TEN PROCESS INNOVATIONS FROM ONE FACTORY

MS GREENFIELD

Tongaat-Hulett Sugar

Abstract

Since 1965, Tongaat-Hulett's Maidstone Mill has introduced a remarkable number of successful innovations.

The paper describes ten of the more significant process innovations implemented over this 35 year period, including mud recycling, evaporator modifications, an entrainment separation device, development of a continuous pan and controls, low grade crystalliser drives and continuous centrifugals for magma production. Although each innovation was developed initially to address a Maidstone factory problem, several have subsequently been widely introduced into both the world's cane and beet sugar industries.

New information is presented on several of the innovations about which numerous technical papers have already been published. On others, such as the Kestner heater and pumpless Kestner juice recycling, no information has been previously published.

This review is intended to encourage engineers and technologists to further innovations in the Industry.

Keywords: innovations, mud recycling, evaporators, continuous pans, centrifugals, brix control

Introduction

The former Tongaat Sugar Mill was renamed Maidstone Mill following the merger in 1982 of the Tongaat and Hulett companies to form Tongaat-Hulett. Although covering both eras, in this paper only the current name of Maidstone will be used.

Since 1965, Maidstone has evolved from a factory with two milling extraction lines totalling 210 tch, to two diffuser lines totalling 470 tch. During this period factory changes have included many novel concepts that have proved successful at Maidstone. Although each innovation was developed initially to address a Maidstone factory problem, several have subsequently been widely introduced into both the world's cane and beet sugar industries.

Some of the ten innovations discussed here have been described in past technical literature but others are previously unpublished. They are listed in factory process sequence rather than chronologically, as this makes for easier following.

Maidstone innovations

1. Mud recycling (1997)

Following construction of the Komati Mill, Bosch Projects reviewed its design to create a conceptual 'future factory' of even lower capital and maintenance cost, without sacrificing performance. One of the concepts, proposed by a former Maidstone engineer, was to recycle the mud from the clarifiers directly to an appropriate stage along the diffuser. This would do away with the entire filter station, including bagacillo plant, mud mingler, filters, vacuum system, condenser water system and filterpress disposal plant (Bosch, 1996).

This Filtrafusion™ concept was mentioned in discussions with Tongaat-Hulett and Maidstone Mill decided to undertake trials of the system. The process proved immediately successful, as reported by Meadows *et al.* (1998). Maidstone (and others) have now adopted it as their permanent system, and Jensen and Govender (2000) have quantified most of the resultant savings for Maidstone Mill.

The process is now also being adapted for milling tandems (Moor and Yeo, 2001).

2. Kestner evaporator with integral heater (1973)

When extending the evaporator station in 1973, Maidstone decided to install two Kestner-type vessels in parallel as the first effect vapour cell. Reasons for this were to reduce costs and to minimise retention and sucrose destruction.

In designing the Kestners, the juice was introduced centrally at the base of the vessel and constrained to flow upwards through the central 36 tubes of the calandria (Figure 1). At the top of the calandria, a hood with an easily removed cover forced this juice back down the surrounding 40 tubes. This effectively provided two force-fed passes of juice, wherein the heating process was akin to that in a conventional tubular heat exchanger (i.e. not reliant on vapour bubbles for flow).

Two advantages of this design were that:

- it ensured that the juice was already flashing by the time it reached the tubes of the conventional part of the calandria
- it provided an excellent distribution of juice and flash vapour across the area of the evaporator.

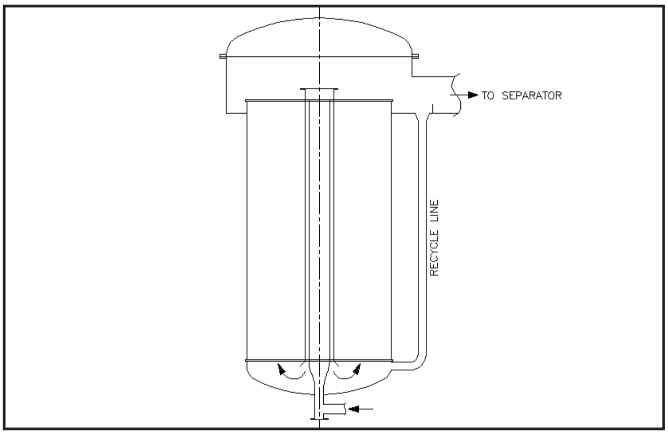

Figure 1. Kestner with integral heater and pumpless juice recycle.

