PINHOLE GRATE CONVERSIONS OF TWO 30 T/H BOILERS AT SOUTH NYANZA SUGAR COMPANY, KENYA

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Abstract

The paper discusses experience gained from rehabilitating two 30 t/h ISGEC John Thompson boilers at South Nyanza Sugar Company (SONY) in Kenya. The conversion included the replacement of the existing dumpgrate stokers with steam cleaned air, cooled stationary grates (pinhole grates), new forced and induced draught fans, three drum bagasse feeders, pneumatic spreader equipment and automatic boiler controls.

Introduction

The steam requirements at SONY are supplied by two ISGEC John Thompson boilers. The boilers are of the three pass configuration fitted with dump grates, and were originally designed to supply 30 t/h of steam at 320°C and 20 bar. During the 1994 crushing season, the boiler plant proved to be the limiting factor in overall mill production. The authors' company was approached to engineer a solution to increase the total steam output and improve the availability of the plant for the 1995 season. This paper describes in detail the modifications made to the boilers with particular emphasis on the steam cleaned, air cooled grates that were installed.

The design stage

The objective was to increase the boiler output by 20% from 30 t/h to 36 t/h while maintaining the final steam pressure. This was a considerable increase and detailed design calculations were performed to ensure that the mechanical performance and availability would not be jeopardised.

The main areas of concern were the following:

- Gas temperature leaving the furnace
- Grate and furnace heat release rate
- Gas velocities
- Final gas temperature
- Steam release rate
- Final steam temperature
- Superheater pressure drop.

Table 1 lists some of these figures for the initial and final conditions. The gas temperature leaving the furnace remained below the 1050°C mark, above which furnace slagging and superheater fouling can become a problem. The grate heat release rate was marginally higher than the design ratings used for dump grates and revolving grates. The volumetric heat release rate was within accepted design parameters, ensuring sufficient residence time to minimise carry over and unburnt carbon losses.

The gas velocities increased by approximately 20-25% but were still maintained below 20 m/s, and even lower, in the critical erosion region of the main bank second to third pass baffle.

The final gas temperature increased by approximately 40°C due to the higher heat load and the slightly lower efficiency. The steam side required no modifications as the steam drum release rate, superheater pressure drop and the final steam temperature all proved to be within reasonable limits.

Table 1
Some important upgrading parameters

Parameter	Units	Existing	Uprated
Furnace exit temperature	°C	916	956
Grate heat release rate	GJ/m^2h	9,1	11,0
Final gas temperature	°C	246	262
Efficiency on gross calorific value	%	65	63

The scope of supply

The scope of supply to achieve the upgraded condition consisted of the following:

Combustion equipment

Three new bagasse feeders were fitted to each boiler replacing the original single drum feeders. The new feeders are of the three drum type, driven by geared motors and controlled with AC inverter drives. The feeders are of a non-standard width to suit the narrower, existing upper bagasse chutes. The installed power for the three drum feeders is approximately 50% of that of single drum feeders which, although a small saving, still adds to the overall plant efficiency. The metering characteristics are also considerably better. New pneumatic spreaders were also installed. These are also a non-standard size to suit the front wall tube manipulations.

Grate

The existing dump grate was removed and replaced with a new steam cleaned, air cooled stationary grate, more commonly known as a pinhole grate (see next section).

Draught plant

The decrease in the final gas densities and the subsequent increase in the volume flow rates and gas side pressure drops warranted new, more powerful induced draught (ID) fans. The original idea was to decrease the fan speed from 990 rpm to 740 rpm to reduce the erosion rate.

On further investigation, the diameter of fan required to produce the same head at the lower speed had the same tip speed as the fan operating at 990 rpm. The advantage of having the slower speed fan was therefore abrogated.

The slower speed fan would also have been considerably larger and therefore more expensive. The decision was made to install an ID fan running at 990 rpm. The forced draught fans were also replaced to handle the larger volumes of under grate air that were required. The existing secondary air fan was changed from a 'hot' fan to a 'cold' fan.

Controls

New boiler automatic controls were installed to complement the existing controls. These consist of a new furnace pressure control loop and a master pressure control loop that controlled the bagasse feeder inverter drives and the ID fan inlet dampers. In addition, an uninterruptible power supply (UPS) was installed to protect the boiler instrumentation supply.

The pinhole grate conversion

Many grates in the sugar industry were actually designed for the fixed bed firing of solid fuels and not the suspension firing of fibrous fuels. The fuel/ash layer on the grate provided the protection from the luminous radiation and was also responsible for the combustion air pressure drop. These fuels also invariably had a high ash content, so one of the main features of the design was to incorporate a definite mechanical means of discarding the ash. Suspension fired boilers, particularly bagasse fired units, are quite different. The ash content is low and the bulk of the fuel burns in suspension. This means that the grate is largely exposed to furnace radiation and the grate configuration has to generate the under grate air pressure drop. Discarding of the ash is not as serious a problem as with solid fuels.

