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PNEUMATIC SPREADING OF FIBROUS FUELS AND COAL IN BOILER COMBUSTION CHAMBERS

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Abstract

The need to burn coal and bagasse in the same furnace and the almost simultaneous need to build bigger boilers led to the introduction of spreader firing in the Natal cane sugar industry in 1954. The paper describes the development of the fuel spreading equipment from purely mechanical, through combined mechanical and pneumatic to a single pneumatic spreader, capable of handling fuels having a wide range of ballistic properties. The effectiveness of the latest design is illustrated by way of three examples.

Introduction

The need to burn coal and bagasse in the same furnace and the almost simultaneous need to build bigger boilers led to the introduction of spreader firing in the Natal cane sugar industry in 1954. Initially mechanical spreaders were used for both fuels with either separate or dual feeders. While mechanical spreaders worked well with coal they were ineffective on bagasse. Dual feeders were also found to have severe limitations. In time separate feeders became the norm coupled to separate distributors: a mechanical one for coal and a pneumatic one for bagasse. Today combined pneumatic distributors are used for both fuels. This paper describes the development of these distributors and their application to the following boilers:

- A bagasse/coal/furfural residue fired boiler
- A hearth type boiler uprated by 50%
- A bark fired boiler where the effect of pneumatic spreading and an integrated combustion air system improved the efficiency and operation of the unit.

Early designs

Figure 1 shows the arrangement of a typical furnace installed in 1965 fitted with separate coal and bagasse feeders and spreaders. The single drum bagasse feeders were driven through variable speed hydraulic couplings. They functioned well with short chutes and milled bagasse. The short chutes with their limited storage, however, led to combustion instability. The feeders, which were typical of the design used extensively at the time, were mechanically complicated and difficult to maintain. They were not able to handle wet smalls. The pneumatic bagasse spreaders and the mechanical coal spreaders both suffered from severe distortion when alternative fuels were fired.

The introduction of taller chutes to stabilise combustion and the move to diffusers which produce a bagasse with felting properties resulted in overloading and choking of the single drum bagasse feeders. This led to the development of the three drum feeder.

A single drum coal feeder was developed to handle wet smalls. Trek chains were welded loosely to a drum to drag the coal through the feeder. When out of the coal stream the slack chains shed adhering coal, with the result that the feeders became self cleaning.

A satisfactory combined coal/bagasse spreader which would solve the wear and distortion problems took longer to develop. The idea of combining the two spreaders into one unit to minimise distortion was sound. It meant that irrespective of which fuel was being burnt the spreader was always air cooled and hence distortion free. Furthermore, using air to distribute both fuels meant that there were no moving parts and hence minimal wear. The problem however, was that while bagasse could be distributed pneumatically without any difficulty, the ballistic and drag characteristics of coal were incompatible with this form of distribution.

The development of a pneumatic spreader for combined fuel firing

A paper study carried out in 1983 showed that far more air was required to distribute coal effectively than was required for bagasse. It also showed that with the nozzle design used at the time, the larger coal particles would fall short while the lighter ones would be carried to the rear of the furnace. This was the opposite of what was required with a continuous ash discharge stoker. There were indications, however, that if the larger particles could be given sufficient momentum they might well spread as far, if not further than the lighter ones. Correct nozzle design was of paramount importance with the design of the secondary air system almost equally so.

The rig show in Figure 2 was built to determine what combination of parameters provided the best spread. It was positioned over an open area bounded by walls having plan dimensions similar to that of a 130 t/h boiler furnace. A 1 000 mm × 1 000 mm grid was formed to collect the coal. Samples from each grid cell were graded to determine size and mass distributions. The following parameters were varied:

- Nozzle design
- Deflector plate geometry
- Nozzle air pressure
- The arrangement of the nozzle in relation to the deflector plate, and
- The angle of the deflector plate.

