TEN ENGINEERING 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 author has been directly and indirectly associated with this factory throughout the period and, in this paper, describes ten of the more significant engineering innovations.

Each engineering innovation originated with the need to solve a problem in the mill. Although none was initiated with a view to future commercial sale, several have evolved into successful commercial products (e.g. the Tongaat Shredder, sieve plate scrubbers and perforated plate de-watering rolls).

New information is presented on several of the innovations about which numerous technical papers have already been published. On others, such as the quick release cane knives, diffuser dry feeding and elimination of diffuser mixed juice screening, no information has been previously published.

The paper concludes with brief comment on factors that have contributed to this mill being so prolific in its innovations.

Keywords: innovations, cane knives, cane shredders, diffusers, boilers, flue gas scrubbers

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 is 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. Several of these 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Some of the ten innovations discussed here have been described in past technical literature but others are previously unpublished.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 understanding.

Maidstone innovations

1. Quick-release cane knives (1979)

With the advent of diffusers and continuous crushing, there was pressure on the time available for weekly maintenance stops. Labour costs also increased. In order to facilitate four-hour knife and shredder hammer changes, the old bolted knife attachment system was replaced by a single quick-release pin attachment (Figure 1).

Securing the knives merely involves dropping them into the rectangular slot and fitting the free-clearance pin, which is secured in place by a simple split pin. Because of the forward-tilted knife mounting, both the centrifugal and the cane reaction forces on the knives are in the same backward direction. This ensures that although loosely mounted, the knife remains firmly located against stops in the working position. No 'rattling' occurs and wear is minimal. This system has proved most satisfactory for 22 years.

2. The Tongaat shredder (1972)

During the 1960's, Payne (1968) demonstrated the value of fine preparation for cane diffusion and Australian technologists such as Crawford (1969; 1971), Shaw and Shann (1970), Clarke and McCulloch (1970) and Cameron (1970) developed heavy duty shredding for milling purposes. By 1970, it was realised that the performance of Maidstone's two milling tandems, one of which was preceded by a Gruendler and the other by a Searby shredder, could be improved by heavy duty shredding.

Maidstone studied the Australian research and considered the installation of a Walkers Heavy Duty unit on the larger tandem. However, this was of the same basic disc-and-spacer design as all other commercially available units. As size and duties were increased, limitations of this design became apparent. Most important were high hammer, hammer bar and disc stresses and the need for costly, complex hammer shapes to achieve 100% coverage across the width of the shredder.

Maidstone therefore decided to design and manufacture its own shredder, utilising a novel rotor of alternately staggered profiled plates (Figure 2). This design provided, *inter alia:*

- an exceptionally rigid and robust assembly
- low and evenly balanced shear, compressive and tensile stresses in the rotor plates, hammer bars and hammers
- simple rectangular hammers giving slightly more than 100% width coverage.

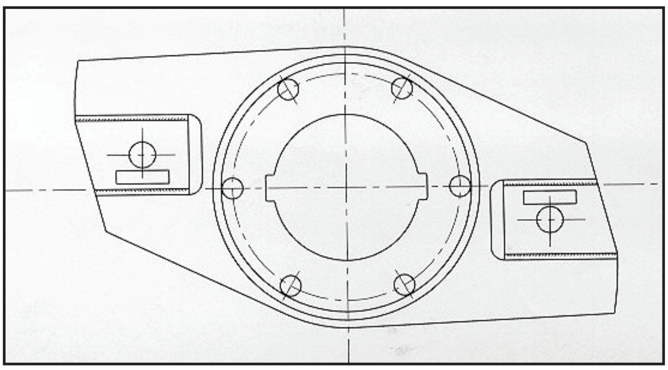

Figure 1. Quick release cane knife palms (anti-clockwise rotation).

