IMPROVING OLDER SUGAR MILL BOILERS

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Abstract

Improvements which can be made to sugar mill boilers when they are being moved or *in situ*, are listed. Examples of such improvements are given.

Introduction

Sugar mill boilers are specialised in that they are designed to burn bagasse fuel, and in the case of the South African sugar industry some are also capable of burning supplementary coal fuel.

Design and construction norms are continually changing, and older boilers can be improved in detail or can undergo major redesign to reduce maintenance costs, improve thermal efficiency or increase output. Where bagasse is used to produce by-products, including power for export, improved boiler thermal efficiency is especially desirable.

Boilers can be uprated or improved under two conditions:

- With the boiler in place;
- When the boiler is being moved.

When a boiler is not being moved, the options for improvements are limited because the costs of major modifications are difficult to justify. When the boiler is being moved, the cost of modifications will be a marginal cost because the cost of dismantling and re-erecting will already have been taken into account in the cost of moving the boiler. Major modifications can take place at little or no extra cost.

Areas where uprating or improvements can take place

It is important that improvements are not carried out in isolation, but that the effect of a change on the entire boiler thermal design is checked. For instance changing the furnace to membrane-wall construction may reduce the combustion temperature unacceptably, adversely affecting the entire boiler operation. It is recommended that the advice of a competent boiler designer be sought before making any major change or improvement.

The following are areas where improvements or uprating can be considered.

Fuel and combustion systems

Feeders: Some older bagasse feeders are maintenance intensive and give an erratic fuel feed to the furnace, adversely affecting thermal efficiency. Modernising and simplifying these feeders is an easy and relatively low cost improvement.

Spreaders: Modern pneumatic spreaders give better fuel distribution over the grate, and require less maintenance than older mechanical spreaders. Some old style dual purpose spreaders (bagasse and coal) failed to distribute either of the widely different fuels optimally.

Grates: If coal is to be burnt in significant quantities, changing from a dump grate to a continuous ash discharge (CAD) grate will improve thermal efficiency. A pin-hole grate will require less maintenance than either a dump grate or a CAD grate, and it may be economical to change to this type of grate, depending on the nature of the fuel(s) to be burnt.

It must be born in mind that the nature of coal fuel varies considerably from one country to another. A grate which works well with coal from one country might not perform as well with different coal. The grading of the coal (*e.g.* peas, mixed smalls, duff or pulverised fuel) can also impact on grate requirements.

Furnace: If the boiler has previously been conservatively rated as regards furnace and grate heat release rates, it may be possible to uprate the furnace to burn more fuel.

The design of an old furnace may be improved, *e.g.* by increasing the height to permit better combustion of bagasse fuel. Membrane walls can be installed. This will also reduce air leakage into the furnace. In any case the amount of refractory should be reduced if possible in order to minimise maintenance costs. However, some refractory may be necessary to maintain stable combustion, particularly with high moisture bagasse.

Secondary air (SA): Modern secondary air systems differ considerably from older designs. The volume of secondary air is now a greater percentage of the total combustion air and the pressure is higher to ensure good turbulence and mixing in the furnace. Secondary air nozzles are also provided at different levels to enable the combustion conditions to be adjusted.

Gas circuit

Generating bank layout and gas velocities: Because of the abrasive nature of bagasse ash, especially in the South African industry where relatively large percentages of sand in bagasse are the norm and have increased with the introduction of diffusers, acceptable gas velocities across the generating tubes are now lower than previously.

The number of gas passes in the generating bank (also known as the main bank) are now often lower. For example, single pass generating banks are now the norm for new boilers in the South African sugar industry, whereas three pass boilers were previously the standard, with a few two pass installations.

Reducing the number of gas baffles has also helped to reduce the number of changes of direction of the gas and hence the areas where turbulence and entrained grit erode the outside of the tubes. Moving tubes away from these areas of turbulence, and protecting tubes with erosion shields is now common practice (Moor, 1985).

Generating bank exit gas temperature: Some older boilers have excessive gas temperatures at the exit from the generating bank (boiler outlet). These temperatures can be reduced by redesigning the generating bank and furnace configuration.

