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FIBROUS FUEL DENSITY COMPENSATION IN BOILER COMBUSTION AT SEZELA

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Abstract

Fibrous fuel fed to the boilers at Sezela is characterised by wide variations in density. This situation has arisen because of the by-product facility at Sezela which utilises a portion of the mill bagasse and in doing so converts the remainder into 'residue'. The bulk density of residue is roughly three times that of bagasse and the variability in proportions of the mix of residue and bagasse leads to the variability in fuel density. Use has been made of nuclear density meters to control combustion in the face of such variability and this paper describes the development work undertaken at Sezela.

Introduction

Smithchem, a by-products operation at Sezela, takes part or all of the mill bagasse (depending on its production rate) and sifts out the fines which are returned immediately to the mill boilers. The coarse fraction, and steam, are fed into reactors where furfural is manufactured from a very small portion of this fibrous feedstock and extracted in the steam discharge. The remaining fibre, termed residue, is discharged from the reactors and directed to the mill boilers. Due to the flashing of the steam/water mixture contained in the fibres as they leave the pressurised reactor and emerge into the open air, the fibres 'explode' and the residue is characterised by extreme fineness at a moisture (after drying) of around 51 percent. The density of pure residue is about three times that of bagasse. Thus a Sezela boiler can be presented with a fibrous fuel that can range from the density of mill bagasse to that of a fines/residue mix at any instant in time, depending on factors such as:

- how many reactors are in operation relative to the mill cane rate
- mill stopped but reactors still in operation (fed from Smithchem coarse bagasse store)
- Smithchem stopped but mill still crushing.

History of combustion problems

During the early period from around 1973 up to about 1986 the quantity of mill bagasse converted to residue was insufficient to cause serious combustion problems in the mill boilers. However the steady progress made by Smithchem in expanding their furfural production each year eventually led to instability as the fuel composition changed from a lower to a higher proportion of residue.

A phenomenon experienced from 1986 onward was termed a 'puff' and occurred when some production disturbance caused the fuel composition to change rapidly from mainly coarse to mainly fine. The volumetric feeders, continuing at the prevailing speed, would suddenly feed three times the mass of fuel into the furnace as the density increased. This would blanket the fire, depress the steam rate and lead to an even faster feeder speed.

Meanwhile, the boiler would shed load and the pile of residue on the grate would dry and then rapidly ignite, creating a pressure excursion throughout the furnace and flues. There were many of these 'puffs' and although not terminal, they caused thousands of Rands damage cumulatively.

The typical sugar industry bagasse-fired boiler

The problems occurred most seriously on Sezela's No. 1 boiler. It operates in parallel with No. 4 boiler, which is similar in size, and delivers steam to the range at 3 100 kPa gauge pressure.

It is a large three-pass John Thompson Africa boiler of 140 tons per hour capacity, with airheater, economiser and wet scrubber designed to operate on bagasse only, but capable of being started up on coal. The seven bagasse feeders are driven off a common line shaft which itself is driven by a variable speed DC motor. The boiler is not representative of the sugar industry in this respect as it is more common to find the feeders individually driven.

As can be seen from Figure 1, the typical bagasse feeder is a volumetric device. The three drums are interconnected and the metering is carried out by the two counter-rotating small drums, while the larger drum 'cards' off the bagasse presented to it. The volumetric feed rate is thus set by the distance between the two rollers at the nip multiplied by the length of the rollers, which gives a cross-sectional area in the horizontal plane, and finally multiplied by the downward velocity of the bagasse at the nip. The units are thus cubic meters per hour.

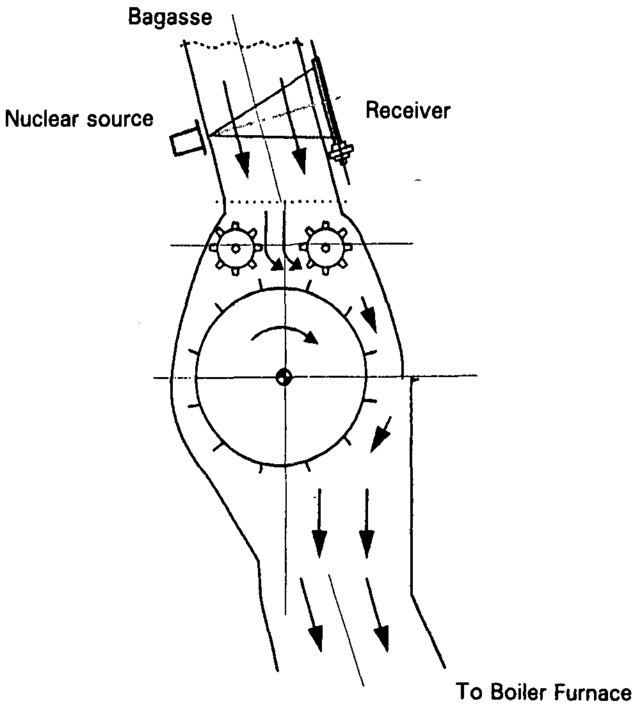


FIGURE 1 Sectional elevation of a typical bagasse feeder and nuclear density meter

