RE-ASSESSMENT OF SOME EQUIPMENT INNOVATIONS AT MAIDSTONE MILL

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Abstract

Many innovations made in factories are reported at congresses of Technologist associations shortly after implementation. These reports usually cover origin, design and commissioning of new equipment, together with initial operating results. However, true success is only proved by reliable performance over a sustained period. In this paper a number of previously reported innovations from Maidstone Mill are reviewed after extended periods in service. Items reviewed are the Tongaat shredder, sieve-plate scrubbers, louvre-type entrainment separators, novel crystalliser drives, boiler main-bank and fan drive improvements and a direct-from-field cane delivery system. Extended service has provided additional maintenance and performance data. Protracted use has confirmed the success of most, but problems have been experienced with some.

Introduction

Over the past 20 years, some 30 innovations introduced at Maidstone Mill have been reported at SASTA and other technologist association congresses. Most reports were made shortly after implementation and therefore comprehensively covered the origin, design and commissioning of the new equipment, but could only cover initial operating results and expected future maintenance. A number of these innovations are now re-evaluated following extended service, and their long term performance and maintenance requirements are re-assessed.

Each item is reported upon by referring to the original SASTA report, followed by an assessment of performance over time, long term reliability and maintenance requirements.

Tongaat shredder (1972)

The first Tongaat shredder was installed at the start of the 1972/73 season (Moor, 1973). The purpose of the design was to provide a heavy duty, high efficiency shredder with low maintenance requirements.

Of many features described in the paper, most important was the unique rotor design of alternately positioned profiled plates rather than the traditional round disc and spacer construction (see Figure 1). This provided three very important benefits: full width hammer coverage without the use of 'club head' hammers, an extremely rigid rotor assembly and a balanced low-stress construction, with maximum working tensile compressive and shear stresses in the discs, in the hammer bars and in the simple rectangular hammers, all at less than 70 MPa.

The shredder has proved an outstanding innovation. Its performance met the highest expectations and the effects of greatly improved preparation on the extraction performance of the milling train were described at the congress of the International Society of Sugar Cane Technologists (ISSCT) two years after commissioning (Moor, 1974). The original 1 500 x 2 130 mm shredder is still in service and there are now about 80 units installed in more than 20 countries.

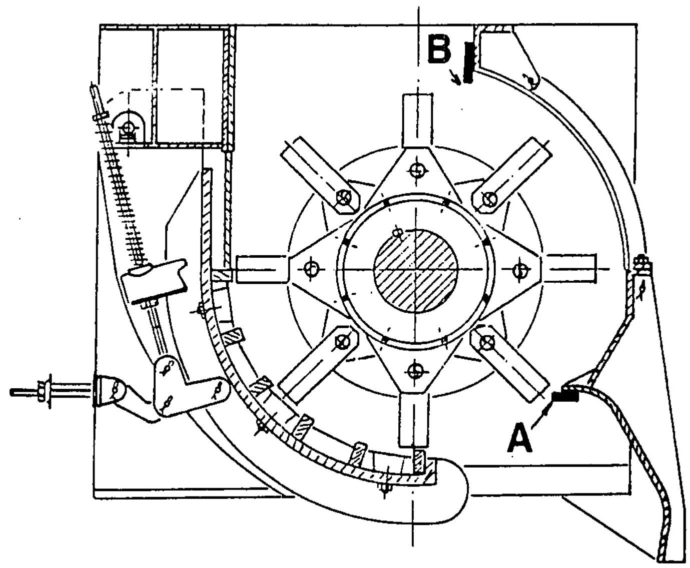

FIGURE 1 Tongaat shredder — rotor and windage control.

After nineteen years in operation the first shredder has confirmed its design intention of a low maintenance, no-nonsense machine. During this period:

- It has processed 16,2 million tons of cane at an average of 16% fibre - a total of 2,6 million tons fibre
- Preparation quality has averaged 91,2 PI despite a slightly under-powered drive for most of the period. The original 900 kW turbine was replaced with a 1 200 kW unit in 1987. This has increased available power from 25 kW/t fibre/h to a fully adequate 40 kW/tf/h at current lower throughputs.
- Several bearing problems have occurred during the life of the shredder. The original bearings were 180 mm nominal bore spherical roller bearings, type 23140 CK/C3, mounted on tapered sleeves. Fretting occurred on the landing under the sleeve, probably due to an insufficiently fine machined finish on the shaft and/or insufficient compression between sleeve and shaft. After three such failures, a modified shaft with tapered landings to carry the bearings without sleeves was fitted in 1975. Since then, a further three bearing failures have occurred, all attributable to lubrication faults.
- Apart from bearing problems and hardfacing the leading edges of the plates, the rotor has required no maintenance for 13 years (12 m tons cane, 2 m tons fibre). Plant history records include:

'21/1/76. Found hammer bar holes to be oval. Engineers satisfied. Holes to be bushed in three to four years' time.'

