"Bagasse" is the term applied to the waste fibres of sugar cane, after the sugar juices have been extracted in the mills. It consists of fibre and water, plus a certain amount of sugar juices. The amount of fibre and moisture varies considerably, being largely influenced by the nature of the soil, type of cane, and the sugar juice left over after milling depends upon the efficiency of the milling process. This waste product has a fairly high calorific value, and is used for firing the boilers that supply steam to the mill.

In a sugar mill the steam consumption is fairly high, for, apart from the actual milling for extracting the juices from the cane, the remainder of the work of the mill almost entirely depends upon the use of steam for the various processes. In some sugar mills the steam consumption is in the vicinity of 30,000 lbs. per hour, but in larger mills it would be as high as 100,000 lbs. per hour.

The cost of extraneous fuel, such as wood or coal, is usually high owing to transportation costs, so that the question of obtaining the whole output from the boilers, with bagasse as fuel, without the use of extraneous fuel, is one which receives mill managements' close attention. Bagasse is available free of cost, and if it were not possible to use it as fuel, it would have to be disposed of by some means, and the cost of disposal could easily amount to some shillings per ton, so that it stands to reason that if this bagasse can be used to maintain the steam services in the mill, a supply of cheap steam is assured.

In the case of some mills, it is impossible to maintain the steam services without the use of extraneous fuel, but it is always the aim to keep such consumption as low as possible; for, the lower the consumption of wood or coal, the greater is the economy, provided, of course, that the steam services in the mill are maintained. It is not so long since all sugar mills, including mills in other parts of the world, as well as in Australia, were compelled to augment the supply of bagasse with wood or coal to enable the mill to carry on; but, since the advent of the vertical tube type of watertube boiler in sugar mills, and improvements in furnace design that have followed the installation of this type of watertube boiler, some mills have been able to obtain their total steam requirements from
Bagasse, and others who have equipped their old-fashioned boilers with modern furnaces, have been able to cut down the consumption of extraneous fuel to a very appreciable extent. With increased furnace efficiency, and with some provision for pre-drying the fuel before it is fed into the furnace, it would appear as though the time is now not far distant when a surplus of bagasse will be achieved. This surplus could be used for various purposes, as instanced by the manufacture of insulating boards, known as "Cellotex," from bagasse fibres.

The use of pre-heated air, and forced draught, have also greatly enhanced the prospect of having excess bagasse available. The development of the bagasse furnace and boiler settings has been going on over a number of years, always with the idea of reducing the cost of steam, and the result has been reflected by at least doubling the efficiency of the bagasse fired boiler. With the old-fashioned plant it was considered quite satisfactory if a boiler gave an efficiency of 40%, and very often mills would run for long periods at a lower efficiency than this. The carbon dioxide in the flue gas with such a plant would be anywhere between 4% and 6%. As a result of improvement in design of furnace, and improved boiler settings the efficiency of bagasse fired boilers has been increased to well over 70%. Some consulting engineers calling tenders for steam-raising plants for sugar mills, have insisted upon a guaranteed efficiency for the boiler of 76%, and have laid down very stringent penalties for each 1% short of the required 76%, and at the same time no provision is made for bonuses for exceeding the required efficiency.