The combustion control loop, shown in Figure 2, varies the speed of the feeder as more or less fuel is required to meet the steam demand and it has been fortunate for the sugar industry that in general the density of bagasse does not vary at a particular mill. Therefore the requirement for the injection of a controlled amount of energy into the furnace (mass rate multiplied by energy per unit mass) has evolved into a much simpler requirement which is volumetric rate multiplied by energy per unit volume. However, the moment the density of the bagasse varies, then a particular volume of bagasse will contain an unknown amount of energy and the combustion control loop will become more unstable.

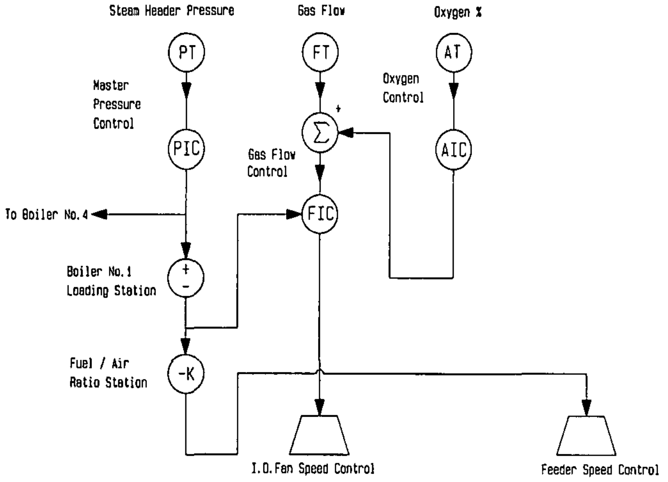


FIGURE 2 Typical combustion control loop

Density compensation experiments

It became evident in 1987 that a strategy had to be developed urgently and the engineering team at Sezela set to work on density compensation.

A nuclear density meter was purchased and installed on a feed chute on No. 1 boiler toward the end of 1990. During the 1991 season it was hooked into combustion control and evaluated. It seemed to improve the boiler response to density changes and so a programme to confirm these findings scientifically was set up for completion before the end of the 1991 season.

Two matched nuclear density meters were purchased for use on chutes number 2 and 5 on No. 1 boiler. However prior to their installation one was set up in a laboratory environment for tests.

The first requirement was to show that the absorption of the gamma rays passed through the fibrous fuel was proportional to density. Various samples of fuel were made up to have different densities (by varying the proportions of bagasse and residue) and dried in a large oven to constant dryness. The steel box was filled with each sample in turn and the results are shown in Figure 3. A diagram of the apparatus is given in Figure 4. Knowing the weight of the sample and the dimensions of the box, the density could be calculated. The relationship was shown to be linear.

Secondly, it had to be established what effect variations in fuel moisture would have on the density measurement. In this test a single sample of bagasse was weighed and the moisture was determined. The moisture was then varied in steps by adding a known mass of water and in each case the absorption was recorded with the same amount of fibre being packed into the box. Thus, in effect, the gamma rays 'saw' the same amount of fibre in each case, but the amount of moisture present varied. It was felt that this method would give a clear picture of the effect of moisture. The procedure was repeated for a sample of residue. The results are shown in Figure 5, and the moisture effect was found to be linear.

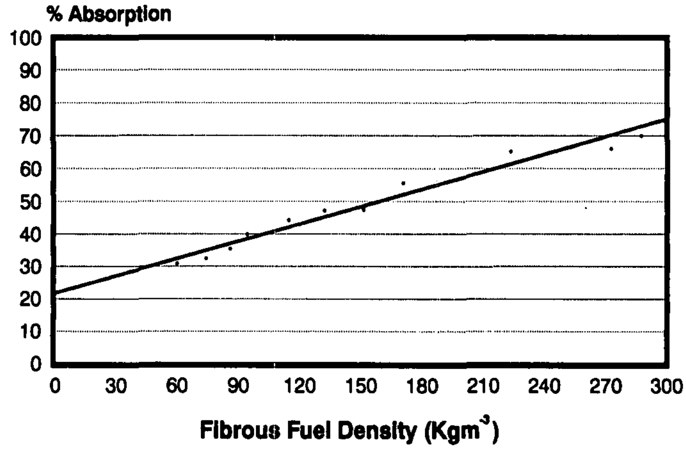


FIGURE 3 Relationship between fibrous fuel density and % nuclear absorption, with fibrous fuel maintained bone dry

