PRESENT AND FUTURE TRENDS IN PLANT FOR STEAM GENERATION IN THE SUGAR INDUSTRY

G. S. Hall

ABSTRACT
A review of present day designs in use in many parts of the world illustrates the approach of the designer to the overall boiler plant. Some specific requirements to ensure a reliable solution at an economic cost are discussed. Reference is made to the present tendency for larger unit capacities and its likely extension in the future. An indication is given of the comparable cost differential between bagasse, coal, and oil as fuels for steam generation. The possible uses of bagasse as a raw material for the manufacture of both particle board and paper indicate that bagasse is not a waste product but a useful by-product of the sugar industry and has a real value as a raw material for other process industries.

INTRODUCTION
The steam requirements for a sugar estate depend to a large extent upon the products of the estate, the environmental conditions and the climatic and soil conditions in the area. Boilers, for instance, may only be used for providing the sugar mill with power and process steam. If, however, the mill is associated with a sugar refinery the steam requirement is considerably increased. Alternatively, the sugar mill boilers may be required to provide electric power to serve the local community and also the climatic and soil conditions in the area may be such that the cane can only be grown economically with irrigation and hence a further load is placed upon the sugar mill boilers.

The natural fuel for the steam boilers is bagasse, since it is readily available. However, the boiler load may not be restricted to the cane crushing season. Furthermore, the range of requirements is such that in some instances there is a surplus of bagasse and the boilers may be required to act partially as incinerators, and at the other extreme the natural fuel may be insufficient and a supplementary fuel may sometimes be necessary even during the crushing season.

It reflects, therefore, considerable credit on the ability of the boiler suppliers and the sugar mill boiler house staff that it is seldom that a serious loss in sugar production is directly attributable to the non-availability of steam. The robustness of the equipment and the efficiency of the boiler operators is emphasised by the fact that despite present day communication facilities material assistance is sometimes not immediately available.

Bagasse throughout the world is fairly consistent with regard to dry ash free analysis. The oxygen content is relatively high and as raw bagasse will contain between 45% and 55% of moisture by weight, the calorific value is low, as also is the combustion air requirement. Add to this the variability in fibre length, dependent upon the sugar mill machinery, i.e. the number of
FIGURE 1.
mills in tandem, the number of knife sets, and whether or not a shredder is used, and it can be seen that a considerable problem is faced by the furnace and combustion equipment designer to cater adequately for the fuel together with the higher ranking coal or oil supplementary fuel.

Ash content of bagasse rarely falls outside the range of 1.5% to 2.5% by weight, although on recent occasions the use of mechanical harvesting and carrying techniques, together with the occurrence of cyclonic weather conditions during the cane growing period has led to specifications for the bagasse to be burned with ash contents 3 or 4 times that to which we have been used. It is
not expected, however, that this will have any marked effect on present designs of boiler equipment, other than the obvious increase in ash quantity discharged from the bottom of the furnace and its subsequent handling.

METHOD

It is in fact the method of dealing with the furnace ash that has in many instances determined the combustion equipment. For instance, where manual
ashing can be tolerated then cells or cells with false floors, i.e. pile burning on a dumping grate, provide a simple and robust solution. Fig. 1 and Fig. 2, however, when continuous ashing is specified, moving grates are preferred, Fig. 3.

Supplementary fuel, especially coal, as in the case of South Africa, often restricts the choice of combustion equipment, and part suspension combustion, as instanced by rotogrates (Fig. 4) or dumping grates (Fig. 5) with the major portion of the combustion air introduced below the grate, offers an efficient solution.

The selection of combustion equipment for pile burning or part suspension burning is dependent upon several factors, for instance, steam capacity required, quantity, quality and cost of labour, permissible variation in steam production to allow for cell de-ashing, and the number of units in service.

Refractory cells with or without grates are limited in cross sectional plan area and many cells are necessary and advisable to maintain a continuous, although varying, steam output. The combustion air circulates through the refractory walls around and between the cells and enters through tuyeres arranged at varying levels throughout the height of the fuel pile. The disadvantages of this combustion equipment are high excess air and hence lower thermal efficiency,
inability to cater for rapid fluctuations in steam demand by reason of the large quantity of green fuel in the pile and inability to apply full automatic control to the fuel feed.

For part suspension combustion the fuel is fed down a chute to the air swept spout (Fig. 6). The air injected through the spout spreads the bagasse across the desired width of the grate and the height of the spout above the grate, together with the air pressure applied, governs the grate length that can be evenly covered with fuel. A rotating damper in the air supply cyclically varies the air pressure to the spout and hence ensures that the bagasse is evenly distributed over the length of the grate. Present combinations of spout height and pulsating air pressure can successfully cater for grate lengths up to 6.4 m. However, the air swept spout does not control the quantity of fuel fired, but only distributes it over the grate. A variable speed metering conveyor (Fig. 7), is used to control the flow of bagasse to the air swept spout and it is this feeder unit that can be automatically coupled to the boiler control to provide only sufficient fuel to the furnace to balance the steam requirement. However, to avoid duplication of feeding equipment to the furnace when coal is the supplementary fuel, a feeder using an electrically driven rotor adequately caters for spreading either fuel over grates up to 5 m in length (Fig. 8). In this instance
it is very important to increase the speed of grate travel when firing coal, owing to the higher ash content of the fuel.