A few years ago it would have been absolutely impossible to get anywhere near this degree of efficiency with the boiler settings, and types of furnaces employed for burning the bagasse. To begin with, the underfired type of boiler was extensively used for sugar mill work. This boiler was fired in much the same way as we see them fired nowadays, with woodshavings and sawdust at sawmills. No special attention was given to the design of the furnace or boiler setting. The bagasse was simply thrown on to the firebars, and burnt so long as it was available. When there was insufficient bagasse, logs of wood were used or alternatively coal, to maintain the steam output. Owing to the moisture, and the nature of the fuel, it was absolutely impossible to keep up an even rate of combustion. With a good charge of wet fuel the fires would almost be extinguished, whilst on the other hand, the fuel would gradually dry by the moisture being driven off, and combustion rates would jump from practically nil to as high as 60 or 70 lbs. per square foot of grate area or even higher, according to the
draught. The difficulty of maintaining a constant steam supply at a regular pressure under these conditions can readily be visualised. When the green bagasse was thrown on to the grate, the whole furnace would be cooled down, the walls would be almost black; but gradually the moisture would be driven off, the furnace conditions would rise to a normal heat liberation, only to be retarded once again when fresh bagasse was fed in. This went on continually, and periodical boosting of the boiler by using wood or coal was absolutely imperative. The alternative to this was to fire mixed proportions of bagasse and extraneous fuel in an endeavour to maintain even furnace conditions and a regular steam pressure and output. The evaporation of the boilers fired under the conditions outlined above would be somewhere in the vicinity of 1.75 lbs. of steam per square foot of heating surface per hour, and the efficiency would be anything from 30% to 40%. Then the Dutch oven form of furnace was developed. With this furnace the boiler setting was extended to provide a furnace chamber, wherein combustion could take place without exposure to the cold surface of the boiler. This was a step in the right direction, and the results obtained were an improvement on those obtained from boilers not fitted with the Dutch oven.

The bagasse fuel is fed into the Dutch oven through openings in the top. Auxiliary fire doors are provided in the front wall of the furnace, through which coal or logs could be fed in, when extraneous fuel is required. Bagasse entering from the top of the furnace forms a series of pyramids on the fire bars, consequently the fire is generally irregular and patchy. There would be dense quantities of fuel in some places on the grate, through which no air could penetrate, whereas in other parts of the grate there would be only a small amount of fuel through which a very high percentage of the draught from the stack would be concentrated. Under these conditions the fire would develop large holes, and the carbon dioxide would be somewhere about 6% or 7%; and the loss due to flying particles of unburnt fuel would be sometimes as high as 16% or 18%. To help to bring about even distribution of air through the fuel bed, the pyramid grate was developed for use in the Dutch oven type of furnace. The fuel was still fed into the furnace from the top, and took up its natural angle of repose in the form of a pyramid; but the provision of a pyramid grate meant that the pyramid of fuel was hollow, and the draught through the fuel bed would be fairly evenly distributed.

Another development made possible with the Dutch oven furnace was the stepped type grate, and experience shows that the stepped type of grate with the proper setting is the best
form of furnace construction for dealing with bagasse having a high moisture content. With the stepped grate, the fuel is fed from the top of the furnace as before, or it could be fed into the furnace through a series of doors in the furnace above the grate dead plate. Generally speaking, when the fuel is fed into the furnace through the roof, the fuel is delivered by means of a conveyor, but when firing takes place through the doors at the front of the furnace, this is carried out by hand. The stepped grate consists of a series of horizontal fire bars, arranged to form steps; hence the name of "stepped" grate. The pitch of these horizontal bars is approximately 4 in., and the angle at which the grate is inclined from the horizontal is varied according to the nature of the fuel. With bagasse containing approximately 50% moisture, it has been found that the best angle for the gate is 55 degrees from the horizontal. Grates, however, are fitted with an adjustable device, which enables the angle of the grate to be adjusted to meet requirements. A stepped grate is usually provided with a dead plate area, equalling the active burning area of the stepped grate, and a horizontal grate is provided at the foot of the stepped grate, on which combustion is completed. The horizontal burning off section of the grate is fitted with sliding bars. These can be withdrawn to enable the fire to be cleaned. A reverse arch is often provided in conjunction with the stepped grate, to give a retort effect. This arrangement assists combustion by driving off moisture, and promoting early ignition when the fuel reaches the active area of the stepped grate.

With the development of the stepped grate, there was also a trend towards increasing the length of the gas travel before the gases pass over the boiler heating surface. The first Dutch ovens were extended about 5 ft. 6 in. in front of the boiler setting, whereas the more modern Dutch oven form of furnace construction extends to 20 ft. and even 25 ft. in front of the boiler setting proper. One result of this longer gas travel has been a very marked reduction in the quantity of unburnt fuel passing through the boiler. Prior to the adoption of the longer gas travel, the country for a considerable distance from the mill, and in the direction covered by the prevailing winds, was covered with ashes and particles of unburnt bagasse, soot, etc., which created considerable nuisance. With the more modern boiler settings, and more efficient combustion, this nuisance has been practically eliminated, and loss by way of flying particles is for all practical purposes negligible. Incidentally, it is not to be assumed that the long gas travel alone would prevent the scouring of particles of fuel and soot, etc. In addition to the long gas travel, the velocity of the gases must
be such as to allow these particles of fuel to fall out of suspen-
sion; and beyond the furnace proper, and before the boiler
heating surface, there should be a combustion chamber of
sufficient volume to enable complete combustion to take place,
and where the particles of ash and soot can be left behind, so
that the gases passing over the boiler surface are comparatively
clean.