Spread quality was defined in terms of size/mass distribution versus furnace depth. Initial tests with a standard bagasse spreader used at the time indicated that the mean depth of spread of coal at plenum pressures of 6 500 to 8 500 Pa was 2,9 to 3,5 m. Air volume, the angle of the distributor plate and the flow pattern of the air as it leaves the nozzle and traverses the distributor plate were identified as key design factors.

A satisfactory spreader was gradually developed with a larger deflector plate and with the nozzle repositioned to improve air distribution. For specific deflector plate inclinations the distance which the coal could be spread was

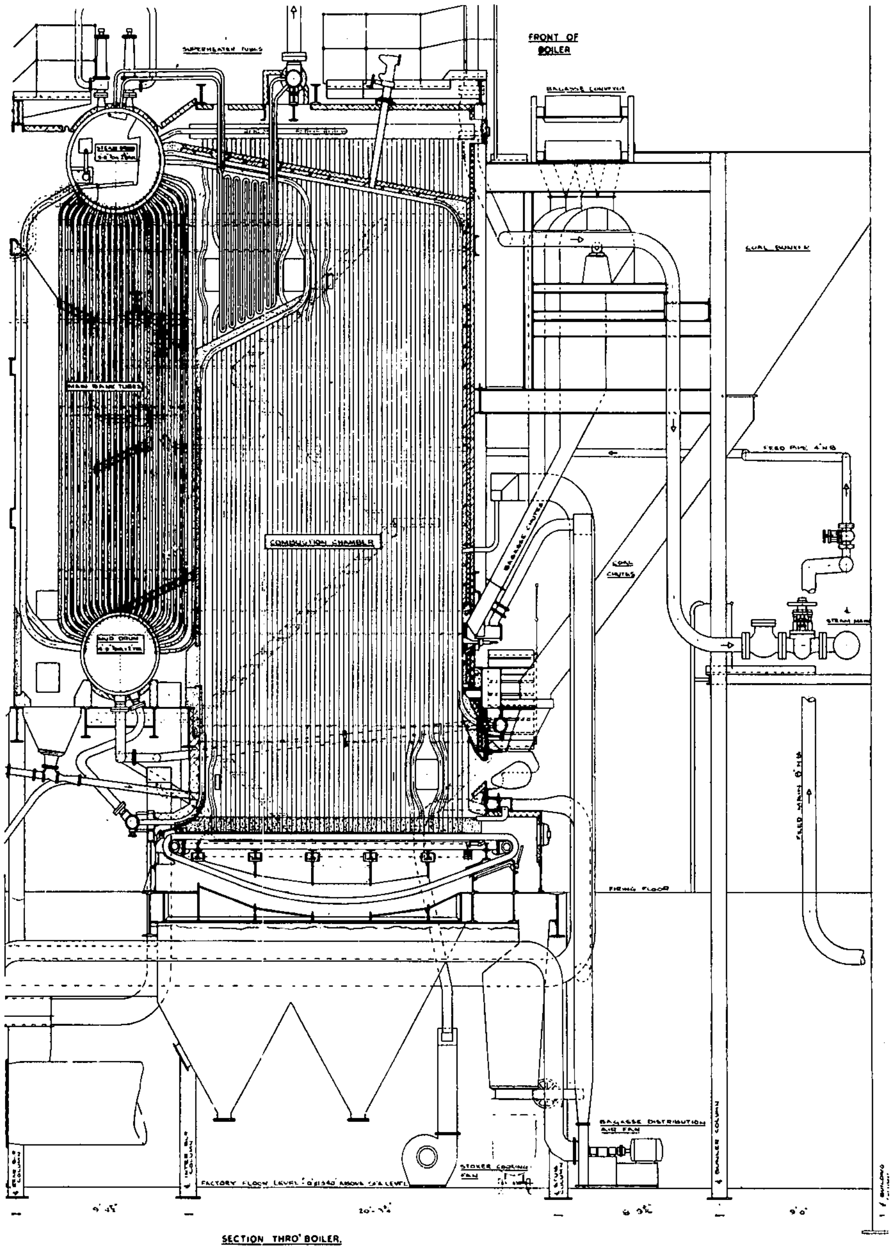

FIGURE 1 Furnace arrangement with separate mechanical coal spreaders and pneumatic bagasse spreaders.

