PULVERISED COAL FIRING OF SMALL BOILER PLANT

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Abstract

Pulverised coal firing of sugar mill boilers as an alternative to stoker firing is suggested. The broad advantages of pulverised coal firing are pointed out, with some reference to the economic type and size of mill to use. Reference is made to development of pulverised coal firing of a different type of boiler, and the facets of this development which may be applicable to sugar mill boilers, The coal handling scheme is described, together with the storage, conveying, feeders and burners. Special reference is made to the dust collectors, as these could be the key factor in deciding between a pulverised coal firing system as against any other system. Ceramic packed towers are described. There is a brief discussion of the boiler configurations applicable to pneumatic firing of coal and bagasse.

Introduction

The design of boilers for firing of coal and bagasse in the South African sugar industry has settled into the standard spreader stoker design configuration. Changing conditions, notably the stricter air pollution regulations, coal with a high proportion of duff, the larger boiler units, and the rising cost of labour, call for a closer look at firing system design.

The suggestion is made that pulverised coal firing allied with pneumatic firing of bagasse may prove an attractive alternative to the sugar industry.

Historical note

Pulverised firing is not new. The first pulverised coal fired power station in this country was Congella, built in the late 1930's. With the exception of one South West African station, ESCOM has installed only pulverised coal fired boilers for many years. In the industrial field the only notable pulverised coal fired boilers are the thirteen 159 ton/hour boilers at Sasol. For many years Sasol boilers were notorious for high dust emission until they installed electrostatic precipitators.

Current coal supply situation

A surprising sight recently was of the Railways ballasting a railway line on the Bluff, using duff coal as the ballasting material. With the closing down of the mills at Congella Power Station, the situation has been reached where all consumers of coal in Natal are clamouring for the same grade, at a time when the collieries are being pushed to their production limits for coal. Obviously the collieries are not in a position to dump the duff which arises from their mining and washing operations, and insist on shipping the fine coal to consumers, along with the nuts and peas. This results in acute handling problems, blinding of the grates and consequent clinkering.

Why pulverised coal firing?

The firing of coal in pulverised form offers great advantages. Once it has been pulverised, it becomes a homogeneous, controlled powder, which no longer has to be burnt in contact with cast iron grates. The burner resembles an oil burner, inasmuch as combustion takes place in suspension in a very short space of time. As the burner can be turned on and off at will, it is possible to apply the highly developed technology that has gone into oil burner automatic sequenced start up and supervision controls. The ash produced from pulverised coal firing is in a finely divided powder form, the greater portion of which is carried through to the dust collector and continuously discharged as a slurry in water. The furnace and the heat exchange surfaces for pulverised coal firing and for bagasse firing have very much the same requirements, inasmuch as the fuels are both abrasive to a certain degree and velocities through the banks have to be chosen high enough to prevent the settling out of dust particles, but low enough to prevent erosion of tubes.

Coal milling

Without entering into a detailed discussion of the intricacies of milling, the major problem at this stage of development relates to capital and operating costs versus throughput.

Pin mills and hammer mills of various designs are sold for small throughputs in the range of half a ton per hour upwards, but these units have very high maintenance costs associated with their operation, especially on the rather abrasive South African coal.

Ball or tube mills can be used for milling coal quite successfully, but they are not favoured because of high capital cost, high space requirements, and the long down time when grinding components have to be changed.

