

could get more sugar through dilution.

Mr. Godfrey replied that there were other ways of getting every ounce out of the cane and that was by extra milling plant, increasing the crushing units and so on.

The Chairman asked if the extra mills would be sufficient without a due proportion of maceration.

Mr. Godfrey replied that they would have to have a certain amount of maceration.

Mr. Truscott stated that in a certain mill it was easy to get 97% extraction from dilution, so it proved that by proper methods they could not help getting a higher extraction. The more water they put on the more sugar they got, there was no disputing that.

Mr. Pullar replied that a similar contention had been considered by better men than himself, and the result had been that one of the sugar firms had decided to sell bye-product power. Why had they done that? For the reason that they had to burn coal to get heat to evaporate water that they added to the sugar. Why had they power to sell? Because

instead of wasting it in reducing valves they generated steam at high pressures and superheated and generated electricity. That power was an asset to them, so much so that they decided to sell it to the Municipality. That surely was proof of what, he said, that if they burned their bagasse more efficiently they should have power available for other purposes. That question had been considered not only by local experts but by experts in London. He thought that ought to be sufficient.

At this stage (1 p.m.) the Congress was adjourned for lunch.

On resuming at 2.30 p.m. the following paper on "Types and Designs of Bagasse Furnaces" was read by Mr. John Murray at the request of Mr. P. Murray who was unavoidably absent, the paper having been prepared by a Sub-Committee of the Sugar Technologists' Association consisting of Messrs. L. F. de Frobergville, J. R. Simpson, John Murray and P. Murray.

## TYPES AND DESIGNS OF BAGASSE FURNACE.

(Paper prepared by Sub-Committee of Natal Sugar Technologists Association.)

### Foreword.

When our old ancestral engineers first built a fire with dried sticks of more or less bruised cane with which they evaporated the moisture from their cane juice did they ever visualise that the outcome of their intelligent efforts would be the modern Bagasse Furnace? A detailed account of this wonderful evolution would fill a volume, and can only be recalled in our limited space with fervent thankfulness that their repeated and determined efforts have led the way to progressive success; and finally building on these successes and a better understanding of the peculiarities of this fuel we have now been able to so design our furnaces and accessories in such a way as to reduce to a minimum the great losses that have previously been unavoidable. So much so indeed is this the case that no modern factory requires to use extraneous fuel except in such countries where the cane contains so much moisture that the quantity of fuel available is small. These very valuable and important results are only obtained by unremitting care and team work of attendants as well as a liberal and broad minded administrative policy. Thus with the idea of assisting or interesting those more closely connected with or responsible for the erection and design of furnaces we are publishing the following as appendices:—

1. The Theory of Combustion as applied to Bagasse.

2. The Composition of Natal Bagasse as a fuel; and economies attendant upon modern improvements and care in design.
3. Typical Drawings and Settings of Boilers and furnaces from various parts of the world.

It is now our intention to try and interest you with the following report in which reference will be made to several of the numbered drawings.

### Burning of Bagasse.

In considering the burning of Bagasse it must be understood that the fibre or combustible portion of the sugar cane forms, on an average in Natal 16.2% on weight of cane as compared with an average of 12% in the other important sugar growing countries. Also that it contains from 47 to 50% of moisture when entering the furnaces.

### Quality of Bagasse.

It must not be considered that Natal Bagasse is of inferior quality for steaming purposes to that of other countries. This is shown in Appendix (1) Page 5 in which a list has been made of practical tests carried out by such authorities as Messrs. L. Blacklock, E. W. Kerr and R. S. Norris of the calorific value of bagasse in Louisiana, Hawaii and Natal. There is nothing therefore to prevent our Sugar Industry from obtaining just as good furnace results as these of other parts of the world.

### Quantity of Bagasse.

Also owing to the fact that the fibre content of our sugar cane is, as pointed out, above the average we are able to afford the steam for the treatment of juices from the Uba cane which are of a far more refractory nature than any other known. This important feature of the Uba cane is most appreciated in those factories where white sugar is made, and where a large supply of steam is essential.

With a properly designed and constructed boiler, and given that the result of the plant is modern and efficient no extra fuel should be necessary even for the week end purposes of stopping and starting up. This subject of steam balance we hope will be dealt with at a later date by other Committees.

### Furnace Combustion.

We now come to the combustion of the bagasse in the furnace which is of the step grate type specially designed for the purpose (see Fig. 1). The bagasse with its large content of moisture is fed continuously into an opening at the top of the furnace vertically above the top of the step grate; and the principle of combustion is as follows: In zone A of the diagram the moisture in the Bagasse is evaporated by the heat reflected from the roof of the furnace, and if the furnace is not properly constructed this does not occur, and we know this is the case in many of the Natal furnaces. In the next lower zone B the bagasse being dry the volatile matters are now distilled off and radiate heat to the roof which is reflected back to zone A to dry the bagasse. The design of the roof is of great practical importance for this duty. The next stage is the lowest zone C where the fuel now mostly consists of carbon; and where combustion is completed and only ashes left. Great stress must be laid on the necessity to have the furnace roof of correct shape as it is realized that this has been the cause of failure of many otherwise well designed settings.

### Design of Furnaces.

The design of the Furnace should be such that the gaseous products from the three zones should firstly be intimately mixed by passing through a constricted passage shown at D in diagram, and impinged on the opposite wall of a relatively large internal chamber E where the gases are thoroughly mixed; and by reverberation the walls of this chamber become incandescent thus completing combustion before coming in contact with the comparatively cool boiler shell. Ash is deposited in this chamber owing to the velocity of the gases being greatly decreased; and arrangements have to be made to relieve this ash at stated periods through a conveniently placed opening. A spy hole for observation purposes should be pierced in a side of this chamber.

### Furnace Temperatures.

The following is a list of furnace temperatures with their corresponding colours of the fire:—

Appearance of Fire .	Temp. deg. F.
Red just visible . . . . .	977
Red Dull . . . . .	1290
Red Cherry dull . . . . .	1470
Red full . . . . .	1650
Red clear . . . . .	1830
Orange deep . . . . .	2010
Orange clear . . . . .	2190
White heat . . . . .	2370
White bright . . . . .	2550
White dazzling . . . . .	2730

We wish here to draw your attention to Fig No. 2 which shows a furnace that does not fulfil the ideas of an ideal design, firstly the roof in this furnace is so constructed that there can be practically no heat radiation from zones B to A or from zones C to B. Also the products of zones A. B. and C are not mixed properly this resulting in incomplete combustion.

Having dealt hitherto with step grate furnaces we must now consider the Flat Grate Type. There are many adherents of this type who hotly contest its merits as against the Step Grate and it is unquestionable that good results are obtainable from it. The proportions and design are different to the step grate furnace as may be noted in Fig. Nos. 3 and 4 (appendix 3), but they are essentially alike in one main feature viz the roof of both types must be as flat as possible, or of the segmental arch type rather than the semi-circular, so that efficient radiation may result in order to evaporate the moisture in the entering bagasse.

### Boiler Heating Surfaces.

We shall next draw your attention to the amount of boiler heating surface required for a sugar factory with their corresponding areas and volume of flues, all of which have to be carefully proportioned for the proper working of the boiler plant. The usual heating surface required in boilers of a factory of predetermined capacity is given by various authorities as 500 sq. ft. per ton of cane per hour. From figures gathered from twelve of our Natal factories an average of 461 sq. ft. per ton of cane per hour, varying from 338 to 620 has been obtained; but it must be noted that those factories showing the smaller heating surfaces are in every case adding to their boiler plant. On Page 5 of appendix 2 you will note that it is calculated that a boiler requires 1.12 lbs. of bagasse per square foot of heating surface. Taking the weight of bagasse as being one third that of cane 595 sq. ft. heating surface will be required for one ton of cane.

### Grate Areas.

With regard to Furnace Grate Area this is generally calculated proportionately to the heating surface, and for modern mills with finely crushed

bagasse a ration of 100 of heating surface to 1 of grate area is considered a good practice.

The figures of twelve Natal factories show an average ration of 78.2 to 1; varying from 57.9 to 120 to 1; the reason for this great variation being that factories whose heating surfaces are small have proportionately large grate areas or vice versa.

In Natal 80 to 163 lbs. of bagasse is consumed per square ft. of grate area, and it will be noted that in Appendix 2 ideal conditions give the figures as being 112.

The problem of the size of grates for burning bagasse is one that is of great importance, and is worthy of more attention. Our local results might be carefully tabulated, in order that a definite understanding of the correct size to instal can be arrived at.

It has been found in Hawaii—the country of high extractions and fine crushing—that the finer the bagasse is crushed the smaller the grates should be in proportion to the heating surface. It is also a *sine qua non* that the grate area be well covered continuously with a bed of fuel; and it would add considerably to our knowledge if local results of alteration in grate areas were carefully noted with the object of tabulating same for future reference.

#### **Furnace Volume.**

The volume of our furnaces next claims our attention. The combustion chamber should not be of less capacity than a quarter cubic foot per square foot of heating surface though in Natal this rule is not adhered to, many being too small. In observing this rule care must be taken that the furnace roof be not raised too high above the grate to spoil the radiating or drying action on the bagasse.

