A SURVEY OF THE HEAT LOSSES AND THEIR BEARING ON THE FUEL POSITION IN A SUGAR FACTORY

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Introduction.

In considering the invitation to present a paper to this Congress, the author was faced with some difficulty in deciding upon the subject to be discussed, but eventually he resolved upon a treatment of the subject of "Heat Losses in the Factory," which would be quite general, but which it is hoped will provoke some discussion and particularly set Factory Executives thinking as to how they are to achieve the seemingly impossible task of providing the requisite steam from a lesser quantity of by-product fuel, due to the advent of soft canes.

It will readily be conceded that unless one is in a position to study closely over a reasonable period of time, the operations of any one factory, or a group of them, it is difficult to present sets of figures of any real value, and upon which some argument may be raised in order to bring out the salient features of the points at issue.

The Author has, therefore, had recourse to generalisation and certain hypothetical conditions, which he hopes will not be dismissed lightly as of little consequence, but will be studied carefully, as he is sincerely of the opinion that factories can help themselves considerably by a study of the points raised and avoid any serious capital expenditure in doing so.

Steam Production from Available Fuel.

It is essential in the first place to be in possession of some very definite data regarding the possible output of steam from the available fuel at any phase of the factory's operations, and in order to check up on this, to determine as well, the total amount of process steam required by the factory on a basis of average conditions.

To simplify matters in regard to the first point is the object of a chart which the author has prepared and which will readily signify other interesting ratios commonly used day in and day out in the Sugar Factory. (See Fig. No. 1).

Explanation of How to Use Chart. (See Fig. 1—Sheet 1.)

Starting from the R.H. horizontal origin and choosing the ratio of cane to sugar normally experienced, and proceeding vertically upwards to meet the quota of sugar permitted to the Factory, a mark can be made from which, by moving horizontally to the left to the vertical origin, a determination is immediately made of the cane to be crushed in the season. Continuing this horizontal line to the left until the diagonal is reached prescribing the hours of the season aimed at, and from this dropping a vertical line to the L.H. horizontal origin, the crushing rate per hour is determined, and if the vertical line is again continued to meet the chosen diagonal in the third quadrant of the chart representing the percentage of "Bagasse on Cane," a horizontal line drawn from this to the right to meet the lower vertical origin prescribes the tons of bagasse to be expected from the factory.

In the fourth quadrant, the diagonals represent the varying moisture content experienced and if the weight of the Bagasse is connected by horizontal line to the average moisture experienced in fuel, a vertical line dropped to the lower horizontal line will give a figure representing the total available heat value in B.T.U.s. of the Bagasse as it is delivered from the mill. To arrive at this figure, certain values have been ascribed to the combustible elements of the fuel and it is necessary to make this clear so that there can be no misunderstanding.

Accordingly, the following notes are submitted as forming a fair basis for determining the calorific value of fuel.

(a) 1 Pound of dry fibre is taken as having a calorific value of 8350 B.T.U.s.
(b) 1 Pound of sucrose (and other sugars) left in Bagasse has a value of 7120 B.T.U.s ascribed to it.
(c) A constant value of 3.5% sucrose in Bagasse is taken as holding throughout, the variables in the composition of fuel being FIBRE and MOISTURE.

Therefore to the varying heat value of fibre in 1 pound of Bagasse, owing to the various percentages of moisture met with, a constant will be added equal to

\[ 0.035 \times 7120 = 250 \text{ B.T.U.s. to represent sucrose}. \]

The resultant figure will represent the GROSS calorific value of 1 lb. of fuel.

Thus we can calculate the heat value of 1 lb.
RAW SUGAR FACTORY RATIOS & HEAT AVAILABLE FROM BAGASSE

DIAGRAM NO. 1

NETT CRUSHING HOURS PER SEASON.

PRODUCTION OF SUGAR PER SEASON IN TONS

% BAGASSE ON CANE.

% MOISTURE IN BAGASSE

SHEET 1.
of bagasse at any moisture content, with a reasonable degree of accuracy and the values obtained are plotted as indicated in the lower right hand quadrant of the Chart, from which the total available heat per hour is obtained. It is necessary now to turn to a continuation of the Chart. (Fig. 1—Sheet No. 2).

To avoid considerable and tedious work in catering for varying temperatures and pressures of steam met with in the Industry in the construction of this part of Chart, the simple expedient was resorted to of plotting diagonals representing heat added to 1 lb. of water in Boiler to form Steam. As an illustration let us take two cases:

(a) Saturated Steam at 100 lbs. per sq. in. gauge.
(b) Superheated Steam at 150 lbs. per sq. in. gauge and 500°F.