'16/3/79. Rotor disc (hammer bar) holes oval by ± 3 mm.'

By the 1985 off-crop, the ovality had increased to between four and five millimetres. A new rotor incorporating heavier 200 mm nominal bore bearings was fabricated and the original rotor, still in serviceable condition, was put aside as a spare.

The rotor of a second 1 500 x 2 130 mm shredder installed on the Maidstone diffuser tandem in 1977, was similarly replaced while still serviceable in 1987 after 10 years and nearly 10 m tons cane.

- The hammer bars have on average lasted 2,8 seasons each, processing some 2,5 m tons cane per set. This compares with previous Maidstone experience of ±400 000 tons per set of Gruendler hammer bars and 300 000 tons per set of Searby hammer bars.

- The shredder hammers, if maintained as originally specified by mild steel build-up with a 2-3 mm welded hard overlay, can generally be run for two weeks (50 000 tons cane), turned, and run for a further two weeks on the opposite face. On this duty cycle, a set of hammers normally lasts for approximately 60 weeks of service (1 500 000 tons cane) before being replaced because of 1,5-2,0 mm ovality in the pivot hole.

  It should be noted that, if sand levels are high (ash in cane greater than 1,5-2%), the 2 + 2 = 4 week duty cycle has to be reduced to a maximum of three weeks before removing the hammers for re-welding.

- The original shredder has been subjected to a large number of rocks, cane knives, heavy steel tramp, chain slings and hooks and other hard and tough extraneous matter without suffering any substantial mechanical damage.

- Remarkably few design changes have been found necessary over the years. The only differences between currently manufactured 1 500 x 2 130 mm Tongaat shredders and the original 1972 unit are that bearing sizes have been increased from the original 180 to 200 mm, the mounting of grid bars in the washboard has been simplified (although the grid profile remains unchanged), and pneumatic or hydraulic grid loading devices are offered as optional alternatives to the original spring loaded toggle arrangement.

On presentation of the 1973 paper, a design feature widely discussed was the absence of replaceable bushings from both rotor discs and hammers, since bushes were being incorporated into other shredders at that time. The designers believed that bushes should not be necessary in the Tongaat shredder because of the low stress levels (less than 70 MPa – see above), minimised hammer oscillation, and locking plates which prevent the hammer bars from rotating in the rotor plates. This opinion has been vindicated by the long life achieved on hammers of up to two years and on rotor plates of 10 to 13 years without bushing.

An aspect of operations not covered in the initial reports was windage. When changes were made to cane knife configurations or to the spray hood on the discharge, it was found that the shredder windage patterns changed. This sometimes resulted in messy juice and pith-rich sprays. On other occasions it led more seriously to chokes, as the normal free flow of cane into or out of the shredder was disturbed. Once it was realised that the shredder rotor, with its hammers turning at 1 200 rpm in the casing, effectively formed a powerful radial-bladed fan, the solution was simple.

Two adjustable plates were fitted at the 'cut-water' and expansion points (A and B in Figure 1) and, by small adjustments to the clearance between either or both of these and the hammer tips, the shredder windage could be changed from sucking at the discharge to blowing strongly. The ideal setting was found to be neutral or slightly blowing, as this ensured free cane flow without discharge of a messy spray. The shredder is a success in all respects.

Sieve-plate scrubbers (1974)

As Maidstone was the first factory to install a new boiler following the introduction of air pollution legislation in 1970, it was forced to install the first high efficiency scrubber. The unit chosen was a Peabody (Moor, 1972). This was a sieve-plate scrubber incorporating target plates above the perforations in the main tray (which occasionally led to blockages) and cleaning sprays below the main tray which suffered from severe erosion.

Maidstone thereafter tried Brandt-Ducon scrubbers, with disastrous results from corrosion/erosion, before adapting work done by Ravnö and Judd (1973) to design their own simple sieve-plate scrubbers (Moor, 1977). Design parameters developed for these have been used successfully on five scrubbers at Maidstone Mill, two of which have been measured, both providing scrubbing efficiencies in excess of 98,5% with exit particulate emission levels of less than 150 mg/normal m^3.

There was initially considerable debate on whether to use hot fans which would be subject to erosion, or cold fans downstream of the scrubbers, which would be smaller and require less power but would be subject to corrosive conditions. The broad consensus was eventually reached that wet fans were preferable provided they were downstream of a reasonably efficient droplet eliminator.

Having suffered considerable wear on the hot induced draught (ID) fans of Maidstone's No. 7 boiler, a neat arrangement of wet ID fans located on top of a concrete scrubber was decided upon for Maidstone's most recent No. 8 boiler (Moor, 1985). This minimises the length of ducting and stack subjected to corrosive flue gases.

All Maidstone's sieve-plate scrubbers and associated fans operated satisfactorily until 1989 when an effluent management programme began and various streams providing make-up water to the scrubber circuit were cut back or eliminated. This reduced the surplus inflow which had previously provided a continuous partial flushing of the scrubber circuit. As the circuit was closed, pH control became more important because of the mill's large coal-burning requirement. This was effected by dosing with milk of lime, attempting to keep the circuit pH between approximately 5,5 and 7,0. A build-up of suspended solids in the scrubber water circuit was noted. Fans and sieve plates required more frequent cleaning.