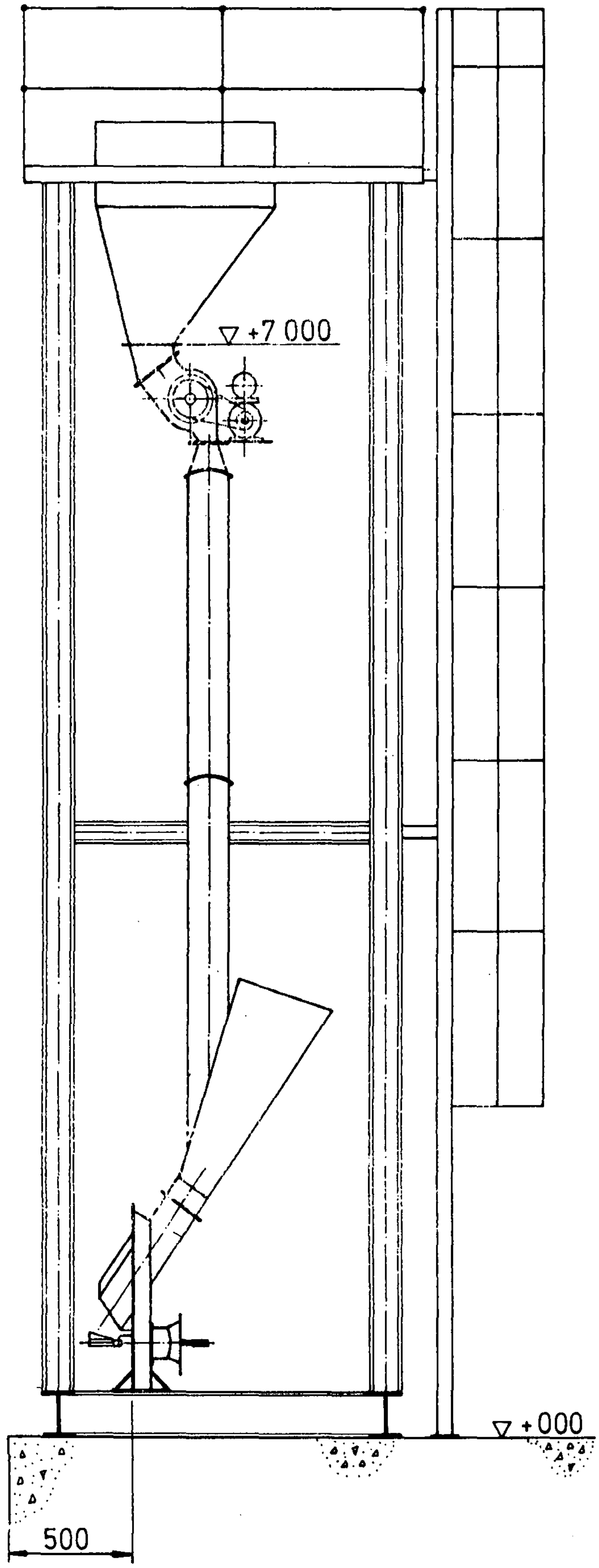

FIGURE 2 Arrangement of test rig used to design a pneumatic spreader for distributing coal.

found to be related by an equation having the following form:

$$D = a + b.Q \qquad \ldots.(1)$$

$$\text{Where } Q = K.A \sqrt{2p.d} \qquad \ldots.(2)$$

The type of spread obtained with insufficient distribution air for different coal size fractions is shown in Figure 3. The large particles do not reach the back of the furnace. In contrast, as shown in Figure 4, with the correct air flow to impart sufficient momentum to the fuel, most of the coal including the largest particles, reaches the rear.