Airheater improvements: Bagasse-fired boilers normally have air heaters, but enlarging and/or improving an airheater may be feasible. The gas path can often be improved to eliminate dead spots and reduce tube erosion. High undergrate air temperatures when burning coal are sometimes the cause of excessive grate maintenance. Modifications to ensure adequate bypass dampers and ducts may be necessary.

Economiser improvements: Where a boiler does not have an economiser, it is likely to be cost effective to install one, especially if considerable quantities of coal are burnt. Precautions must be taken to prevent acid dew point corrosion in economisers when coal is burnt.

Draught plant: Where modifications to the gas path are being considered, flue gas scrubbing is being introduced, and/or the boiler output is being uprated, the capacity of the fans must be checked. Fans must have ample reserve capacity to ensure rapid response to changing firing conditions and load swings. If the mechanical design of a fan permits, it may be possible to uprate it by speeding it up slightly. If the fan drive incorporates a gearbox or belt drive this can be accommodated relatively easily, but if the fan is driven directly by an electric motor, the options are more limited.

In the case of an induced draught (ID) fan it may be worthwhile to install a variable speed electric motor. This will permit a moderate speed increase and will also consume less power than a damper controlled system. It will also reduce wear on the fan at part loads. The motor's variable speed controls will have built-in "soft-start" characteristics. This will eliminate the need for special switchgear needed to start these high inertia loads. Variable speed can also be achieved by a variable speed coupling, but this will not have the speed increasing facility, will require more maintenance, and is less energy efficient.

Steam circuit

Steam drum scrubbers: If the boiler does not have steam scrubbers, installation of these should be considered to eliminate carry over of chemicals into the superheater. This is especially important if the steam passes to turbines.

Safety valves: If the boiler output is being increased, the capacity of the safety valves for the new duty must be checked.

Superheater: If the capacity of the boiler is being increased, the steam pressure drop across the superheater must be checked in relation to the allowable working pressure in the drum.

It may be necessary to carry out extensive modifications to the superheater to ensure the correct final steam temperatures at higher outputs and/or after modifications to the combustion chamber.

If a non-self draining superheater is being modified, the possibility of changing it to a self-draining design should be considered. This type is less prone to tube distortion and requires less supervision during start-up.

Pressure part support: Some boilers have pressure part support systems which permit differential expansion between the furnace and generating bank sections, or between the furnace and grate. These expansion areas can be the cause of excessive air leakage and maintenance problems. During a boiler rebuild, consideration can be given to modifying the support system.

Instrumentation

Good instrumentation is necessary if good boiler performance is to be achieved. Operator workload can also be reduced. Older boilers seldom have good combustion and drum water level controls. These can readily be improved (Magasiner et al; 1984). O_2 and/or CO_2 meters are also necessary if optimum combustion conditions are to be achieved. Grate rail temperature thermocouples are valuable in ensuring that grates are not subject to excessive temperatures. Thermocouples may also be installed on pendant superheaters to monitor any possible overheating during boiler start-up.

Examples of boiler modifications

Darnall mill No. 1 boiler

B & W boiler. 85 t/h maximum continuous rating (MCR); 3,2 MPa (abs); 380°C. Bagasse and coal fired. This boiler did not have an economiser, so one was fitted.

Gas temperature leaving air heater before fitting economiser:	284°C
Gas temperature leaving new economiser:	170°C
Improvement in thermal efficiency:	7%

Felixton II mill Nos. 1,2 and 3 boilers

B & W boilers. 150 t/h; 3,2 MPa (abs); 390°C. Bagasse and coal fired.

These boilers had economisers, but space had been left for more tubes to be added. Nineteen extra vertical rows were added, bringing the total number of rows to 47 in each economiser.

	Water out C	Gas out C
Before adding extra tubes	173	186
After adding extra tubes	180	161
Improvement in thermal efficiency:	1.5%	

Darnall mill No. 3 boiler (ex Empangeni mill No. 1 boiler)

B & W boiler. Originally 45 t/h; 3,2 MPa (abs); 380°C. Bagasse and coal fuel.

During the move the following changes were made:

- MCR: Facilities built-in for later uprating to 60 t/h.
- Efficiency: Estimated 3% increase.
- Feeders and spreaders: Replaced with modern types.
- Furnace: Membrane walls installed, most of the refractory eliminated. Furnace internal shape altered to improve combustion and superheat temperature characteristics.
- Generating bank: Changed from two- to one pass.
- Drum support system: Modified to eliminate differential expansion.
- Drum internals: Replaced with new type.
- Secondary air: Redesigned.
- Superheater: Redesigned and changed to self draining.
- Air heater and economiser: Improved.
- ID fan: Changed to variable speed AC drive.
- Instruments: Modernised.