Tests during 1982-84 on a number of first effect vessels at Tongaat-Hulett mills showed these Maidstone vessels to have the lowest average retention time. This minimises Vukov degradation losses (Vukov, 1965), one of the principal objectives of the Kestner-type vessel. Purchase *et al.* (1987) attributed Maidstone's lowest undetermined loss in the S.A. industry largely to their evaporator configuration.

The station was expanded in 1995 with the introduction in parallel of a further larger Kestner from the closed Mount Edgecombe Mill. It then proved difficult to balance flows between the vessels due to the additional pressure drop across the heating stage of the Maidstone vessels. They were therefore converted to conventional flow by removing the components from above and below the calandria that separated off the tubes of the 'juice heater' section.

3. Pumpless Kestner juice recycle (1995)

Following these 1995 expansion changes, it was observed that the tubes on all three of the Kestner vessels fouled far more rapidly than previously and that the measured heat transfer rates, even immediately after cleaning, were significantly lower than previously. These effects were seriously affecting the capacity of the new station. After extensive inspections, investigations and brainstorming, results from long tube evaporator pilot plant trials being conducted at Felixton Mill suggested that the problem might be related to the reduced juice flow rates in the tubes. The average flow per tube in the Maidstone vessels had been reduced from 1.1 kg/min per tube to less than 0.7 kg/min per tube. This reduction fell exactly within the critical range for both fouling and heat transfer rates identified at Felixton (Walthew and Whitelaw, 1996).

If this were the cause, the obvious solution would be to install recirculation pumps on the Kestners. The simpler (but less obvious) solution implemented was to fit a small weir across the bottom of the juice/vapour transfer pipe to the separator, with a juice return line from upstream of this weir to the space below the Kestner calandria (Figure 1). By correctly sizing the downpipe, this device automatically recycled 80 to 100% of the nominal juice throughput, sufficient to raise the flowrate to above the safe minimum of 1.25 kg/min/tube, using the evaporation lift in the tubes to 'pump' the recirculation juice.

The results were immediate and dramatic. Heat transfer rates which had previously ranged over a two week cycle from 3.0 (clean) to 1.8 kW/m^2/K (fouled), improved to 3.2 (clean) to 2.6 kW/m^2/K (fouled). This effect was confirmed by a reduction of 60 to 80% in the volume of scale removed on scheduled mechanical cleaning by rotary cutters (as measured by number of wheelbarrow loads!).

The recycle circuit does not increase overall retention time and Vukov losses, as the volume of juice in the vessel is unchanged. The principle is recommended for any long tube evaporator with a wetting rate of less than 1.4 kg/min per tube.

4. Coarse entrainment separation louvres (1974)

The original spiral entrainment separators on an old Fletcher evaporator line collapsed and were replaced with stainless mesh demisters. However, the height above the calandrias in these vessels was too low to allow disengagement of even the coarse splash and the demisters fouled quickly, requiring removal for cleaning every fortnight.

A staggered double bank of 110 x 110 x 3 mm 90^o angle sections of type 430 stainless steel were mounted heel-down across each vessel, slightly inclined for drainage of entrapped liquid, approximately 700 mm below the demisters. The lower bank louvres were mounted 165 mm apart, with the upper bank aligned above the gaps in the lower bank. These proved so effective in arresting the coarse splash that it was possible to extend the demister cleaning cycle from the previous two weeks to ten weeks.

Archibald and Mack (1978) extended the concept with more layers, providing almost complete entrainment separation.

The same concept, using similar gas velocities, was subsequently employed in other juice evaporator and flyash scrubber installations at Maidstone.

5. Jigger steam for continuous pans (1975)

In 1975, Maidstone introduced the first continuous pan in South Africa. This was a 64 m^3 Fives-Cail Babcock (FCB) pan – at that time, twice the size of any other continuous pan. FCB offered their standard instrumentation of three ganged controls, based on the conductivity at approximately the 4th, 12th and 15th compartments. Maidstone considered this inadequate and opted instead to design their own instrumentation with individual brix / feed control on each of the fifteen compartments (Graham and Radford, 1977).