By the 1990/91 season, the scrubber circuit was almost completely closed and Maidstone for the first time experienced a phenomenon previously reported at Felixton, namely an extremely hard calcium-based build up. At Felixton, this had blocked off sieve plate holes completely. At Maidstone, the main effects were a build-up on the droplet eliminator vanes and choked drains from the droplet eliminators, which reduced their efficiency. The build-up then extended to the wet ID fans, resulting in severe imbalance and on one occasion shattering a fan bearing. Unlike previous deposits, these were so hard that protracted and costly hydroblasting was required to remove them and serious production losses were incurred.

After discussions with Felixton and Tongaat-Hulett's Technical Management Department, it was concluded that the cause of the problem lay mainly in poor pH control from the crude milk of lime dosing arrangements into the scrubber circuit. A more sophisticated control system has now been installed and it is hoped that this will permit a return to trouble-free operation.

Despite these problems, it is considered that sieve-plate scrubbers remain the simplest, most practical and cost effective means of flue gas cleaning from bagasse/coal boilers, but good pH control and effective solids removal from circulating water is essential.

Of concern for the future is that type 430 stainless steel has proved most satisfactory for the sieve plates, but suppliers of this material appear to be attempting to phase it out in favour of either 3CR12 or the austenitic stainless steels (types 304 or 316). Type 3CR12 is insufficiently resistant to corrosion for this application and the austenitic stainless steels are more costly than 430 and are also less resistant to chloride attack so that they may well be inferior for scrubber fabrication.

Louvre-type entrainment separator (1974)

Maidstone has a Fletcher evaporator tail originally designed for external entrainment arrestors and therefore with low disengagement heights above the calandria. To reduce carry-over, these vessels were adapted in 1971 to accept wire mesh demister entrainment arrestors. Because of the low disengagement height, these demister screens fouled up rapidly and needed to be cleaned on a monthly cycle (second, third and fourth effects) and a two-monthly cycle (first effect). Cleaning involved removing the screen sections from the vessels, boiling them in a caustic soda solution, sometimes augmented by pounding with wooden poles to dislodge hard particles, and re-installation within the vessel. This procedure was costly not only in labour but also in replacement screens, since the life of a screen is directly related to the number of times it is subjected to cleaning.

Demister screens in vessels with higher disengagement spaces required cleaning far less frequently and, from visual observation through the vessels' sight glasses, it was concluded that the main cause of rapid fouling was the effect of gross splashing impinging on the screens, as opposed to the fine entrained droplets which the demisters are designed to remove. It was therefore decided during 1974 to protect the demister screens of the final vessel from this gross entrainment by installing an experimental double bank of 110 x 110 mm, 90° angle louvres in the final vessel (see Figure 2). The angles were pressed from 3 mm type 430 stainless steel and suspended on stainless steel hanger bolts.

This installation was not directly reported in a SASTA paper but was referenced by Archibald and Mack (1978) as a source of design information for their Darnall multi-layer louvre entrainment separator. Whereas the Darnall separator was designed as a 'stand-alone' unit and effectively removed 90% of the previous entrainment loading, the original Maidstone unit was designed only to protect the subsequent demisters and enable them to perform their function efficiently.

The two-layer Maidstone unit effectively achieved this objective and, during the 1975 off-crop, similar louvres were installed in the remaining three vessels. The demisters in all four vessels now require cleaning only once a season. The louvres have required minimal maintenance during their 16 years in service.

Two-layer louvres were also installed below the demisters in Maidstone's kestner separators in 1977 and reduced the demister cleaning cycles on these vessels from twice to once a year.

