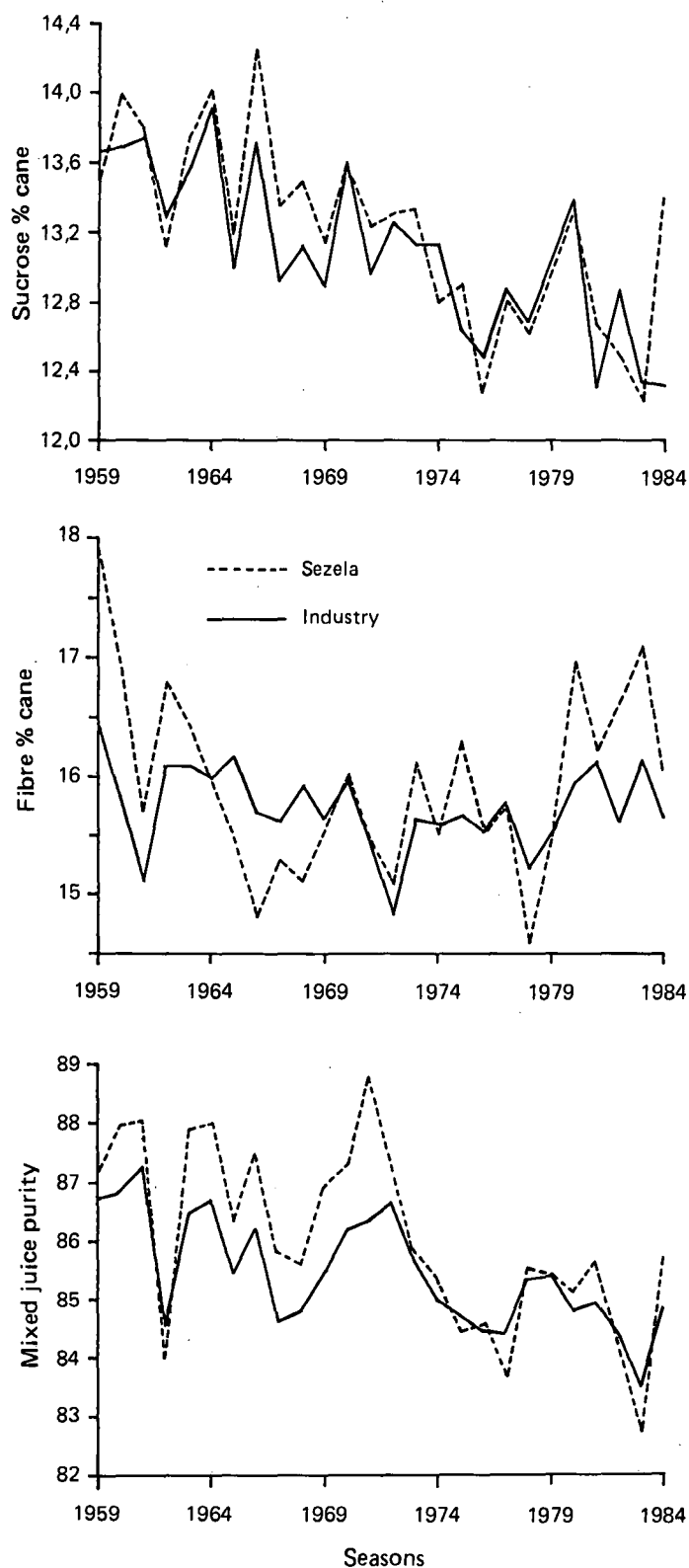


FIGURE 1 Sucrose % cane, fibre % cane and mixed juice purity⁶

installed on the shredder and each of the heavy-duty five-roller pressure-fed Walker mills, to replace the outdated horizontal engines. Until the second major expansion (1975-76) cane was processed by a 5-mill Walker tandem operating at 250 TCH. Following the introduction of diffusion in the early 1960's and its development at other factories, including the Company's own plant at Pongola, a bagasse-type diffuser was installed at Sezela in 1976. It operated in parallel with the Walker mill train and processed an additional 90 to

100 TCH after the closure of the Renishaw mill. The hourly throughput of 150 to 165 TCH in 1959 thus rose to 247 TCH in 1966 and to 340 TCH in 1976. The move from pure milling to bagasse-diffusion was determined by:

- the closure of Renishaw mill which made available a complete cane preparation line together with two mills complete with drives; ideal for de-watering duties.
- installation and maintenance costs were much lower than for a milling train;
- higher sucrose extraction could be achieved.