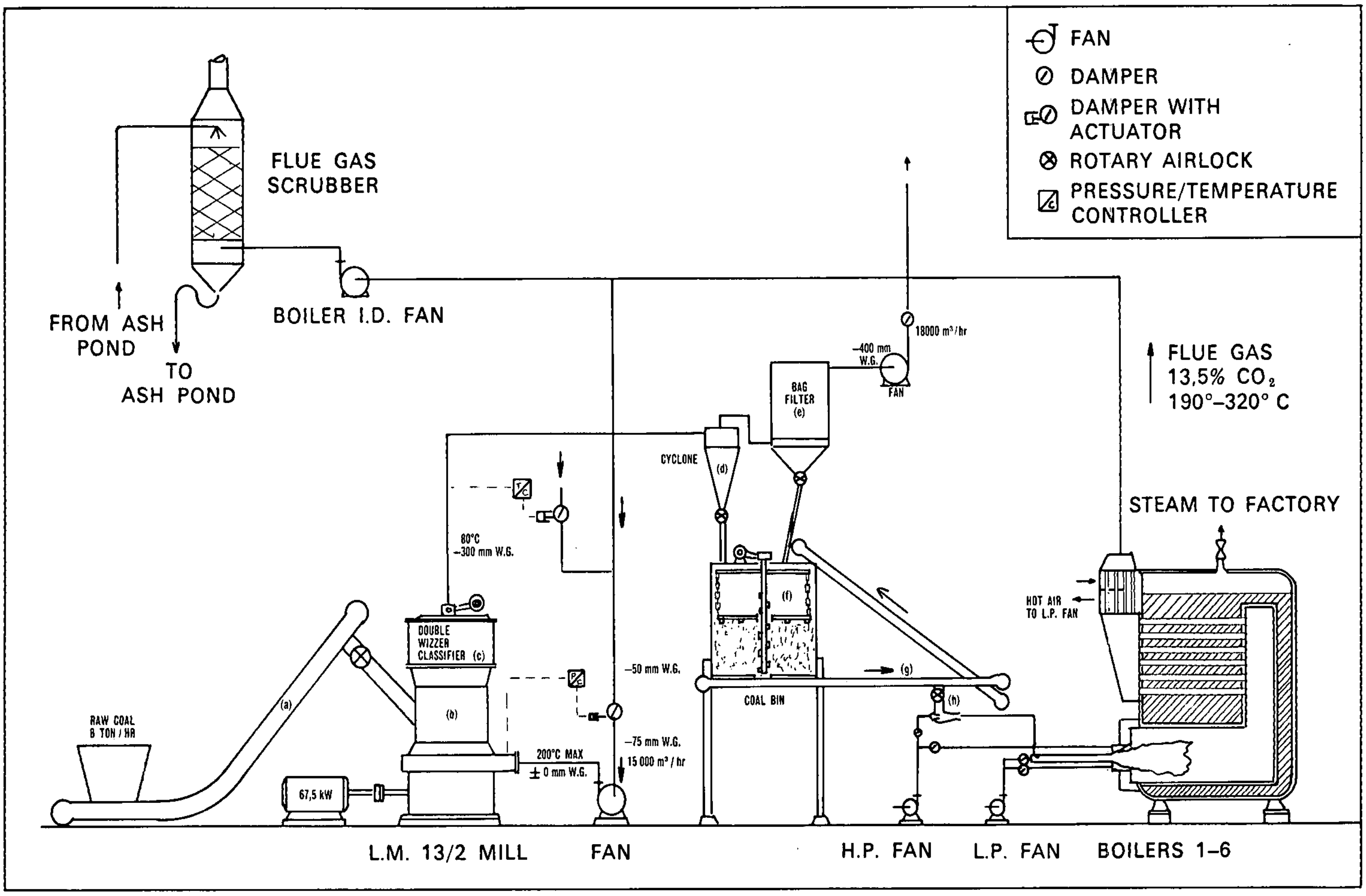
Roller mills are not a feasible proposition much below a 5 ton per hour capacity rate, which relates to a steam production of some 50 tons per hour. Milling component life can vary from 3 000 hours to 20 000 hours, and one make of hydraulically loaded mill is so equipped that rollers and grinding tables can be renewed in a single shift.

All the modern ESCOM stations use one of the roller mills available. The standard power station arrangement would be one where each burner is fed by a mill, the fuel requirements for the boiler being metered as unmilled coal being fed to each mill. The mill would be airswept by combustion air which carries pulverised coal to the burner.