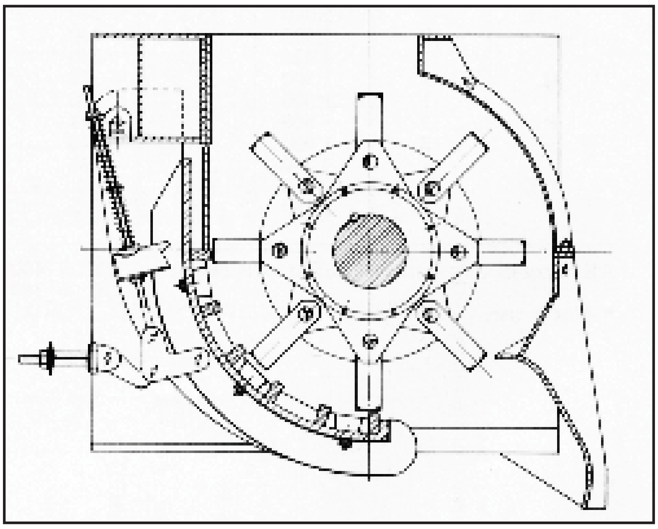

Figure 2. Tongaat shredder.

In a detailed description of the shredder, Moor (1973) acknowledged that several other features of the design (e.g. washboard, hammer proportions, tip speed) drew heavily on the Australian research.

The shredder was immediately successful, resulting in a 4% increase in throughput, first mill extraction increasing by 12% and overall extraction by 0.7%, with no other changes to the 7-mill tandem (Moor, 1974). It has also proved exceptionally reliable and low in maintenance, with the original rotor plates processing 12 million tons cane (2m t fibre) before replacement (Moor, 1991).

Since the introduction of the first unit at Maidstone, the unique rotor design has been widely accepted as the most satisfactory in all respects. Many (200+) conventional Tongaat shredders have been installed, but also many of the recently introduced 'whole stick' shredders make use of the Tongaat rotor concept.

In 1978, the Tongaat shredder earned a Certificate of Merit award from the South African National Productivity Institute for an 'outstanding achievement in productivity improvement'.

3. Perforated underfeed rolls (1970)

During the late 1960s, Maidstone increased imbibition rates and also introduced imbibition recycling (diverting juice extracted at the first squeeze to the following mill's juice tray, to return as additional imbibition). With the increased volumes of juice, the solid shell underfeed rolls appeared to lose effectiveness due to slippage. There was also a greatly increased flow of juice over the top roll.

To improve the draining capacity from the first (underfeed roll) squeeze, new underfeed rolls were constructed of perforated plate drums supported on a double-spiral screw (Figure 3). Longitudinal round bars welded externally on the drums assisted feeding. The perforations were 12 mm diameter at 25 mm triangular pitch. This gives a 23% open area which allows free drainage of juice out of the squeezed cane. Any small bagasse particles that pass through the perforations with the juice, are screwed outwards from the centre of the roll by the spiral screw, so that the drum is self cleaning.

These perforated underfeed drums provided a low-cost solution to the removal of the 'easy' juice. This same concept has since been utilised by former Maidstone technologists in the successful design of low-pressure diffuser megasse de-watering devices now operating in several South American factories.

4. Linear belt cush-cush screen (1988)

In 1988, Maidstone wished to replace their high-maintenance and unhygienic vibrating cush-cush screens with an alternative system. Limited headroom below the millhouse crane meant that an additional pumping stage would be required if conventional DSM screens were to be used. A novel solution was to use a coarse (400 micron) monofilament cloth linear belt. The screening through this belt was by gravity without vacuum assistance, followed by a spring-loaded dewatering roller, allowing for a relatively simple installation. Two belts were purchased and rotated on a two-weekly cycle that allowed thorough cleaning without extending mill stops. Belt changing was simple and took less than 30 minutes.

As reported by Gierke (1989), the system proved effective and lower in both maintenance and operating costs than the previous vibrating screens. However, when this milling train was converted to a diffusion line in 1995, mixed juice screening was no longer required (6. below) and the installation was removed.