Maidstone were concerned that circulation with the notoriously viscous South African low purity massecuites would prove more difficult than in FCB's other installations. During commissioning, this was proved correct. Management was not prepared to compromise by boiling at low brixes and therefore installed steam jiggers on the bottom of the pan underneath the calandria (Graham and Radford, 1977).

These jiggers were connected to first effect vapour, with provision made for an alternative feed from the calandria incondensible gas vents. The jiggers immediately solved the circulation problem and are now a standard feature in Tongaat-Hulett C massecuite continuous pans. As Maidstone has no shortage of process steam, the incondensible connections are not normally used. However, in beet factories incondensible jiggers provide circulation enhancement with minimal waste of energy and are probably more energy efficient than electrically driven mechanical stirrers.

6. The Tongaat-Hulett continuous pan (1982)

Before the FCB continuous C pan had been commissioned, Maidstone management was concerned that the cross-sectional design left pockets where massecuite was likely to settle and other areas where short-circuiting was likely. On commissioning, the FCB continuous pan produced a sugar reasonably free from fines and of a CV comparable to that from the old Maidstone batch pans (Graham and Radford, 1977). Nevertheless, some concern remained and on inspecting the pan after shutdown, it was evident that build-up did occur in some areas. Significant short circuiting was confirmed by tracer tests in 1980 that showed performance equivalent to 9 mixed tanks-in-series for this 15-compartment pan (Rein *et al.,* 1985).

Maidstone therefore produced drawings in 1978 of a pan with a cross-section designed to give better flow direction. These plans were shelved pending sufficient justification for another pan. By 1981, pan capacity was a problem and the design was resurrected to generate capital estimates for a new B pan planned for 1983. Shortly thereafter, Hulett Sugar's new Felixton II mill project was approved. The Felixton Project Team knew of Maidstone's plans and offered to assist with drawing and construction resources if Maidstone would advance their programme and specifically provide for testing on A, B and C massecuites. This was agreed and the pan was commissioned in April 1982 (Figure 2).

The pan proved immediately successful, even on the more difficult high purity duty – so much so that after testing, Maidstone management decided to retain the pan permanently on A massecuite. Kruger (1983) described these initial results. Tracer tests on C boiling showed a performance equivalent to 23 perfectly mixed tanks-in-series from the 12-compartment pan, vs. the 9 mixed tanks for the 15-compartment FCB pan (Rein *et al*., 1985). On A boilings, the performance was equivalent to 17 tanks-in-series.

On the strength of these results, it was decided to use this design for continuous A, B and C boiling in the new Felixton II mill (Renton, 1985).

Many Tongaat-Hulett continuous pans have since been sold for both cane and beet duties.

In 1995, Maidstone installed a 120 m^3 Tongaat-Hulett C pan and switched the FCB pan to B duty. Due to ongoing maintenance and performance problems with the FCB pan, during the 2000 offcrop the Mill staff themselves modified its lower casing to the Tongaat-Hulett profile and installed a vertical tube calandria (McNaughton, 2001). Mill management report that these modifications have been extremely successful, contributing to record boiling house performances during the 2000 season, when this factory achieved the lowest 'corrected reduced boiling house recovery' in the Industry. Maidstone

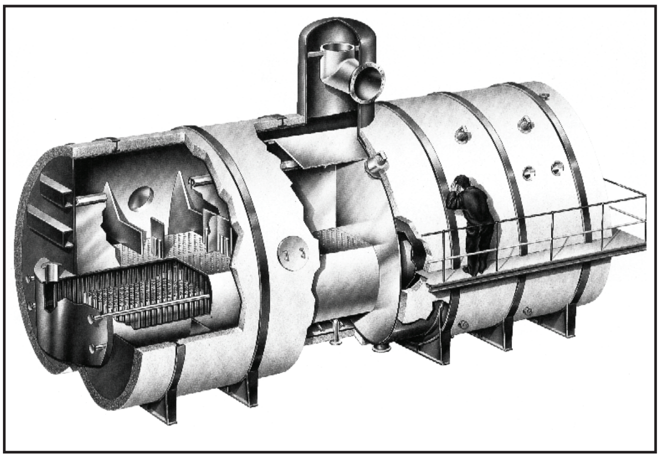

Figure 2. Tongaat-Hulett Continuous Pan.

thus now uses its own design of continuous pans on A, B and C boilings.