#### **Flue Areas.**

Let us next regard the area of flues or passages that lead from the feed hopper to the chimney. The area of passage between furnace and heating surface of boiler should be in the case of water tube boilers one square inch per square foot of heating surface; and in the case of smoke tube boilers  $5/6$  square inch per square foot of heating surface; and for the passage after leaving the boiler this area should be  $3/5$  square inch per square foot of heating surface. (Appendix 2).

#### **Chimney Draught.**

With regard to the subject of chimney draught this is quite an involved subject and each particular boiler plant must be studied for their own distinctive features which may include atmospheric humidity, altitude above sea level, use of waste gases in pre-heaters or economizers, total length of horizontal flues, etc.

#### **Furnace Air Supply.**

Air supply to the furnace for combustion purposes is most important, as the use of either too much or too little air means a loss of heat either by dilution or else by incomplete combustion; and in either

case the loss of heat may be serious. Under present conditions air may be admitted into a furnace in either of the following ways:—

**FIRST.**—Natural draught conditions in which case the bagasse should be fed into an enclosed or mechanical hopper to exclude air entering with bagasse.

**SECOND.**—Cold air may be blown in below the grates at a pressure to reduce the vacuum above the grate to zero, commonly known as balanced draught.

**THIRD.**—Hot air may be blown in in a similar manner to No. 2 the heating of this air being brought about by transference of the heat of the waste gases in a pre-heater to the air to be used in the furnace.

Great stress must be laid on the discreet use of air for furnace purposes; an example in point may here be given. It was found at a certain factory that on opening the flue dampers the furnace temperature was greatly reduced, and by calculation this occasioned 100% increase in losses in flue gases by excess air being drawn in which loss would require 17% more bagasse for fuel. This instance would point to a defective furnace design. Every factory should aim at satisfactory fuel combustion and test their flue gases systematically; and with this in view the engineer and chemist should collaborate closely in order to obtain the utmost efficiency in this important subject.

#### **Pre-Heaters.**

Recently pre-heaters have been tried in this country. These machines are designed for the purpose of utilizing the heat out of the waste gases to raise the temperature of the air that is being supplied to the boiler furnace. The unavoidable heat lost in the waste gases from the boiler is approximately 30% of the total heat in the bagasse, and by the efficient return of this heat into the furnace in the form of hot air an increase of 22% in steam may be obtained. (Appendices 1 and 2).

If the greater part of the moisture in the bagasse is driven off by the waste gases by a process originally used in Mauritius the saving in heat would be about 17%. We wish to draw your particular attention to the important fact of the superior efficiency of the pre-heated air system.

Another important point about pre-heating is that it increases the furnace temperatures considerably, thereby greatly increasing the ratio of heat transference to the boiler, thus increasing evaporation.

#### **Economizers.**

The economy of feed water heaters by "waste gas economizers" as supplied by the Greens Economizer Co., should next be considered. With properly designed and proportioned economizers say of  $1\frac{1}{2}$  times boiler heating surface an increase in steam production of from 10% to 20% may be expected.

Feed water heating to at least 200 deg. F. is essential to the life of a boiler besides adding to its efficiency, and should on no account be omitted in favour of air pre-heating, although a judicious com-

ination of the two should be worth the capital outlay and maintenance and also give great efficiency.

### Feed Water.

Factories often have to use river water containing mud and other dissolved impurities, and it is very injurious to boilers to use this as feed water besides considerably lowering the steaming efficiency. Some kind of purification system should be undertaken. This is not a costly installation, and on account of the benefits derived should not be omitted. Should quick lime and alumina ferric be used as the chemical reagent for settling, a good rule for the size of the reservoir is a capacity of 250 gallons per ton of cane crushed per 24 hours.

### Purification Tanks.

Reservoirs of this type are in use at Colenso, Mt. Edgecombe, Umbogintwini and Umfolosi.

Mr. H. H. Dodds has also drawn our attention to this matter in his paper read before the S.A. Association of Analytical Chemists in 1919.

### Soot Deposits.

The loss due to carbon and ash deposits on and in boiler tubes and other heating surfaces is often more than is estimated, and as the conductivity of the heating surfaces varies conversely as the thickness of this deposit great care should be taken that surfaces

be regularly and properly cleaned; and when cleaning boiler tubes that a stiff brush of the proper size be used at stated intervals during the week as well as at week ends. As an example of this loss due to deposit consider a clean boiler surface as giving no loss of heat transference, then with 1/16 in. deposit there would be a loss of 26%, and with a 3/16 in. deposit a loss of 69% would be incurred.

### Design and Appendix.

We are putting forward certain designs of furnaces that have been found useful in this and other parts of the world, which we hope may be of use to those interested. Nos. 1 and 2 Appendices have also been printed with the hope that they may be of use to the engineer in his attempts to solve this most difficult problem of bagasse furnace design.

In conclusion the Committee have to thank the various factory managements for their courtesy in supply particulars of their plants and also drawings of boiler settings. Also they are indebted to various other firms and friends who have assisted. It is to be regretted that shortness of time has prevented the further development of this paper. But if it should be even merely the means of raising a debate or other constructive criticism on the subject, the object of the Committee will have been amply achieved.

## Appendix No. 1

### Boiler Plants.

Heat is motion. When heat is applied to a body, a change takes place in its molecular arrangement, the molecules are displaced, they move, and by this displacement or movement, cause the different phenomena of heat, light and electricity. The application of heat causes an increase in the temperature as well as in the volume of the body and in the case of a liquid, the temperature rises until it reaches the boiling point, whence it remains stationary until the whole of the liquid is converted into vapour or steam. If the liquid is in a closed vessel, a further application of heat will cause the temperature to rise and a pressure will be exerted in the vessel; the more heat being applied, the higher will be the temperature and the greater will be the pressure.

The atmosphere exerts a pressure on the surface of the earth, which has been found to be 14.7 lbs. per square inch and the absolute pressure is the sum of the atmospheric pressure and of that marked by the gauge or in other words, a 100 lbs. pressure corresponds to an absolute pressure of 100 gauge pressure and 14.7 lbs. atmospheric or 114.7 lbs. absolute per square inch.

When heat is applied to water at 32 deg. F., the temperature rises until it reaches the boiling point or 212 degs., F. and the number of units of heat absorbed are  $212 - 32 = 180$  per pound of water.

These units are called British Thermal Units or

B.T.U. and the heat unit is the quantity of heat necessary to raise the temperature of water One degree Fahrenheit from 39 degs. to 40 degs. F.

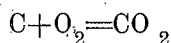
The quantity of heat necessary to convert one pound of water at 212 degs. F. into steam at 212 degs. F. is called Latent Heat. It is this heat which is absorbed by the liquid for its conversion into steam at the same temperature and pressure. In the case of water the Latent Heat is 965.7 at 212 degs. F. and atmospheric pressure and the total heat necessary for the conversion of 1 lb. of water at 32 degs. F. to steam at 212 degs. F. is  $180 + 965.7 = 1145.7$  B.T.U. and the absolute pressure will be 14.7 lbs. per square inch. If the pressure in the closed vessel or boiler rises to 100 lbs. gauge the absolute pressure will be 114.7 lbs., the temperature will be 337.6 degs. F., the Latent Heat will be 875.6 and the total heat units will be 1185 B.T.U., as recorded in the Steam Tables in Engineer's Manuals.

If the Steam is meant to be "Superheated," that is, to have a temperature superior to that recorded in Steam Tables for the same pressure, more heat must be applied. In the calculations then, the number of degrees of superheat must be multiplied by the Specific Heat of superheated steam, which is .47 and which may be taken in round figures as .5. In the example above, if the steam is to be superheated to 400° F., the calculation is:—

$337.6 - 32 + 875.6 + .5 (400 - 337.6) = 1212.4$  B.T.U.

## BAGASSE AND COMBUSTION.

When a substance is burnt, the oxygen of the air combines with the substance, oxidises it, produces heat and gives off Carbon Di-Oxide as the final result of combustion.



Combustion therefore needs Oxygen or Air to be complete. When the quantity of air is insufficient, the combustion is incomplete and one atom of Carbon is united to one of oxygen to form Carbon Monoxide or CO. Whilst, when air is supplied in sufficient quantity, the whole of the Carbon is burnt into Carbon Di-oxide and the number of B.T.U. evolved is 3.17 times more than that produced by the combustion into CO, where it is only 4600 B.T.U. per lb. carbon.

Bagasse is the residue left after the cane has been crushed by the mills. It is a complex mixture of woody fibre, sugar, glucose, wax, sand, other organic solids and water; the proportion of these different constituents depending on the pressure of the mills on the water spread over the bagasse and on the quality of the cane. Water forms generally nearly half of the weight of the bagasse, varying between 45 and 51 or 52%, the balance being fibre which ranges between 43 and 48% and the solids from 4 to 7% of the bagasse.

Fibre or Cellulose has the formula  $C_6H_{10}O_5$  meaning that 6 parts of carbon (Atomic weight 12), unite with 10 parts of Hydrogen (at weight 1) and 5 parts of oxygen (at weight 16) to form the organic compound Cellulose. The percentage of these elements are: CELLULOSE— $C_6H_{10}O_5$ .

6 of Carbon or 6 by 12 equals 72, = 44.44%.