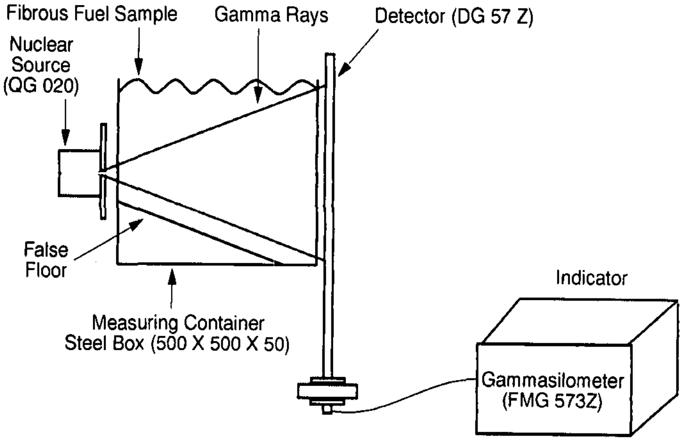


FIGURE 4 Nuclear density meter experimental appartus

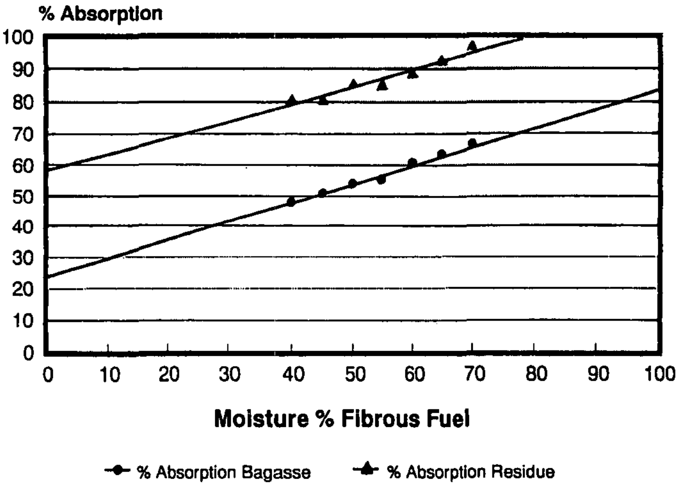


FIGURE 5 Relationship between moisture % fibrous fuels and % nuclear absorption for a constant dry fibre mass per unit volume

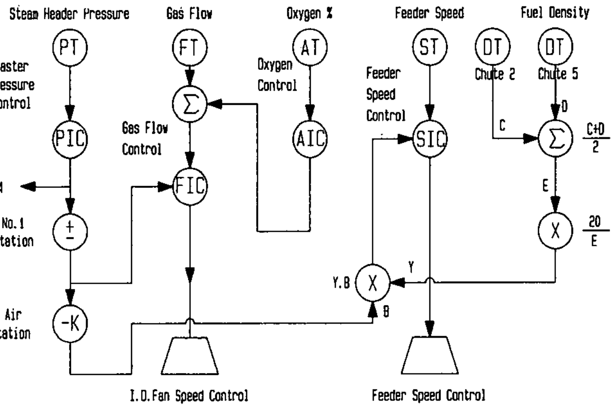
Fortunately it was found that, provided the fibrous fuel moisture did not vary more than ± 2 percentage points (which is indeed the case, the range in service being 51 ± 2 percent most of the time) the change in percent absorption was not more than ± 3,2 points and this corresponded to a density variation of ± 7 percent.

Since confidence in the instruments was now established, it was feasible to install them on the chutes mentioned above and to carry out full scale tests.

The boiler installation and testing

The two nuclear meters were installed just above the feeders on the chutes from the slat carrier. They were sized to pass gamma rays through the steel platework making up two of the four sides of the chute.

Their outputs were summed and averaged and incorporated into the combustion control loop as shown in Figure 6.



FIGUR 6 Fuel density compensation added to combustion control loop

The boiler was fed with residue rich fuel and then a step change to mill bagasse and back again was arranged. The nuclear meter output signals and the feeder's speed were recorded in Figure 7. The boiler handled the disturbance without any operator intervention and full supply of steam to the prime movers was maintained throughout the test.