5. Diffuser dry feeding (1977)

By the mid-1970s, Maidstone's capacity was under pressure and it was decided to replace the inefficient 1.68 m milling tandem with an Egyptian-type cane diffuser (Moor, 1978). A

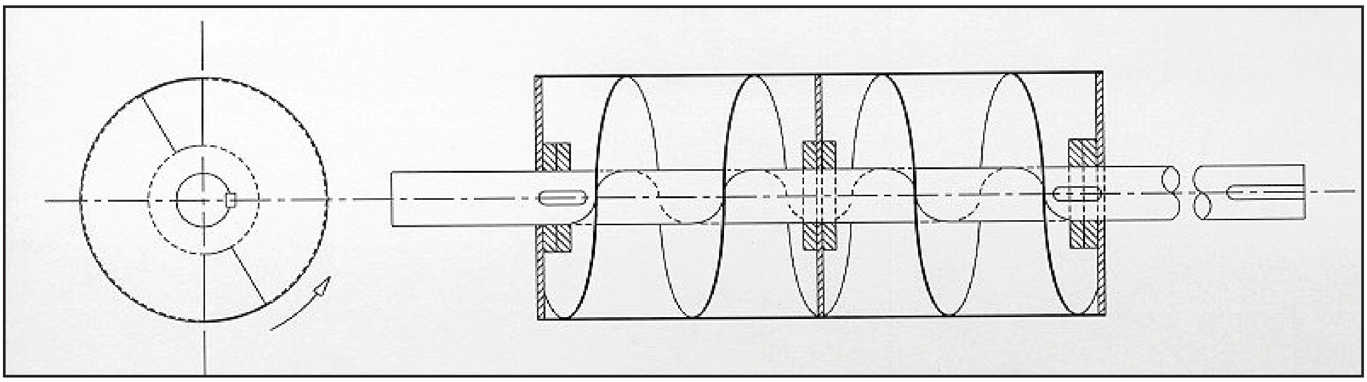

Figure 3. Self-cleaning perforated underfeed roll.

licence was purchased from BMA, who supplied a set of standard drawings and process flow information. However, Maidstone wanted a number of changes and designed a diffuser to fit exactly within the dimensions available between a set of existing house columns.

One of the changes implemented was to enable dry feeding of the cane ahead of the first scalding juice application. This was wanted because of the belief that the conventional sluiced feeding led to fines segregation, which thereafter formed blinding layers in the bagasse bed.

For dry feeding, it was necessary to change the normal sloping feed plate to almost vertical, so that the dry shredded cane would settle without hanging up on the feed plate. As far as is known, this was the first rectangular bed diffuser to incorporate dry feeding, a practice which has since become standard in both BMA and Tongaat-Hulett diffusers.

6. Elimination of diffuser mixed juice screening (1977)

Because dry feeding of the diffuser results in a stable bed before the application of any juice, it was felt that most of the fines normally present in processed juice from a diffuser would be filtered by the bagasse bed. It was therefore decided to use smaller aperture perforations (10 mm instead of 12 mm) in the screens of the first two stages of the diffuser and attempt to operate without any other screening of the juice from the diffuser.

Again, this was a 'first' which proved entirely satisfactory and which has since been implemented on Maidstone's second diffuser and several other Tongaat-Hulett diffuser installations.

7. Chokeless direct contact heater for press water (1977)

Another innovation on Maidstone's first diffuser was a direct contact heater on unscreened press water, with vapour from the first effect as the heating medium. The design of the heater was similar to a disc-and-donut type rain condenser, except that the trays were not perforated, were conical and incorporated long saw-toothed peripheries to maximise the length of juice curtains.

The heater was mounted directly over chokeless weirs feeding the press water to immediately ahead of the final set of lifting screws.

The original heater is still operating entirely satisfactorily. The principle has since been used on other diffusers, with a unit at Malelane operating on vacuum vapour described by Singh and Allwright (2000).

8. Sieve plate boiler flue gas scrubbers (1973)

In October 1970, the South African sugar industry was made subject to new air pollution legislation, which required that emissions from all new boiler plant be not more than 400 mg/Nm^3. This limit was likely to be reduced to 150 mg/Nm^3 within a few years. A 35 t/h boiler was already under construction at Maidstone and a Peabody perforated plate type scrubber was ordered for it. This was the first scrubber in the South African industry. It cleaned the flue gases to a level of 44 mg/Nm^3 (Anon, 1972), but was subject to wear of the nozzles, blockages beneath the target plates and fouling/blocking of the entrainment separator vanes (Moor, 1972).