10 of Hydrogen, 10 by 1 equals 10, = 6.17%.

5 of Oxygen or 5 by 16 equals 80, = 49.39%.

Similarly, SUCROSE,  $C_{12}H_{22}O_{11}$  represents 42.10% of Carbon 6.43% of Hydrogen and 51.47% of oxygen.

GLUCOSE,  $C_6H_{12}O_6$  represents 40.00% carbon, 6.67% Hydrogen and 53.33% Oxygen.

By the simple inspection of these formulae, it can be seen that the ratio H to O corresponds to that forming water, or in other words, the proportion of hydrogen to oxygen in these three organic bodies is exactly that which produces water. The hydrogen will combine with the Oxygen present in the body itself to form water without the interference of oxygen from the air and therefore produces no heat.

Using Dulong's formula for the calculation of the theoretical heat values of fibre, sucrose and glucose, the B.T.U. in one pound of the substance is  $14,600 C + 62,000 (H - \frac{1}{8}O)$ .

It will be noticed in the calculations that the quantity between brackets when worked out amounts to nothing.

$$\begin{aligned} \text{FIBRE B.T.U.} &= 14600 \times .4444 + 62000 \\ &\quad (.0617 - \frac{.4939}{8}) \end{aligned}$$

$$\begin{aligned} &= 6488.24 + 6200 \times \\ &\quad .4936 - .4939 \\ &\quad (\frac{\quad}{8}) \end{aligned}$$

$$= 6488.24 \text{ B.T.U. per pound.}$$

$$\text{SUCROSE} = 6146.60 \text{ and}$$

$$\text{GLUCOSE} = 5840 \text{ B.T.U. per pound.}$$

As the Organic matter in the bagasse is usually taken as having the same heat units as Fibre the calculation of heat value can be worked out.

The analyses of bagasse of several mills have been condensed and an average composition has been obtained for the calculation. Bagasse per cent cane works out at 36.68%.

Average composition of Bagasse:-

SUCROSE .....	3.71%
NON SUGAR .....	1.34%
FIBRE .....	45.52%
WATER .....	49.43%

Non sugar includes about 0.14% glucose, and 1.20% wax, other organic substances and also a little sand. Taking the composition of the bagasse, the theoretical heat value as calculated above for each constituent per pound will be:-

$$\begin{aligned} &.0371 \times 6146 + .0014 \times 5840 + .012 \times 6488.2 \\ &+ .4552 \times 6488.2 = 3267.5 \text{ B.T.U.} \\ &\text{per pound of Bagasse at 49.43 Moisture.} \end{aligned}$$

In the valuable "Experimental Study of Bagasse and Bagasse Furnaces" by Prof. E. W. Kerr, M. E. published in the Louisiana Experiment Station Bulletin of August 1909, some interesting figures are given concerning the heat values per pound of Fibre, Sucrose, Glucose, etc. These figures have been produced by Stahlman and Langbein before the British Institution of Civil Engineers and they obtained 7533 B.T.U. per pound of cellulose, 7120 per pound of sucrose and 6748 B.T.U. per pound of glucose.

Calculating on these data, the B.T.U. obtained per pound of bagasse will be:-

$$\begin{aligned} &.0371 \times 7120 + .0014 \times 6748 + 1.012 \times \\ &7533 + .4552 \times 7533 = 3793.01 \text{ B.T.U.} \end{aligned}$$

In this case, the non sugar or organic matter has been considered, giving the same B.T.U. as cellulose. There is already a difference between the value ob-

tained by the Calorimetric Test of the individual bodies constituting the bagasse and the calculated theoretical heat values of these bodies.

Mr. L. Blacklock, Chemist of the Hulett's Refinery, has made several tests to detect the heat value of the bagasse of several of our mills and very obligingly communicated the results of his tests.

Moisture of Bagasse	Nett Heat Value per pound	Dry Bagasse
48.72	3774 B.T.U.	8330 B.T.U.
48.32	3785	8231
48.36	3894	8350
49.74	3738	8396
50.60	3665	8414
52.96	3318	8300
56.54	3024	8400
59.24	2739	8330
Avg. 51.75	3452 B.T.U.	8344 B.T.U.

Working on these figures, the total solids in the bagasse being .5057, the Gross Heat Value per pound of dry bagasse 8344 B.T.U., then for a moisture of .4943, the B.T.U. 4219.56 and the difference between this figure and the previous one is—

$$4219.56 - 3793.02$$

$$4219.56$$

equals 10.1%, indicating that the calculated value is 10.1% less than the actual calculated calorimetric value.

Prinsen Geerligs mentions the following formula for the calculation of the Heat value of bagasse by taking the calorific values of its constituents.

Calorific value = 8550 Fibre + 7119 Sucrose, + 6750 Glucose—972 water and divided by 100. Working out this formula the nett calorific value equals  $8550 \times .4552 + 7119 \times .0371 + 6750 \times .0014$  minus  $972 \times .4943 = 3665.06$  B.T.U. which is nearly the same figure from actual tests made here.

Referring to the tests carried on by Prof. E. W. Kerr in Louisiana and by Mr. R. S. Norris in Hawaii, the nett heat value of bagasse with varying moistures from these two regions is recorded together with the results obtained by Mr. L. Blacklock in Natal.

To establish a comparison between the results obtained in Louisiana and Hawaii and those in Natal, the nett heat value per pound of bagasse of various moistures has been calculated on the same basis as has been done for the two other countries, that is, the temperature of the air during combustion and that of the stack which has been taken for the two others at 500 degs. F. have been considered and the results are shown in the following table. Hawaii figures are lower than those of Louisiana and Natal probably on account of the nature of the cane there.

Moisture of Bagasse.			Nett Heat Value per lb.		
Lousiana.	Hawaii.	Natal.	Louisiana.	Hawaii.	Natal.
48	48	48	3750	3615	3741
48	49	49	3654	3522	3646
50	50	50	3558	3428	3550
51	51	51	3462	3335	3455
52	52	52	3366	3241	3358
53	53	53	3270	3148	3263
54	54	54	3174	3054	3166
55	55	55	3078	2961	3071
56	56	56	2981	2867	2974
57	57	57	2886	2774	2879
58	58	58	2789	2680	2782
59	59	59	2694	2587	2687
60	60	60	2598	2494	2592

The average heat value of bagasse from Calorimetric tests in Louisiana is 8360 B.T.U. per pound of dry bagasse, in Hawaii, the heat value is 8100 B.T.U. per pound and in Natal, the average has been found to be 8344 B.T.U. which is very nearly the same as the Louisiana bagasse.

The gross heat produced by the combustion of the Natal bagasse at .4943 moisture will be  $8344 \times .5057$  equals 4219.56 B.T.U. per pound; but part of this heat will be consumed for the evaporation of the water contained into steam from and at 212 degs. F., and if it be assumed that the temperature of the air be 70 degs. F. and that of the flue 500 degs. F. the number of B.T.U. lost will be  $.4943 (212-70 + 965.9 + .5 (500-212))$  equals 618.76. Deducting this quantity from the total of 4219.56 there remains 3600.80 which is the nett thermal value of one pound of this bagasse and the percentage of loss is

$$4219.56 - 3600.80$$

$$4219.56$$

equals 14.7% therefore 14.7% of the heat generated will be taken to convert the moisture into steam from each pound of bagasse. But again, the nett heat value obtained will not be utilized in totality by the boiler, a certain part will be lost through radiation and other causes and will be delivered to the chimney by the flues. The EFFICIENCY of a boiler is the ratio between the heat absorbed by the water in the boiler and that supplied to the boiler and is safely taken as 60% or 60% of the heat supplied are taken and 40% are lost.

Total heat supplied by one pound of bagasse  
= 3600 B.T.U.

Heat absorbed by boiler, 60% = 2160 B.T.U.

Radiation and other losses 10% = 360 B.T.U.

Heat lost in the flues 30% = 1080 B.T.U.

Total . . . . . 3600 B.T.U.

As the heat lost to dry the bagasse amounts to 618.76 B.T.U. there is nearly double the quantity lost in the flues or in other words all the bagasse can be thoroughly dried by the heat which is lost and the efficiency of a dry machine needs only be

$$618.76$$

$$1080$$

equals 57% to dry the bagasse.

## WEIGHT AND VOLUME OF AIR FOR COMBUSTION.

The atomic weights of carbon and oxygen being respectively 12 and 16, the molecular weight of carbonic acid is 44 and 2.67 parts of oxygen are required for 1 part of carbon. As there are 23 parts of oxygen in air, the quantity of this latter will be 11.61 parts for 1 of Carbon. Similarly to burn Hydrogen and produce water, 8 parts of oxygen or 34.78 parts of air are required. Assuming the temperature of air to be 80 degs. F., 1 part of air will occupy 13.6 cubic feet and 1.61 lbs. = 157.89 cubic feet per pound of carbon and 472 cubic feet per pound of Hydrogen. If there is an excess of air of 50% the volume will become  $157.89 + 78.94 = 236.83$  cf., and if 100% excess,  $2 \times 157.39$  equals 315.78 cubic feet.