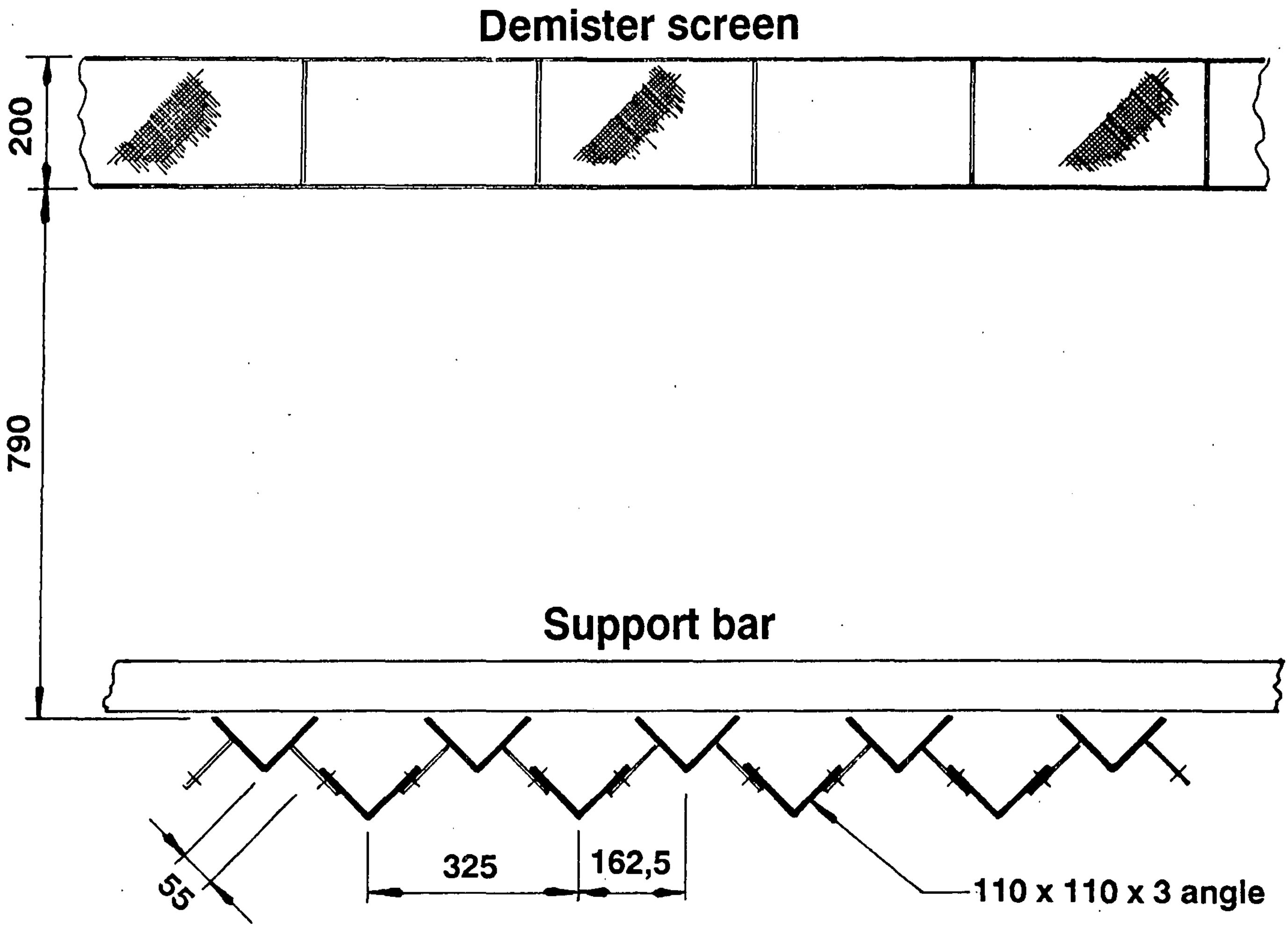

FIGURE 2 Double louvre gross entrainment arrestor.

Technologically the best protection for demister screens is undoubtedly an adequate disengagement height of not less than about 5 m above the liquid level, together with steady boiling conditions (with no 'spouting'). However, where old equipment precludes this option, a double-layer angle louvre gross entrainment protector provides an effective alternative solution. Cleaning cycles for demisters can be further extended by a water washing spray installation such as that at Illovo, described by Taylor (1987).

Oilpower crystalliser drives (1984)

Greenfield (1984) reported on the design and installation of a novel multi-cylinder continuous action hydraulic motor, selected to drive the rotors of two new 130 m3 vertical crystallisers at the Maidstone factory. Attractive features of these drives were their simplicity, using standard hydraulic cylinders with no reduction gearing, their suitability for high torque/low speed drives, the constant torque/variable speed characteristics obtainable with hydraulic drives and their reasonable cost.

The first two drives were installed on vertical B crystallisers which were planned in future to be converted to C-massecuite duty. The drives were therefore designed to deliver an ultimate torque of 275 kN.m although on their B duty the loading would be well below this figure. This is the origin of the motor designation 'Oilpower HM 275'.

The design allows transmitted torque to be measured very easily by measuring with transducers the tension in the two torque-arm linkages through which the torque reaction is conveyed from the drive back to the crystalliser shell (see Figure 3).