The stationary grate provides an elegant solution to these problems. It is not new technology, however, and the Hawaiian sugar industry has been using the pinhole grate since the seventies, while the Australian sugar industry has been advocating the use of pinhole grates for the suspension firing of bagasse since the early eighties.

The basic grate construction consists of an array of tubes onto which the grate bars are clamped. The grate can be arranged in one of two ways:

- The tubes can form part of the pressure parts, which is normally an extension of the furnace rear wall across the depth of the boiler to a front wall header. The grate support now becomes an integral part of the natural circulation system. This arrangement, as shown in Figure 1, is commonly referred to as a water cooled pinhole grate.

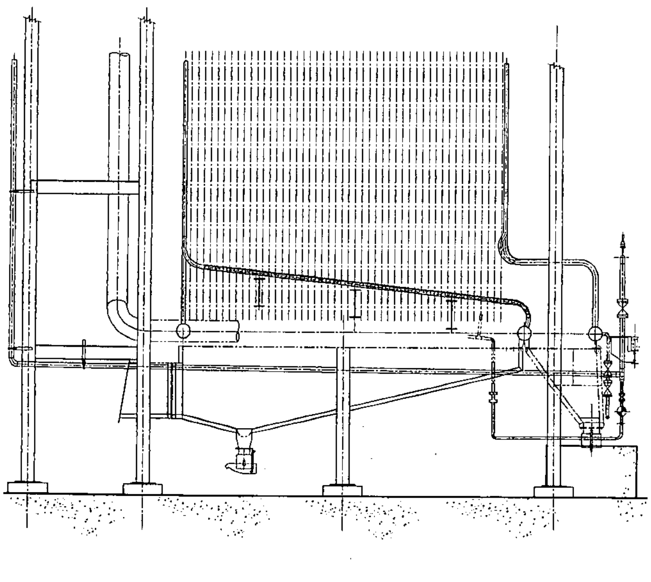

FIGURE 1: A general arrangement of a water cooled pinhole grate

- The tubes can alternatively be arranged on a self supporting structure and be connected to a cold air ducting system. The incoming air is distributed into the grate tubes and then introduced into the furnace through nozzles as rear secondary air or into the air plenum as preheated primary air. A general arrangement is shown in Figure 2.