The calculation of air excess from flue gas analysis is done thus. In air, Nitrogen occupies a volume 3.76 times greater than that of oxygen and if N represents the proportion of nitrogen found and O that of oxygen, then volume of air employed

$$\frac{\text{theoretical quantity}}{\text{N-3.76 O}} = \frac{\text{N}}{\text{O}}$$

If the analysis gave 8 for oxygen and 79 for Nitrogen, the excess will be—

$$\frac{79}{79-3.760} = \frac{79}{79-30.08} \text{ equals } 1.612 \text{ equals } 61.2\%$$

Water evaporated per pound of fuel and evaporation per square foot of heating surface.

The evaporative tests on boilers made by Prof. E. W. Kerr show an evaporation from and at 212 degs. F. of 4.27 lbs. per square foot of heating surface per hour. Tests made here showed an evaporation of 3.27 lbs. per sq. foot per hour; other results from eleven mills in Natal and recorded by Mr. P. Murray, show an evaporation of from 2.98 to 4.38 lbs., giving an average of 3.64 lbs. for the Natal mills per square foot per hour.

The evaporation from and at 212 degs. F. per pound of dry bagasse was found to be 4.7 lbs. and 2.26 lbs. per pound of bagasse containing 52.1% moisture in Louisiana. The average of pounds of bagasse burnt per square foot of grate area per hour has been given by Mr. P. Murray as 92.5. As the ratio heating surface to grate area works out an average of 64.5 to 1, therefore, the average weight of water evaporated per pound of bagasse per hour is 2.54 lbs., which is not far from the figure 2.26 obtained above.

## Appendix No. 2

	Natal Estates.	Ottawa Estate.
Sugar . . . . .	3.37	4.34
Fibre . . . . .	46.33	47.29
Moisture . . . . .	49.51	47.15
Undetermined	.79	1.22
	<u>100.00</u>	<u>100.00</u>

Bag'se % on cane 32.13 . . . . . 32.33

Take an average bagasse as:—

Sugar 4%; Fibre 47%; Moisture 49%  
and 32% bagasse on cane.

The usual fuel value of dry bagasse is taken as 8300 B.T.Us per lb. so a bagasse having 49% moisture would have a fuel value of:—

$$\frac{100-49}{100} \times 8300 = .49 \times 8300 = 4067$$

$$\times \left[ (212^\circ - 90^\circ) + 970 + .48 (550^\circ - 212^\circ) \right] \\ = 4233 - 614. \\ = 3619 \text{ B.T.Us per lb. of wet Bagasse.}$$

Babcock and Wilcox formula gives—

$$8550 \times .47 + 7119 \times .04 - 972 \times .49 \\ = 4018.5 + 284.76 - 476.28 \\ = 3826.9 \text{ B.T.Us.}$$

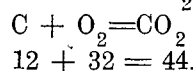
### Fuel Value from Theory.

The average composition of dry bagasse is taken by Deerr as 46.5% carbon, 6.5% hydrogen and 46% oxygen.

The atomic weight of:—

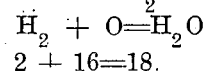
Carbon	is	12
Hydrogen	„	1
Oxygen	„	16
Nitrogen	„	14

Carbon burns to CO<sub>2</sub>



So for combustion 12 lbs. of carbon requires 32 lbs. of oxygen.

Hydrogen burns H<sub>2</sub>O



So 16 lbs. of oxygen requires 2 lbs. of hydrogen, therefore:—

$$.465 \text{ lbs. C requires } .465 \times \frac{32}{12} \text{ lbs. oxygen.}$$

$$=1.24 \text{ lbs. oxygen.}$$

$$.065 \text{ lbs. H requires } .065 \times \frac{16}{2} \text{ lbs. oxygen.}$$

$$=.520 \text{ lbs. oxygen.}$$

Oxygen required to burn C in 1 lb of bagasse=1.24 lbs

" " " " H " " " = .52 lbs

Total . . . . . 1.76 lbs

but there is already .46 lbs. of O present so  
1.76—.46=.13 lbs. oxygen is required.

The air has 23% oxygen, 1% water and 76% nitrogen so the amount of air required for combustion is:—

$$1.3 \times \frac{100}{23} = 5.65 \text{ lbs. per lb. of bagasse.}$$

The products of combustion will then be:—

Due to carbon . . . .465 + 1.24 = 1.7050 CO<sub>2</sub>

Due to Hydrogen . . .065 + .52 = .5850 H<sub>2</sub>O

Introduced with air 5.65 x .01 = .0565 H<sub>2</sub>O

$$5.65 \times .76 = 4.2940 \text{ N}$$

Total . . . . . 6.6405 lbs.

but as bagasse has 51% dry matter and 49% water, the above results must be multiplied by .51 & .49 added to the water giving:—

$$\text{CO}_2 = 1.705 \times .51 = .86955$$

$$\text{H}_2\text{O} = .6415 \times .51 + .49 = .81716$$

$$\text{N} = 4.294 \times .51 = 2.18994$$

3.87665 lbs.

With 50%, 100% and 150% excess air these figures would be:—

	Net.	50%.	100%	150%
CO <sub>2</sub>	.869	.869	.869	.869
H <sub>2</sub> O	.817	.832	.845	.860
N	2.190	3.284	4.378	5.472
O	2.190	.331	.663	.994
	3.876 lbs	5.316 lbs	6.755 lbs	8.195 lbs

Specific Heat of gases at 600° F and 1900° F Average

CO <sub>2</sub>	.215	.258	.236
H <sub>2</sub> O	.475	.561	.518
N	.248	.263	.255
O	.217	.23	.223

To raise the products of combustion of 1 lbs. of bagasse 1° F.

	Net.	50%	100%	150%
CO <sub>2</sub> x .236	.205	.205	.205	.205
H <sub>2</sub> O x .518	.423	.431	.437	.445
N x .255	.558	.837	1.116	1.395
O x .223	—	.074	.147	.221
	1.186	1.547	1.905	2.266 B.T.U.s.

but the full value of bagasse is about 3600 B.T.U.s per lb. so the temperature increase reached in combustion in each case is:—

	3600	3600	3600	3600
	1.186	1.547	1.905	2.266
=	3035	2326°F	1889°F	1588°F

showing the reduction in temperature caused through excess air.

The heat taken away by the exhaust gases in each case are at 600° F.

	Net	50%	100%	150%
CO <sub>2</sub> x .215	= .1868	.1868	.1868	.1868
H <sub>2</sub> O x .475	= .3670	.3952	.4041	.4085
N x .248	= .5431	.8144	1.0857	1.3571
O x .217	—	.0718	.1438	.2157
	1.0969 x 600	1.4682	1.8204	2.1681
	(=658	(=881	(1092	(1300
	B.T.U.s)	B.T.U.s)	B.T.U.s)	B.T.U.s)

showing the increase in heat lost by having too much air admitted to the furnace.

So the heat available for evaporation in the boiler

	3600	3600	3600	3600
is less	658	881	1092	1300
	2942 B.T.U.s.	2719 B.T.U.s.	2508 B.T.U.s.	2300 B.T.U.s.

but 1 lb. of steam at 100 lbs. pressure requires 1066.5 B.T.U.s. to raise it from 150° F. so each lb. of bagasse will evaporate

	2942 lbs.	2719 lbs.	2508 lbs.	2300 lbs.
	1065.5	1065.5	1065.5	1065.5
=	2.76	2.55	2.35	2.16 lbs. water



Since the heat lost by radiation is about 5% these figures will reduce to:—

= 2.522      2.423      2.233      2.052 lbs.  
of water evaporated per lb. of fuel (bagasse).

The usual amount of air admitted to furnaces is usually 100% in excess so that if another 50% is admitted in excess the fuel value would be reduced roughly 8%.

By preheating the air with exhaust gases a considerable saving of heat is affected, as follows:—

Pounds of air per lb of fuel (for ordinary bagasse):

Net.	50%	100%	150%
5.65 x .51	8.475 x .51	11.3 x .51	14.125 x .51
= 2.88	= 4.32	= 5.76	= 7.2

Supposing air is raised from 80° F to 480° which means that air would be raised 400° from exhaust gases.

So B.T.U.s required to do this would be 400 x specific heat x weight of air per lb. bagasse.

400 x .24 x 2.88	400 x .24 x 4.32
= 276.5	= 415
400 x .24 x 5.76	400 x .24 x 7.2
= 553	= 691.0

So that B.T.U.s to exhaust after preheating air up to 480° F would be:—

658 — 276	881 — 415
= 382	= 466
1092 — 553	1300 — 691
= 539	= 609 B.T.U.s.

% heat regained from exhaust gases by preheating:

276 x 100	415 x 100	553 x 100	691 x 100
658	881	1092	1300
42%	47%	50.5%	53%

This means that heat available for evaporation will be increased as follows:—

Available heat without preheating	2942	2719	2508	2300
Extra heat gained by preheating	276	415	553	691
Total	3218	3134	3061	2991

This will mean a saving of fuel of:—

276 x 100	415 x 100	553 x 100	691 x 100
2942	2719	2508	2300
9.4%	15.3%	22%	30%

So that plants using large excess of air will find great advantage in using preheaters by saving a large amount of fuel, varying from 15% with 50% excess air, to 30% with 150% excess air.

If bagasse was totally dried each lb. of bagasse would give: 8300 x 51 B.T.U.s.