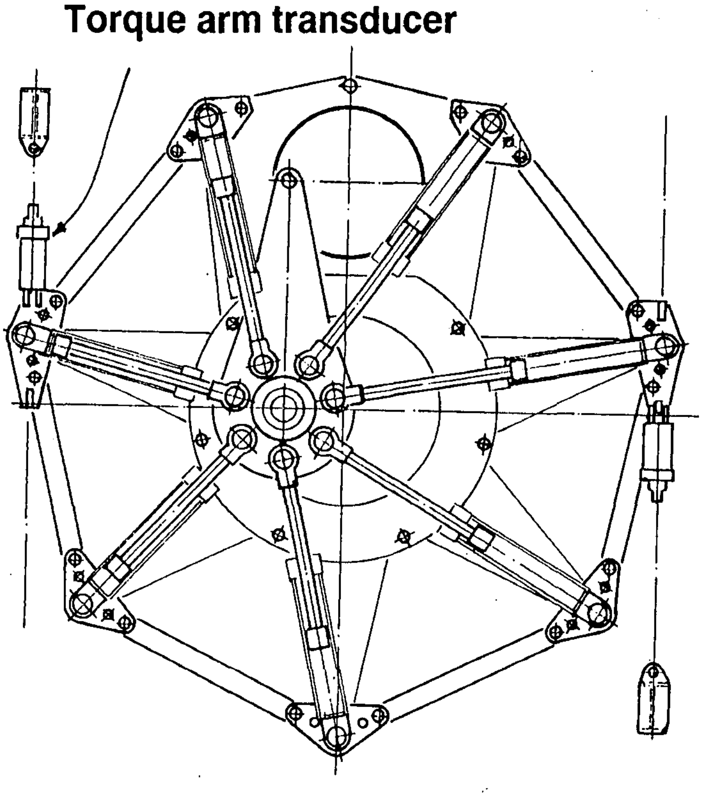

FIGURE 3 Multi-cylinder hydraulic drive.

In his 1984 paper, Greenfield reported on the trouble-free commissioning of the drives although no testing had yet been done. Operating torque was subsequently measured by the transducers at only 60-80 kN.m. On these light loadings, the drives proved extremely satisfactory. Apart from twice replacing worn pins and bushes of DX bearing material and once renewing seals in the hydraulic cylinders, minimal maintenance was required during five years' service on B-massecuite.

For the 1989/90 season, the entire crystalliser station was modified to provide additional A-massecuite retention time. This modification involved, *inter alia*, converting the two vertical crystallisers from B to C-massecuite and installing two new, even larger (158 m^3) 4,38 m diameter C crystallisers. On the strength of the history of trouble-free service from the multi-cylinder drives and their competitive price, it was decided to select the same drives for the two new crystallisers. Consideration was given to larger units able to provide a higher torque but, as the torque required for the new crystallisers could not be accurately estimated, it was decided to replicate the existing 275 kN.m drives and, if necessary, allow the new crystallisers to rotate more slowly to match the available torque.

From April 1989, all four drives were therefore subjected to the much more arduous C-massecuite duty. Apart from two weld failures, no abnormal maintenance was required during the first year of operation.

During the 1990 off-crop, modifications were made to the two 158 m^3 crystallisers to improve their heat transfer. These involved additional cooling water paths on some of the cooling fins, and extended scrapers attached to the rotor elements to improve the rate of shear of the massecuite immediately adjacent to the stationary cooling elements.

These modifications had a two-fold effect on the torque required to turn the rotors: the increased shear gradient needed additional mechanical effort and the improved cooling efficiency resulted in lower temperature massecuites which also increased viscosity and shearing force requirements. These resulted in the torque on the drives during the 1990/91 season increasing to measured figures of up to 228 kN.m. The increased torques and power requirements precipitated a series of drive failures to the extent that there were few periods during the season when all four drives were operational.

It is a common characteristic with hydraulic drives that their mean time between failures (MTBF) drops rapidly once the maximum design powers and hydraulic pressures are approached. However, this was not considered an acceptable explanation for the rash of failures and more thorough investigations were undertaken to determine underlying causes for the failures. It was concluded that the failures were all attributable to one or more of three causes:

(a) Mechanical under-design of some structural plates and welds. This was remedied by using heavier plates, adding supporting brackets to reduce flexing and increasing all welds from 3 to 8 mm

(b) Excessive wear of the main (large bore) journal and bearing, possibly due to inadequate lubrication of the DX bearing material. These journals have been re-machined and new bearings were made from Vesconite Hilube. These appear promising but were only installed towards the end of the 1990/91 season

(c) Wear in service resulting in cylinders coming onto load at or on the wrong side of top dead centre, leading to attempted 'self destruction'. This resulted in damaged rams and pivot pins. It is hoped to overcome this problem by widening the neutral band where the cylinders are inactive on either side of top and bottom dead centre.

A great deal of engineering effort was put into these drives during the 1990/91 season and ensuing off-crop, unfortunately with little expert assistance available from the agents.

The concept of the drive remains attractive. Efficiencies (hydraulic to output power) varied between 79 and 85%, even at speeds of rotation as low as 0,083 rpm at an output torque of 196 kN.m. However, acceptable reliability has yet to be achieved when operating at or close to rated maximum duty. Perhaps this will be attained in 1991 and warrant a third report to SASTA.

Gapped boiler main tube bank (1984)

The design philosophy of Maidstone's 150 t steam/h John Thompson boiler, which incorporated a number of innovations to provide high reliability and exceptional thermal efficiency, was described by Moor (1985). Unique features of this boiler included a 2 m diameter top drum, a wide gap through the main bank of generating tubes, a heat recovery station comprising air heater/economiser/air heater, an unusual scrubber configuration and twin DC-drive ID fans.