Assuming feed water to enter Boilers at 180°F., a figure common enough in Natal and Zululand factories, it will be clear that

\[(180 - 32) = 148 \text{ B.T.U's. already exist in water.}\]

The total Heat in Steam for (a) = 1189
" " " " " " (b) = 1271

Heat required to convert water into Steam:

for (a) = 1189 - 148 = 1041 B.T.U's.
(b) = 1271 - 148 = 1123 B.T.U's.

Diagonals representing these values or the nearest even number are plotted in increments of 50 B.T.U's. so as to give as wide a field of application as possible to the Chart and it might be well to add that because one's choice falls on the value of 1041 or 1271 B.T.U's. it does not mean that the pressure of steam is necessarily the same as that prescribed above. It will be clear that this difference can exist with a different pressure of steam and a different feed water temperature entering Boilers and thus the Chart has a wide application.

Having determined the total heat available from Fuel, a line can be dropped vertically to meet the particular diagonal representing Heat to Water and from this point a horizontal line to the left, meeting the vertical origin will give the total steam available at 100% Thermal efficiency of Boiler Plant.

Unfortunately this efficiency is beyond practical accomplishment and we have to be content with something of the order of half this ideal value. It should be emphasized, of course, that when we talk of thermal efficiency we refer to the gross Calorific value of Bagasse i.e. the value based on available heat in the fuel and a percentage only of which reaches the water in Boiler, converting it into steam. No allowance is previously made for heating the moisture existing in fuel and on which value called the "nett calorific value" some people sometimes make their calculations.

The left hand quadrant of the extended chart contains various diagonals representing efficiencies from 50% to 70% and by choosing the one representative of the Factory Boiler Plant and drawing a horizontal line from the already determined 100% value to the new value, a point will be obtained which, on dropping therefrom a vertical line to the L.H. bottom origin, will determine the total steam available per hour for the initial conditions chosen. The requirements of the factory at exhaust or process steam pressure are probably already known or should be, and a comparison can thus be made readily between available and required steam.

**Process Steam Required.**

Equally necessary as mentioned above, is a knowledge of the steam requirements of process plant which will fall usually in a Raw Sugar Factory under the following headings:

1. Clarifiers.
2. 1st Heating of Juice.
3. 2nd Heating of Juice.
4. Evaporation.
5. Vacuum Pans.
7. Centrifugals.

There are other minor consumers, such as Sulphur Towers, etc., which can generally be neglected because of their low order of usage.

A proper balance between production and consumption is, of course a vital necessity for economic operation, and since the live steam or the major part of it is utilised to produce power before it is consumed in process operations, it follows that losses take place between the point of production and the points of consumption. These losses can become a very serious obstacle to economic operation, as well as a burden to the engineering staff, and remembering the warnings which have been sounded at this Congress in past years, that the advent of soft canes was going to put the engineers into an early grave, because of the lack of bagasse fuel, one cannot but come to the conclusion that any suggestion which will lighten this burden will be welcome.

Process requirements in steam are comparatively easy to calculate, and each Factory Engineer ought to make a special study of this work, for not only is it an interesting study, but it is illuminating as well, for one soon realises some of the weaknesses which can exist in a system where heat is essential, but is looked upon as a very cheap and easily-got commodity in a Sugar Factory.
It is this very cheapness which leads to all sorts of abuses in its utilisation, and which ought to be stopped.

The Author has repeatedly heard it said—"Oh! we run very well here; we are a balanced factory." Meaning, of course, that practically every particle of Bagasse is utilised in the production of sugar; whether it is efficiently utilised never seems to enter into the picture and does not matter! Now this was all very well when the price of sugar was much more remunerative to the producer and waste here and there in the factory could be tolerated.

Today, with keener world competition and marketing difficulties, the producer has a new set of conditions to meet, and it is essential to be in front of his competitors continuously.

It must be remembered that the basis on which efficient operation is judged is assuming a higher value every year, i.e. it is continually being raised owing to new achievements in the economic sphere of operations and what was considered a fine result a few years ago, is now relegated to very ordinary practice today. That is what is known as "progress." It is imperative, therefore, to see that continual scrutiny is given to all aspects of economy and that the long view is kept in the forefront of any proposals.

These points may seem self-evident, but it is considered that they can bear repetition.