The arch of the Dutch oven has gone through some changes
during the development of this furnace from its early stage to
its present form. The first Dutch ovens had a simple hori-
zontal sprung arch; the gases travelled along this, and turned
at its end to the first boiler passes. Then a Drop Nose type of
arch was tried. This arch slopes downwards to the end next to
furnace, the slope being about 15 degrees from the horizontal.
The end of this arch terminates with a vertical drop of about
12 in., the object of which is to give the gases a downwards
sweep before they turn to meet the boiler heating surface.
The latest form of arch is the flat suspended type. This arch
is usually 15 ft. to 20 ft. above the grate, and over the combustion
chamber proper the arch is horizontal, sloping downwards from
about 2 ft. nearer the boiler setting than the end of the grate;
the arch taking a downward sweep. The angle of this incline
being about 30 degrees to 40 degrees from the horizontal. This
is continued down to the nose of the arch, which is located only
a few feet above the firing floor level. The nose of the arch
is practically on the centre line of the mud drum of the vertical
tube type of watertube boiler. The result of this sloping arch
ensures that the gases pass over the whole of the heating sur-
face in the first bank of tubes; and as the first 30% of the
boiler heating surface performs 90% of the work done by the
boiler, the advantages of having this heating surface brought
into intimate contact with the hot gases of the combustion
chamber is at once apparent.

A form of furnace developed overseas is the “Pot” type, or
“Cook” furnace as it is called, which is suitable in some cases
where forced draught is used for the combustion of bagasse.
This furnace is constructed in a horseshoe shape, and made in a
number of cells, according to the width of the boiler. The
average size of a “Pot” furnace is about 5 ft. wide by 7 ft.
from front to rear. The curved walls are hollow, and are
pierced with tuyeres, so that the hollow walls which serve as
air ducts discharge air into the furnace through the tuyeres
provided in the walls for this purpose. There are no fire bars
used in the construction of this grate, the hearth is simply a
dead area, usually constructed of fire bricks, all of the air
required for combustion being blown in through the tuyeres.
With this form of grate high rates of combustion and furnace efficiency can be maintained. During the last few years there has been a trend towards this form of furnace construction in Queensland. It is also adopted in Fiji, Cuba, Java, and elsewhere; but so far as we are able to ascertain, this form of furnace has not found favour in India, where they are inclined to adhere to the orthodox stepped grate. It would appear from results that have been obtained in Queensland, that the best form of grate for burning bagasse is a combination of the stepped grate and the Cook furnace. With this combination the characteristics of the Cook grate are incorporated in the furnace side walls, and in the bridge wall, which are hollow, to provide a wind box through which forced draught could be blown through the tuyeres into the fuel bed—also over the fuel bed, when over-fire air is required. Two zones are provided for the forced draught, each with its own separate control, which enables a better control of combustion to be obtained. It is quite obvious that a higher pressure is required for the air close to the floor of the furnace than is required adjacent to the incandescent zone of the fuel bed. The forced draught is also admitted in the chamber below the stepped grate, and is blown through the fuel on the grate into the combustion chamber.

A boiler recently installed by Messrs. Mossman Sugar Mill, North Queensland, incorporates most of the recent developments for a bagasse fired boiler, and some detail of this particular boiler unit, and its accessories, will afford an insight into a typical modern sugar mill boiler unit.