A full review of the operating and maintenance performance of this boiler would require a paper on its own. However, brief comment is included here on two of its features, the gapped main bank and the twin ID fans (see following section).

Forming of the main bank tubes to allow a 400 mm wide transverse space between the tubes in the area where the upper baffle ends (see Figure 4) was first introduced on this boiler and has subsequently been applied in other boilers in Mauritius (Magasiner, 1987) and Australia (Munro, 1990 personal communication). The gap was designed to completely avoid tubes in this high-turbulence erosion zone and to provide easy access for inspection and maintenance.

The boiler has had to operate at or above its 150 t/h maximum continuous rating (MCR) for considerable periods during the past few seasons. Inspection of tubes from the gap is very easy (once a suitable scaffold has been erected) and has shown that erosion is not completely eliminated by the gap. A small amount of polishing (rather than erosion) was found in the area marked 'A' in Figure 5 after three seasons' operation. Protective shrouds were made by longitudinally halving 300 mm lengths of 2,11 mm wall type 316 stainless steel tube and fastening these with jubilee clamps over the affected areas. After a further four seasons, the shrouds were inspected during the 1991 off-crop and found to be in good condition with maximum erosion of 0,3 mm and not needing replacement.

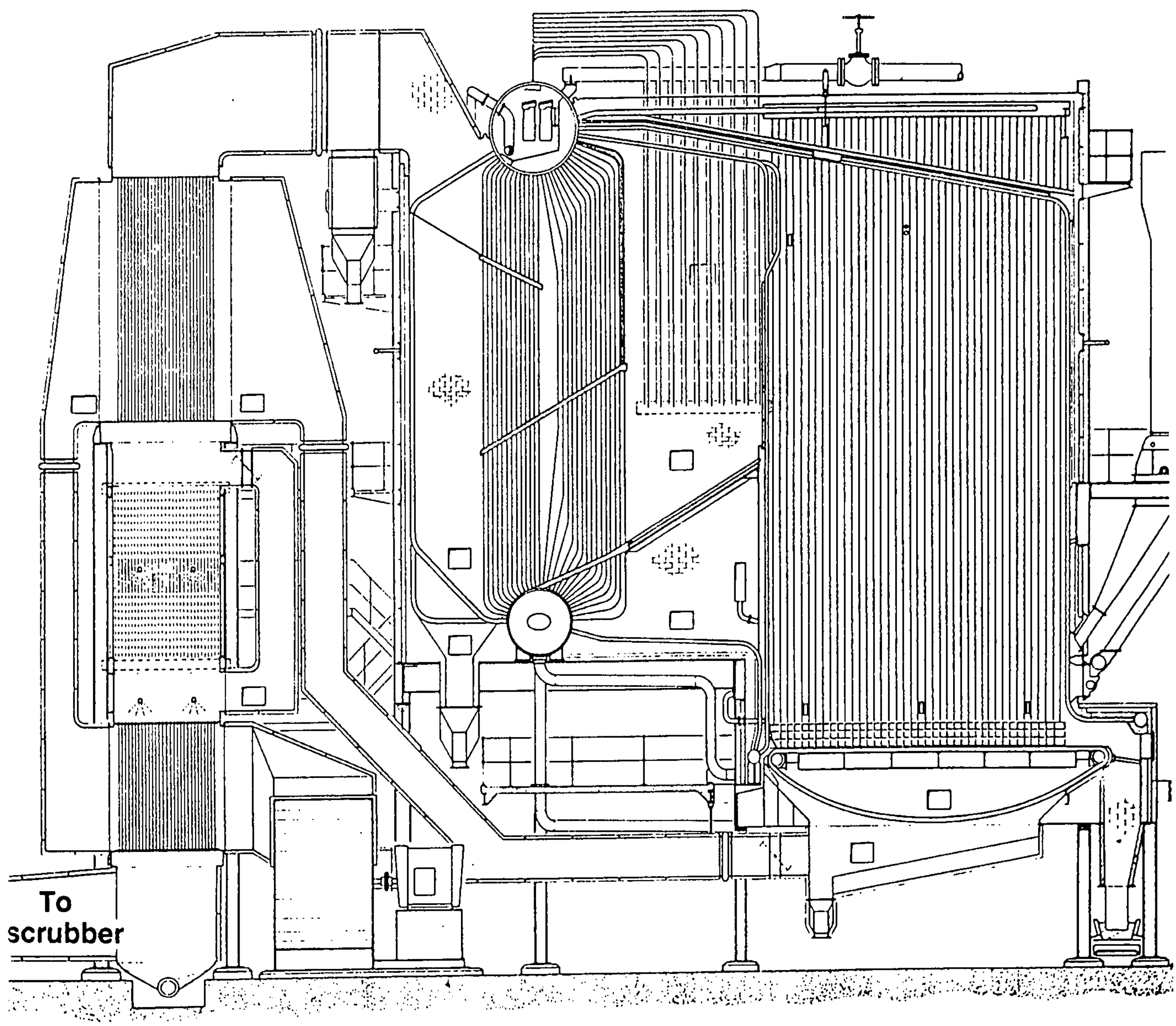

FIGURE 4 Boiler with gap in main generating bank.

