

ENERGY MANAGEMENT WITH PARTICULAR EMPHASIS ON STEAM RAISING — GLEDHOW SUGAR MILL

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Abstract

A practical method of monitoring coal-fired boiler efficiency is described. Results obtained from the firing of various grades of coal as well as proposed boiler modifications to optimise combustion efficiency are presented.

Introduction

Gledhow Mill exports depithed bagasse to neighbours, Sappi Fine Papers, for the production of various grades of paper. The total mass of 82% clean fibre blown during the 1987/88 season amounted to 223 614 tons which represents 44% of total bagasse produced by the mill and diffuser.

This tonnage obviously varies from year to year and depends upon factors such as season length, fibre % cane, crush rate etc.

Sappi's two storage slabs can hold a combined mass of 50 000 tons of fibre.

The resultant deficit in fuel energy is made up by firing coal, 63 716 tons being burned during last season. At an average landed cost of R58,77/ton this equates to R3 744 589/season, and makes Gledhow the largest consumer of coal in the sugar industry.

Combustion Problems

At Gledhow, 96% of steam raised on coal is produced by a Yarrow 100 ton/hour M.C.R. stoker fired boiler fitted with an economiser. This boiler steams at an average of 75 to 80 tons/hour and uses coal spreaders for the distribution of coal onto the grate.

A decline in the steam to coal ratio as well as clinker formation on the grate of this boiler led to an investigation into its efficiency as well as the chemical composition of the coal being fired.

Behaviour of ash at high temperatures is related to its chemical composition and the ash fusion temperature of the coal describes this behaviour. Most furnaces are not designed to handle ash that fuses into a viscous liquid and sets to form a hard clinker on cooling.

It was decided to determine the boiler efficiency by the overall loss method and then compare this to the efficiency as derived by formula.

This method would highlight areas of major loss and they could then be improved upon either through adjustment to firing parameters, alteration to boiler design or change of coal specification.

Description of Tests

The initial test was conducted firing pea coal mined in the Piet Retief area with supplier's claimed specification as shown:

Gross Calorific Value	: 27.61 MJ/kg
Water	: 2.6%
Ash	: 15.7%
Volatiles	: 21.8%

Fixed Carbon	: 58.5%
Sulphur	: 0.78%
Ash Fusion Temperature (flow)	: 1 300 deg. C

The boiler was set up and steamed under steady load conditions of 80 tons per hour with the three other bagasse fired boilers taking the load swings. All operational parameters such as induced draught, forced draught, grate speed, feeder speeds etc. were monitored and recorded. The entire test was conducted over a 6 hour period and the following variables were measured:

1. Coarse ash mass, temperature and unburnt carbon % ash taken off the front of the boiler grate.

These samples were taken by opening the ash hopper doors and allowing the ash to discharge onto the floor of the Boiler House where it was immediately quenched with water to prevent further burn-off.

2. Total mass and percentage unburned carbon in fly ash. This measurement was achieved by screening the hydro-seal water discharge from the seven fly ash hoppers over the six hour test period.

The dark colour of the fly ash samples screened was indicative of high carbon loss which was later verified by the laboratory results.

3. Flue gas analysis to determine the boiler's combustion efficiency which included oxygen and carbon monoxide content and final flue gas temperature. These values were required for calculation of stack losses and flue gas samples were taken after the last of the heat recovery equipment, namely the economiser, using a portable combustion optimiser.
4. Total coal mass fired during the test was measured with a nuclear belt weigher installed on the coal belt which feeds the coal bunkers.

Finally, the total mass and temperature of live steam being generated was measured using installed mass flows and temperature sensing equipment.

All ash collected during the test period was weighed and samples of each hopper, together with samples of coal fired during the test were sent to an independent laboratory for analysis.

After analysis and calculation the following picture emerged:

1. Coarse ash loss	: 6.23%
2. Fly ash loss	: 7.05%
3. Dry stack loss	: 7.19%
4. Radiation loss	: 3.00%
5. Blowdown loss	: 0.30%
Total	: 23.77%

Therefore the boiler's efficiency as measured by the total loss method was 76.23%, which compared well with the calculated overall efficiency of 75.22%; the difference of 1.01% being due to errors in measuring equipment, unknown radiation losses and stack flyash loss.