It was confirmed that at least two nuclear meters per boiler were necessary as inspection of the trace in Figure 7 showed that the time lag between the step change in fuel density reaching chute number 5 after chute number 2 was about 3 minutes and this is a long time in combustion dynamics.

The theoretical time lag, which is merely a function of carrier speed and distance between chute openings, was a fraction of the measured time lag and the discrepancy could have arisen from any of the following factors:

- a chute choked
- a chute empty
- irregular feed on the carrier due to inadequacies of the fuel reclaim system
- a feeder shut down for dumping a section of grate
- a feeder stalled

Applications elsewhere

The use of feeder speed modification in relation to variations in fuel density has applications in any sugar mill where the run-of-mill bagasse is altered by a downstream by-product operation such that the physical characteristic of density can vary rapidly with time.

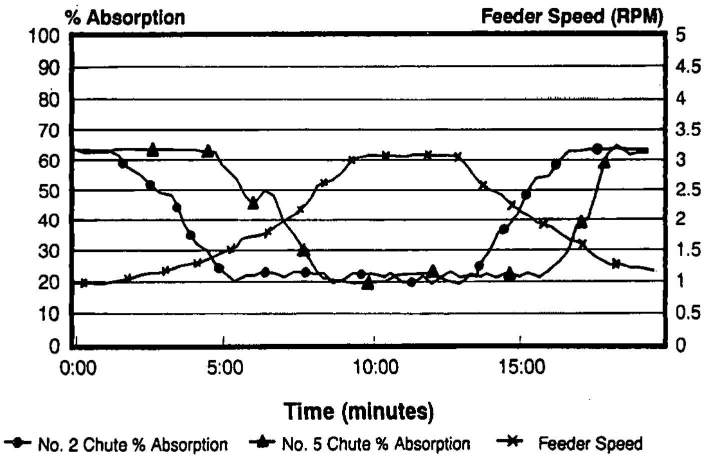


FIGURE 7 Chart recording depicting control loop response (feeder speed) to change in fibrous fuel density

The first example that can be cited is that of Felixton sugar mill where the run-of-mill bagasse is divided into two fractions namely 'pith' and 'fibre', of which the latter is used for paper manufacture. The 'pith' is burnt in the boilers and any 'fibre' fraction that is not utilised by the paper manufacturer (either due to inefficiency of the separating process or cessation of the export effort) will find its way to the boilers as well in a variable manner that will cause the fuel density to fluctuate with respect to time.

In a similar manner, other mills that use a fraction of the run-of-mill bagasse for by-products may find the application useful. These by-product operations include the following:

(a) animal feeds
(b) pelletised bagasse
(c) board plant

Possible future developments

The amount of gamma radiation absorbed is a function of both the dry fibre density and the moisture content. Fortunately at Sezela it was found that the typical range of fibrous fuel moistures was sufficiently small to render the effect of moisture variations on density measurement negligible.

If the application, however, is planned for a plant where the variations in fuel moisture are significant, then possibly an infra red moisture analyser would have to be included in the measurement and control loop. A computing controller would be able to feed the required amount of energy into the furnace knowing the moisture and density of the fuel.

The recordings have shown that better control will be achieved in proportion to the number of fibrous fuel feeder chutes that are fitted with nuclear density measurement units. The units, however, are costly and a possible future development would be to arrange for a single unit to measure fuel density in the conveyor feeding the boiler and to use this signal in the combustion control loop.

Conclusions

The strategy has proved remarkably successful and although the costs for the one boiler were high, as detailed in Table 1, the benefits in avoiding structural damage from 'puffing' and the ability to maintain steam supply through phases of disturbance have been enormous.

The fact that the need for density compensation at Sezela came about over a period of years led to the belated conclusion that as long as the change in density occurred reasonably gradually, the conventional control strategy with integral action was adequate. It was only when the rate of change exceeded a certain threshold level that density compensation was needed to combat the vicious cycle that led to the 'puff'. The other three boilers at Sezela have a substantial coal feed which has provided a stable combustion characteristic that was lacking in the bagasse only boiler, and have thus been less susceptible to 'puffing'. However it is felt that, in time, fuel density compensation should be extended to them as well.

Table 1

Nuclear density compensation costs

Instrument	Endress & Hauser gammasilometer FMG 573Z source QG 020 detector DG 57 Z
Isotope	Caesium 137
Strength	185 Mega-Bequerels
Cost	R24 500 each
For 2 off	R49 000
Combustion controller programmable	Foxboro multiloop model 761
Cost	R6 800
Installation cost	R1 500
Total cost	R57 300