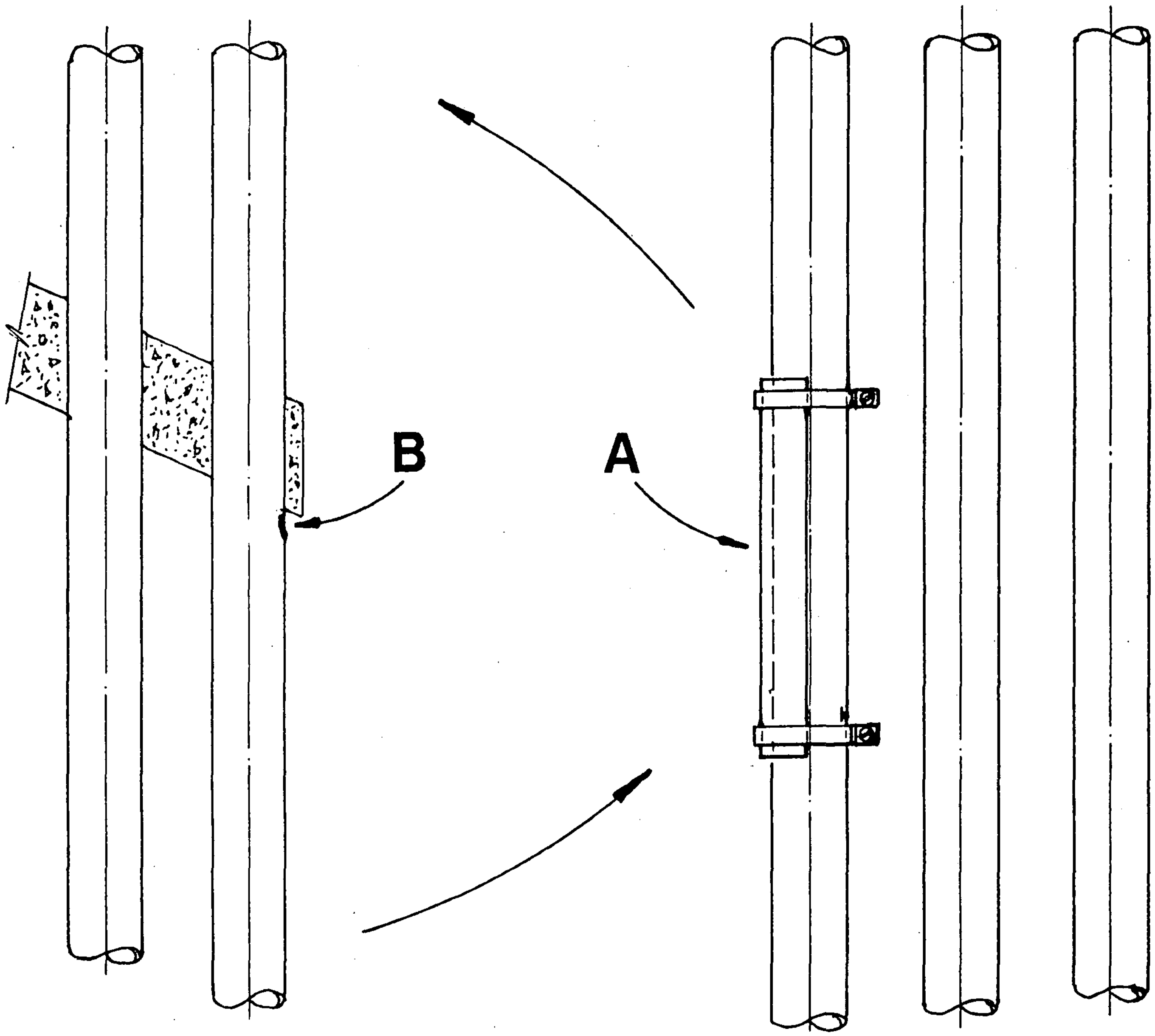

FIGURE 5 Main bank detail in erosion zone.

However, during the 1991 inspection a small area of localised genuine erosion extending over 30 mm was found on the row of tubes immediately below the end of the upper baffle, at 'B' in Figure 5. A maximum of 1,26 mm tube thickness had been washed away in this area. This is somewhat less than half the loss of thickness that could be tolerated before risk of failure, but is still of concern.

It is believed that the erosion in this area was aggravated by the baffle construction, which extended only 2-3 mm beyond the tubes into the 400 mm gap and caused a high turbulence zone at the tube surface. Short shrouds cast into the baffle have now been fitted over the eroded portion of these tubes and the baffle extended approximately 80 mm into the gap to move its end effect away from the tubes.