The boiler is a vertical tube type of watertube boiler, containing 6045 square feet heating surface, designed for a normal working pressure of 200 lbs per square inch. The equipment comprises forced and induced draught fan, plate type air preheater, step-cum-Cook grate, and automatic bagasse feeders. The furnace on the Mossman grate extends 20 ft. in front of the boiler setting proper. It is fitted with a flat suspended arch, with an inclined nose. The angle of the incline is 35 degrees from the horizontal. The height of the horizontal portion of the furnace arch is approximately 16 ft. above the grate. The stepped grate is inclined at 53 degrees from the horizontal. It is divided into two zones, the upper zone which is a dead plate or drying zone contains 60 square feet, and the lower zone or active burning area of the stepped grate contains 60 square feet also. In addition, there is a lower horizontal grate area, constructed of movable fire bars, which contains 48 square feet grate area; making a total of 108 square feet of active grate area, as grate areas are usually considered.
There is, however, an additional combustion capacity, which is provided by a series of tuyeres in the bridge wall, and along the side walls of the furnace. These tuyeres commence at the level of the horizontal grate, and finish at a point 6 feet above the hearth. The forced draught is admitted into the furnace through these tuyeres in the side and bridge walls, and also into the furnace from the wind box below the inclined stepped grate; so, strictly speaking, a portion of the side walls, and a portion of the bridge wall, should be considered as active grate area. The bridge wall is oversailed at the top, and is inclined back towards the stepped grate. This provides a retort-like effect, with the idea of permitting early combustion of the fuel. Preheated air for combustion is delivered into the furnace by the forced draught fan, and reaches the furnace at a temperature of approximately 400 degrees F.

On the Mossman boiler a definite attempt was made to pre-dry the bagasse by bringing it into contact with hot gases from the furnace. Along the top of the furnace, arranged in close proximity to the automatic bagasse feeders, a series of ducts were arranged. These ducts were connected to the first boiler pass, and each one was fitted with a damper. As the draught in the boiler pass is slightly higher than in the furnace, this enables a flow of hot gases from the furnace to pass through these ducts, consequently a good proportion of the moisture from the fuel is drawn off before it reaches the furnace. This arrangement does not, of course, affect the heat loss incidental to the moisture content of the fuel. What it does is to increase combustion rates and combustion efficiency by giving higher furnace temperature; and it increases the steaming capacity of the boiler unit.

With wet fuel, containing up to 50% and more of moisture, combustion rates are limited, and notwithstanding special care being given to furnace design and exposure to cold surface, etc., it is possible to suspend combustion entirely by delivering too much wet fuel into the furnace.

The Mossman boiler contains 6045 square feet heating surface, and is fitted with an air heater of the plate type, containing 5500 square feet heating surface approximately, so that the heating surface of the preheater is almost equal to that of the boiler itself. The gases enter the preheater at approximately 650 degrees F., and are reduced to 400 degrees F. at the outlet. The specific heat of the flue gas with 15.3% carbon dioxide at the damper, and with 50% of moisture in the fuel is 0.28 B.T.U.'s per lb, per degree F., so that in reducing the temperature of these gases from 650 degrees F. to 400 degrees F., the
BAGASSE FIRED BOILERS.

The temperature of the air will be increased by 370 degrees F. If the initial temperature of the air is 90 degrees F., the temperature leaving the preheater is 460 degrees F., allowing 60 degrees F. for radiation losses between the air heater exit and the furnace.

The thickness of the fuel bed is controlled on the Mossman boiler by automatic bagasse feeders. Three of these feeders are provided, the bagasse being delivered to them by means of a conveyor. By means of automatic control for the fuel, furnace conditions are kept fairly even, and there are none of the violent fluctuations that are usually experienced when large quantities of bagasse are discharged at irregular intervals into the furnace. The Mossman boiler can evaporate up to 6 lbs. of steam per square foot of heating surface, which is a higher rate of evaporation than is usually obtained from some water-tube boilers that are fired with best quality coal; which goes to prove that given proper furnace conditions and boiler setting, an inferior grade of fuel can be turned to good advantage.