And here the Author wishes to state, in case he is misunderstood, that he is well aware of the very progressive tendencies which are evident in the Industry today, and the opinions offered here are intended as helpful criticism in order to accelerate this progress and make the Natal Sugar Industry the most efficient extant, particularly on the engineering side of its activities.

Steam Losses between Boiler and Process Plant.

These can be enumerated under three headings:

(a) Condensation losses.
(b) Direct-to-atmosphere exhaust.
(c) Steam lost in process

Steam Lost in Process.

An expansive treatment can be made of item (a) and (b), but in regard to (c), unless there is some radical change in the manufacture of sugar, this loss will always be with us, like the poor. It is still a debit, of course, in spite of its necessity, and it cannot be out of place to say that its use should be controlled, for inordinate and unnecessary usage means that steam generation becomes less efficient and more expensive accordingly.

Losses under (c) take place at such stations in Raw Sugar Factories as:—

1. Sulphur Tower-nozzles.
2. Blow-ups.
3. Centrifugals.
4. Filterpresses.

In a Refinery, of course, this list can be considerably extended to include wash, various melting and hot-water tanks, filters, refinery centrifugals and treacle tanks.

Direct to Atmosphere Losses.

The losses under (b) are impressive in the author's opinion, and although they seem less numerous than those in (a) to be discussed next, they are probably of equal value in weight lost per unit of time, at least in some factories which the author has had the privilege of visiting. These losses are as follows:—

(1) Power units exhausting to atmosphere instead of process main, such as:—
   (a) Cranes.
   (b) Winches or Capstans.
   (c) Steam engines driving fans, etc., etc.
   (d) Steam driven pumps and compressors.
(2) Mill engine cylinder pet cock discharges.
(3) Packing gland leakages on steam units.
(4) Leaky joints of steam pipes.

It is remarkable to note how most of these losses are taken as a matter of course apparently, and for this the engineering staff is not to blame entirely.

One is inclined to the view that the factory staff and others do not back up the efforts of the engineers in eradicating or minimising these losses. If their total value was even estimated or deduced from records, the result would be nothing less than astonishing.

It is felt that by tabulating the possible points of loss as above, a better grasp of the problem confronting the engineer when dealing with fuel shortage, will be obtained. It is no light task or problem either.

It is scarcely necessary to indicate in this paper the remedies to be applied to limit the losses under item (b) to as low an extent as is practicable.

The major item of loss is in the direct exhaust of a most valuable commodity into the atmosphere, a loss which is all too prevalent unfortunately.

Exhaust steam piping is cheap enough, and its cost of installation would soon be returned in an appreciably short time by lightening the task of the Boiler Plant, which often enough has to bypass its steam at a comparatively high pressure.
into the process main or plant direct, without doing work on its way, a costly proceeding, as can be demonstrated.

Where atmospheric discharge of steam from prime movers takes place intermittently and may be impracticable to collect owing to remoteness of position or method of operation, then electrified drive is indicated, which, in itself, is the means of a further saving in steam through the superior economy of production at its generating point.

Condensation Losses.

Item (a) may be roughly divided into two sections.

1. Condensation caused through excessive radiation of heat from surfaces in immediate contact with steam on its way to Power Plant or to Process.

2. Condensate losses from the following stations:
   (a) Steam traps discharging to atmospheric drain.
   (b) Steam coils discharging to atmospheric drain.
   (c) Condensate and feed pump gland leakages to atmosphere.
   (d) Leaky joints of feed water pipes.
   (e) Hot well overflow through limited storage capacity.
   (f) 1st Effect evaporator condensate discharge to atmospheric drain due to inefficient means of collecting and returning this pure water to boilers.
   (g) Vacuum Pan condensate as under (f).

The headings all refer to pure condensate fit for feeding direct to Boiler Plant without any treat-
ment for purification, but there is, as the author has seen, also considerable loss in secondary condensate obtained from the evaporation of water in juice which could conceivably be used very effectively, and to a greater extent than is done, for maceration or washing purposes in process.

And having said this, the author wishes to return to a consideration of item (a) i.e., "Condensation losses."

We are now concerned with the transmission of steam from one point to another, and the effect that radiation of heat has on the state of steam at its terminal point.

Not infrequently one observes throughout a factory many points in a steam main, either absolutely devoid of covering possessing the property of resistance to heat flow, or being covered by a very indifferent insulating material.

These conditions are readily appreciated by the Engineer or Technician, but not so by those who make the final decision in regard to expenditure on any scheme. They are, however, of vital concern to the economical operation of the factory as a whole, and should be better understood in consequence.