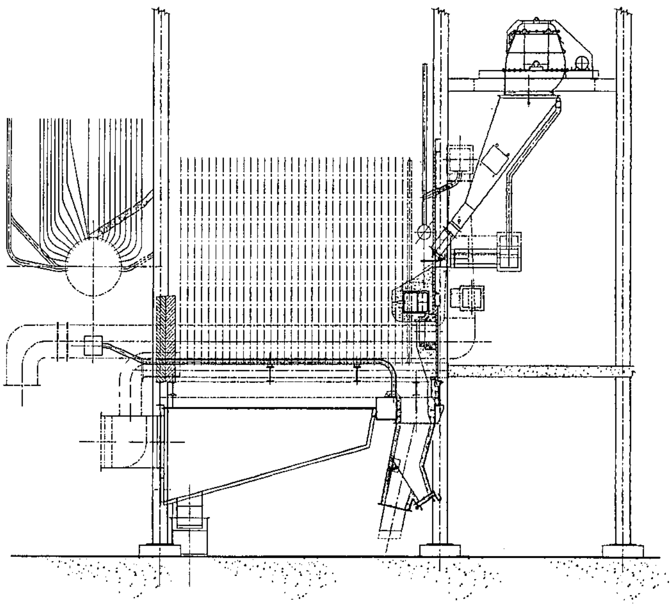

FIGURE 2: A general arrangement of an air cooled pinhole grate

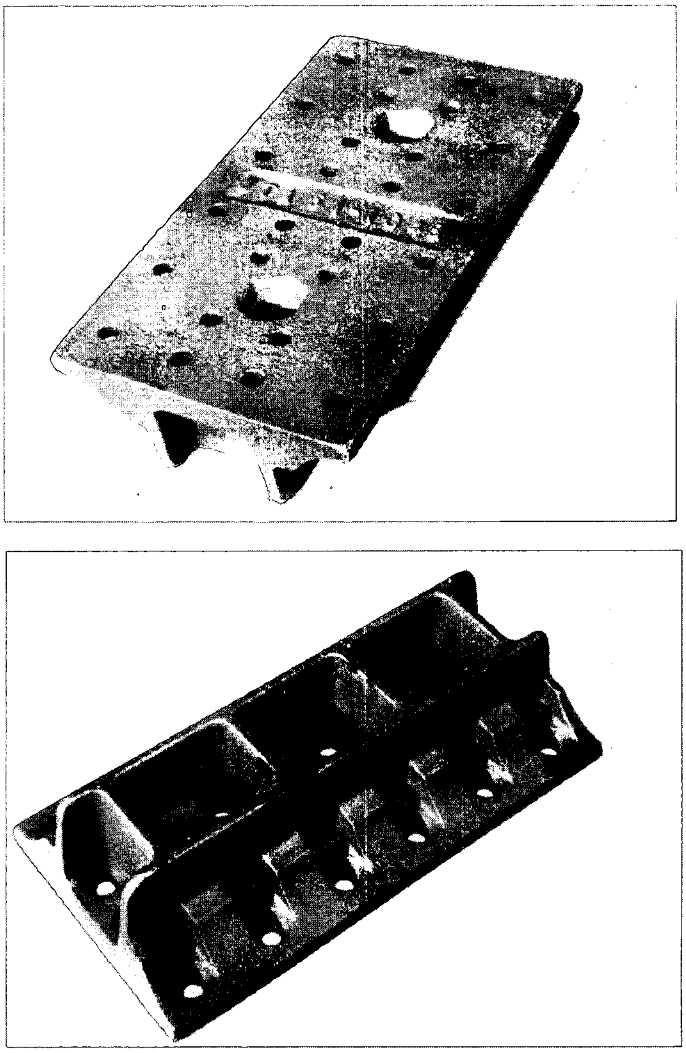

FIGURE 3a and b: A typical pinhole grate bar

Figures 3a and 3b are photographs of a typical grate bar, the material of which should be of a very high quality cast iron with good resistance to creep, high temperature oxidation and embrittlement. The bars are profiled to provide a conductive seating surface with the support tubes.

The cooling mechanism is twofold and is explained as follows:

(a) The grate bars are cooled by conduction to the tubes which in turn are convectionally cooled by the fluid within the tube and the primary combustion air flowing over the tubes. The effectiveness of this mechanism would obviously depend on how good the surface contact is between the grate bar and the tube surface.

(b) The major cooling mechanism is by convectional cooling from the primary under grate air that is forced through the grate bars. The detail of Figure 3b also shows the cooling fins that form part of the bottom of the grate bar. The high pressure drop through the 'pinholes' in the grate not only ensures even air distribution, but also uniform cooling over the whole grate area.

Ash is removed in batches similar to the method employed on the dump grates. Instead of dumping a section, a series of steam jets are actuated to propel the ash along the grate into a corrosion resistant, refractory lined hopper traversing the front of the boiler. The steam is issued through a series of low profile nozzles that protrude through the grate at spaced intervals. The cleaning is done in a set sequence to maintain good combustion and minimise the unburnt carbon loss.

The grate conversion at SONY

The SONY boilers were retro-fitted with air cooled grates. The existing dump grate steel work was modified to support the new grate. Care had to be taken to allow for thermal expansion of the grate components by utilising sliding beam supports. The boilers are bottom supported so the bottom furnace seal does not have to cater for any relative movement. Details of the conversion are shown in Figure 2.

The secondary air fan delivery ducting was rerouted and connected into the grate inlet box which traversed the width of the boiler. The air that has then passed through the grate tubing is introduced into the rear of the furnace as secondary air. The nozzles had to be relocated relative to the grate, in line with standard practice.

Since the boiler was originally designed with a dump grate, there is no vestibule beneath the front wall for collecting the coarse ash. The ash hopper therefore had to be located within the furnace plan area. A nose section had to be built just below the spreaders to prevent significant quantities of unburnt bagasse falling into the front ash hopper. This section had to be cast with refractory to withstand the high furnace temperatures. This in itself posed another problem. How was the refractory nose going to be supported and cooled? A novel solution was proposed, and the nose was cast around another secondary air duct that fulfilled three purposes:

- To create a rigid support beam, around which to cast the nose.
- A cooling duct to dissipate the heat energy absorbed by the nose.
- A secondary air duct that allowed the placement of dribbling nozzles along the furnace side of the nose to minimise the bagasse falling into the coarse ash hopper.

A new riddlings hopper was fitted onto the grate steel work. The grate steam cleaning pipe work was divided into four sections. Each section was actuated by a ball valve located in front of the boiler on firing floor level. The manifold on firing floor level was in turn fed by an existing saturated steam line.