The type of air heater favoured for sugar mill work is the sectional plate type, although the regenerative and tubular types of preheaters have been installed and operated with reasonable success in some mills. The plate type heater is constructed usually of mild steel plates 14 gauge in thickness. The heater is usually arranged for two passes on the gas side, and one or two passes on the air side. The gas and the air streams should be split up into narrow strips, so as to reduce the hydraulic depths to a point where a maximum flow of heat from the hot coal side can be obtained. The gas streams should be about \( \frac{3}{4} \) in. thick, and the air streams should be about \( \frac{1}{2} \) in. thick. These depths provide for a reasonable hydraulic depth, and if the velocity of the gas and air is maintained somewhere about 30 ft. per second, satisfactory results should be obtained, without the passages becoming fouled with deposits of soot and other matters from the gases. The air heater should be provided with an arrangement of dampers to provide easy method of bye-passing the heater with the gases, while the boiler is being cleaned with the soot blowers or soot lance. When the gases are carrying a large amount of impurities, such as removed by the soot blowers, they should be delivered direct to the stack without passing through the heater.

It has been found that preheaters working with bagasse fired boilers are subject to corrosion, if precaution is not taken to ensure that no condensation can take place on the heater plates. To prevent condensation the air from the forced draught fan should always be delivered to the heater at a temperature of
170 degrees F. or more. This increase in temperature of the air can be obtained by recirculation, that is, the forced draught fan draws off sufficient air from the preheater to increase the temperature of the air drawn from the atmosphere by the desired amount. Supposing the forced draught fan has to supply 2200 lbs. of air per minute for the furnace, the temperature of the atmosphere being 90 degrees F. To increase the temperature of this air to 170 degrees F. approximately 41,000 B.T.U.'s would be required. To obtain this heat, the forced draught fan would have to draw off from the hot side of the preheater 773 lbs. of air per minute at a temperature of 400 degrees F. This can be done by means of a small duct connecting the hot air outlet of the preheater to the forced draught fan. A damper should be incorporated in this duct, and the amount of hot air drawn off for recirculation should be varied to suit conditions. If the atmospheric temperature rises, less hot air is required of course, and vice versa.

The temperature gradient across the plates of the air heater will allow condensation of the wet gases to take place when recirculation is not employed. Flue gas is a poor vehicle for heat, and in the cooler zones of an air preheater, where recirculation is not provided, the plates in contact with the gases would have a temperature only a few degrees above the temperature of the air. If the temperature of the air is 90 degrees F., the temperature of the plates on the gas side would be a few degrees above this, probably 95 degrees F. or 96 degrees F. This would permit condensation, as there would be a film of gas in contact with the plate, at approximately the same temperature as the plate. Therefore condensation is bound to occur, and this will be accompanied by corrosion, and the plates would be eaten through in a few hours.

The preheater is usually arranged above the main flue, between the boiler and the stack. When the air heater is in service, the gases rise up through the elements in one half of the unit, into a turning duct at the top, and flow downward through the second half of the unit back into the flue. A damper is provided in the upward path, and also in the downward path, between the air heater and the flue. A third damper is provided in the flue between these two points, so that by closing the flue damper and opening the other two dampers, the gases pass through the air heater on their way to the stack. Alternatively, by closing the dampers in the inlet and outlet to the preheater, and by opening the damper in the flue, the gases are delivered straight to the stack, and bye-pass the air heater. The air side of the heater is sometimes provided with a single pass, and with this arrangement the forced draught fan is
Bagasse Fired Boilers.

Supported on the heater structure, and blows straight through the preheater in a contra flow to the gas. Some heaters have two passes on the air side, as well as two passes for the gas; and with this type the air flow is transverse to the gas flow. The fan discharges into the heater at one side, and the first pass is across the elements of one half of the heater to a turning duct on the opposite side to the fan. From the turning duct the air returns back through the other half of the heater into the hot air discharge duct, which connects up to the main duct leading away to the furnace. It is from this hot air discharge duct that the air for recirculation is usually taken, in those cases where recirculation is employed. The main hot air duct between the heater and the furnace is usually constructed in concrete below the firing floor level, and is cast along with the concrete foundations for the boiler.