It is of interest to note that the latest FCB designs incorporate a lower vessel cross-section similar to that of Tongaat-Hulett (Journet, 1999).

7. RF pan and evaporator controls (1976)

Conductivity control of the FCB continuous pan proved simple, except that the measuring electrodes drifted out of calibration as they became coated with a layer of static massecuite. They therefore required regular cleaning, sometimes resulting in mechanical damage.

To eliminate probe cleaning, prompted by the work of Reichard and Vidler (1975), Radford experimented with the measurement of conductivity by radio frequency (RF) in the range of 20 MHz to 50 MHz. The use of RF enables measurement of both resistance (or conductivity) and reactance. Radford found that conductivity was a good indicator of low purity mother liquor brix but was relatively unaffected by crystal content of massecuites, whereas capacitive reactance was a good indicator of crystal content but was relatively unaffected by brix. This finding presented obvious promise for new methods of pan control.

With the introduction of Maidstone's A continuous pan in 1982, RF probes were used commercially for the first time to measure and control A massecuite quality in respect of both brix and crystal content. They proved far superior to conventional conductivity control on the 85^o purity massecuites, as reported by Radford and Cox (1986) and by Rein (1986). The probe was also used successfully to control high purity refinery white boilings, an application far out of the range of conductivity controls (Radford *et al*., 1987).

Radford and Cox (1986) also reported on the remarkably close correlation between syrup brix measurements by RF probe and by nuclear density meter. The RF probe is both safer and considerably less costly than the nuclear density device and is now widely used for both evaporator and remelter brix control.

The RF probe has undergone continuous improvement as new electronic devices and probe construction materials have become available. Recent developments are to be reported by Love *et al.* (2001).

8. Continuous crystalliser station (1966)

In 1965, the Maidstone pan station comprised twelve 27 m^3 batch pans and thirty-three horizontal crystallisers of the same capacity. As was normal at that time, a maze of gutters and gates below the pans enabled each pan to be struck into any one of several crystallisers. This made for complex operations and record keeping of each strike to achieve the desired retention time. There were inevitably errors and overflows.

Maidstone pioneered the simple process of interconnecting the As, the Bs and the C crystallisers into sets in series, with suitable arrangements to prevent short-circuiting. This greatly simplified operations, saved labour, stopped overflows, eliminated many gutters and optimised retention in the existing crystalliser capacity. The concept was too simple to publish, but within a few years nearly all South African mills had followed suit.

9. Unique hydraulic crystalliser drive (1984)

For the 1984 season, Maidstone increased crystalliser capacity by the installation of two 135 m^3 vertical crystallisers, designed for either B or C massecuites. For C duty, the requirement was a maximum torque of 275 kN.m at an operating speed variable from 0.5 to 1.3 r.p.m.

Tenders were called for a variety of drives, including DC electric and hydraulic motors, with or without reduction gearing, and chain-and-sprocket or worm-and-wheel final drive.

As reported by Greenfield (1984), it was decided to select a novel direct-coupled hydraulic drive, of a design with some similarities to a radial piston aircraft engine. A smaller prototype of this 'Tamhe' design had been successfully proven on one of Maidstone's 27 m^3 horizontal crystallisers in 1983. After minor teething troubles had been resolved, the new large 7-cylinder units operated entirely satisfactorily, and when two further 158 m^3 vertical crystallisers were added in 1989, these too were fitted with Oilpower's Tamhe hydraulic motor drives.

Advantages of the drive include:

- no gearing required
- high efficiency
- smooth, continuous torque, which is easily and directly measured and controlled
- constant torque over full speed range from 0 to maximum
- ease of maintenance by mill staff
- no threat of obsolescence, since all components are easily manufactured.

Apart from having ideal characteristics for the drives, these units were then also the most cost competitive. With subsequent developments of AC variable speed drives and high reduction, low cost epicyclic gears, they are probably no longer the lowest cost option.

10. Centrifugal housing for minimising crystal damage (1985)

Maidstone has generally adopted a boiling scheme of remelting C sugar and using B magma for its VHP (>99.3°pol) final product A sugar. The crystal damage caused by the continuous B centrifugals was therefore a serious concern. 'Washing out' or dissolving the fines created in the magma used additional steam and pan capacity and, although not measured, presumably produced a footing with smaller crystals and larger CV than would otherwise have been possible.

