OPERATING EXPERIENCE WITH HIGH COMBUSTION EFFICIENCY CONTINUOUS ASH DISCHARGE ZONED STOKERS

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Abstract

The paper describes the design concept, construction and operating experience of a number of recently installed John Thompson Africa (JTA) zoned continuous ash discharge (CAD) stokers.

Key operating parameters are discussed. Performance details of a boiler prior to and after retrofitting a zoned stoker are reviewed, confirming a considerable improvement in thermal efficiency when burning coal. The importance of availability, especially for co-generation plants, is also covered in the paper.

Keywords: Stokers, CAD stokers, combustion efficiency, coal firing, retrofitting, boiler availability, optimising boiler performance, zoning.

Introduction

Continuous ash discharge (CAD) stokers are regularly installed in sugar boilers where there is a need to supplement the primary fuel, bagasse, with coal. This requirement may arise from an energy imbalance such as a factory with a refinery or a by-products plant. Alternatively, when there is a need to generate power for export in the off-crop when bagasse is not available, a CAD stoker provides the means to burn coal with high plant availability and efficiency.

Extensive tests were recently done on two JTA CAD stokers installed in the sugar industry.

The first is a 52 m² unit retrofitted into a coal and bagasse fired Yarrow boiler, which has been operating primarily on coal. The second is a 67.2 m² unit supplied as part of a new 150 t/h bagasse/120 t/h coal fired boiler project.

Both boilers are located at the same sugar factory site and are extensively instrumented. As the units had to undergo formal acceptance testing as part of the contract conditions, accurate performance data was obtained.

The arduous conditions under which both stokers were operated confirmed that the design of this new generation of stokers improved the robustness of the unit and made maintenance even more "user friendly".

Selection of stoker

When only bagasse has to be burnt, this is economically achieved by using a steam cleaned stationary grate.

However, where there is a requirement to burn both bagasse and coal (or a combination of the two) in the same unit, boilers for the sugar industry are usually fitted with a continuous ash discharge (CAD) stoker. Figure 1 shows a typical cross-section of a bagasse/coal fired boiler fitted with a CAD stoker, coal and bagasse feeders, fuel distributors and secondary air system.

A CAD stoker is ideally suited to the requirements of spreader firing of coal in watertube boilers.

Stoker construction

The JTA CAD stoker is manufactured in single and double mat versions depending on the physical grate area required.

Each mat is driven by a variable speed drive through a reduction gearbox. A high torque universal coupling device connecting the gearbox to the stoker allows free expansion of the stoker despite the gearbox being rigidly attached to the boiler steelwork. The stoker is catenary tensioned to achieve optimum loading and eliminating the need for separate tensioning devices.

Each mat is made up of a series of bands consisting of grate bars attached to a pair of chains. The grate bars are manufactured from high grade, heat resisting cast iron, substantially ribbed to provide rigidity as well as a large surface area to maximise the cooling effects from the undergrate air.

The grate bar width is kept short to minimise distortion and reduce the loading on each pair of chains. The chains are driven by toothed sprockets on the front shaft and pass over guide rollers at the rear. The sprockets and rollers are attached to 150mm diameter shafting carried in carbon bushed bearing housings. All these components are very conservatively rated to ensure extended service life and low maintenance.

The grate bars run on a series of cast iron skid rails bolted onto the stoker frame. Metal temperature thermocouples are embedded in the skid rails to provide monitoring and alarm functions. Twelve thermocouples were fitted to each of the stokers discussed in this paper.

Various features are incorporated to ensure that, as far as reasonably possible, foreign matter such as stones, tramp iron and the like will not result in damage to the grate. Spring loaded shoes at the front of the grate prevent the grate from opening prematurely which would allow the entrapment of such foreign materials. The grate bars are designed to hang open on the return chain strand allowing riddlings to fall freely into the undergrate hoppers.

Air sealing around the stoker is achieved using a combination of undergrate, deadplate and floating seals. Substantial development has gone in to the determination of the design and material of construction of these components.