To illustrate the Heat Loss, which can occur from the wall of a perfectly bare pipe or tank surface to atmosphere, and on the other side of which a comparatively high temperature exists, Figure 2 should be referred to.

Consider the particular loss of heat with steam at 100 lbs./sq. ft. dry saturated, i.e., a temp. of 338°F., which is indicated on curve as 815 B.T.U's. per sq. ft. per hour.

The atmospheric temperature of factories is probably on the average 75°F. so for our purpose we will take 800 B.T.U's as the loss from a sq. foot of pipe surface.

Now a pound of steam at 100 lbs./sq. ft. has a total heat of about 1,189 B.T.U's. Of this, however, about 180 B.T.U's exist in the condensate in the pipeline so that the heat lost by 1 lb. of steam in pipeline is (1189-180) or 1009 B.T.U's.

Consequently 1 sq. foot of bare surface is responsible for the condensation of 800 lbs. or 0.795 lbs. of steam per hour.

To get what one might call a spectacular view of this loss a reference to the following tabulation will be illuminating.

<table>
<thead>
<tr>
<th>Steam lbs.</th>
<th>Average Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagasse lbs.</td>
<td>Fuel, tons</td>
</tr>
<tr>
<td>3,180</td>
<td>1,590</td>
</tr>
</tbody>
</table>

This is at an evaporative ratio of 2 lbs. water per lbs. of Bagasse actual.

A 6 in. diameter steam pipe 12 ft. long has an area of 20 sq. ft. and if left uncovered would be responsible for the following losses per season on the same basis.

Steam
Equivalent Bagasse
31,800 lbs.
(16 tons)

A flanged joint of a 6 in. pipe, B.S. Tables F. & H., bared 3 in. behind each flange, represents a total area exposed for radiating heat, of 2 ½ sq. ft.

A glance at such a feature in any factory cannot fail to impress the onlooker with the fact that it represents a near approach to a radiating fin as incorporated on air cooled I.C. Engines and other mechanisms for the purpose of dissipating heat as rapidly as possible

No one can deny that in most factories this feature is all too prevalent. Eight such flanges left uncovered over 4,000 hours would be responsible for the same loss as the above-mentioned 20 sq. ft. of 6 in. piping.

Bare surfaces occur all over the factory, as well as poorly insulated ones, but it is extremely difficult to accumulate data in respect of the total surface in this condition. It is a task, however, which engineering executives should assign to themselves in order to organise a real frontal attack on this serious source of waste.

To give a fairly complete list of typical surfaces might lead to the action necessary, and this is given below—

1. Exposed parts of boiler drums, piping etc.
2. Exposed parts of steam prime movers (Engines pumps).
3. Bare steam and hot water pipes and flanges.
4. Poorly insulated pipes and flanges.
5. Exposed valve bodies and such fittings.
6. Steam traps.
7. Clarifiers and subsiders.
10. Vapour transfer pipes in evaporators.
11. Bare top and bottom covers of heaters, evaporators and pans, as well as badly insulated bodies of these vessels.

Besides these, there are doubtless other pieces of equipment all adding their quota to the general aggregate.

It should be emphasized, of course, that the losses in these parts of process plant will vary, due to the different temperatures of the working fluid. For instance, the heat loss, as already mentioned, for steam at 338°F. amounts to 800 B.T.U./sq. ft. per hour, whilst for a bare pipe or surface containing steam at 250°F. (about 15 lbs./sq. ft.) the loss is about 450 B.T.U. (see Figure 2).

It will be clear, therefore, as the temperature of the working fluid lowers, that a lesser thickness of first-class insulating material will be warranted, alternatively, the same thickness of a poorer insulating material; and this is where the technician enters the picture to determine the economic aspect of each problem, and establish the savings due to either method. He would also select suitable material for the specific conditions.

At this stage it is timely to refer back to the remarks in the opening paragraphs of this paper, namely, to the difference between water actually evaporated into steam and the quantity of steam required by process. The three losses enumerated were:

(a) Condensation losses.
(b) Direct-to-atmosphere exhaust.
(c) Steam lost in process.

and together are responsible for this difference.