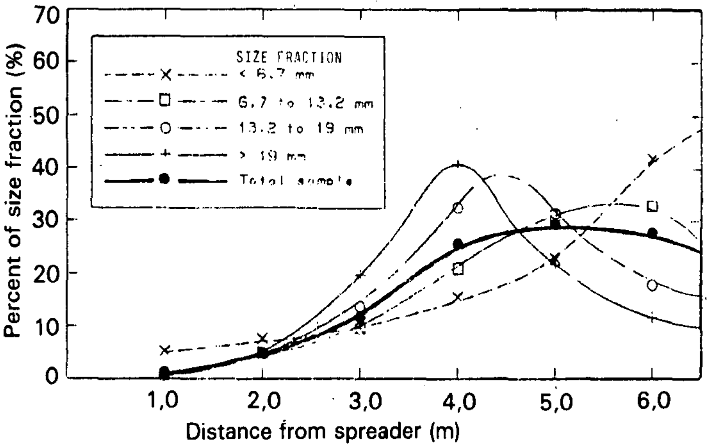

FIGURE 3 Spread characteristic with inadequate air flow.

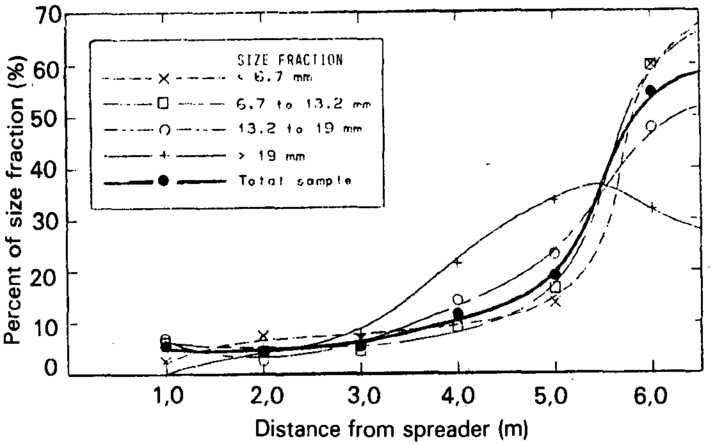

FIGURE 4 Spread characteristic with correct air flow.

From the results a dual feeder was developed which could be offered with some degree of confidence.

Application at Sezela

The system was first incorporated on the 130 t/h bagasse/coal/furfural residue fired boiler installed at Sezela sugar mill in June 1984. Plant layout on this installation dictated the use of variable speed screw conveyors for the coal feed and three drum feeders for the fibrous fuels. Figure 5 shows the arrangement of the plant. Spread is satisfactory and constant excess air conditions can be maintained over a 2 : 1 turn down ratio on all three fuels. Combustion is stable over the normal factory operating range.

Application to hearth type furnaces

Many of the older cane sugar factories are equipped with boilers fitted with hearth type furnaces. These units which are labour intensive to operate can be modernised and usually uprated by installing pneumatic spreaders at a fraction of the cost of new plant. In doing so capacities can be typically increased by 30 to 50%. Furthermore the units can