The draught loss across the preheater varies considerably. On the air side it might be anything from .5 in. water gauge to 1.25 in. water gauge, and on the gas side it might vary between .3 in. water gauge and 1 in. water gauge. The draught loss depends upon the velocity of the gases or air, the arrangement of the various passes, and the areas subject to friction, etc.

The air preheater has undoubtedly contributed very materially to the improved results now being obtained from bagasse fired boilers. It can increase the efficiency of the boiler unit by anything up to 15% by recovering up to 60% of the heat from the waste gases.

The automatic bagasse feeder has also played a big part in the advance of the bagasse fired boiler. With it, it has been possible to obtain regular furnace conditions by controlling the admission of the fuel into the furnace, and regulating this in terms of the ability of the grate to handle the fuel; that is to say, if the grate is capable of burning 150 lbs. of fuel per square foot per hour, the automatic bagasse feeders will feed just this amount into the furnace, the rate of feed being controlled within fairly fine limits.

There are various forms of bagasse feeders, and they are all more or less effective in their application. The feeder consists of a mild steel housing, about 2 ft. long, in which is arranged a rotating paddle with six blades. These blades extend for the whole length of the drum or housing, and are a fairly close fit to the inner diameter. The bagasse enters the drums through an opening in the top, and leaves through an opening in the bottom. Both of these openings extend to the full length of the drum, so that the incoming bagasse falls on to the paddle between the vanes, and the rotating paddle carries the bagasse
around, and it drops out through the opening in the bottom of the paddle chamber, which might be termed a bagasse valve, into the furnace. The paddle is rotated by means of a ratchet and pawl. The pawl is carried on a bell-crank lever, one arm of which is oscillated by means of a connecting rod. The other end of the connecting rod is fitted to an extension of what is known as a “feel” rod. The feel rod is a pivoted member, one end of which passes into the combustion chamber, and rests upon the blanket of bagasse on the dead plate. The rod is pivoted at a point about 4 in. in front of the furnace door, so that it is free to move up and down in a vertical direction. A crank shaft is arranged on the furnace front wall a foot or so above the pivot of the feel rod, and by means of a connecting rod between the crank shaft and the extension of the feel rod the feel rod can be oscillated up and down, which motion is transmitted to the arm carrying the pawl, which in turn rotates the drum, and feeds bagasse into the furnace. The connecting rod between the crank shaft and the feel rod terminates with a slot, the length of which is equal to the travel of the rod. In this slot is fitted a pin attached to the extension of the feel rod, so that when the crank connecting rod is oscillated it can pull the end of the feel rod, or alternatively it could push the feel rod in one direction, but it cannot both push and pull, owing to the slot. Therefore, if there is a thick blanket of bagasse on the grate, the feel rod will be lifted by the thickness of this bagasse, so that when the crank shaft rotates the connecting rod simply idles up and down by means of the slot and pin arrangement, and does not oscillate the feel rod. If the thickness of the blanket of bagasse on the grate is reduced by half, the connecting rod will idle for half a stroke and push the feel rod half a stroke. This will cause an engagement of so many teeth on the ratchet driving the bagasse feeder, and so cause bagasse to be fed into the furnace. Should there be a sudden cascade of fuel down the grate, causing the feel rod to drop on to the dead plate, then the full stroke of the crank would be imparted through the two connecting rods to the pawl and ratchet gear, and the full rate of feed would be applied to the feed paddles, which would be rotated and deliver a maximum rate of feed into the furnace.

It is obvious that this form of control can be set for any desired rate of feed, and a constant thickness of the fuel can be maintained on the grate. This enables the furnace conditions to be kept regular, and an even rate of combustion will follow. As stated previously, this is of paramount importance when dealing with waste fuel, having the characteristics of bagasse in its raw state, and containing anything up to 55%
of moisture. The bagasse feeders are generally arranged in a line across the front of the boiler. A furnace 12 ft. between the walls would require at least three feeders, which could all be driven by means of a 3 h.p. motor, which would transmit the drive through a worm reduction gear to the crank shaft.