—  
100  
= 4233 B.T.U.s.

but bagasse with 49% moisture has a calorific value of 3600 B.T.U.s., so the saving in drying is:

4233—3600  
—  
3600 x 100%  
= 62300  
3600  
= 17.3%.

So heating the air gives much more efficiency than drying bagasse. Drying bagasse is more difficult to control owing to liability to fire, also the air heating usually includes balanced draught which with the increased temperature in the furnace increases the boiler rating greatly.

#### Volume of Gases.

Volume of 1 lb. of gas at 32° F at atmospheric pressure =

	At 600° F	At 1900° F
CO <sub>2</sub>	8.14	17.53
H <sub>2</sub> O	19.91	42.89
N	12.76	26.49
O	11.2	25.75
		53.72

gas expands 1/492 for every 1° F rise in temperature. So the volume of gases with 100% excess air at 600° F will be:—

CO <sub>2</sub> lbs	.869 x 17.53	= 15.23 cu. ft.
H <sub>2</sub> O	.845 x 42.89	= 36.24 cu. ft.
N	4.378 x 26.49	= 115.97 cu. ft.
O	.663 x 25.75	= 17.07 cu. ft.
		184.51 cu. ft.

and at 1900° F.

CO <sub>2</sub>	.869 x 39.04	= 33.92 cu. ft.
H <sub>2</sub> O	.845 x 95.59	= 80.77 cu. ft.
N	4.378 x 61.21	= 267.97 cu. ft.
O	.663 x 53.72	= 35.62 cu. ft.
		418.28 cu. ft.

So that the volume of gases in the furnace is 2.26 times as much as when they emerge from the boiler.

The usual evaporation for a multitubular boiler burning bagasse is 2½ lbs. per square foot per hour, but it was already seen that fuel burned with 100%

excess air evaporates roughly 2.23 lbs. per lb. of fuel so a boiler requires  $\frac{2.5}{2.23}$  lbs. fuel per square foot = 1.12 lbs. bagasse.

An 8 ft. x 16 ft. boiler has a heating surface of 2144 square foot, so it will require:—

$$2144 \times 1.12 \text{ lbs. bagasse per hour} = 2401 \text{ lbs.}$$

The grate area is usual 1/100 of the heating surface = 21.44 sq. ft. So the grate will burn:—

$$2401 \text{ lbs. per hour per square foot.}$$

$$\frac{21.44}{100}$$

$$= 112 \text{ lbs.}$$

The gases go along the bottom and sides and out the tubes and the 8 ft. x 16 ft. boiler has 118 tubes 4 in. bore giving a total area through the tubes of 10.29 square feet, so the exhaust gases leaving the boiler at 600° F will have a velocity of:—

$$184.5 \times 2401$$

$$\frac{\quad}{10.29 \times 60 \times 60} \text{ feet per second.}$$

$$= \text{roughly } 12 \text{ ft. per second.}$$

Deerr says exhaust gases going to the chimney, the velocity allowed is 20 to 30 feet per second.

If the gases at 1900° are taken going through the tubes the velocity would be roughly 27 ft. per second.

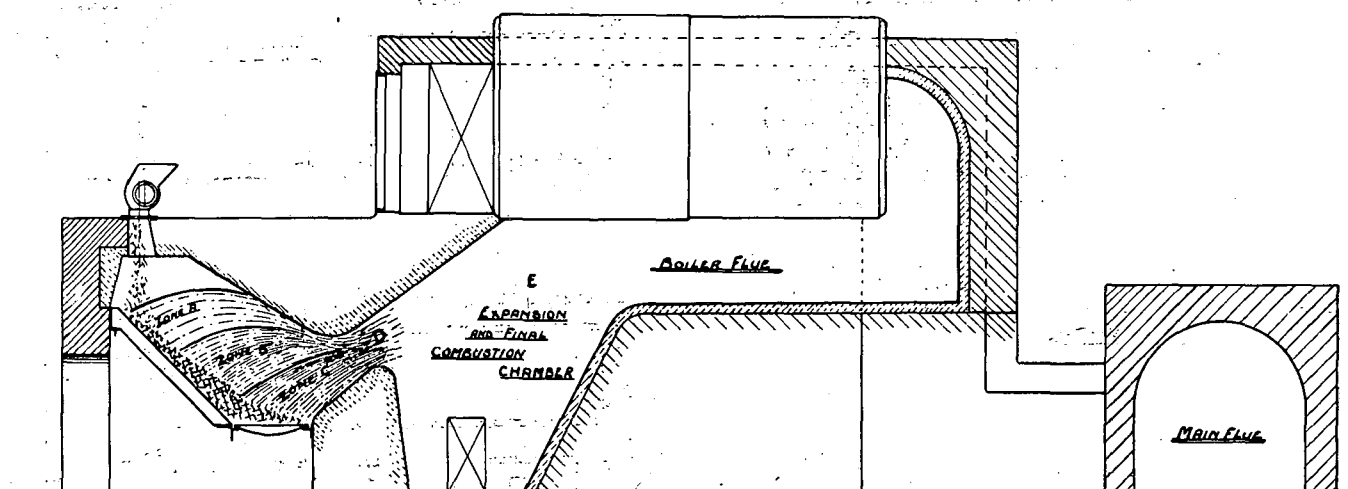
In working out the area of the flues, these should be slightly more than the area of the tubes after the furnace and slightly less than the tubes after the boiler.

It is usual to allow 10 square inches for every 12 square foot of boiler heating surface before the boiler and 6 square inches after the boiler. This would give 12.4 square ft. and 7.4 square ft. respectively for the 8 ft. x 16 ft. boiler and comparing with 10.29 square feet through the tubes.

## Appendix No. 3.

### Typical Drawings and Settings of Furnaces from Various Parts of the World.

Referred to in Paper on Types and Designs of Bagasse Furnaces.



ZONE A ~ STEAM

" A ~ VOLATILE MATTER

" C ~ CARBONS

" Q ~ CONSTRICTED PASSAGE

DIAGRAMATIC

BAGASSE FURNACE

Fig. 1

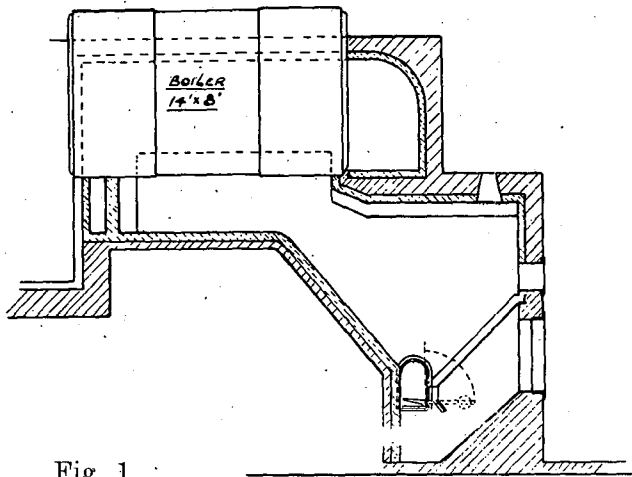


Fig. 1.

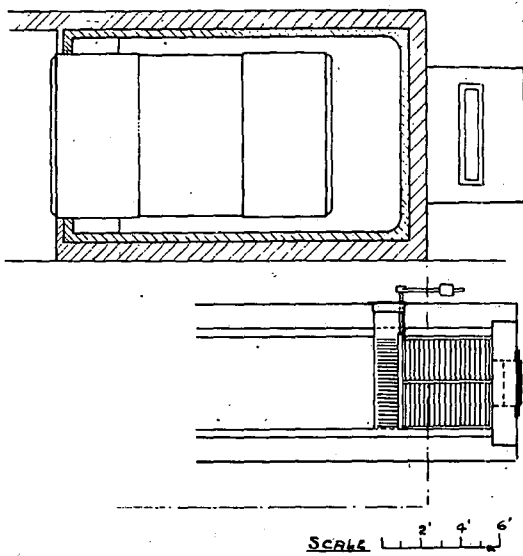
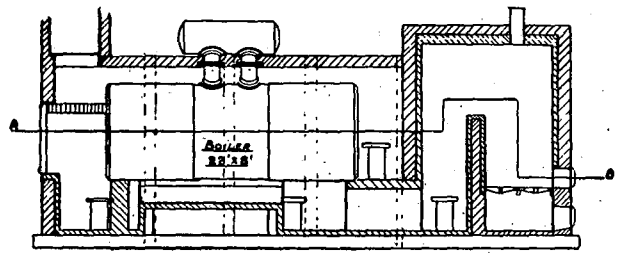


Fig. 2.

NATAL



SECTION TWO RA

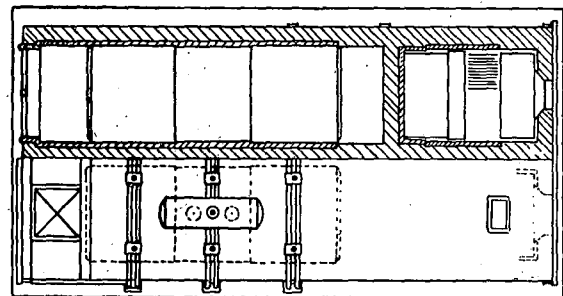


Fig. 3.