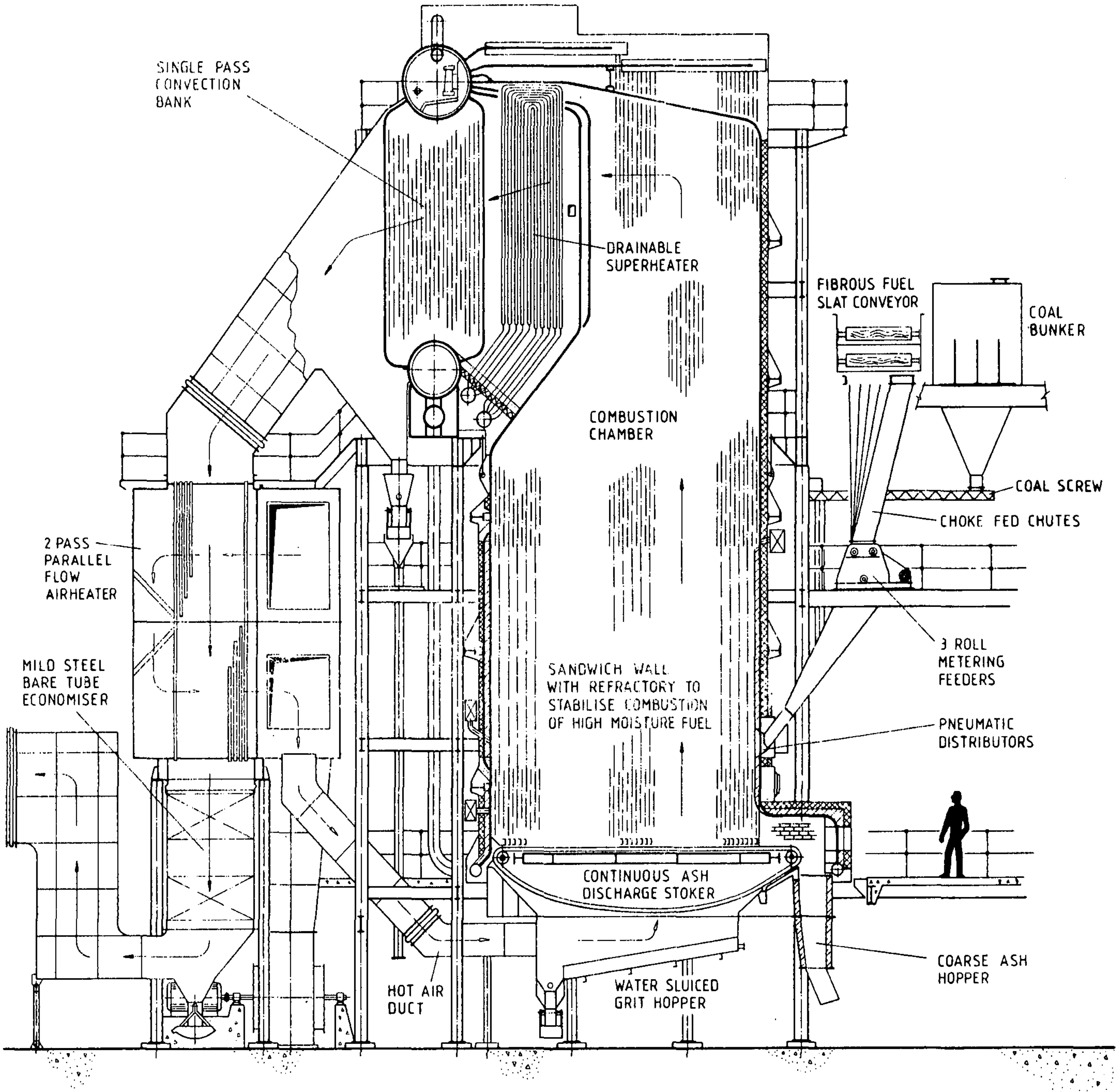

FIGURE 5 Furnace arrangement of a boiler with a pneumatic spreader for spreading coal, bagasse and furfural residue.

then be controlled automatically and mechanical de-ashing equipment installed.

In 1985 Compagnie de Beau Vallon, Mauritius decided to modernise their 30 t/h 1958 Stirling boiler installed at their Riche en Eau factory. Management wanted to increase the capacity of the unit to cater for increased factory throughput and to mechanise de-ashing. Modifications to uprate the boiler from 30 to 45 t/h included:

- A modified furnace
- A dump grate stoker
- Three drum bagasse feeders, spreaders and chutes.
- Extra furnace heating surface
- Larger draught plant
- An hydraulic ash sluicing system
- Hydraulically sluiced mud drum hoppers, and
- Automatic combustion controls.

Figure 6 shows the arrangement of the furnace before it was modified. Figure 7 shows the arrangement of the plant after it was modified.