To be able to control the distribution of primary air along the length of the stoker, undergrate "zoning" is incorporated. This consists of a series of small, self-cleaning hoppers each fitted with a damper capable of being adjusted whilst the boiler is on-line. Figure 2 shows a typical arrangement of the zoning hoppers.

The combustion process

Coal and bagasse require to be fired quite differently. Coal is distributed over the width of the stoker towards the rear wall of the furnace where it ignites and continues to burn as it travels

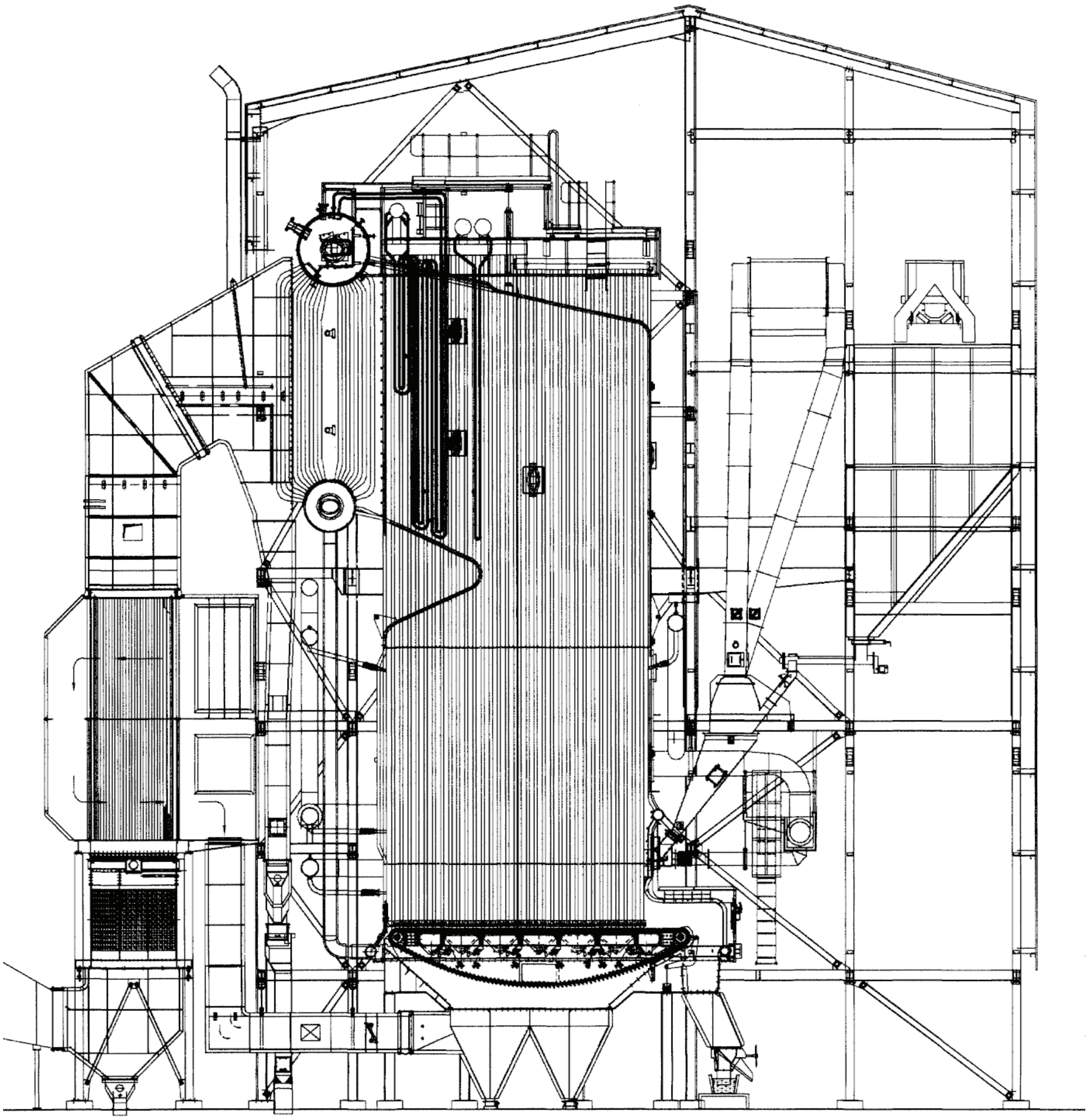

Figure 1. Typical cross-section of bagasse/coal fired boiler.