CUAR

SCALE 1' 2' 4' 6'

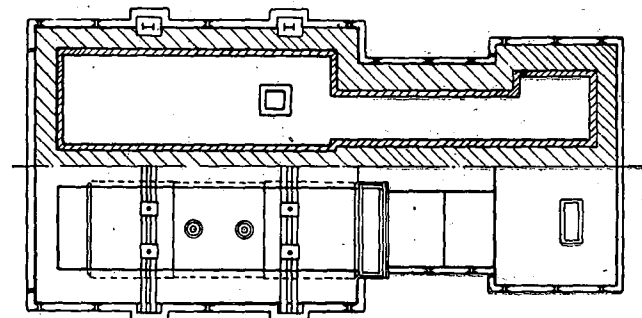
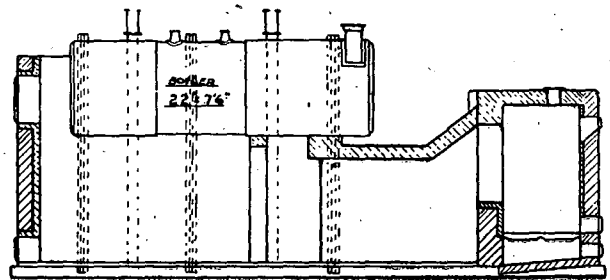
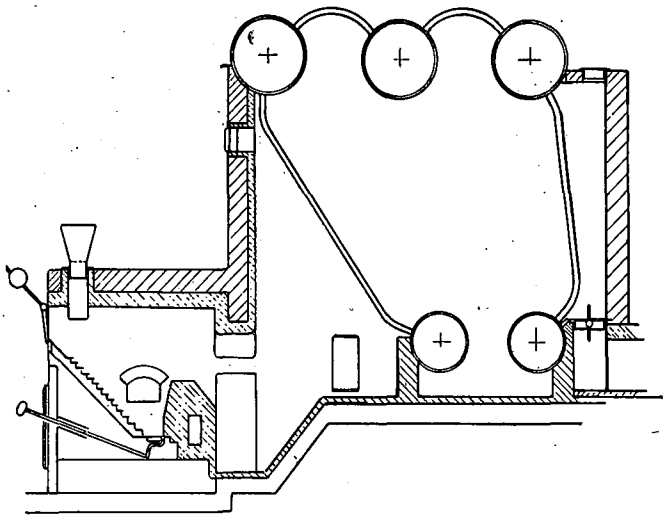


Fig. 4.

CUAR

SCALE 1' 2' 4' 6'

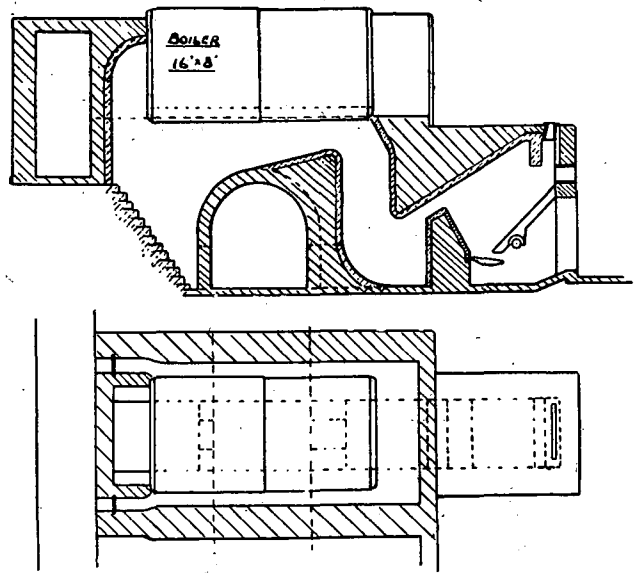


STIRLING BOILER  
3660 D' H.S.  
Fig. 5.

NATAL

SCALE 2' 4' 6'

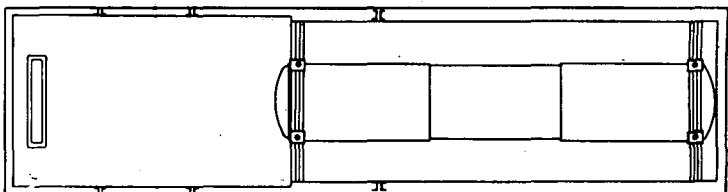
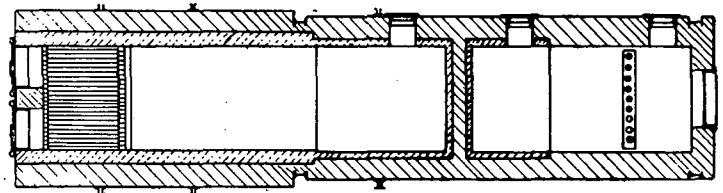
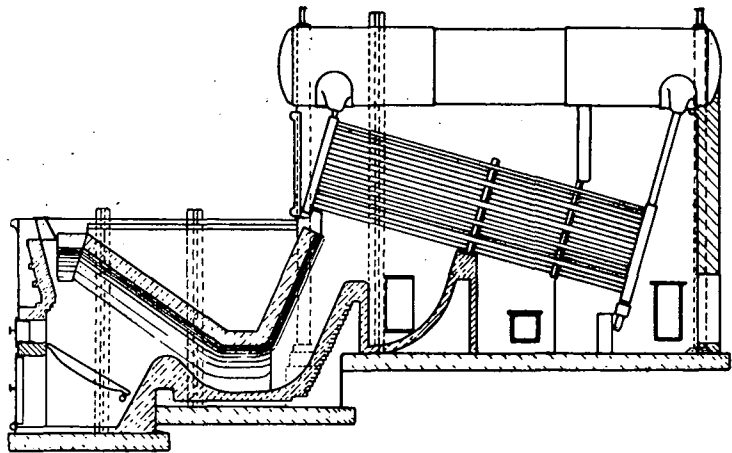
Fig. 5.



SCALE 2' 4' 6'

Fig. 7.

NATAL

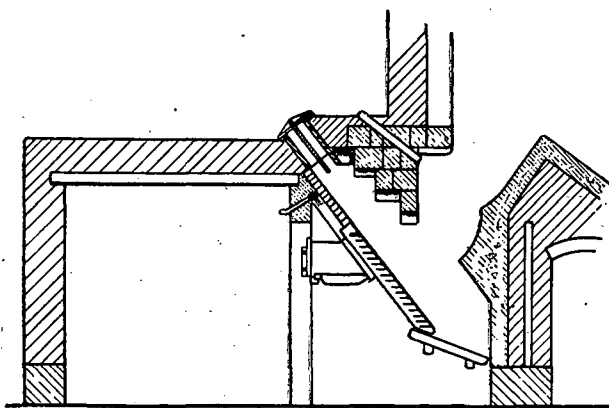


A.S.W. BOILER  
2010 D' H.S.

WEST INDIES

SCALE 2' 4' 6'

Fig. 8.



SCALE 2' 4' 6'

Fig. 6.

JAVA PROCATATIONS

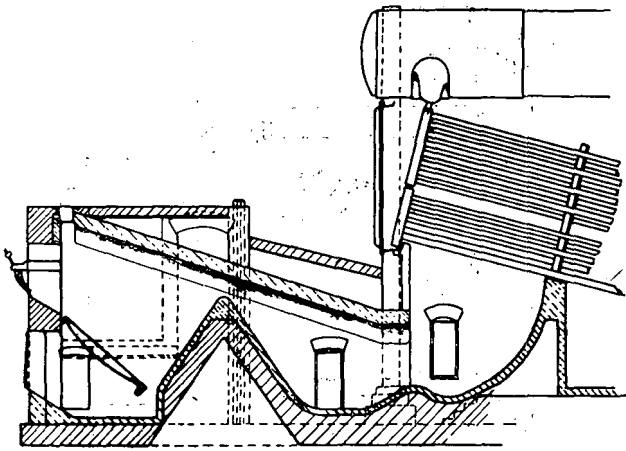


Fig. 9.

WEST INDIESB. & W. BOILER  
5764 D. H.S.

SCALE 2' 4' 6'

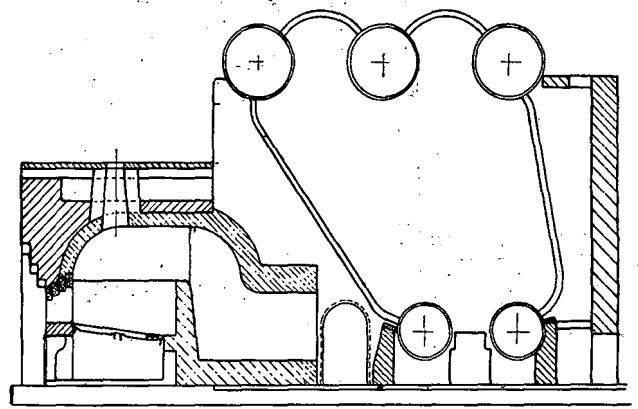


Fig. 10.