The plant was commissioned as planned in June 1986, in time for the new season, and has since steamed at 45 to 52 t/h. Steam pressure is maintained at ± 3% of design. Steam temperature at MCR is within 10°C of design.

When re-evaluating the performance of the boiler a conservative view was taken of the effect which uprating from 30 to 45 t/h would have on efficiency. The GCV efficiency was calculated to drop from 63 to 62%. In practice less fouling takes place than was anticipated with the result that nearly 2% more steam is generated per kg of bagasse even though it carries over 50% more load.

Pneumatic spreading of bark

After 30 years of operation the GCV efficiency of the power boiler burning bark at Usutu Pulp was found to have fallen

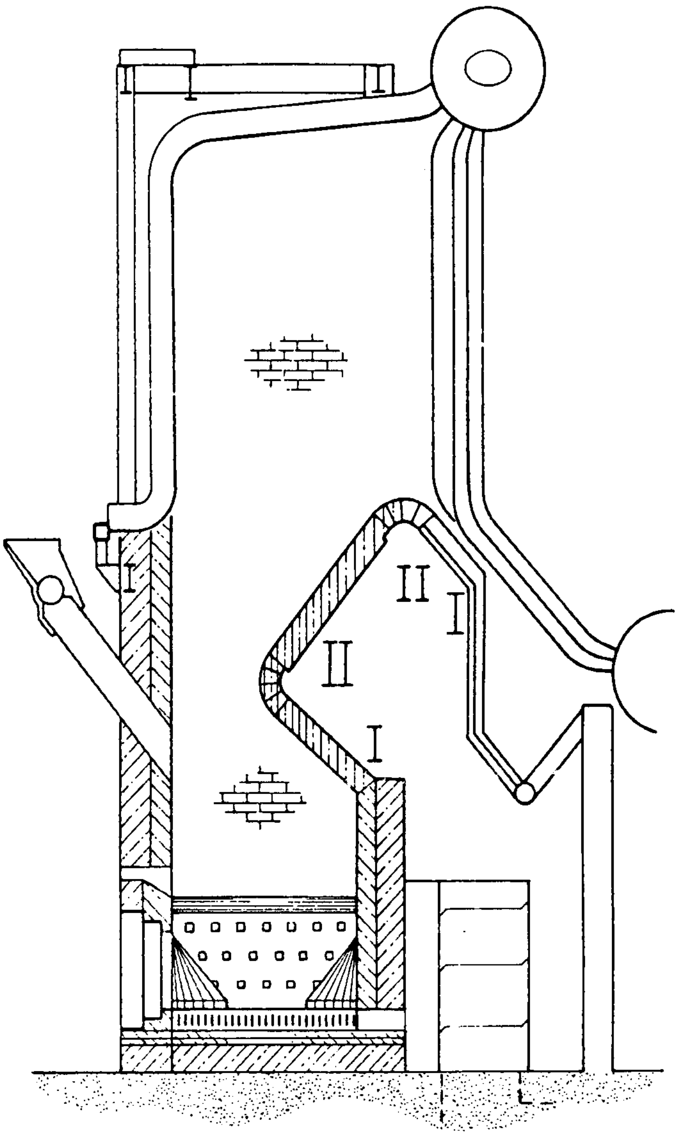

FIGURE 6 Hearth type furnace prior to conversion.

from 61,9% to 57,2%. Grate maintenance had become excessive and combustion control inadequate. Most of these problems stemmed from poor fuel and air distribution in the furnace resulting in pile burning.

Modifications to upgrade the plant were carried out in 1986. They involved:

- Fitting a new dump grate stoker
- Installing new fuel feeders and dual spreaders for bark and coal
- Improving the primary and secondary air control and distribution systems
- Upgrading the automatic combustion and steam pressure controls, and
- Re-arranging the heat recovery equipment by fitting a new airheater upstream of the economiser to increase undergrate air temperature.

After re-commissioning most of the bark was found to burn in suspension with only a small portion burning on the grate. Regular dumping of accumulated ash now prevents slagging and reduces grate maintenance.