One factory will definitely have a different result from another when referred to a percentage-on-total-output basis, by reason of the different mode of steam utilisation, but this variation chiefly will be concerned with items (a) and (b). In other words, there should be fair uniformity in usage between factory and factory under item (c) i.e. steam lost in process, and it would be interesting for the Industry as a whole to see how this loss does come out. for. in the author's opinion, it should be round about a figure of 8% of total steam produced. Nevertheless variations in methods of operation may quite well account for 1% or 2% difference. Items "a" and "b" would also be responsible for a further 6.5% or so at the very least, but it is extremely difficult to do anything more than generalise on this point, for the only direct and safe way to secure reliable figures is to have the steam flow measured to all live steam users, as well as from boiler plant, and in addition calculate the process demands so that losses may be ascribed to live and exhaust sides of factory and measures taken to eliminate as far as possible obvious waste. The percentages quoted above, however, are reliable for one case the author has in mind, and it is for a factory looked upon as a pattern of good management.

But there is no reason why an illustration should not be given of what these losses, together with others to be mentioned, may mean to any factory, and in the summary which will be given for convenience towards the end of this paper, the whole matter will be laid out in a simple form which it is hoped will appeal to readers.

Make-up Water to Boiler Plant.

Before passing on to the above summary, however, it will be interesting to draw attention to the question of make-up water to boiler plant.

In a modern Power Station there are equally as many steam and water pipes and potential leakage points as in a Sugar Factory, and in a well-run Power-station the total make-up water has not to exceed 2½% to 3%. With values of steam and water pressure as a rule in a Sugar Factory less than half Power Station practice there surely should be less excuse for leakages and almost deliberate running to waste of ideal feed water.

Putting the value of make-up, which might be called theoretically avoidable, at 6%—a very low figure for some factories, it will be seen that some leeway requires to be made up even there in the conservation of hot water and steam at points of avoidable leakages and losses if the standard set by a Power Station is to be reached. And there is no logical reason why it should not be!

Consideration of a Hypothetical Case to Illustrate Savings Possible.

For the purpose of drawing conclusions from the foregoing very limited treatment of heat losses, it is proposed to consider some hypothetical factory crushing 100 tons of cane (Uba variety) per hour and to calculate possible savings which it is felt can be made in steam production and consumption in order to bring out clearly the points already made and to emphasize others. and from these to arrive at the total fuel saving.
The following data will form the basis of this investigation:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Season</td>
<td>4000 hours</td>
</tr>
<tr>
<td>Crushing rate per hour</td>
<td>100 tons</td>
</tr>
<tr>
<td>Type of Cane</td>
<td>Uba</td>
</tr>
<tr>
<td>Bagasse % Cane</td>
<td>35%</td>
</tr>
<tr>
<td>Moisture % Bagasse</td>
<td>52%</td>
</tr>
<tr>
<td>Thermal eff. of Boiler Plant (nett)</td>
<td>52%</td>
</tr>
<tr>
<td>(No superheaters)</td>
<td></td>
</tr>
<tr>
<td>(No economisers)</td>
<td></td>
</tr>
<tr>
<td>(No air-preheaters)</td>
<td></td>
</tr>
<tr>
<td>Flue gas temp. at back end</td>
<td>550°F</td>
</tr>
<tr>
<td>% CO₂ in flue gases</td>
<td>10%</td>
</tr>
<tr>
<td>Temp. of Feed to Boilers</td>
<td>200°F</td>
</tr>
<tr>
<td>Steam pressure in Boiler Plant</td>
<td>100 lbs./1°F</td>
</tr>
<tr>
<td>Temp. of Steam</td>
<td>Dry Saturated</td>
</tr>
<tr>
<td>Total Heat of Steam at 100°F</td>
<td>1.189 B.T.U.S</td>
</tr>
<tr>
<td>Heat in Feed Water</td>
<td>168 B.T.U.S</td>
</tr>
<tr>
<td>Total Heat to be Added in Boiler Plant</td>
<td>1021 B.T.U.s</td>
</tr>
</tbody>
</table>

If we refer to Fig. (1) again, we will find that these conditions will permit 141,000 lbs. of steam per hour to be available at Boiler Plant on the average.

This as will be seen represents \( \frac{141,000}{200,000} \) or 70.5% on Cane.

As to the Steam required by process, the Author would refer to Noel Deerr's analysis of the steam consumption of a Factory given as a percentage on cane, on page 332 of his standard and excellent treatise, particularly the first section of his tabulation, where syrup is concentrated to 55° Brix, all of which figures in the Author's experience, bear out good practice as we know it in Natal.