The next scrubbers installed at Maidstone were two Brand-Ducon multivanes, which suffered catastrophic corrosion-erosion from the acid circulation water on bagasse/coal boilers. Maidstone therefore developed their own irrigated sieve plate scrubber design. The first unit was installed in 1973 to replace one of the failed Brand-Ducon units (Moor, 1977). The design proved immediately successful, achieving final emission levels of 90-120 mg/Nm^3, removing > 99% by mass of the total incoming particulate matter. Virtually 100% of larger particles were removed and over 95% of particles < 10 microns. The pressure drop across the unit was 60-70 mm water gauge. There were no blockages and no areas of high erosion.

Maidstone has subsequently installed a further six trouble-free units, three on 1400 kPa boilers that have since been scrapped. Minor improvements to the design have been made and emission levels of 30-70 mg/Nm^3 such as measured at Darnall (Boshoff and Yeo, 1999) are now the norm.

By 2000, 21 of the 35 wet scrubbers in the South African sugar industry were of this design and several had been exported to other industries.

A further interesting and successful innovation from Maidstone's scrubber experiences was the development of a 'sliding belt' conveyor to handle the corrosive and messy smuts and ash from bagasse and coal boilers. This relatively low cost conveyor, described by Moor (1977), eliminated severe maintenance problems of belts on conventional idlers or chain-and-slat systems previously used.

9. Gapped main tube bank for boilers (1984)

Maidstone sells 15 t/h of bagasse to an animal feed plant, 20 t/h of 1400 kPa steam to a textile factory and 6-12 MW of electricity to outside users, including the local electricity supply authority. High efficiency and reliability were therefore key considerations in the specifications for a new boiler commissioned in 1984.

To avoid outages due to main bank tube erosion, boiler suppliers recommended single-pass designs. However, the main bank is the most cost-efficient heat transfer area of the boiler, and much less heat can be transferred in a single- than in a three-pass configuration. For the efficiency required, a three-pass design would be significantly cheaper.

In discussions with John Thompson Africa, it was noted that the three-pass tube failures invariably occurred in the turbulent zone around the tip of the top baffle, in the middle of the main bank. This area was inaccessible for inspection or repairs, so that the failures resulted in major retubes.

The simple solution proposed was to manipulate the tubes to leave a 400 mm wide gap through approximately the centre of the main bank, such that there were no tubes in the area around the end of the top baffle (Figure 4) (Moor, 1985). This gap also provides useful access across the full width of the boiler for inspection of the main bank and, if necessary, tube protection or repairs.

By 1991, after seven seasons, two small areas of erosion had been detected and simple remedial measures were taken to prevent further wear (Moor, 1991). By the 1997 offcrop, remote field eddy current inspection of the entire main bank showed again the original localised wear in the row of tubes on each side of the gap, with 'defect severity between 0 and 20% of wall thickness'. Management reports that by the 2000 offcrop inspection – after 16 years' service – there was no further deterioration. This is despite protracted operation at or above MCR and fairly high bagasse ash loadings of 3 to 4% from the diffusers. During 1999 and 2000, the ash included that from clarification mud recycled to the diffusers (Moor, 2001).

The gapped-bank design has since been implemented on a number of boilers at other factories, mostly during retubing of previously conventional three-pass main banks. However, the concept has recently also been incorporated by John Thompson Africa into single-pass main banks to facilitate inspection and maintenance.

Another novel efficiency feature of this boiler was heat recovery plant comprising airheater-economiser-airheater (Figure 4). The second airheater was provided with type 430 stainless steel tubes and 'double skin' tube plates to counter corrosion from final gas temperatures as low as 120 to125^{o}C on both bagasse and coal fuels (Moor, 1985).

10. Large diameter boiler top drum (1984)

Despite modern three-element controls, Maidstone's boilers suffered from occasional low and (rare) high water trip outs. These were caused by an abnormal load swing, a slug of wet bagasse, and/or a 'standing wave' in the top drum. The latter phenomenon - reported from several factories with modern boilers - was manifested by a persistent, significantly higher water level at one end of the drum than at the other. The 1984 boiler was planned to enable increased electricity exports to customers such as a textile factory for whom power interruptions are extremely costly. Water level outages would therefore be unacceptable.

An obvious means to stabilise the level would be to provide a much larger water surface area. Surprisingly, the boiler suppliers (John Thompson Africa) found that the overall cost of a 1900 mm diameter drum would be very little more than for a 1200 mm drum. This was because the improved ligament efficiency from the wider pitched tubes offset the higher forces due to the larger diameter, so that a comparable drum wall thickness could be used (Figure 4).