The extraction obtained with bagasse diffusion was 97,0 for the first season of operation compared with 95,2 for the Walkers mill. During the period between 1976 and 1980 great strides were made in the development of cane diffusion.² Although these diffusers were a few circulating stages longer than bagasse diffusers there was no need for a pre-extraction mill.

Their adoption at other factories in the Company and in the industry greatly influenced the decision to install cane diffusion at Sezela during the final expansion of 1981-84. The hourly throughput rose to 422 TCH in 1984 and the extraction was 97,2 %. Figure 2 illustrates the change in extraction and the hourly throughput respectively over the 25-year period.

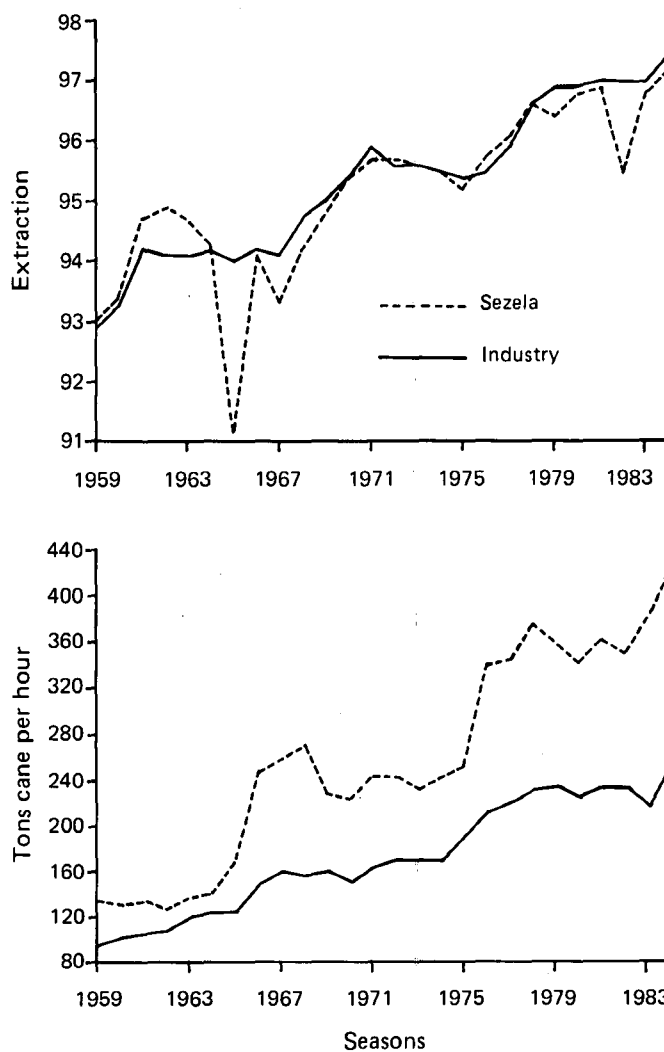


FIGURE 2 Extraction and throughput for Sezela and the industry⁶

Present Design of the Extraction Plant

There are two parallel cane preparation lines each feeding one diffuser. Rubber belts are used as conveyors for shredded cane. They are simple in design and are less maintenance intensive than conventional slat cane carriers. On each preparation line cane is fed through a set of leveller knives with a clearance of 1 m from the belt and then through a set of heavy duty knives contra-rotating against an anvil plate. The knifed cane is then fed to a "Smith-designed" shredder.