The question of predrying bagasse has received attention from sugar mill engineers from time to time; but up to date nothing concrete has been done in this direction, and so far as the writer is aware the methods adopted on the Mossman boiler represent a maximum of what has been done towards predrying in this country. Some form of drying that would reduce the moisture content of the fuel before it enters the furnace would greatly increase the steam output of the boiler plant. In all probability it would increase the output of the average boiler by anything up to 50%. There are several methods of drying that suggest themselves, such as low pressure steam heated rotary dryers; or alternatively the dryers could be heated by means of waste gases; or direct heating could be carried out by means of special independent bagasse fired furnaces. The amount of fuel consumed for the latter method of drying would be more than compensated for by the increased efficiency that would be obtained from the boiler with dry fuel. One method of drying bagasse, and one which would, in the writer’s opinion, be very effective, would be an arrangement similar to that adopted by the State Electricity Commission for drying the raw, wet, brown coal before it is delivered on the grater at the Yallourn Power Station. This is a series of staggered louvres, arranged in the combustion chamber, which are in contact with the hot gases, and over which the coal flows on its way to the grate. This arrangement would of course necessitate very much higher boiler settings than anything yet attempted for sugar mill work; but it would not be so great as at Yallourn, as the time required for drying bagasse should be less than that required for lignite. The diffusion rate for moisture in bagasse is probably considerably higher than it is for brown coal; and this will of course affect the drying time.

The writer would suggest a slight modification to the Yallourn arrangement, and would provide for the gases that have been used for predrying the fuel to be ejected to the atmosphere through an auxiliary stack. This stack would have to be mounted on top of the combustion chamber drying shaft, the gases and moisture being discharged from this stack instead of passing through the boiler to the main stack. The need for improvement in furnace design for the combustion of bagasse has been felt for a long time, and many designs and suggestions have been put forward, mostly along the lines indicated above.
There is, however, one exception, and this is the "Mattekovich" furnace. This furnace differs from all existing types, and incorporates a special arrangement for predrying the fuel and mixing of the gases. The main furnace shaft is fitted with a series of tubes, which are connected to the boiler circulating system, and the fuel is fed down on to the grate through rows of tubes. A special auxiliary grate is arranged in front of the main grate, the idea being that the hot gases given off by this portion of the grate will mix with the moisture-laden fuel, and drive off the moisture from the fuel as it passes down through the hot tubes. The amount of fuel fed into the furnace is divided, so that a certain percentage falls on the auxiliary grate, and the main bulk being delivered on to the main grate. The amount of fuel fed on to the preliminary grate can be varied of course to suit the conditions of the fuel generally, the main idea of the grate being to generate sufficient heat on the primary grate so that when the gases given off pass through the incoming fuel the moisture will be driven off, and the volatiles will be prepared for combustion almost as soon as the fuel reaches the main grate. Claims are made also for the mixing of the gases provided for by this arrangement, and it is also claimed that high rates of combustion per square foot of grate area can be obtained from this furnace.

So far as the writer knows, this form of grate has not yet been put into actual practice in any Australian mill, but rates of combustion up to 200 lbs. per square foot of grate areas are being obtained with "Cook" furnaces and Cook-cum-stepped grate furnaces, and in view of this the high initial cost of the "Mattekovich" furnace will no doubt prove an obstacle to the wide adoption of this form of grate.

The average composition of bagasse is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>23.25%</td>
<td>46.5%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>3.25%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>23%</td>
<td>46%</td>
</tr>
<tr>
<td>Water</td>
<td>50%</td>
<td>Nil</td>
</tr>
</tbody>
</table>

The thermal value of bagasse on a dry basis is 8300 B.T.U.'s per lb. With 50% of moisture, the thermal value is 4150 B.T.U.'s per lb.

The products from combustion of bagasse without excess air are: 0.852 lbs. carbon dioxide from carbon, 0.293 lbs. water vapour from hydrogen, 0.500 lbs. water vapour from moisture, and 2.175 lbs. of inert gases. The total weight of gas per lb. of fuel is 3.82 lbs. With 30% excess air, the total weight of the products of combustion per lb. of fuel is 4.667 lbs., the
extra weight being made up from .194 lbs. oxygen and .652 lbs. nitrogen. The theoretical amount of air required per lb. of bagasse burnt is 2.82 lbs. But it is not possible, of course, to have complete combustion without an excess of oxygen; and with 30% excess air, 3.67 lbs. of air are required per lb. of bagasse, and this, under good operating conditions, will give 15.2% carbon dioxide in the flue gases if the boiler setting is in good condition, and the infiltration of air through the setting is prohibited.