Swindells and White (1980) reported that little crystal damage occurs in massecuite moving along the centrifugal screen. Most of the damage is caused by the impact of crystals moving at high velocity from the basket striking crystals already stopped on the monitor casing (or striking the casing itself). This was confirmed by tests carried out by Tongaat-Hulett in 1982 at their Triangle mill in Zimbabwe on a BMA K850 centrifugal with part of the monitor casing cut away, and in 1984 at Darnall on a large casing K850 (Rein and Archibald, 1989).

The Triangle tests showed that within about 2.7 metres from leaving the basket, the crystals had already decelerated sufficiently to suffer almost no impact damage. However, 6 m diameter monitor casings were an impractical solution for the limited space and headroom at Maidstone. A two-part solution was therefore proposed:

- A larger than usual distance to the casing wall, to effect some deceleration, and
- A casing surface in the impact zone inclined downwards at about 30° (instead of nearly square) to the trajectory of the crystals, so that they would be deflected away rather than be stopped and build up.

These objectives were achieved by fabricating a 6 m x 3 m casing, housing two conventional BMA K850 rotating elements. A baffle across the top separated the sugar from the two machines. As shown in Figure 3, the sides of the casing and the centre baffle were inclined downwards at approximately 30° in the impact zone (a little above the top of the baskets). The rectangular shape was chosen so that the casing could be manufactured at the mill and so that a non-stick high-density polyethylene lining could be fitted in the impact zone if crystal build up occurred. In the event, no lining was required.

No measurements have been made to compare the crystal damage from this station, but the pan boilers at Maidstone reported that it was not necessary to wash the magma from this installation, whereas this was previously essential.

It was noted with interest that the Broadbent continuous high-grade centrifugal at Darnall, derived from those developed in

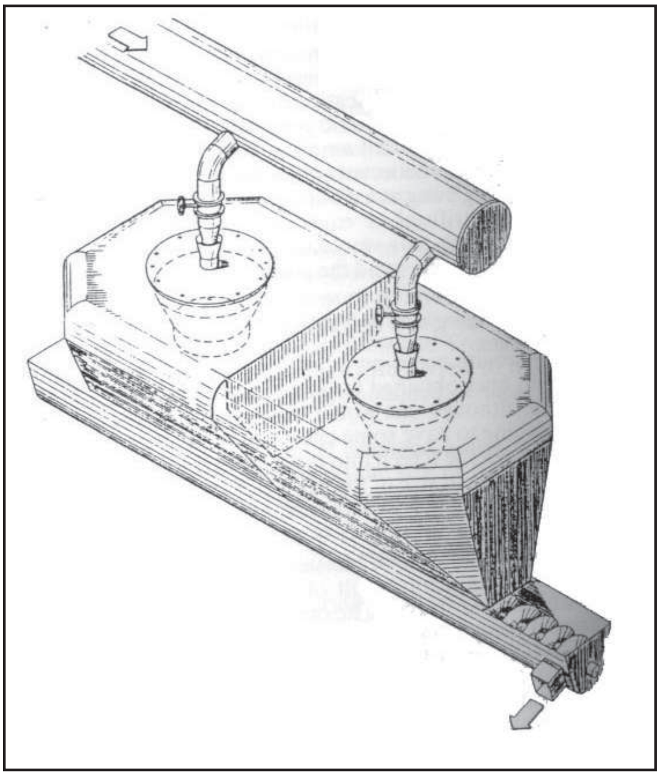

Figure 3. Centrifugal housing for magma sugar.

Australia in the 1990's, incorporates a similar principle of oblique impact angles to minimise crystal damage (Zondo *et al,* 1998).

Conclusion

This paper reviews ten process innovations and a companion paper (Greenfield, 2001) reviews ten engineering innovations from the same factory. At the end of this latter paper, brief consideration is given to what factors were believed to have supported this innovative climate. The conclusion was a team of extremely competent, committed engineers operating within an enabling management climate.

A further message from this experience is that, despite the long history of the Industry, there remain limitless opportunities for significant improvements in its equipment and manufacturing processes. This provides stimulating prospects for its engineers and technologists.