The diffusers stand in the open on the two sides of a building which covers the de-watering mills and accommodates a workshop. All cane, bagasse carriers and extraction equipment are monitored and controlled from the main panel in a dedicated control room overlooking the cane yard, diffusers and mills. The cane diffusers are of BMA design and are capable of handling 250 tons cane per hour each. They are moving bed-type fitted with two sets of lifting screws and 12 pumping stages. Press water is returned untreated before the second set of lifting screws about a third of the length of the diffuser from the discharge end.

Each diffuser is followed by two de-watering mills, retained from the Walker mill-train installed during the first expansion in 1965. They have been arranged for parallel operation at 125 tons cane per hour each and had their speed reduced from 3,0 to 1,6 rpm by the installation of an additional high speed gearbox. Because of uncertainty as to the behaviour of diffuser bagasse of high moisture content (78%) and at high temperatures (80°C), Sezela installed a sixth underfeeder roller on these mills to improve feeding, thus converting them to six roller units.

The Evolution of Manufacturing Processes

Clarification and Filtration

Until the early 1960's clarification by juice sulphitation was common throughout the industry. This process was replaced in 1966 by lime defecation, and to-day hot-liming using lime saccharate is practised. Settling of juice is done in 3 fast-flow trayless clarifiers of Australian design (SRI) modified to reduce retention time of muds and ensure better displacement of juice at the lower levels. This was necessary following a 50% reduction in mud volumes with cane diffusion. With milling muds of about 9% solids were drawn off and in order to obtain the same consistency with diffusion, draw-off of muds had to be delayed for long periods to allow compacting. These delays caused purity drops of some 5,0 points between mixed juice and filtrate which increased undetermined losses.

Research work at the Sugar Milling Research Institute however showed that muds with solids content of below 4% improved filtration and reduced losses in Filter Cake.³ This, in combination with steam injection to maintain a high temperature of muds (80°C) in transit to the filters, has reduced the purity drop below 1,5 points. The influence of diffusion on filtration compared with milling is shown as follows

	Filter Cake (% Cane)	Loss in F. Cake (% Pol in Cane)	Filter Area (m ² /tch)
Milling (1973)	5,28	0,28	0,86
Cane Diffusion (1984)	1,45	0,16	0,18 — 0,26

Evaporation

The evaporator evolved from quadruple effect operation in the early 1960's to quintuple effect evaporation following

the 1965–66 expansion. Maximum steam economy was required to supply the needs of the back-end refinery, and those of the furfural plant which was commissioned in 1974. The final expansion of the sugar factory in 1981–84 also coincided with a major expansion of the chemical (furfural) plant. This called for the supply of additional bagasse and high pressure steam to supply the bagasse digesters. In order to meet these new requirements the final evaporator design involved maximum bleeding of first and second vapours and the introduction of Mechanical Vapour Recompression (MVR), discussed briefly in the section on Energy.

In order to provide the large heating surface required for MVR and vapour bleeding duties as well as to reduce the retention time of juice at high temperatures, kestner-type long tube vessels were installed in the first effect, and semi-kestner vessels in the second effect. The kestners have tubes 7 m long and 50 mm o.d. while the semi-kestners use identical tubes 3,5 m long.

Evolution of the Boiling Process

Raw sugar of 98,5 pol used to be produced in Natal until about 1966. The universal single magma 3-boiling system was used which resulted in the production of a mixture of first and second sugars of notoriously poor filterability, with high ash and starch levels. In order to improve the refining properties of South African raws, the boiling process was modified. It is now based on the well-known effect of purification by re-crystallisation and produces very high pol (VHP) sugar of 99,3 pol.^{4,5} 'C' sugar is completely melted and returned to syrup. 'B' sugar is made into a magma with water or clear juice to a purity of 90 and used as a footing for 'A' massecuites. Any excess 'B' sugar is also melted and returned to syrup. VHP sugar is produced from 'A' massecuites only, thus obviating a mixture of two sugars varying crystal size and purity. VHP sugar is produced to meet stringent specifications, as follows:—

Pol	99,3 °S	(min.)
Moisture	0,18 %	(max.)
Conductivity ash	0,20 %	(max.)
Starch	150 ppm	(max.)
Specific grain size	0,65 — 0,75 mm	
Mean aperture	0,7 — 0,8 mm	
Fines (thru' 600 μm)	30 %	(max.)
ICUMSA colour (420 mm)	1350	(max.)