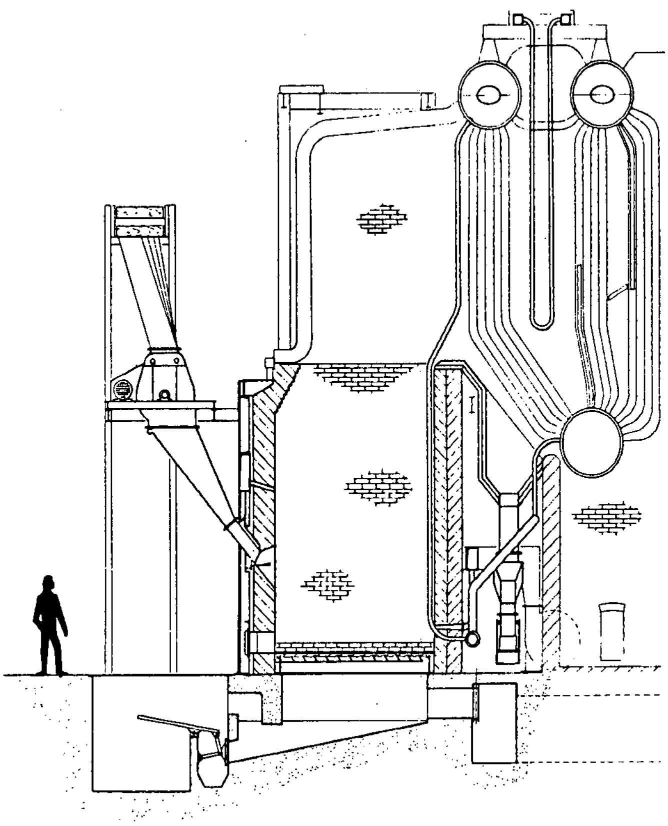

FIGURE 7 Modification of furnace with pneumatic spreading equipment.

The tall chutes supplied with the new bark feeders prevents tramp air entering the furnace. This together with the improved primary air system and the re-arrangement of secondary air nozzles allows the unit to operate at 15,7% as opposed to 10,8% CO_2.

Moving the airheater from downstream to upstream of the economiser has increased the undergrate air temperature by about 50°C. Fuel drying in the furnace is now more efficient which contributes significantly to minimising pile burning.

The coarse bark particles have ballistic characteristics somewhere between coal and bagasse.

Table 1 schedules the unit's original design characteristics, its performance immediately prior to being modified and its present performance. It is now producing 14,6% more steam per unit of fuel than it did previously.

Table 1

Performance of a Bark Fired Boiler retrofitted with pneumatic spreading equipment when burning 9 600 kg/h of 50% moist bark containing 2% ash

		Original design	Performance after 30 yrs operation	Performance after modifications
Evaporation	kg/h	20 440	18 890	21 650
Steam pressure	kPa(g)	4 270	4 270	4 270
Steam temperature	°C	430	430	435
Feedwater temperature	°C	140	126	140
Final gas temperature	°C	215	250	208
Final gas CO2	%	10,8	10,8	15,7
Undergrate air temp	°C	160	160	210
GCV efficiency	%	61,9	57,2	65,8
Fuel flow rate	kg/h	9 600	9 600	9 600

Conclusions

Pneumatic spreading of ballistically imcompatible fuels can be accommodated in one piece of machinery provided that distribution nozzles are correctly designed and secondary air is introduced in the right quantities, at the right pressure and in the right places. The success of the system has been demonstrated at Sezela.

Pneumatic spreading can also be used to increase the capacity and efficiency of boilers fitted with hearth type furnaces and of older units fitted with mechanical spreaders.

Acknowledgements

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APPENDIX 1

List of symbols

A - nozzle area (m^2)
D - mean distance of spread (m)
K - coefficient of discharge for the spreader (-)
Q - mass flow rate (kg/s)
a,b - linear regression constants for equation (1)
d - air density (kg/m^3)
p - spreader windbox pressure (Pa)