### Consumption of Steam per cent. on Cane Syrup Concentrated to 55° Brix (Noel Deerr)

<table>
<thead>
<tr>
<th>Number of Effects</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>4.1</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>1st Heating of Juice</td>
<td>15.4</td>
<td>15.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Re-heating of Juice</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Evaporation</td>
<td>33.1</td>
<td>24.8</td>
<td>19.9</td>
</tr>
<tr>
<td>Graining</td>
<td>18.2</td>
<td>18.2</td>
<td>18.2</td>
</tr>
<tr>
<td>Steam pipe loss</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>74.1%</td>
<td>65.8%</td>
<td>60.9%</td>
</tr>
</tbody>
</table>

You will note that where a quadruple effect is in operation the total steam required by process amounts to 65.8%, which is made up of 4.6% steam on cane lost by condensation and leakage (items (1) and (6) respectively), and 61.2% steam on cane for stations 2 to 5.

You will note also that no mention is made in this table of steam served to centrifugals, blow-ups, sulphur tower nozzles, etc. but if the 6% of total production of steam mentioned previously as being consumed by these further stations is added as a percentage on cane—being as a matter of fact 4.3%—we will get a total demand for steam practically equal to the production at the boiler plant thus: \((65.8% + 4.3%) = 70.1\) per cent. Fig. (3) will illustrate the point made, fairly clearly.

The figures used in the compilation of this diagram are taken from Deerr, as stated, but though they are representative of good average practice, the Author feels bound to say that the conditions are not so happy in the Industry if an average is taken all through.

Nevertheless, we will consider what improvements are possible so as to arrive at a figure of steam consumption more in accordance with the figure of production anticipated from the crushing of soft cane.

### Boiler Plant.

The test figures obtained by Dr. Hedley in recent years record a steady improvement in boiler thermal efficiency after the installation of superheaters, and air heaters and, of course, by improved combustion particularly, through the adoption of a more scientific type of furnace.

In the foregoing data an efficiency based on net calorific value of fuel is assumed of 52% where the back end temperature is 550°F, and the moisture content of bagasse 52%.

If we were to assume that this temperature of 550°F by the installation of an air heater fell to 350°F, the increase in efficiency is given by the formula:

\[
\text{Increase} = \left[\frac{(t_a - t_i)c}{1.8}\right] - \left[\frac{(t_a - t_i)c}{1.8}\right]
\]

\(t_i\) = atmospheric temperature.

\(t_a\) = flue gas temperature before installation of air heater.

\(t_c\) = flue gas temperature after installation of air heater.

Constant "c" varies with the CO₂ content of flue gas and moisture content of fuel.

An increase of 10% in Thermal Efficiency can be safely reckoned on under the conditions mentioned.
Fuel saving due to this increase

\[
\text{Increase in efficiency} \times 100 = \frac{10 + 100}{52 + 10} \times 100 = \frac{62}{62} = 16\%
\]

Alternatively, if additional steam is required by process having the same quantity of fuel available, the increased evaporation is

\[
\text{Increase in effy.} \times 100 = \frac{10}{52} = 19.2\%
\]
Increase in Efficiency due to Superheating.

This aspect is taken up at what may appear a later stage in this diagnosis than is due to it, but it is because the average factory as it exists today is not in need of highly superheated steam until modernisation of factory power plant takes place and as this paper is dealing essentially with the problem of the average factory there is no need for superheating steam beyond, say, 50° to 100° F. The object of the low state of superheat is to counteract in live steam ranges, and in engine cylinders, the tendency to condense quickly when coming in contact with comparatively cool surfaces which are difficult and impracticable to insulate. In addition, the volume on superheating is kept at a reasonable figure, roughly 7% increase for 50° F. superheat and 15% increase for 100° F. thus keeping velocities for existing pipework at about 162 ft. and 172 ft. per second respectively if saturated steam was formerly at 150 ft. per second.

But it should be noted that the above-mentioned reason for superheat does not excuse the continuation of bare surfaces or poorly insulated ones for the heat loss will be greater, due to the steeper gradient of temperature from the steam to the atmosphere and in the case of a bare surface would increase from 800 B.T.U s./sq. ft./per hour to 1050 B.T.U s. approximately for a 50° F. temperature rise, i.e. a 25% increase!

In the Boiler Plant, doubtless a 2½% increase at least in thermal efficiency is possible and practicable, due to superheating. That is to say, a fuel saving of

$$\frac{2\frac{1}{2}}{62 + 2\frac{1}{2}} = \frac{2\frac{1}{2}}{64\frac{1}{2}} = 3.9\%$$ is likely to be achieved.