Erosion with the gapped tube bank is clearly far less than in conventional multi-pass boilers (Magasiner *et al.* (1984), and Johnson (1990)) and is confined to small areas which are easily accessible for maintenance or protection. All other tubing had a light exterior film of dust when inspected during the 1991 off-crop, but no signs of erosion.

The main bank gap principle is therefore assessed as a satisfactory solution to the serious erosion problems previously experienced in this area in multi-pass boilers.

Dual induced draught fans (1977, 1984)

On both the above 150 t/h boiler and on a 120 t/h boiler commissioned in 1977, two ID fans operating in parallel were installed to enable 60-70% MCR to be generated even if one ID fan or its drive were to fail. DC drives were chosen for these fans to provide low-powered soft starts, ease of control and minimised fan wear (compared to damper control).

However, this facility has been used all too often - the DC drives are not as reliable as hoped in the hostile boiler environment, and seven major DC motor outages have been experienced over the past six seasons. These are both disruptive and costly. Were a boiler to be specified now, the dual fan concept would still be followed but with variable speed AC motor drives instead of the more 'fussy' DC motors.

In order to limit loss of production when a DC drive fails, a smaller fixed speed AC motor drive with soft start has been ordered. This standby drive has been designed for a speed which, together with the full power of the remaining DC drive, will enable the boiler to achieve maximum continuous rating.

Direct delivery of cane (1988)

Statham (1990) reported on a new mode of cane delivery direct from harvesting in the field to the mill, using mini-spiller trailers. Presented in the Agricultural Session, the primary motivation had been to reduce cane transport costs, with higher revenue from increased sucrose (fresher cane), a further important consideration. Full co-operation was offered on this project by the mill which also saw considerable potential benefits.

Maidstone mill has limited crane capacity for unloading bundled cane and little storage for bundles. Allowing the miller-cum-planter (MCP) to deliver bundles direct to the mill was not feasible as this would set a precedent for other growers close to the mill. The MCP was therefore required to deliver cane in spiller trailers with a capacity of not less than 12 tons per tip and which would fit existing millyard cane unloaders. Twelve-ton trailers were considered too heavy for infield use by the MCP as these would cause compaction and field damage in wet conditions.

A decision was made to use two six-ton trailers in tandem, arranged so that the hilo unloader spiller bar would pick up the flaps of both trailers simultaneously. These trailers would be loaded directly infield by a Bell grab loader. As reported by Statham, the system immediately worked well. Average payloads of 14 tons per rig were 15-20% above design. The trailers proved exceptionally clean with the least road spillage of all cane vehicles in the Maidstone area, and the tipping worked smoothly.

From the mill's point of view, pleasing features of the spilling action were that negligible cane remained in the trailer and lifting was apparently effortless. This latter unexpected feature was attributed to a slight upward widening taper in the cross-section and a shallower overall depth than hilo trailers. This, together with true lateral positioning of cane stalks from the grab loader, resulted in such a low 'break-out' force that, in the second batch of trailers manufactured, the normal hold-down bar was completely eliminated.

However, of greatest benefit to the mill was fresher cane. By eliminating transhipment sidings, cane on the direct delivery system arrived at the mill on average at least 24 hours fresher. This and other measures adopted by the MCP have improved the average quality of their cane dramatically over the past two seasons. Enthusiasm generated by this success has led to a joint MCP/mill initiative for the 1991/92 season, designed to bring in some cane 36 hours fresher.

Cane from steep land cannot be loaded by grab onto the existing spiller trailers. The MCP therefore wished to direct-deliver this cane in bundles on new self-loading spiller trailers. However, the mill could not accommodate more daytime direct- delivery cane from the MCP without upsetting the day/night balance. Loading bundles from steep land clearly has to be a daytime operation. The MCP has therefore made arrangements to change the grab loading on two estates to a night operation. As far as can be established, this will be the first instance of 24 hour field operations in the South African sugar industry.

At the time of writing, the required triple bundle side-loading trailers have been tested on a pilot scale but have not yet been unloaded at the mill, and the night operation of Bell loaders has not yet been tested. However, both mill and agricultural management are confident that the new systems will work.

For the mill, the principal benefit of these direct delivery initiatives will be cane on average between 24 to 36 hours fresher. From the work of Wood *et al.* (1972), Lionnet, (1986) and Wang *et al.* (1986), it is estimated that this will improve sucrose by some 0,2 percentage points and purity by at least 0,6%. From the 190 000 tons cane per annum being direct-delivered, these improvements yield an extra 380 tons of sucrose and, from the SJM recovery formula, an extra 470 tons of sugar production. (Sugar production increases both because of additional sucrose and the smaller proportion of total sucrose lost in molasses.)

At 1990/91 sucrose and sugar prices, additional pre-tax revenue to the MCP is R135 000 (B-pool) and additional net pre-tax revenue to the mill is R218 000 (mainly B-pool). These benefits will be less with the lower export prices in 1991/92, but are nevertheless substantial.

Acknowledgements

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