Drying of sugar is done using two auto-controlled fluidised bed driers of 50 tons capacity. They have replaced rotary type louvre-driers and were chosen on the basis of lower capital and maintenance costs and are well suited to automation. The level of starch is generally controlled by the use of the commercial high temperature tolerant enzyme — analyse which is dosed in the evaporator juice line between the third and fourth effects.

Introduction of Continuous Pans

Development and expansion over the 25 year period had resulted at Sezela in a conventional pan-station consisting of batch pans situated at upper factory level. The second expansion of 1975–1976 saw the installation of four additional large 85 m³ pans to produce 'A' and 'C' massecuites while four 42 m³ pans installed in previous years were dedicated to 'B' boilings. During the final expansion (1981–84) the additional pan capacity required was partly provided by the installation of a 90 m³ Fives-Cail-Babcock (FCB) continuous pan for 'C' boiling (1981), while the existing pans were re-allocated to boil 'A' and 'B' massecuites. The reasons for the installation of a continuous 'C' pan were:

- to tie-in with continuous crystallisers and centrifugals installed in previous years,
- to benefit from experience acquired at the Company's Gledhow mill where an identical pan was installed in 1978 for similar reasons, and
- continuous pans were well adapted to automation, requiring minimum supervision while their steam demand was more regular.

To complete the 'C' station capacity requirements, a second 90 m³ continuous Sugar Research Institute (SRI) pan was installed in 1984. Whereas the FCB pan is fitted with horizontal stainless steel tubes stacked in a nest to provide the heating surface, the SRI pan has a "floating" calandria with mild steel welded vertical tubes. The FCB pan has 12 control loops to the SRI's 7 and the massecuite path is shorter in the SRI pan which consists of 3 distinct sections with separations between them.

Both pans have performed well with a slightly better grain distribution and exhaustion in the SRI pan. Figure 3 shows the boiling house recovery from 1959 to 1984. The severe dip in the case of Sezela is mainly due to the effect of a very severe drought as well as the poor performance of the new 'C' crystalliser station (see below). Figure 3 also shows that the boiling house recovery seems to follow a trend similar to that of the mixed juice purity (See figure 1). Continuous pans are now used on 'B' massecuite (Felixton, Illovo) and 'A' massecuite (Felixton, Maidstone).