Let us take 3.25% as easily attainable.

To this figure, of course, should be added a percentage saving due to more economical use in the mill engines and juice pump cylinders, etc. a figure which can only be arrived at with accuracy from specific tests, and consequently difficult to obtain. This may be neglected, therefore, so that whatever total figure we arrive at as a saving in fuel can be taken as the least to be expected in ordinary operation.

Elimination of Half Condensation.

It has been stated that half the existing loss due to drainage of good condensate to waste, and leakage of steam in system can be recovered in order to be equivalent to Power Station practice in the question of make up. The total loss in this respect was 6% and if we recover 3% due to improved insulation and stoppage of leaks, and such like remedies, thus making an addition of 3% of total steam production available for work in producing power or serving a heating station, this would be equivalent to:

- 3% on 141,000 lbs. hour = 4,230 lbs.

This represents 2,100 lbs. of Bagasse.

Savings on Steam Consumption in Process Plant.

Under this heading we can touch upon possible savings due to improved insulation and due also to a better application of the principles of heat transmission.

The former is doubtless a difficult thing to estimate unless one is in complete possession of all relevant data to enable one to calculate losses due to badly insulated parts of the equipment, but it cannot be disputed that in most factories in Natal the additional steam required on this account must be of a formidable value.

It will be generally agreed that much can be done to improve matters in this respect and particularly between 1st and 2nd heating stations, and between the latter and evaporator. The bare surface exposed must reach hundreds of square feet, and even though it seldom exceeds a temperature equivalent to atmospheric boiling point, many hundreds of pounds of bagasse must be consumed needlessly to make up for this loss, which, by the way, adds considerably to the discomfort of the factory atmosphere, and actually promotes inefficiency in operators.

The value of a cool atmosphere in a factory seems to be little appreciated.

It would not be difficult to find 5,000 sq. feet of such surface at a temperature of 200° F. or more in a factory crushing 100 tons per hour, and at 300 B.T.U s. loss per sq. ft. (see Fig. 2) we have 1.5 million B.T.U s. shooting off into the surrounding atmosphere. If steam is fed at 10 lbs./sq. ft to this surface, and the condensate is at 190° F. say, we lose 1,000 B.T.U s. for every 1 lb. of steam condensed needlessly.
Consequently, in this case 1,500 lbs. of steam are so lost, which is equivalent to 750 lbs. of Bagasse, or roughly 1% fuel saving possible at least.

It should be noted most carefully that we are taking very conservative figures in these calculations, especially in view of the fact that the bare surface loss is for calm conditions.

Moreover, if we examine the steam consumption of evaporators in their normal operation, it will be found that an appreciable amount of their total requirements is spent on heating juice up from temperature of entry to the ebullition temperature in 1st effect, which is a definite loss, and seriously limits the capacity of the evaporator since it is performing the function of a heater, a duty which should be confined to the proper equipment all suitably lagged to prevent loss of heat.

It might be interesting and instructive to say here that a calculation carried out by the author indicated in connection with the performance of a quadruple Evaporator operating in a well-run Factory that 13% of the total heat in the form of steam served to the 1st effect was consumed simply to heat the incoming juice to ebullition temperature.

It can be said with assurance that half this quantity would probably be enough to carry out this function in the properly designed and applied apparatus set aside for it, with much gain, not only in steam consumption but in more efficient operation of Evaporation permitting increased capacity.

However, in this latter consideration, we will take no account of any fuel saving so that we cannot be accused of being too optimistic in this analysis.

In the Author's opinion, it should easily be possible to reduce the 61.2% steam on cane, to a lower figure for process work by considering closely the whole heat cycle and the ordinary straightforward improvements possible.

Conservation of Condensate at Higher Temperature

It is felt that sufficient attention is not paid to this aspect of feed water, and since all condensate returned from process plant is at atmospheric temperature or above (in some cases 230 to 240° F.) there is no reason why by a combination of reduction in make-up water and maintaining a closed system of feed to boilers, a temperature of 200° F. cannot be maintained, i.e. 20° F. above highest existing feed temperature in Natal Factories.