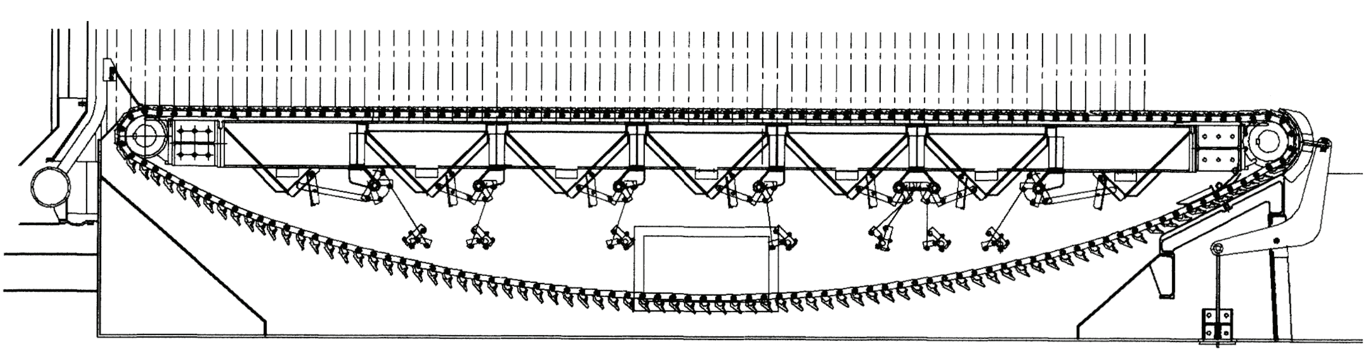

Figure 2. Typical arrangement of zoning hoppers.

to the front of the furnace where burn-out occurs and the ashes are discharged. The amount of air required to efficiently burn the coal and control the formation of various emissions varies along the length of the stoker.

Unlike coal, bagasse is burnt largely in suspension and requires a substantially different undergrate air distribution pattern.

The undergrate zoning provides the means to vary the air distribution to accommodate the specific requirements of each fuel. Zoning is also used to compensate for variations in the heating value of the coal, particle sizing, ash content and volatile matter, all of which can have a major effect on the propensity of coal to ignite and burn efficiently.

The complete combustion system

A stoker is only one part of a complex combustion system comprising fuel feeders, spreaders, and primary and secondary air systems. It is necessary to consider all of these components, and their interaction, when optimising the performance of a boiler.

Because of their substantially different physical characteristics, independent fuel metering devices are used for coal and bagasse. Coal is metered by means of variable speed screw conveyors whereas bagasse is metered via three-drum fibrous fuel feeders. A combined coal/bagasse pneumatic spreader ensures proper distribution of the fuels. Considerable development work was carried out to ensure that the spreader provides an ideal distribution pattern for both fuels, specifically being capable of spreading heavier coal particles to the rear of the stoker (Magasiner and Naude, 1988).

Combustion efficiency on coal

When bagasse is not available and significant quantities of coal have to be burnt to support the steam demand, combustion efficiency is an important factor. The following are some of the parameters that affect the combustion efficiency:

- The stoker rating
- Coal quality and grading
- The thickness and distribution of coal on the stoker
- Stoker speed
- Primary air quantity, distribution and temperature

Secondary air distribution, pressure and quantity

Some of these parameters are affected by the physical design of the stoker (e.g. the grate area and pressure drop across the grate), some by the source and handling methods of the coal, while others are dependent upon the skill of the operator.