Because of the strictures on mill size, it is suggested that this direct firing arrangement may only be economical for boilers of 150 tons per hour steaming rates and higher. For smaller boilers, in order to have the economy of a relatively large roller mill with low costs per ton milled, it is necessary to have a centralised mill feeding several burners and in this connection a concept of centralised milling with pulverised coal storage and transport systems has been developed.

Overall scheme

Reference to the flow diagram (Figure 1) illustrates the scheme. The raw coal is metered and elevated by the bucket elevator (*a*) to the coal mill (*b*). The mill is air swept, and the coal is discharged from the rollers into the classifier (*c*), where oversize material is returned to the mill and the finished product is transported to the cyclones (*d*) and the bag filter (*e*). The circulating air is drawn from a stack or furnace and enters the mill at a temperature of up to 200° C, so that the moisture content of the pulverised product is reduced to below 2%. This circulating air is monitored to keep the O_2 content below 9%, to reduce the explosion and fire danger.



A closed tank (*f*) is used to store the pulverised coal. It is removed from the tank by means of scraper conveyors (*g*), and fed to each feeder (*h*). The surplus coal not required by the feeder is recirculated back to the tank. Provision is made for the loading of road transport vehicles through scraper conveyors for re-sale to consumers in the fashion of oil deliveries.

Handling

The properties of the powder may be summarised as follows:

(1) Pulverised coal is easily fluidised by gas or mechanical agitation.

(2) The powder will alter from a free flowing powder to a compacted mass under pressure, from vibration, or just time.

(3) The powder will bridge across converging chutes, and across relatively large openings.

(4) When it is free flowing, it will leak through the smallest orifice or crack.

(5) When compacted, it can be cut back to a vertical wall.

(6) The powder acts as a lubricant to sliding surfaces.

(7) If packed in hygroscopic and porous containers (e.g. paper bags), spontaneous combustion may take place. This takes the form of a gradual heating up to glowing heat, which spreads slowly through the mass of coal.

(8) When packed in airtight containers (e.g. plastic bags or steel vessels), spontaneous combustion does not occur.

(9) The powder is not hygroscopic to any appreciable extent.

Basically, if the rules applicable to handling bagasse are followed, a perfect system results! Pneumatic transport has been avoided as the introduction of air leads to condensation and coagulation of coal, raises the danger of explosion, kindles any possible spontaneous combustion, and causes a dust problem.

Storage and conveyance

In the development totally sealed circular flat bottomed tanks have been used for the storage of the pulverised coal. The vessel is fitted with an agitator gear, designed so that a rake "floats" on the surface of the coal in the bin (like a bagasse recovery rake). The pulverised coal is kept agitated by flights on a central shaft, and the coal is withdrawn through an opening in the bin concentric with this shaft.

A scraper conveyor withdraws coal from the bottom of the bin, circulates coal past each feeder to keep the coal reservoir on the feeders full, and returns the surplus to the top of the bin.

Coal feeder

The success or failure of a pulverised coal system depends heavily on the feeder. A feeder was required which would meter out coal down to the rate of 50 kgh^{-1}, completely evenly and without choking. It was decided that it was not desirable to deliver the coal into the suction side of the primary air fan, mainly because of the subsequent wear on the fan, the fact that each feeder/burner requires a separate fan, and the long response time from feeder switchoff to coal stoppage at the burner.

A feeder was therefore required which would deliver the coal/air mixture at a pressure above atmospheric, at an even rate. Various types of feeders were tried, starting off with screw conveyors with non-return valves, pulse type feeders, and venturi meters. A conventional rotary valve was ruled out because of the air leakage which occurs past such a unit, and because of the blockage which occurs in the inevitable converging passage to the rotary valve.

The eventual feeder design decided on comprises an upper coal reservoir which has an egg beater type agitator in it to keep the coal fluidised. From this reservoir the coal drops through to a horizontal star wheel through about 5 to 15 degrees of the circle. This star wheel carries the coal through 180 degrees to the discharge port, where the coal is dropped through into a venturi chamber. This venturi chamber is fed with relatively high pressure air, which induces an air flow from above the star wheel into the venturi, and delivers the coal/air mixture out of the venturi at a pressure sufficient to supply the burner. The response time of such a feeder is approximately 0,1 s.