Maidstone mill No. 2 boiler (ex Mount Edgecombe Mill No 1 Boiler)

B & W boiler. Originally 91 t/h; 1,4 MPa (abs); 270°C, but pressure parts designed to accommodate 3,2 MPa (abs); 380°C. Bagasse fuel.

During the move the following changes were made:

- Steam conditions: Uprated to 3,2 MPa (abs); 380°C
- MCR: Uprated from 91 to 100 t/h.
- Feeders and spreaders: Replaced with modern types.
- Generating bank: Changed from three- to two pass to reduce gas velocities.
- Superheater: Redesigned for new steam conditions and changed to self draining.
- Air heater and economiser: Redesigned and replaced, improving thermal efficiency by 2%.

- Draught plant and ducting: Redesigned, to provide balanced flows across boiler and eliminate "standing wave" in top drum.

Secondary air fans changed from "hot" to "cold" and speed reduced.

- Instruments: Modernised.
- ID Fan drive changed to variable-speed.

Eston boiler uprating

With the move of the mill from Illovo to Eston the crushing rate increased from 200 to 230 TCH. The combined boiler MCR rating was required to be 160 ton steam per hour at 3100 kPa and 400°C. Eston is 750 meters above sea level which necessitated some design changes. Tables 1 and 2 give statistics of the old and updated boilers (where FW = Foster Wheeler boiler and ICAL = ICAL boiler). Note that the information on the ICAL boiler is limited.

Foster Wheeler: The Foster Wheeler boiler has a completely new draft system, i.e. new ID, FD, SA fans and ducting. The old SA system was too large and large quantities of bagasse were always on the grate. There is provision for an economiser. A new undergrate redesigned sluice will be installed. The superheater tube diameter has been increased and redesigned and a new header will be fitted. The mud hoppers have been redesigned at the front and rear of the mud drum. New boiler outlet gas ducting will be installed. The SA nozzles at the rear of the boiler will be moved. All the gas ducting has been replaced. Both boilers are being raised 3700 mm above ground floor and ash will be sluiced to the smuts dam. A common stack for both boilers will be installed.

ICAL boiler: The ICAL boiler SA and FD fans are reused but the ducting has been redesigned with special attention to the SA air distribution. The FW scrubber is used on this boiler and the existing ID fan is moved from being a dry fan to a wet fan after the scrubber. The boiler outlet gas ducting from the boiler to the stack has been replaced. An economiser has been fitted after a new air heater. A new main bank will be fitted. The bagasse feeders will be modified. A submerged ash conveyor and crusher will be fitted. The ICAL boiler can be fired on bagasse and coal.

Table 1

Major changes to Eston boilers

Boiler	FW	Ical
Eston mill (MCR (t/h)	105	55
New main bank	New	Yes
New air heater	New	Yes
Economiser - was not fitted before	No	Yes
SA fan	New	Old
ID fan	New	New
Forced Draught (FD) fan	New	Old
Scrubber	New	Ex-Fw

Conclusions

Sugar mill boilers are expensive and important items of plant. Improving and modernising older and less efficient boilers is technically feasible, and is generally economically viable and should be given serious consideration.

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REFERENCES

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

Table 2

Detailed description of changes to Eston boilers

		Illovo FW	Eston FW	ICAL Illovo bagasse	ICAL Eston bagasse	ICAL Illovo coal	ICAL Eston coal
MCR	(t/h)	95	105	49,9	55	38,4	41,6
Fuel burned	(t/h)	45,8	54,14		27,68		5,04
Gas temperature ex air heater	°C		260		331		278
Gas temperature ex economiser	°C	24,3			231		176
Gas temperature ex scrubber	°C		69		69		40
FD air ex heater	°C	227	231		216		177
Efficiency on GCV	%		61,95		63,47		83,24
Efficiency on NCV	%	80,7	81,26		81,26		85,99
Date of installation		1980	1995	1975	1995		1995
Feed water temperature	°C	107		104	104	104	

Fan drive changed to variable-speed.