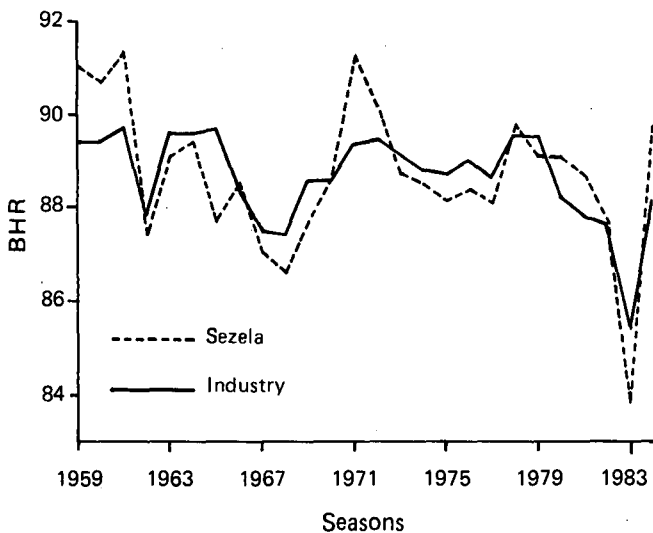


FIGURE 3 Boiling House Recovery from 1959 to 1984⁶

Crystallisers

All three massecuites are water-cooled before curing. 'A' crystallisers are connected together in series to provide continuous operation. They are conventional horizontal units formerly part of the 'A' and 'B' stations, now re-grouped. Crystallisers for 'B' and 'C' massecuites are of the vertical type. 'B' crystallisers are fitted with vertical rotating cooling elements of an earlier design with 7 m long and 50 mm o.d. finned tubes. The drives consist of constant torque hydraulic motors, of 7,5 kw each. For 'C' massecuite, six vertical crystallisers each of 100 m³ are arranged in three groups of two units in series. When they were first installed (1983) they were fitted with vertical rotating cooling elements made of 100 mm vertical tubes. These proved to be very inefficient with poor plug flow and insufficient cooling, resulting in high

molasses losses. The vertical elements were replaced the following year with static horizontal water-cooling tubes arranged in stacks. Rotating arms are provided between the rows of tubes and assist the flow of massecuite. These modifications have proved very successful.

Vertical crystallisers have the main advantage of standing on their own foundations with no steel supporting structure being necessary. They stand in the open at Sezela with no building being provided, and occupy less ground space than horizontal units. In all, 14 vertical units totalling 916 m³ are installed for 'B' and 'C' massecuites. Figure 4 shows the general improvement in final molasses purity and the molasses percent cane.

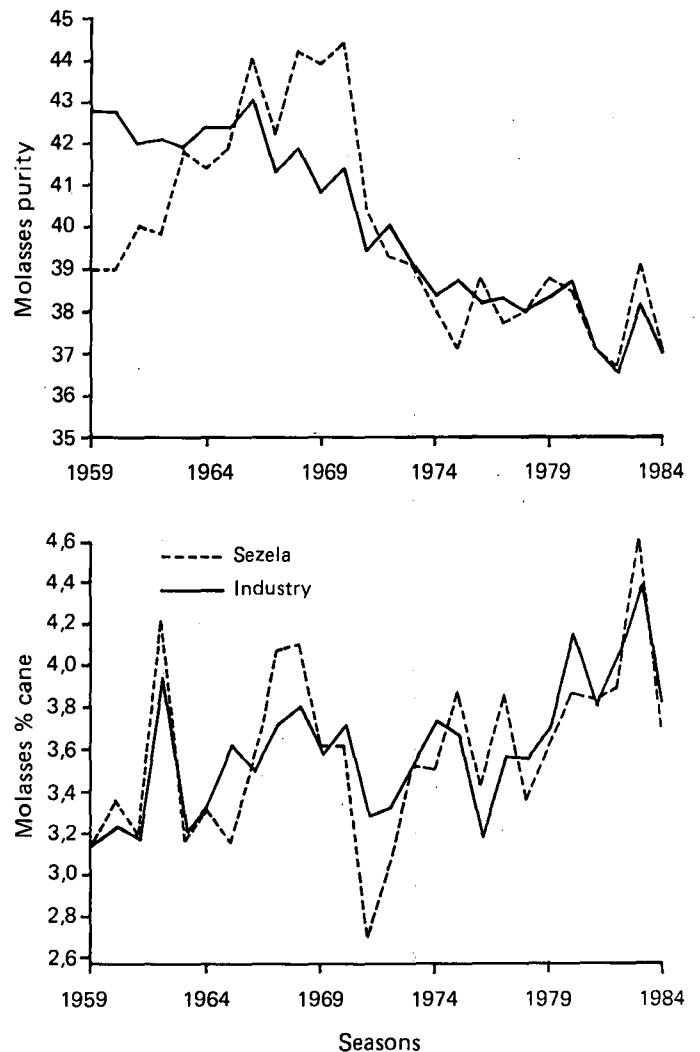


FIGURE 4 Final molasses purity and molasses percent cane for Sezela and the industry⁶

Whereas the molasses purity has declined the quantity of molasses shows a gradual increase.

Curing

Curing of 'A' massecuites is done in modern batch type centrifugals while for 'B' and 'C' massecuites continuous machines have replaced batch-type. The introduction of continuous centrifugals has allowed the handling of 'C' massecuites of lower purity and has greatly contributed to reducing the loss in final molasses. It has permitted a substantial saving in labour, and has reduced maintenance costs greatly. Final molasses is cooled down to below 45°C in a plate heat-exchanger before storage.