Operating experience

The front end at SONY sugar consists of one set of cane knives and a four mill tandem. Although the extraction rate and final bagasse moisture are on a par with the other mills in Kenya, the cane preparation for use in suspension fired boilers was not ideal. The coarseness of the bagasse and the fibre length meant that a large proportion of the bagasse actually burnt on the grate and not in suspension. In the initial commissioning stages there was a tendency towards slag build up on the refractory lined rear wall at grate level. The wall effect in this relatively small furnace also contributed towards slagging in the furnace. This was rectified by introducing the rear secondary air at a lower point in the furnace.

The under grate air temperature was in the region of 225°C. The air side pressure drop across the grate was ±260 Pa at maximum continuous rating (MCR) conditions. The combustion was stable and did not demonstrate any pulsations. The secondary air was running at an average of 2000 Pa at the inlet box and exiting the grate cooling support tubes at approximately 120°C.

The steam cleaning was found to be ineffective at first. This was due to insufficient pressure available at the grate steam header. The problem was resolved by increasing the line size from the saturated steam header to reduce the pressure drop. Grate cleaning proved to be successful after this modification.

There is a general shortage of power in Kenya, and the sugar mills have to rely heavily on their own generating sets to provide energy for the mill. During peak demand periods, the 415 V line voltage can drop to as low as 340 volts. This posed a significant problem for starting the high inertia ID fans during peak hours. The normal procedure was to black out the entire mill and use all the available power to start one boiler. Once the boiler was on pressure, the turbo-alternator (TA) set turbine was brought up to operating speed. At this point, the power to the boiler was shut down and the TA set switched on line. Having the UPS at this stage was a major advantage, as the boiler controls and dampers had a continuous power supply during this switching period. The other problem that caused many delays was the fact that the bagasse feeder inverter drives kept tripping out on low voltage during the pressure raising stage.

Once the TA set and the one boiler were on line, it was a matter of normal procedure to start the second boiler. Boiler No 2 steamed successfully at the uprated conditions without any adverse affects. Boiler No 1 only managed to reach 32 t/h with the ID fan damper fully open. The large number of tubes blanked off in the main bank, and the by-passing of gas through damaged baffles, resulted in high back end temperatures. There was also a significant quantity of air ingress confirmed by the low CO_2 content at the ID fan inlet.

There is no doubt that this boiler will attain it's uprated design condition once the main bank, gas baffles and rear duct work are repaired.

Projects experience

It was an extremely fast track project, with only 17 weeks from the placement of the order to final commissioning and handing over. The scheduled offcrop was only five weeks, and the erection and commissioning had to be completed within this period. The bulk of the plate work and steel work was manufactured locally in Kenya while all the other components were either sourced or manufactured in South Africa. The consignments that were shipped via Mombasa took an average of 40 days to reach the site. In order to keep to the short delivery date, the authors' company airfreighted a number of consignments to Nairobi. These consignments included the ID fans, FD fans and refractories. The project was completed on time and within budget.

Conclusions

The steam cleaned stationary grate offers a number of advantages over conventional grates for the suspension firing of bagasse. Experience with these grates has proved to be more than satisfactory in the Australian industry and has now been proved in the African industry. More specifically, some of the major advantages are:

- The method of disposing of the ash does not embody any dynamic components and therefore none of the associated problems of mechanisms operating in a harsh mechanical environment.
- The efficient grate cooling system allows the use of relatively high temperature under grate air without danger of damage to the grate. This also eliminates the problem of 'puffing' that is often associated with large load swings and high fuel moisture content.
- The uniformity of the grate ensures a long term, even distribution of air over the full grate area.
- The dual cooling mechanism allows for increased turn down without overheating the grate, provided all the air settings are correct and there is good contact between the grate bars and the cooling tubes.
- The water cooled grate resolves the problem of having expansion seals at the furnace to grate interface on girt and top supported boilers.
- There is essentially no limit to the size of grate that can be built.
- The initial capital outlay for a new boiler fitted with a pinhole grate will be slightly higher than the same boiler fitted with a dump grate, but considerably lower than a revolving grate.
- A well designed and erected grate has the potential of reducing annual offcrop maintenance costs to a very low level and unscheduled maintenance costs to zero.
- The air cooled stationary grate is better suited to retro-fits where more flexibility is required and the boiler design does not allow for much freedom in modifying the pressure parts. Even the old hearth or Dutch oven type furnaces are easily retro-fitted with air cooled pinhole grates and suspension firing equipment. The relative cost of the grate is much the same as a dumping grate.

In conclusion, the stationary steam cleaned grate is an attractive proposition both technically and economically, where conventional grate installation and maintenance costs are high, and the boiler is essentially fired on bagasse.

Acknowledgements

The authors would like to thank South Nyanza Sugar Company and John Thompson Africa (Pty) Ltd for allowing them to publish this paper and our colleague Rob Merry for his valuable input on the operational aspects.

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