Moor (1985) has reported the remarkable drum level stability that resulted from the low cost 1900 mm drum. The benefits derive from the larger surface (less affected by 'water volume' fluctuations and lower steam release/m^2), wider gap between

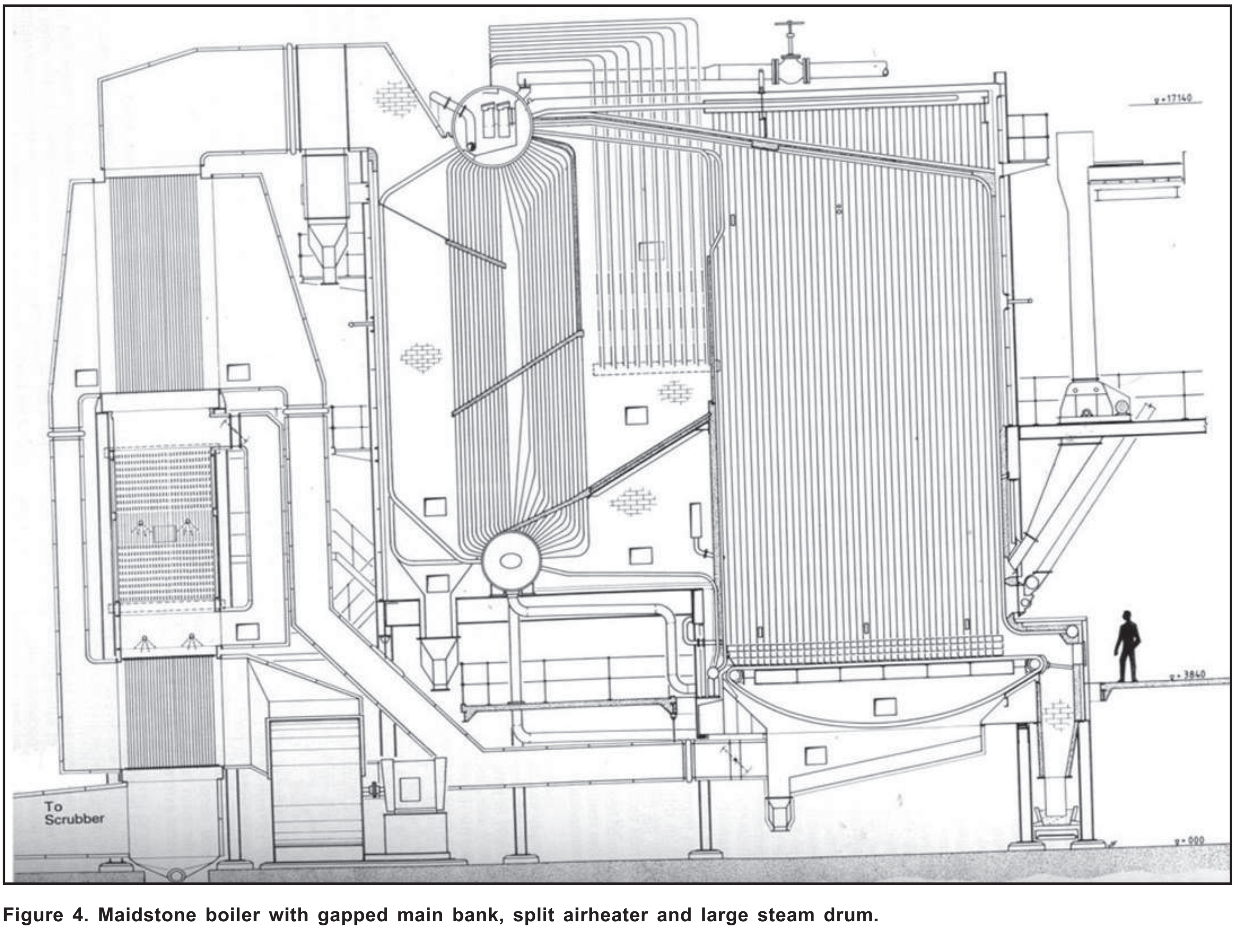

Figure 4. Maidstone boiler with gapped main bank, split airheater and large steam drum.

high and low cut-outs and larger cross-section reducing the standing wave.