Assuming the ambient temperature is 90 degrees F., the heat lost due to 50% moisture is 649 B.T.U.’s, basing on a flue gas temperature of 650 degrees F. The heat loss in the combined water is 376 B.T.U. The total loss due to moisture is 649 + 376 = 1025 B.T.U. The heat loss in the dry flue gases at 680 degrees F, amounts to 488 B.T.U. Allowing 6% loss for radiation and heat loss by flying particles, the total heat loss is: 1025 B.T.U. in wet gas, 485 B.T.U. in dry gas, 246 B.T.U. radiation, etc.; thus the total loss will be 1756 B.T.U. Therefore the amount of heat available for steam is 2394 B.T.U. per lb. of fuel burnt. Assuming the whole of this available heat to be absorbed by the boiler, there would be an efficiency of 57.9% on the gross calorific basis, and 71.9% on a net calorific value.

The flue gases can be reduced to 350 degrees or 400 degrees F. with an air heater, and the heat thus gained is returned to the furnace as preheated air and an increased efficiency amounting to 8 to 15%.

The writer hopes that the foregoing has been of sufficient interest to provoke some discussion, whereby some help may be derived for those interested in the burning of low grade and waste fuels.

Mr. E. H. G. Morris said the paper had been especially interesting to him, because he had been associated with the sugar industry almost from childhood. In his early days it was the practice of the mills to put in a small boiler, which was fired by natives, who threw in the bagasse together with a few logs. To have reached about 70% efficiency seemed to him to be a marvellous achievement. He would like some further information concerning the statement of Mr. Gamble that the temperature at crushing was about 90 degrees. In his experience crushing usually took place in the winter, when there was plenty of frost, so that it was unlikely they would have a temperature of 90 degrees.

The President said that Mr. Gamble had informed them that the pot type of furnace was not satisfactory, yet it seemed to find favour in most sugar refineries. One great difficulty would
be the cleaning of the grate, but he presumed that could be overcome. He wondered if there was any method of disintegrating the fuel before it passed into the furnace.

Mr. G. E. Gamble said the temperature at crushing depended on the locality of the mill. He had simply set down 90 degrees as a basis for consideration. In tests carried out during milling operations the boiler house temperature had been found to be 90 degrees, and even higher. The Bagasse-Cook furnace was certainly a distinct advance on anything previously available in Queensland. Its chief drawback was the difficulty of feeding it, and the likelihood of the furnace requiring feeding at the wrong moment. Attempts had been made to incorporate firebars on the floor, but that method tended to blow the fuel out. The draught must be retained, and at the same time some method employed for discharging the ashes from the furnace. The advisability of the disintegration of the bagasse depended on circumstances. It would have to be dried first, which meant handling it. The bagasse was taken direct from the mill and carried by conveyors to the furnace. If they had to handle the material it would be robbed of some of its value. They would have to get a season in advance. The economical method was to take it direct from the mill and burn it.

Mr. J. W. Williams asked if the Wilton or Meldrum types of furnace had been used. The cleaning would be much simplified, because it would burn the clinker. There would be no ash left at all. The firebars were the tuyeres. The bagasse would be fed up to the firebars and be lifted up. Almost anything could be burnt in a Wilton grate.

Mr. G. E. Gamble said he was not aware if the Wilton grate had been tried; but here again they would have the problem of hand-firing. In his opinion the best form of grate was the Cook grate. It was definitely designed for that class of fuel. The Wilton was an excellent grate, but he would hesitate to use it for firing a large boiler. If there was a fair amount of molasses in the bagasse it would form a glassy slag, and would blanket the fire right out.

Mr. W. R. Pollock said the Metropolitan Tramway Board had some "turbine" furnaces in which during the coal strike some years ago English coal was burned. It formed a large amount of clinker, which trickled over the bars like treacle, and was very difficult to remove.
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