REFERENCES

Archibald, R. and Mack, C. (1978). A simple and inexpensive evaporator entrainment separator. *Proc S Afr Sug Technol Assn.* 52: 36-38.

Bosch Projects (Pty) Ltd. (1996). The removal of mud using a diffuser. Republic of S.A. Letters Patent No. 96/7462. Patent Office, Pretoria.

Graham, W.S. and Radford, D.J. (1977). Preliminary report on a continuous C pan. *Proc S Afr Sug Technol Assn.* 51: 107-111.

Greenfield, M.S. (1984). The selection of a novel crystalliser drive. *Proc S Afr Sug Technol Assn.* 58: 102-106.

Jensen, C.R.C. and Govender, G. (2000). The implementation and optimisation of mud recycling at Maidstone Mill. *Proc S Afr Sug Technol Assn.* 74: 336-334.

Journet, G. (1999). One design, three pans. A large flexibility of use. *Proc Int Soc Sug Cane Technol* XXIII: 104-114.

Kruger, G.P.N.K. (1983). Continuous "A" pan boiling trial at Maidstone sugar factory. *Proc S Afr Sug Technol Assn.* 57: 46-51.

Love, D.J., Swan, M.L. and Cox, M.G.S. (2001). Combining temperature measurement with the output of a radio frequency probe and the implications for automatic control. *Proc Int Soc Sug Cane Technol.* XXIV: In press.

McNaughton, M. (2001). Modifications to Maidstone's B continuous pan. Personal communication.

Meadows, D.M., Schumann, G.T. and Soji, C. (1998). Farewell to filters: the recycle of clarifier mud to the diffuser. *Proc S Afr Sug Technol Assn.* 72: 198-203.

Moor, B.StC. and Yeo, W.H. (2001). Clarifier mud recycling to the extraction plant. *Proc S Afr Sug Technol Assn.* 75: In print.

Greenfield, M.S. (2001). Ten engineering innovations from one factory. *Proc S Afr Sug Technol Assn.* 75: In print.

Purchase, B.S., Day-Lewis, C.M.J. and Schaffler, K.J. (1987). A comparative study of sucrose degradation in different evaporators. *Proc S Afr Sug Technol Assn.* 61: 8-13.

Radford, D.J.and Cox, M.G.S. (1986). The use of electrical properties measured at radio frequencies for pan boiling and brix control. *Proc S Afr Sug Technol Assn.* 60: 94-102.

Radford, D.J., Tayfield, D.J. and Cox, M.G.S. (1987). The use of radio frequency for control of a white pan at Hulett Refinery – a preliminary trial. *Proc Sug Ind Technol,* 1987: 555-562.

Reichard, S.R. and Vidler, T.I. (1975). Contactless conductivity measurements in massecuite. *Proc Qld Soc Sug Cane Technol* 42: 249-253.

Rein, P.W., Cox M.G.S. and Love, D.J. (1985). Analysis of crystal residence time distribution and size distribution in continuous boiling vacuum pans. *Proc S Afr Sug Technol Assn.* 59: 58-67.

Rein, P.W. (1986). A review of continuous vacuum pans in Tongaat-Hulett Sugar. *Proc S Afr Sug Technol Assn.* 60: 76-93.

Rein, P.W. and Archibald, R.D. (1989). Crystal breakage in continuous B-centrifugals. *Proc S Afr Sug Technol Assn.* 63: 94-99.

Renton, R.H. (1985). Felixton - a new sugar mill in Zululand. *Proc S Afr Sug Technol Assn.* 59: 1-4.

Swindells, R.J. and White, E.T. (1980). Breakage of sugar crystals on impact. *Proc Qld Soc Sug Cane Technol.* 42: 283-291.

Vukov, K. (1965). Kinetic aspects of sucrose hydrolysis. *Int Sug J* 67: 172.

Walthew, D.C. and Whitelaw, R.W. (1996). Factors affecting the performance of long tube climbing film evaporators. *Proc S Afr Sug Technol Assn.* 70: 220-224.

Zondo, B.I., Hubbard, G.B., van der Merwe, J and Meadows, D.M. (1998). Experiences with a high grade centrifugal at Darnall. *Proc S Afr Sug Technol Assn.* 72: 210-214.