Burners

The burner operates on the principal of slowing down a coal/air mixture in such a manner that the coal remains evenly distributed through the air at the mouth of the burner. The velocity of the mixture at this point is equal to the speed of flame propagation, and ignition takes place here. A pilot gas flame is used for initial lightup. Some distance from the ignition point, high velocity air is introduced into the now ignited coal particles to cause turbulence and shake the individual particles free of the gas pockets of the initial products of combustion. Eddies at the flame edge introduce yet further air into the flame.

Dust collection

Until recently the telling argument against pulverised coal firing has been the question of dust emission, so this aspect requires examination.

Unfortunately, the strictures applied to industry in respect of air pollution have not been promulgated in absolute terms. The sugar industry has taken an extremely commendable lead, inasmuch that specific limits have been published as target figures. Being realistic it must be conceded that the efficiency of the cyclone-type dust collector is not sufficiently high to reduce the dust and grit emission from a normal spreader stoker coal fired boiler to these target limits on a long term basis.

Therefore, at this stage of development in the dust collector field the alternatives are wet scrubbing or electrostatic precipitators. Precipitators are ruled out because of high capital cost, complication of operation, and unsuitability for bagasse dust collection, leaving wet scrubbers.

A variety of wet scrubbers have been installed in Natal, and each unit has proved to be an extremely efficient dust collector. The overwhelming problem in each case has been the corrosion of the metal components.

Accordingly, a non metallic scrubber has been chosen for small boiler pulverised coal firing development, namely, the packed tower so frequently encountered in the chemical industry, with ceramic packings for the tower internals and acid resisting brick or concrete for the vessel itself. Water piping and pumps would be in plastic or rubber lined steel.

The ceramics have the major disadvantage of being prone to cracking, caused by thermal shock. This makes their use with stoker fired boilers doubtful, because of the possibility of the tower running dry while on load, and the water supply being reinstated while the packings are at flue gas temperature. If the fires could be turned off instantly in the case of water failure and overtemperature, the risk of cracking of the thermal packings would be minimised. Alternatively it could be arranged that water supply failure would cause the water supply to remain isolated until such time as the tower could be reduced to ambient temperature at the operator's convenience.

How efficient are packed towers as dust and grit removal devices? The collection potential of packed bed scrubbers is clearly indicated in the test results published by Eckert and Strigel[1] on a test sample of clay dust in an air stream (Table 1). In this case the scrubber was a cocurrent unit. The test tower was packed with a bed of 25 mm plastic interlock saddles, 914 mm deep. The gas rate was 25 000 kg m^{-2} h^{-1} of tower cross section, and the water rate was 4 630 kg m^{-2} h^{-1}. The overall pressure drop was 190 mm water gauge.

These test results can be used to predict a collection efficiency of 99% with a similar scrubber when applied to pulverised coal firing, where the proportion of the dust below 1 micron is likely to be less than 1 %. In order to achieve a dust emission level of 150 mg/Nm^3 from a pulverised coal fired installation, a scrubber would be required of approximately 96% collection efficiency.

It would therefore appear that it is more feasible to reach a 150/Nm^3 emission limit with pulverised coal firing than with stoker firing, because the facility with pulverised coal firing for rapidly turning the flame off allows a scrubber material to be used which would not be fully acceptable with the slower response stoker firing.

It is strongly recommended that a packed tower be tested on a bagasse fired boiler. There is no question of the efficiency that will be achieved, but the possibility of the larger bagasse particles becoming lodged in the bed should be checked by practical trials. The packed tower scrubber could prove to be an economical and efficient dust collector for application to general sugar mill firing.