Whilst most of the combustion air is admitted below the grate, some high pressure secondary air is necessary to contain the fuel close to the grate, provide added turbulence, and to assist in driving off the moisture and burning the volatile constituents in suspension.

The furnace shape and construction is determined by both the principle adopted for bagasse combustion and the type of supplementary fuel, if any. Should pile burning be used, the lower portion of the furnace is usually un-cooled and a refractory arch is provided to reflect as much heat as possible to the pile in order that the moisture in the fuel may adequately be evaporated without lowering the pile surface temperature below the spontaneous ignition temperature of the fixed carbon. The arch setting, however, is not required with
ITEM | DESCRIPTION
1 | FUEL INLET HOPPER
2 | FEEDER CONVEYOR DRIVE MOTOR
3 | SPEED VARIATOR
4 | REDUCTION GEAR
5 | DRIVING SHAFT
6 | IDLER SHAFT
7 | FEED ROLL DRIVE MOTOR
8 | FEED BELT AND PULLEYS
9 | FEED ROLL DRIVE SHAFT
10 | FEED ROLL
11 | FEED ROLL PINS
12 | FEED REGULATING PLATE
13 | CONVEYOR SPROCKETS
14 | CONVEYOR CHAIN
15 | SCRAPER BARS
16 | CONVEYOR BED PLATE
17 | BOTTOM COVER PLATE
18 | ACCESS OPENINGS

FIGURE 7.
part suspension firing since the moisture and volatile constituents are driven off or burned in suspension and the surface area of the fuel exposed to combustion air is very much larger.

To give broad guidelines to the furnace dimensions for bagasse firing, the plan area is determined by the grate rating and a figure of 3 000 000 to 3 500 000 W/m² of effective grate surface or a rating of 1 600 kg/m² hr of cell hearth area is representative of present day practice. The furnace length is limited by the maximum effective grate length for even distribution of the fuel. The furnace height is sufficient to ensure an adequate time for complete combustion of the fuel and to prevent carry over into the major heat absorbing,
and hence gas cooling, sections of the boiler plant, a measure of this height being given by the heat release rate per unit volume, a figure of 310,000 W/m³ being rarely exceeded. As mentioned above, with pile burning the lower portion of the furnace is refractory whilst the upper section contains water cooled walls. When combustion is by part suspension burning the furnace water cooling can be extended down to grate level. The tubes, however, are refractory covered close to the grate should the moisture content of the bagasse exceed 50%, or when coal forms the secondary fuel. Account must also be taken of the supplementary fuel in order that adequate gas cooling may take place in the furnace to prevent molten ash deposits or high metal temperatures in the superheater or screen at the furnace exit.

The bent tube drum type of boiler is eminently suitable for the absorption of heat by convection from combustion gases, as it offers a closely packed large heating surface mass with minimum cost and space. The surface can be arranged on unequal pitches alternately repeated along the length of the drums to facilitate the removal and replacement of tubes. The water circulation is very vigorous; however, the stream drum must contain efficient steam and water separating equipment, for example cyclones, to ensure long life to the superheater, particularly when dealing with fluctuating steam demands or production rates, as instanced by intermittent hearth or grate ashing. The bank may be arranged with single or multiple gas passes, the passes being either vertical or horizontal. The bi-drum boiler is the most common, but boilers with 3 or 4 drums are often preferred in the Carribbean area.

The superheater is arranged with vertical tubes interposed between the furnace screen and the main boiler sections. To provide a sufficiently large superheater cavity in bi-drum units when a high degree of superheat is required, the furnace rear wall is brought forward in the top portion of the furnace. This has the additional advantage of mixing the gases leaving the furnace, and creating an area of increased turbulence to ensure complete combustion of fuel. The superheater may have its manifolds above the roof of the superheater, i.e. pendant loops, or below the cavity floor, enabling the superheater to be self-draining. The pendant type of superheater is normally preferred as it eliminates a possible cause for build up of ash on the sloping superheater cavity floor.

It is now usual to provide a tubular airheater, gas through the tubes, after the boiler surface to gain the advantage of hot combustion air for the furnace, and to increase the thermal efficiency of the unit. However, it is prudent to restrict the combustion air temperature to a maximum of 220°C to prevent overheating of the combustion grates and an airheater air bypass is frequently fitted to provide this control. Economisers are not often used as the only heat trap, but in addition to the airheater for increased thermal efficiency.

To ensure the cleanliness of the boiler unit hoppers are provided at points of low gas velocity or change of direction, where there is a likelihood of any carryover settling out from the gas stream. A low efficiency, low draught loss grit collector is also provided to prevent erosion of the induced draught fan and to restrict the stack emission. Due to concern about air pollution, it is necessary in some areas at present, and will become universally necessary in future, for more efficient gas cleaning to be provided. Of the proven methods
available for meeting the low outlet dust burden it is suggested that the wet
venturi scrubber is the one with the most promise in the sugar industry.