WEST INDIES

SCALE 2' 4' 6'

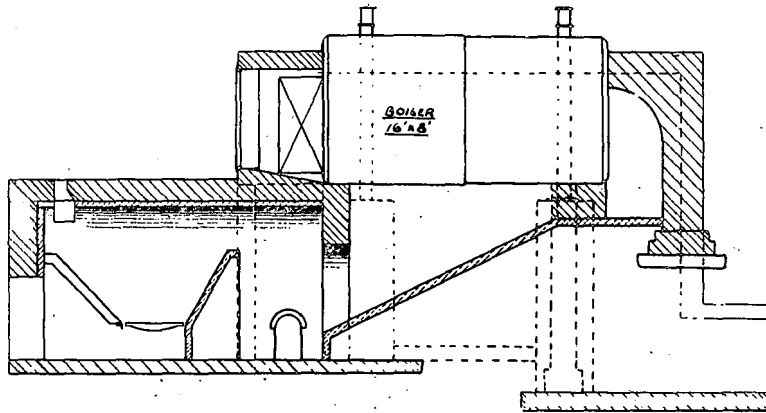


Fig. 11.

NATAL

SCALE 2' 4' 6'

## DISCUSSION ON TYPES AND DESIGNS OF BAGASSE FURNACES.

The Chairman in thanking Mr. Murray, stated that they were all very grateful to Mr. Murray and the committee of the Technologists' Association for producing such an able paper. It was one which should be of great value to the various milling staffs.

Mr. Dodds asked if Mr. Murray had any information regarding the composition of the typical flue gases in sugar factories in Natal. It would be very interesting information to have.

Mr. J. Murray replied that he regretted they were not supplied with any of these figures. A few of the factories had given some information but not in that connection.

Mr. Townsend stated that although he was a sugar planter at present he had also had some experience in mill work and no doubt Mr. Murray would recollect the conditions under which the old boilers were set, with the boiler overhanging the centre of the grate area and a 9 inch space running round the boiler up to about two-thirds of the boiler height into tubes and up the chimney. In those days the mills suffered under greater disabilities than to-day on account of fuel because they had to dry all the fuel before they could use it. When he took over the Sea Cow Lake Estate the first thing he did was to purchase an up-to-date boiler—very much larger than was considered necessary for the mill requirements at that time, and he also put in what was considered to be an up-to-date furnace. The furnace was a step grate and there was a distance of 20 feet from the grate to the face of the boiler. From there there was a 4 ft. flue and there was a wall between the front grate and the cavity under the boiler. This wall ran up to within a foot of the boiler which allowed the gases to run over the chamber under the boiler. All the gases which were passed into the grate came under and had to pass through a set of tubes which caused the air to be heated from the exhaust gases from the boiler. The grate area was about 5 ft. by 9 ft., and the feed was from an opening at the top where the fuel was dropped in small quantities almost continuously. The saving in fuel on that was enormous. The evaporators were not up-to-date, however, they had open evaporators, and that meant an enormous amount of waste steam. With the new conditions the boiler supplied more steam than was required and it was necessary to hold back the fire, with the result that the accumulation of fuel was enormous. The conditions with that boiler had proved to him that the design was not far off efficiency. The chimney was about 70 feet high and it was hardly possible to tell from the chimney whether the mill was working or not as there was simply a vapour, which to his mind proved that the combustion was complete. When the tubes were cleaned out there would not be more than a quarter of a bucketful of dirt and there was

practically no deposit in the tubes. They had to burn trash occasionally and had to water it to obtain efficient combustion. He would like to know if Mr. Murray had seen this particular class of boiler and why it had gone out of date. It was adopted in the early days and gave very efficient work. It seemed to him that at the present time a large number of mills were working with very inefficient boilers. If he saw a chimney belching forth black smoke he would put it down to inefficient boiler installation. The grate area was badly calculated or they were not getting proper combustion.

Mr. J. Murray stated that the furnace described by Mr. Townsend was a fairly good one, so far as he could see, as there was a space of 20 feet from the firebars to the underside of the boiler, and with the wall up to within a foot of the boiler surface it would give a very efficient combustion. The fact of the smoke issuing from a chimney being white did not necessarily mean that there was efficient combustion. With regard to the use of trash, this being a carbon fuel with a short flame it could be burnt under the boiler. The poorer the fuel the longer the flame. By adding water to the trash it made the flame longer. So far as he could see Mr. Townsend had struck something good.

Mr. Pullar in referring to what was termed an ideal furnace illustrated on page 1 of the paper, stated he would like Mr. Murray to explain what the volatiles were that were distilled off the bagasse in zone B. This particular type was shown as one of the most efficient. If he might venture to say so he thought the efficiency depended on the method of burning the bagasse. He had had the opportunity of watching this matter very closely, especially during the last season, and one thing which was very obvious was that the fluctuations in steam pressures in a sugar factory were due as much as anything else to irregular feed of bagasse and irregular boiler feed. The irregular boiler feed could be looked after with apparatus designed for the purpose, and even by hand if reasonable care was exercised, but the regulation of the feeding of bagasse has not yet been satisfactorily arrived at to his mind. On looking at the diagram it was seen that the bagasse was dropped in to zone "A" where it lost some of its moisture by the radiation from the arch, then it gravitated to zone "B" where the volatiles were driven off, then it gravitated to zone "C" where the carbon was burnt efficiently. To start off, where the carbon is burnt is where they need the air. If they had a furnace of that design in his opinion the man who could get the bagasse to flow as described was an artist. In his opinion it did not flow in that manner. It banked up in another way and the heat was under the hopper, and then suddenly it would slither down and the damp bagasse damped the fire. It a meter was installed the variations could be seen as the bagasse

was fed in. That had been observed in more than one place. The first thing to do was to design a better way of feeding the bagasse. If they dropped wet bagasse through a hopper on to a heap of bagasse in a grate they were continually smothering it with the wet bagasse. He would like to know if Mr. Murray could tell them of any design of furnace or grate that had been designed to give a feed of dry bagasse in proper process without giving those fluctuations.

Mr. J. Murray replied that the modern method of crushing with shredders and double crushers and finely dividing the bagasse up was solving the problem enormously. Formerly when they had a jam in the mill it was found to interfere with the quality of the bagasse, but with the more efficient machinery to-day the product was very much better and easier to deal with. He could not say that he had noticed that particular point Mr. Pullar mentioned, but he thought some of the factories here were getting on very well in that respect. However, he admitted it was a very difficult problem, and the drawing submitted had only been shown to illustrate what they thought was the best method. If they had a flat grate it was naturally worse. That was why he considered the step grate was the best. It was not, however, impossible to design something provided they could get the product fine enough to deal with conveniently. He thought they had just as much brains in this country as in Cuba. With regard to volatiles he was not a chemist and no doubt Mr. de Froberville would be able to answer that question better.

Mr. Pullar referred to the question of pre-heaters and asked if it was possible to obtain any available data regarding the increased efficiency actually obtained. The figures given in the paper were more or less theoretical and they had yet to learn that the bagasse was being weighed in connection with these instruments as against the steam measured from the boiler. Those figures should be of some value otherwise they were still on the theoretical side. There was another point he wished to mention. Claims were made for pre-heaters but some claims were also made for economizers. He took it that the claims for the pre-heaters were discounted by the claims for the economizers. They could not have it both ways, and he thought that was covered by the remark that a combination of the two was advisable. There was also one thing which he thought had not been clearly explained and that was under the heading of "Furnace Air Supply" the merits of the three systems were not very clearly defined. Natural draught conditions were all right and there were certain advantages in having the cold air blowing in below the grates as balanced draught. There was no mention made, however, of induced draught which was a very important thing indeed. Any gains that were made by installing pre-heaters must embody balanced draught, so that some of the gains the pre-heaters claimed to give could be obtained without pre-heating. The figures given were difficult to follow and rather misleading, unless it was very clearly defined how much of the gain was due to balanced

draught and how much to pre-heating of air. One advantage was that excess air was cut down and if that was done they had less air to absorb heat from a pre-heater. It was not such a very big figure after all according to reports from various parts of the world. It was common practice nowadays to install pre-heaters. The sugar estate was not looking for the last 5% efficiency in burning bagasse. The cost of air pre-heating must be very high. The cost of economizers was less. With an economizer there was a great advantage which was not mentioned in the paper, and that was practically increased boiler surface. It was always equivalent to a boiler of the same square feet heating surface, and under varying steam conditions there was a system of thermal storage which was a very great advantage in a factory. He had considered another factor in increasing the efficiency of boilers and the method of firing. Experiments had been made by withdrawing a small proportion (15 to 20%) of the gases of combustion from the combustion chamber and returning that proportion under the furnace by means of a fan and adding to it, before it was put under the bagasse, sufficient air to support combustion. The result had been that they could reduce still further the surplus air required for combustion. They obtained a portion of the benefit from a pre-heater and they obtained all the advantages of balanced draught by taking the air through the fuel bed. That was a development which cost very little as compared with the pre-heater. It would be very interesting if they could obtain from Mr. Murray the actual gain per cent by using pre-heated air so that comparison could be made. It was not altogether a new system as delayed combustion was used in a number of industries; the difference being that he took a small proportion of very hot gases.