Boiler configuration for pneumatic firing

The introduction of true pneumatic firing of bagasse in South Africa has not yet been seen. The argument against this

TABLE 1
Performance characteristics of cocurrent scrubber on clay with average particle sizes of 0,7 micron

Particle size	In			Out		
	Weight, g	No. of particles*	Sample weight,* g	Actual weight,† g	No. of particles	% of particles removed
10 micron and over	0,07	$2,8 \times 10^7$	0,00	0,00	0	100,0
5-10 micron	0,03	$2,8 \times 10^7$	0,00	0,00	0	100,0
2-5 micron	0,09	$8,4 \times 10^8$	0,03	0,0006	$5,6 \times 10^6$	99,3
1-2 micron	0,22	$2,6 \times 10^{10}$	0,14	0,0028	$3,3 \times 10^8$	98,7
0,5-1 micron	0,26	$2,46 \times 10^{11}$	0,40	0,0080	$7,58 \times 10^9$	97,0
0,25-0,5 micron	0,18	$1,37 \times 10^{12}$	0,28	0,0056	$4,31 \times 10^{10}$	96,9
0,10-0,25 micron	0,15	$1,12 \times 10^{13}$	0,15	0,0030	$2,24 \times 10^{11}$	98,0
				0,02		

* Number of particles = (Wt. %/25 = Vol.) / Particle Size^3. 1 g Sample assumed Spg. = 2,5.
† Overall Wt. % removal was 98. Wt. out = (Wt. % Out) (1,00 − 0,98).

has been that bagasse moisture contents are too high. Whilst this may be true, preheated air could be used as the conveying/primary air, in which case the bagasse would be reduced in moisture by roughly 2% for every 60° C of air preheat lost in the drying zone.

The boiler could therefore be fitted with two stages of air preheaters. The first stage would be a standard air preheater supplying undergrate or secondary air, while a further preheater would boost the temperature of the conveying/primary air as high as practical.

Should a pneumatic bagasse burner be feasible, allied to a pulverised coal burner, a vastly increased heat release on furnace plan area could be adopted. The total furnace volume cannot be changed materially because of limitations on heat release per area of radiant surface and furnace exit temperature, so the furnace now becomes a tall and narrow box. A striking example of what can be done is the C.E. boiler at Oahu Sugar, on the Hawaiian Islands. This boiler has a furnace some 6 metres square in plan, and 15 metres high, with a single pass tube bank. The output was eventually boosted to 160 ton/hour of steam by introducing pneumatic firing of bagasse and boosting the fans accordingly.

A feature of high heat release on furnace cross section is that there are very few gaps for misguided air to channel through without contacting the burning fuel, and it is very much easier to control the excess air. Combustion Engineering Inc. quote 10% improvement in excess air over stoker fired boilers.

By adopting pneumatic firing of both coal and bagasse, boilers with a far greater output can be built, and single boiler factories become feasible, with the attendant savings in capital cost and operators.

Conclusion

In this country it is usually expected that developments will originate in Europe or the United States. It must be appreciated that the position of coal in relation to oil in Southern Africa is unique in the developed world. Our price ratio between coal and oil warrants the burning of coal down to the smallest appliance in this country, whereas in Europe the difference, even today, is marginal, and coal firing is normally only warranted on a large scale such as the power stations. On the other hand, boiler manufacturers in this country are catering for a very diverse, erratic and competitive market, which swings from feast to famine year by year, and they do not have the resources or the finance available to sponsor any development in this field. It is therefore up to the sugar millers themselves and other organised groups of industry, to recognise the possibilities which are available, and directly or indirectly to sponsor such a development. There are various Government sponsored bodies which can undertake this type of work, but they will normally only do so if commissioned by some outside body.

Although South Africa is blessed with plentiful supplies of coal, its properties do not compare favourably with those of the coals found in Britain or in the United States and therefore special designs are required for its properties.

Acknowledgement

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REFERENCE

1. John S. Eckert and Ralph F. Stringle, Jr. (1974). Performance of Wet Scrubbers on Liquid and Solid Particulate Matter. Journal of the Air Pollution Association, October 1974, Volume 24, No. 10: 962-965.