THE FUTURE

The equipment and design considerations given above have met with
considerable success until now but how will they cater for the future? The
average unit steam capacity, other than for Australia, is presently around 60
to 70 t/h and this can reasonably be expected to increase to 110 to 135 t/h
and more, especially when an irrigation load has to be carried. The cost of
labour is increasing throughout the world and therefore it is to be expected
that continuous mechanical ashing equipment and fully automatic fuel feeding
will become standard requirements.

The above requirements cannot be met with pile burning and it is con-
fidently expected that part suspension burning, with power operated dumping
grates or rotogrates, set beneath fully water cooled furnaces and working in
association with bi-drum boilers, economisers and airheaters under balanced
draught conditions will form the standard equipment.

In this respect it is interesting to note that an Australian company
has on order a bagasse fired unit for an evaporation in excess of 200 t/h.
This unit utilises a twin rotograte with a combined width of 9.75 m and
driven from both sides; the length measured between the shaft centres is
6.9 m. The bagasse is fed to the furnace by metering conveyors through seven
air swept spouts located some 3 m above the grate to distribute the fuel evenly
over the whole surface area. The furnace height required to provide an ade-
quate volume enables oil burners, for 50% load, to be located in the rear wall
below the boiler water drum. It is interesting to note that provision is made
for possible future coal firing on the grate, and thus complete flexibility in
fuel supply is available. The installation is designed for a high thermal efficiency
when firing bagasse alone (71% gross efficiency based on the gross calorific
value of 10 470 kJ/kg).

This unit therefore enables a comparison to be made of the relative value
of the individual fuels and for an equal fuel cost the price per ton of bagasse
(50% moist): bituminous coal (13.6% ash): oil fuel would require to be in
the following ratio 1 : 3.75 : 6. However, this is not a complete comparison
since the capital cost of the boiler house equipment would be considerably
altered should the plant be designed for oil as the only fuel, and also the
relative cost of disposing of the ash would have to be taken into account. Both
the above are greatly to the advantage of the oil fired boiler but less so for
the coal fired unit.

What is the value of bagasse? It may be useful to measure this by looking
at the alternative uses to which it can be put. For instance, bagasse can be
used as a raw material for the manufacture of particle board and also for the
paper industry and it is suggested that in future there could be a tendency
for progressively less bagasse to be fired under sugar mill boilers.

When considering particle board or paper manufacture the crushed bagasse
from the sugar mill requires pre-treatment to separate the pith from the outer
fibres of the cane. Both wet and dry processes are available for de-pithing the
bagasse and a combination of both lead to the greatest efficiency. The pith
is a waste material in the process and becomes available as a fuel to replace
the bagasse in the sugar mill boilers.

The elemental analysis of pith is very similar to that of bagasse but the sizing is finer. There are several sugar mills throughout the world that burn pith in varying proportions with bagasse, but little if any experience is available over a long term of burning pith alone in a steam boiler setting. From the available information it is the variable moisture content, up to 56% in the fuel, that impairs the ability to generate a constant steam quantity in an efficient trouble-free manner. Whilst, therefore, combustion equipment in the form of cells or spreader stokers in furnaces designed essentially for bagasse firing have been shown capable of successfully burning mixtures of bagasse and pith, it is expected that a more generous furnace volume would be necessary to reduce the carryover of this material. It is possible that full suspension firing, as used for pulverised coal or brown coal, may offer the best solution. However, with such a high moisture in the pith, pre-drying using recycled furnace gas would be necessary. Should pith become a major fuel for sugar mills, then considerable development effort is necessary to ensure that a safe, successful and reliable solution is reached. The density and calorific value are such that meaningful testing should preferably be carried out where the pith is in plentiful supply, and the company with which I am associated would welcome an opportunity to co-operate in this development work.

CONCLUSION

It has been shown at previous ISSCT congresses that bagasse is a very desirable raw material from which the whole range of low density to high density particle boards can be manufactured, and that the cost of depithing bagasse is no greater than the chipping of wood as a preparation for board manufacture. Also it has been shown that paper made from bagasse pulp has comparable qualities to those manufactured from other vegetable materials. A value can therefore be put to bagasse and the comparison given earlier in the paper may prove to be more favourable to the use of coal or oil, together with pith, as the fuels of the future for sugar mill boilers.

PRESENTES Y FUTURAS TENDENCIAS EN PLANTAS DE GENERACION DE VAPOR EN LA INDUSTRIA AZUCARERA

G. S. Hall

RESUMEN

Una revisión de los diseños utilizados actualmente en muchas partes del mundo indica la tendencia del diseñador a considerar en conjunto la planta de vapor.

Se discute en detalle sobre algunos requisitos para asegurar una solución real a costos económicos. Se hace referencia a la tendencia actual de dar mayor capacidad unitaria y a su posible crecimiento futuro.

Se hace una comparación de costos entre bagazo, carbón y aceite como combustibles para generación de vapor. Los posibles usos del bagazo como materia prima para la manufactura tanto de tableros de conglomerado como de papel muestran que el bagazo no es un desperdicio, sino un sub-producto muy útil de la industria azucarera y tiene un valor real como materia prima para otros procesos industriales.