Stoker rating

A combination of adequately sized stoker area and grate speed ensures full burn out of the coal by the time the front of the boiler is reached. A wide diversity of views exists amongst stoker manufacturers, boilermakers and boiler consultants on acceptable grate ratings. Traditionally grate ratings have been specified as a heat release rate per square metre . While this approach is acceptable for low ash fibrous fuels and good quality coals, a more practical approach, with poorer quality coals, is to specify the rating on a mass basis. Typical mass based ratings for South African coals range from 220kg/m^2 to 280kg/m^2.

Coal quality and grading

The coal quality and grading are important parameters that need to be carefully evaluated. The lowest cost coal does not necessary mean the most cost-effective operation. Often it doesn't pay to transport coal of reduced heating value over large distances, as the cost per kJ is invariably higher. Also a poorly graded coal can result in segregation, poor spreading and increased carbon losses.

Distribution of coal

Apart from the physical grading of the coal, the design of the feeding and distribution system needs to be carefully matched to the stoker by the boilermaker.

Primary and secondary air supplies

The optimal supply of combustion air is paramount to the combustion efficiency. The zoning facility described earlier allows this to be achieved but the skill of the commissioning engineer in identifying the initial settings and boiler operators who understand the combustion process and are able to make incremental adjustments to suit specific conditions, plays a large part.

As with the primary air distribution, the design and setting of the secondary air system is a combination of efficient design and operator skill.

Operating experience

From the operating experience gained on the stokers covered in this paper, it was clear that the incorrect setting of the major parameters not only directly affects the combustion efficiency, but also impacts on the availability of the stoker (boiler) and the degree of maintenance necessary.

One specific item that fell into this latter category is the design of the coal-handling plant, from receipt of the coal to its discharge into the bunkers. If the design of the coal-handling plant is such that coal becomes segregated when loaded into the bunkers, this invariably results in a segregated pattern existing across the width of the stoker. This results in poor combustion with the associated drop in efficiency, and in some cases physical damage to the stoker can result. The real cost of this to the operator is often underestimated.

Performance data

A very comprehensive set of modern instrumentation was fitted to each of the boilers incorporating the stokers under discussion. This allowed for extensive testing to be carried out.

The installation facilitates the monitoring and adjustment of combustion airflows, pressures and temperatures independently on the left-hand section (LHS) and right-hand section

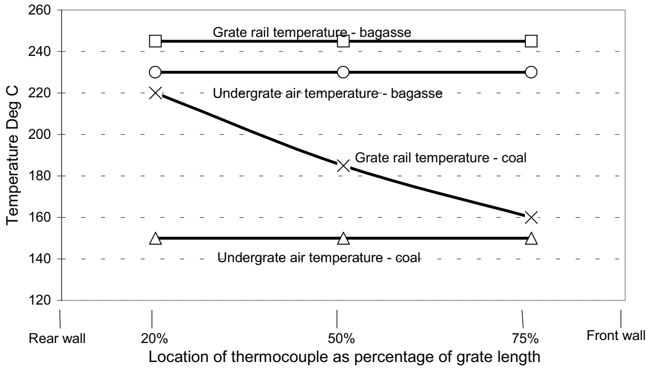

Figure 3. Grate rail temperature profiles.

(RHS) of the stoker. This makes optimisation of the balance between the LHS and RHS of the stoker much easier.

Twelve thermocouples were used to monitor grate rail temperatures (two rear, two centre and two front, on both the LH and RH stokers) yielding large amounts of useful information. For example, by monitoring the temperatures across the grate, it was possible to identify coal segregation, optimise the set up of spreaders etc. Being able to trend selected parameters made it easy to determine the effect of varying one or more parameters.

Figure 3 shows the typical grate rail temperature profile across the length of the grate on bagasse and coal.

Table 1 reflects the measured performance of the Yarrow boiler prior to the retrofitting of a new CAD stoker, feeders and spreaders, and the improvement after upgrading.