Steam and Power

In the early 1960's, steam at a pressure of 1,2 MPa was raised in six 18 ton steam/h water-tube boilers, equipped with bagasse spreaders and dumping grates. During the first expansion of 1965 two additional boilers, each of 57 tons/h @ 2,1 MPa were installed, both units being equipped with spreader stokers and travelling grates. In 1979 the small boilers of the 1960's were discarded and replaced by a large modern 146 tons/h unit to cope with the additional steam demand required by the bagasse-based furfural factory. In the final expansion of 1981-84 a second large capacity 130 tons/h boiler was installed to meet the increasing steam demand of the factory and to supply additional steam to the expanding furfural plant. Whereas the larger boiler is fired on bagasse/residue mixture only, the other three units are designed to be fired on coal and/or bagasse/residue mixture; residue being the bagasse waste returned from the furfural plant. All four boilers are fitted with suspension firing equipment and are equipped with wet flue-gas scrubbers, to comply with regulations. These require that the grit level should not exceed 400 mg per Nm³ at 0°C and 12% CO₂. The sugar factory produces its own power by means of 3 turbo-alternator sets with a design capacity of 16,8 MW.

Chemical Factory, Energy and Vapour Recompression

The chemical (furfural) plant and sugar factory are mutually dependent. Sezela provides energy to the chemical plant in the form of bagasse and high pressure steam. The chemical factory returns steam at exhaust pressure, and also bagasse residual waste. This waste is mixed with the bagasse and the mixture is used to fire the boilers. The residue is of a moisture content of about 52% some 2 points above normal bagasse but the mixture burns well. The total steam requirements for the whole complex could at times exceed the supply available from natural fibrous fuel, especially below 15% fibre on cane. Vapour recompression was introduced to minimise the burning of supplementary fuel by utilising a small margin of let-down to allow the balancing of exhaust steam demand and availability. The MVR installation consists of two 50 ton per hour centrifugal-type compressors driven by steam turbines and operating between the first vapour and exhaust steam ranges.

Effluent Treatment, Water Recycling

All effluents from the sugar factory, chemical plant and village complex are treated in a two stage aerobic activated sludge system followed by a settling and maturation pond. Clear water from the treatment plant is returned as make-up to the cooling-water system of the sugar factory. The overflow from this system is pumped to the flue-gas scrubbers. The smuts laden water is pumped to a settling dam 2 km away from the factory. From this dam overflow returns to the scrubbers by means of a 400 mm-bore polypropylene line.

Automation and Control

With the increase in throughput and the introduction of modern equipment, labour intensive operations have gradually given way to the use of automatic control. In the final expansion of Sezela the major sections of the plant are operated from strategically situated control rooms where skilled personnel operate the instrument panels. Great use is made of two-way portable radios amongst the operating staff, supervisors and managers.

Discussion

During the period under review Sezela Factory has undergone many changes in plant equipment and technology to

satisfy the needs of industrial expansion; these have resulted in:

- (a) An improvement in cane handling and preparation.
- (b) A dramatic increase in extraction by the gradual evolution of the extraction plant from milling to bagasse diffusion and then to cane diffusion at the full throughput of 450 TCH.
- (c) Great improvement in steam and fuel economy by the introduction of kestners, semi-kestners and the installation of mechanical vapour recompression.
- (d) Modifications to the boiling process to produce only VHP sugar with better refining properties.
- (e) The introduction of continuous 'C' pans and vertical 'C' crystallisers and the use of water-cooled continuous crystallisers for all massecuites.
- (f) The use of continuous centrifugals on intermediate and low purity 'C' massecuites which resulted in lower purity final molasses.
- (g) The supply of bagasse and steam for the production of furfural.
- (h) The installation of a very modern boiler house incorporating high efficiency boilers designed to fire on bagasse and furfural residue mixture and/or coal and the installation of wet scrubbers on flue-gases to meet regulations.
- (i) Greater use of plant automation and process control.
- (j) The treatment of all effluents and the recycling of treated water to feed the cooling water tower and the wet scrubbers as well as to convey smuts to a distant settling dam, thus greatly reducing transport costs.