Three areas of major loss were identified from the initial test on the Piet Retief coal.

1. Unburned carbon loss in coarse ash discharging off the boiler grate. This loss is attributed to four factors, namely:
 - (a) Low coal ash fusion temperature.
 - (b) Incorrect coal trajectory from spreader, with coal landing too close to the front of the grate and therefore having insufficient time for complete burn-off.
 - (c) High grate speed.
 - (d) Poor undergrate air distribution.
2. Carbon loss in fly ash caused by the following:
 - (a) Uneven undergrate air distribution which causes channeling and localised areas of high flue gas velocities.
 - (b) A high percentage of duff in coal.
 - (c) High flue gas velocities caused usually by excessive overfire or secondary air.
 - (d) Uneven coal distribution on the grate which can also lead to air channeling in certain areas.
3. Stack losses attributed mainly to excess air volumes with resultant high energy loss in flue gas.

In the case of the particular boiler under discussion, this loss is largely dictated by secondary air volumes that have to be introduced into the furnace in order to maintain a final superheated steam temperature of 400° C.

Several changes were instituted in an attempt to improve upon these high loss areas.

The forced draught duct was modified allowing approximately 40 percent of undergrate air to be introduced into the furnace between the top and bottom sections of the grate in order to achieve improved air distribution.

Two new coal spreaders were designed and installed on a stop-day with distribution plate angles being re-adjusted to accommodate the new geometry.

Pea coal mined at Kilbarchan (in the Newcastle area) with an ash fusion flow temperature of 1 482 deg. C was selected for firing and an immediate improvement in coal burn-off was apparent. Besides the higher ash fusion temperature and a slightly higher gross calorific value, the chemical composition of both coals fired was similar.

No clinkers were formed on the grate and this obviously aided in the more complete combustion of the coal, as well as reducing areas of localised grate overheating which had been experienced during the firing of Kober coal.

Once all modifications had been completed the same test procedure was adopted, ensuring that the boiler was steamed under the same steady load conditions. Results obtained from this test were as follows:

1. Coarse ash loss : 3.21%

2. Fly ash loss : 6.81%
3. Dry stack loss : 5.62%
4. Radiation loss : 3.00%
5. Blowdown loss : 0.29%
- Total : 18.93%

Therefore the boiler efficiency during the second test was 81.07%. The high fly ash loss of 6.81% is attributable in this case to a high visible duff coal content which, although not being monitored at present, will be included in future coal analysis due to its large impact on boiler losses.

Discussion

Boiler modifications as well as a change in coal specification resulted in an overall increase in boiler efficiency of 4,84 percent. Based on 1987-88 figures this equates to a potential annual saving of 3 084 tons of coal, or R181 246,00.

Further developments on undergrate air distribution, grate speeds and excess air levels are planned.

Several control parameters have also been instituted in order to monitor and optimise boiler efficiency. They are as follows:

1. Ash samples are taken from each door of the boiler every two hours, composited, prepared and tested with the aid of an unburned carbon in ash analyser, which measures the conductivity of an ash sample and is calibrated to display carbon % ash. This test is performed and results recorded in the boiler log book once per shift.
2. Coal samples are taken once a shift, composited and sent to an independent laboratory on a weekly basis for analysis.

These results both provide a check against supplier's specification, and form the basis of the coal for fibre energy exchange with Sappi Fine Papers. This exchange is calculated on nett or lower calorific value.

3. Analysis of flue gas to determine combustion efficiency, oxygen, carbon monoxide and temperature. This test is performed once per shift and adjustments to firing parameters are made accordingly.
4. The monitoring of all steam and feedwater flows on the boilers' main and auxillary lines with the installation of orifice plates and associated measuring equipment. This enables boiler blowdown rates and therefore blowdown energy losses to be more closely managed.

This project has demonstrated that there are many factors which affect the efficiency of a coal-fired boiler; but with the correct control and monitoring of all parameters related to boiler operation, considerable financial savings on the annual coal bill can be realised.