The efficiency increase on the upgraded boiler was close to 10 percent. This resulted in significant savings in the cost of coal for the owner, coupled with a much higher availability and commensurately lower maintenance costs.

Table 2 reflects the key performance parameters for the new boiler.

Further Optimisation of Efficiency

A somewhat higher combustion efficiency on coal could have been achieved had the upgraded and new boilers been fitted with a grit re-firing system. However, the decision was taken by the owner not to follow this route as the capital cost of the additional equipment required, coupled with the higher maintenance costs associated with a grit injection system, would not give him the best Total Cost of Ownership (TCO).

A zoned JTA CAD stoker with grit re-firing was recently installed on a sugar factory boiler in Mauritius. This unit fires coal almost exclusively as part of a co-generation system where the additional cost and complexity can be justified by the increase in efficiency that grit refiring provides.

Again the application of a zoned stoker proved to be very successful on this plant where, as it exports power, high availability is of key importance.

Guidelines for Optimum Efficiency

Based on the extremely valuable experience gained on the stokers covered by this report, we would recommend that owners contemplating installing new boilerplant or upgrading existing plant consider the following:

1. Ensure that no compromises are made in the coal supply system. This is false economy and any additional costs of a good system will be more than offset by improved efficiency and lower maintenance costs.
2. Ensure that there are sufficient grate rail temperature thermocouples fitted to the stoker to enable a good picture to be obtained of the overall combustion conditions.
3. Consider fitting robust diverter valves on the main ash outlet chutes so that should the submerged ash conveyor be out of service for any reason, it is still possible to operate the boiler.
4. To obtain optimum efficiency, a stoker needs to be paired with matching feeders and spreaders and a primary and secondary air combustion system specifically designed for the boiler configuration.

Conclusions

Extensive testing of the performance of the boilers and monitoring the operation of the units has proved conclusively that the zoned CAD stokers allow for very efficient operation of the boilers.

Low maintenance costs and high availability have also been experienced with these units. This was primarily due to the

Table 1. Boiler performance before and after upgrading.

Yarrow Boiler		Before upgrade	After Upgrade
Item	Units	Coal	Coal
Steam Flow	tsph	86	86
Steam Press	kPa	2585	3139
Steam Temp	^{0}C	359	338
Fuel Burnt	kg/h	11006	9292
GCV of Fuel 'As Fired'	kJ/kg	27810	28060
Final Gas Temp	^{0}C	182	166
Boiler Effy on GCV 'As Fired'	%	76.8	86.8
CO_2	%	11.5	12.9
O_2	%	8.4	6.5
CO	ppm	230	144
Undergrate Air Temp (Avge)	^{0}C	153	147
Carbon in coarse ash	%	37	13.9

Table 2. Key performance parameters.

New boiler			
Item	**Units**	**Bagasse**	**Coal**
Steam Flow	tph	142	117
Steam Press	kPa	3032	3134
Steam Temp	^{0}C	399	396
Fuel Burnt	kg/h	77584	14695
GCV of Fuel 'As Fired'	kJ/kg	8687	28240
Final Gas Temp	^{0}C	197	196
Boiler Effy on GCV 'As Fired'	%	66.7	85.2
CO_2	%	N/A	12.7
O_2	%	3.1	7.1
CO	ppm	338	156
Undergrate Air Temp (Avge)	^{0}C	230	150
Carbon in coarse ash	%	N/A	13.2

stoker being of robust design to be able to withstand the arduous conditions under which it has to function.

Undergrate zoning was found to be very successful for burning a variety of coal grades, enabling complete burnout of the coal to be achieved. The measured carbon in coarse ash figures achieved are proof of this.

Retrofitting of zoned CAD stokers into existing boilers has also been proven to be a cost-effective initiative.

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REFERENCES

Magasiner, N and Naude, DP (1988). Pneumatic spreading of fibrous fuels and coal in boiler combustion chambers. *Proc S Afr Sug Technol Ass 62*: 79-84.