Mr. J. Murray in referring to the question of pre-heaters. He was interested to hear that Mr. Pullar in Natal but it was only one boiler and he understood they could not get any correct figures. So far as he knew there was one firm only who made pre-heaters. He was interested to hear that Mr. Pullar had come into the field as competition would make things cheaper. He had heard about Mr. Pullar's scheme but understood that it was in the development stage and it was not desirable to mention it at present otherwise the sub-committee would have been only too pleased to have included it in the report. If they looked at the appendix No. 2 attached to the paper they would find it went thoroughly into the question from a theoretical point of view, and there was no doubt that there was very great value in pre-heating air.

Mr. Pullar stated he wished to correct Mr. Murray with regard to the manufacture of pre-heaters. He knew of at least five, probably six manufacturers. But there was only one pre-heater claiming such an enormously high efficiency as the one Mr. Murray had in mind.

Mr. J. Murray stated that with regard to economizers very few factories had them. The trouble was that if they had dirty water they scaled up rapidly and the soot was rather troublesome to take off. If they had a

fairly good water and the people looking after the plant kept it clean no doubt it was an excellent thing. He did not remember seeing one in Cuba or Hawaii when he was there last. He had been reading some papers from America and at some of the superpower stations they were getting as high as 92% efficiency without the aid of pre-heaters. He thought one was as good as the other. Probably a judicious use of the two would be the best.

Mr. Pullar stated the question of pre-heaters possibly was considered quite separately in a sugar factory. In a big power plant they were used because they could not use the economizer to the same extent as in the past because they had to take some of the steam from the turbine to heat the feed water. The most efficient power station in the world, in America, was equipped half with pre-heaters and half without, and he believed that the efficiency of pre-heaters was considerable and they had decided to instal them right through. He understood the improvement in efficiency was within 5%. Five per cent on a big power station in the coal bill was quite a big thing. At Colenso they were using Babcock pre-heaters and had no economizers. At the new power station to be erected at Durban, Babcocks were to be fitted. The use of pre-heaters in sugar factories was more valuable in connection with the wet fuel.

Mr. Townsend stated that he took it Mr. Murray was fairly well acquainted with the types of furnaces in Natal, how many types there were in existence and how many were efficient. He wished to know if the type described on the first page of the paper was in use at all.

Mr. J. Murray replied that that was simply a diagram and was not an actual type of furnace in use in Natal, but if they would look at page 5 of the typical drawings and settings of furnaces they would see one which he knew worked excellently. In that they had the effects they had just been speaking about. They had the various zones and the chambers for the expansion of the gases. He believed there were 25 factories in Natal and Zululand and he felt sure there must be 25 different types of furnaces. He thought the ones put down in Natal were fairly good. There was, however, one bad one shown in illustration No. 10. Some of the others might be modified to the diagram they recommended.

Mr. Townsend stated that he took it all these types were more or less in the experimental stage; there was not one which could be laid down as an absolutely efficient type of furnace.

Mr. Murray replied that he thought No. 5 would take a lot of beating.

Mr. Wickes in referring to the questionnaire which had been sent round asked how many estates knew what their figures were, to which Mr. Murray replied that so far as he could remember there were about six. Some of the answers received they thought indicated better results than the average for those particular factories.

Mr. Townsend stated that in view of the fact that there were at least fifteen different types of furnaces present under operation, and in view of the fact

that it was probably one of the most important things in a sugar factory, he was surprised that apparently no experiments had been made with a view to finding a grate which would evaporate the greatest quantity of water with a given quantity of fuel. He considered that in the interests of the Industry that should be done.

Mr. Murray replied that the engineers had their own ideas. The object of the paper was to give fairly well the volume and areas right through the boilers. In some cases the boiler might have been designed right but they had not the cross section or volume in the grate to carry the gases and he thought the information given in the paper ought to help in that direction. He had no doubt that in time to come the Technologists' Association which had just been formed would do a lot of good in connection with these matters.

Mr. Pullar stated that he considered if the Technologists' Association was to be of real value to the Industry there should be some means of recording ideas and co-ordinating views on these matters. He had spent a lot of time and it seem to him that the industry benefitted more than he could possibly benefit, and unless some co-ordination took place actively they would never get down to the bottom of things. This was one of the most important things. Bearing on this he asked Mr. Murray if he could tell them what ideas he had of the bagasse furnace of the future when they would probably have big steam generating units to deal with. They would then have problems of handling a bigger volume of fuel and it would no doubt limit the size of boiler to be installed. Without knowledge of what size boiler to instal they would not be able to get ahead with the electrification of mills. So that without co-ordination he did not think they would get very far. Coal fire boilers had been developed considerably but there were certain difficulties which had not yet been overcome and he thought they would be faced with the same difficulties in the burning of bagasse.

Mr. Murray referred to the designs of some of the plants now in use where the boilers were about 15 feet in the air which gave plenty of room underneath to work. In America in some of the large plants there were something like 40 feet above. So far as bagasse was concerned he did not think they would have much difficulty with it.

Mr. de Froberville in referring to Mr. Pullar's question with regard to volatiles, stated that he had not gone very deeply into the subject. He could only mention the gases that were produced by the combustion. He could not give exact particulars as he had not considered the matter sufficiently.

Mr. Townsend referred to the efficiency of boilers and asked if it was not possible for experiments to be made to obtain an efficient boiler. At present there was an enormous loss in the boilers and he wondered if by increasing the size or reducing the number of boilers it would not tend to more efficient working and economy in fuel.

Mr. Murray in reply stated that with the multi-tubular boiler if it was made more than 7 ft. 6 ins. it would have to be made of thicker plates, and



if that was done the heat would not go through it quickly. With a smaller boiler the plate was thinner. The thickness of the plate and the diameter affected the heating efficiency of the boiler. With regard to the length of the boiler, the length of tube available governed that and 20 feet was the limit so far as he knew. So far as water tube boilers were concerned he did not know what the limit was but they were very large. One water tube boiler may equal ten multitubular boilers.

Mr. Pullar mentioned that in Germany they were faced with a difficult combustion question through using lignite coal, etc., and he had seen designs of furnaces where the fuel was fed in through a hopper and before it got on the step grate the fuel had a portion of the actual product of combustion withdrawn from the furnace. By so doing it saved the trouble of evaporating the water and raising it to

the temperature of the furnace gases and flue gases. He would like to see that tried with bagasse experimentally. That would probably be a simple method of increasing output and efficiency.

Mr. J. Murray stated that if they would look at the diagram number 4 they would see that at the top of the step grate there was a chamber with a fire bar in it. That could be used either with the gases from the chimney or coal or wood or anything else. That particular furnace was to dry the bagasse at the top of the step grate.

Mr. Pullar pointed out that there was no withdrawing of the vapour or gases.

The Chairman in thanking Mr. Pullar and Mr. Murray remarked on the very good work which the Sugar Technologists' Association had already done, and hoped that they would continue the good work. (Applause).

## THE USE OF BAGASSE AS A RAW MATERIAL FOR MANUFACTURED GOODS.

By A. T. SCURR.

The war of 1914-18 stimulated research into the utilisation of by-products or waste of industries, and indeed, waste of any kind to previously unknown lengths, particularly on the part of the Central European Powers, who were at times hard pressed for feeding stuffs for their animals, as well as raw materials for their munitions of war. The Allies themselves, though not having to find substitutes for their usual feeding-stuffs had to utilise materials other than those previously used for some of the products needed for the carrying on of warfare, as instance the use of horse-chestnuts for the production of alcohol. Since that time economic conditions have demanded, that industry make use to the fullest extent of any possible economies, and the exploitation of its waste material.

This note, then is merely to put forward, the possible uses of one of the waste materials of the cane sugar industry, i.e., Bagasse. They are not all new and some, like the manufacture of paper from this material was suggested many years ago. Confining ourselves to Natal and Zululand all the bagasse is at present used as fuel for steam generation and as such has a low monetary value. The preparation or manufacture from it of a fertiliser—an artificial or synthetic manure, paper, and latterly "celotex" products seem to be the best uses to which bagasse could be put, though to a limited extent it may and has been used in a ration for feeding stock and also in the composition of magnesium chloride cements for floorings, its incorporation in these latter making them more resilient.

The conversion of bagasse, or indeed almost any vegetable matter of a similar nature, into an organic nitrogenous fertiliser is accomplished by its fermentation in heaps in contact with an insoluble or difficultly soluble, but hydrolisable compound of nitrogen, whereby new insoluble organic compounds of nitrogen are formed, by the action of the organisms in the fermented mass. The finished manure is a damp soft mass which is comparable in nitrogen fertilising properties with well matured farmyard manure and which it resembles in appearance. It cannot be said, however, that the bagasse will make as good a manure by this method as cane trash, for instance, owing to its more woody nature.

The most promising uses of bagasse, however, are on lines where its fibrous nature is utilised, namely, as a raw material for the manufacture of paper or straw-board and similar materials. Unfortunately it does not seem an easy matter to treat bagasse satisfactorily for paper making as owing to the distribution of the fibres in the cane they are not all of equal strength when the cane is ripe for cutting and so they respond differently to the chemical treatment necessary for their conversion into paper. The fibres in the outer part of the cane, are of good strength and firm, while those inside are weak, and as they all must receive the same treatment, either such treatment must be severe enough to reduce the outer fibres completely and this will destroy the inner fibres with consequent reduction of yield, or it must be more gentle, a proceeding which will result in no loss of fibre, but which will only partially re-