Key factors supporting Maidstone's innovations

This paper reviews ten engineering innovations and a companion paper (Greenfield, 2001) ten process innovations from the same factory. This prompts the question, "What factors contributed to this innovative climate?" Some were:

- Mill management identified with the Company's business requirements and in turn enjoyed the confidence and support of the Company Board. The mill was accorded total autonomy in technical decisions until merged with the Hulett Group, whereafter there was good co-operation with the Tongaat-Hulett Technical Management Department.
- The technical management team was small, but included high skills in mechanical, chemical, electrical and instrumentation engineering, allied in all cases to practical 'hands on' involvement with the plant. Some members of the team are identified by the References below and in the companion paper on process innovations (Greenfield, 2001).
- Throughout the period, despite occasional changes of personnel, the technical management team was strong in both people and task orientations. It was also well balanced in terms of the 'Belbin' personality criteria, including 'creative ideas men (plants), specialists, resource investigators, implementers, co-ordinators, monitors and completer-finishers'.
- This team was supported by committed, competent foremen and supervisors who participated in all new developments.
- As the implementers were also the originators of the innovations, commissioning was always informed, efficient and free from any 'blaming'.
- The innovations were all to address specific problems in the Mill, never 'forced' for commercial or other reasons.
- Overriding considerations at all times were low capital and operating costs and simplicity. The KISS slogan (Keep It Simple, Stupid!) was prominently displayed in the design office.

REFERENCES

Anon. (1972). SASTA air pollution symposium. *Proc S Afr Sug Technol Assn.* 46: 102.

Boshoff, T.L. and Yeo, W.H. (1999). Reduction of bagasse fired boiler stack particulate emission levels. *Proc S Afr Sug Technol Assn.* 73: 251 - 253.

Cameron, C.D. (1970). Experiences with a heavy duty shredder. *Proc Qd Soc Sug Cane Technol.* 37: 197.

Clarke, C.D. and McCulloch, R.J. (1970). The performance of a heavy duty shredder. *Proc Qd Soc Sug Cane Technol.* 37: 181.

Crawford, W.R. (1969). Mechanics of swing hammer shredders. *Proc Qd Soc Sug Cane Technol.* 36: 329.

Crawford, W.R. (1971). The dynamics of cane shredding. *Proc Qd Soc Sug Cane Technol.* 38: 231-237.

Gierke, W.M.U. (1989). The application of a linear belt filter for cush-cush removal at Maidstone. *Proc S Afr Sug Technol Assn.* 63: 33-35.

Moor, B.StC. (1972). First impressions of a wet type scrubber on a bagasse fired boiler. *Proc S Afr Sug Technol Assn.* 46: 100-101.

Moor, B.StC. (1973). The Tongaat shredder. *Proc S Afr Sug Technol Assn*. 47: 100-105.

Moor, B.StC. (1974). An evaluation of very fine shredding. *Proc Int Soc Sug Cane Technol.* XV: 1590-1603.

Moor, B.StC. (1977). Air pollution control – practical experience at Tongaat. *Proc S Afr Sug Technol Assn.* 51: 133-136.

Moor, B.StC. (1978). The cane diffusion process. *The Condenser, 1978 (Journal of the Tongaat Group),* Interprint, Durban: 48-51.

Moor, B.StC. (1985). A reliable high efficiency sugar mill boiler. *Proc S Afr Sug Technol Assn.* 59: 118-125.

Moor, B.StC. (1991). Re-assessment of some equipment innovations at Maidstone Mill. *Proc S Afr Sug Technol Assn.* 65: 154-160.

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

Payne, J.H. (1968). Cane diffusion – the displacement process in principle and practice. *Proc Int Soc Sug Cane Technol.* XIII: 103-121.

Shaw, M. and Shann, D.S. (1970). Preliminary experiments in cane shredder research. *Proc Qd Soc Sug Cane Technol.* 37: 171

Singh, I. and Allwright, J.A. (2000). Presswater heating using a direct contact heater with sub-atmospheric pressure vapour. *Proc S Afr Sug Technol Assn.* 74: 280-284.