Having listed the major plant and technological changes, it is of interest in conclusion to review the results obtained at Sezela and for the industry in terms of Extraction, Boiling House Recovery and Overall Recovery. Figure 5 illustrates the changes in performance.

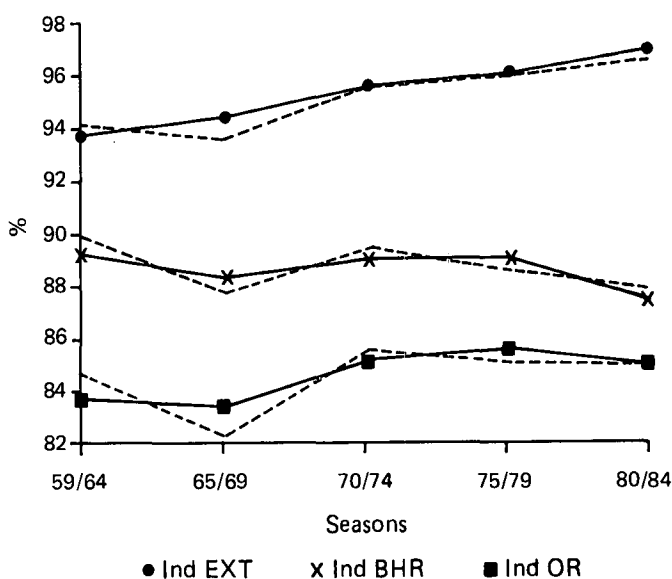


FIGURE 5 Extraction, Boiling House Recovery and Overall Recovery for Sezela and the industry⁹

It is evident that Extraction has played a major role in helping the Overall Recovery to increase by about 1% at Industrial Average and approximately 0,4% at Sezela. BHR on the other hand shows a marked decline of some 1,5%

for both Sezela and the industry. This is cause for concern, especially when considering the high cost involved in modern installations as well as the application of top technology. Although higher levels of extraction will reduce the purity of Mixed Juice to Process, the deterioration in cane quality should not be ignored (see Figure 1.) Any future significant improvement to Boiling House Recovery and therefore Overall Recovery will largely depend on a higher purity of cane delivered to the feeder tables of our factories.

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APPENDIX

Equipment and power used for raw sugar production at Sezela

Extraction Plant	No. 1 Line	No. 2 Line
Total installed power kw/tfh	164	150
Cane Preparation kw/tfh	100	91
Dewatering mills: Total roller vol. m ³ /tfh	0,37	0,34
Diffusers: Screen area m ² /tch	2,22	2,06

Clarification, Evaporation	
Juice Heaters: Heating surface m ² /tch	8,7
Clarifiers (Trayless): m ³ /tch	1,0
Evaporators: Heating surface: m ² /tch	59,6

Boiling House	
Vacuum Pans: Volume m ³ /tch	A 0,70 B 0,40 C 0,60*
Crystallisers: Volume m ³ /tch	A 1,77 B 1,88 C 1,58

Centrifugals	
Batch type: 'A' mc: D ³ H/tch**	34,3
Continuous: 'B' mc: W ² V/tch**	170,0
'C' mc: W ² V/tch**	291,9

Steam and Power Generation	
Electricity *** kw/tch	44,3
Boilers: Maximum Continuous Rating: tons steam/tch	0,82

- * This includes 0,42 m³/tch for the capacity of 2 continuous pans.
- ** Empirical values used in S. Africa to compare centrifugal capacities,
 - D = Basket diameter (batch types)
 - H = Basket height (batch types)
 - W = Speed of rotation (cont. types)
 - V = Volume of cone formed by basket (cont. type)
- *** Electricity generated by steam driven generators, installed: 16,75 MW.