If we take returnable condensate as 63.5% on cane, an increase of 2.4% from previously tabulated figure and considered a reasonable achievement, we have a saving of:

\[
\frac{20 \times 1,000 \times 200,000 \times 0.635}{1,270} = 2,540 \text{ lbs. steam}
\]

\[
1,000 \text{ B.T.U. (Added in boiler)}
\]

\[
\text{Equivalent Bagasse} = 1,270 \text{ lbs.}
\]

\[
\text{1.8%}, \text{say 1.75%}
\]

Summary of Fuel Savings:

<table>
<thead>
<tr>
<th>Item</th>
<th>Station</th>
<th>% Fuel Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boiler Plant</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>(a) Air Heating</td>
<td>3.25%</td>
</tr>
<tr>
<td></td>
<td>(b) Superheating</td>
<td>3%</td>
</tr>
<tr>
<td>2</td>
<td>Elimination of condensation in factory live steam system by improved insulation</td>
<td>1%</td>
</tr>
<tr>
<td>3</td>
<td>Improved Insulation of process plant</td>
<td>1.75%</td>
</tr>
<tr>
<td>4</td>
<td>Conservation of condensate at higher temp. say 200° F. in place of 180° F.</td>
<td>25.0%</td>
</tr>
<tr>
<td>5</td>
<td>Total savings</td>
<td>25.0%</td>
</tr>
</tbody>
</table>

Now, this total may seem fantastic to some, but it is, in the Author's opinion, a perfectly reasonable expectation.

Taking the saving under item (1) for instance:

It will be appreciated that the moisture content of fuel plays a large part in carrying off useful heat, and as an illustration, a heat balance of an hypothetical boiler plant is given below, based on a gross calorific value of 4,100 B.T.U.s. in bagasse fuel, having a moisture content of 51.5%.

The major items of loss have been calculated assuming an exit temperature of flue gases at 350° F., all conditions applying practically as in the calculated saving of fuel under review, but the steam temperature and pressure were of a much higher value than 338° F. and 100 lbs/"G. The calculated efficiency as will be seen was 64.1% based on gross C.V. of fuel, the loss in flue gases due to adherent and inherent moisture being 23.2%. Radiation and unburnt fuel losses are very safe estimates for the type of furnace and setting contemplated in this case, and are pretty well standard for reasonably well run plants. For a brick setting, the radiation loss might be put up 1%, but not more, which would
reduce the heat imparted to steam to 63.1%. It is significant that one prominent manufacturer of boiler plant was prepared to guarantee 68% under similar circumstances. That statement should dispel any fear that may arise as to the accuracy of fuel-saving possible under less onerous conditions as far as steam pressure and temperature are concerned.

**Heat Balance.**

<table>
<thead>
<tr>
<th>Items</th>
<th>B.T.U's</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gross heat value of 1 lb. of bagasse</td>
<td>4,100</td>
<td>100%</td>
</tr>
<tr>
<td>2. Heat carried off by moisture in Flue gases at 350°F. (calculated)</td>
<td>950</td>
<td>23.2%</td>
</tr>
<tr>
<td>3. Heat carried off by dry Flue gases at 350°F. (calculated)</td>
<td>286</td>
<td>7.00%</td>
</tr>
<tr>
<td>4. Heat lost by radiation (say) (modern encased boiler plant)</td>
<td>123</td>
<td>3.00%</td>
</tr>
<tr>
<td>5. Heat lost in incomplete combustion of fuel (say)</td>
<td>110</td>
<td>2.7%</td>
</tr>
<tr>
<td>6. Heat imparted to water (by diff.)</td>
<td>2,631</td>
<td>64.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,100</td>
<td>100%</td>
</tr>
</tbody>
</table>

In regard to other savings in fuel, sufficient has been said to justify such expectations, and in the opinion of the writer, a clear case can be made out for the improvements indicated.

**Effect of Soft Canes on Steam Production and Usage.**

It is understood that the varieties of soft canes under most intensive and popular cultivation are Co. 281 and Co. 290, with a preference in some quarters for P.O.J. types, such as 2725.

Whether this is correct or only approximately so it will be assumed that all three varieties are equally cultivated, harvested and milled by one factory. Any modification necessary can be made by those interested and new results obtained to show the true position.

The following table illustrates the results in terms of sucrose and fibre, and these are compared with Uba cane figures:

<table>
<thead>
<tr>
<th>Variety of Cane</th>
<th>Avg. Sucrose Content</th>
<th>Avg. Fibre Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co. 281</td>
<td>14.84</td>
<td>14.46</td>
</tr>
<tr>
<td>Co. 290</td>
<td>14.85</td>
<td>12.54</td>
</tr>
<tr>
<td>P.O.J. 2725</td>
<td>15.96</td>
<td>12.15</td>
</tr>
<tr>
<td><strong>Averages</strong></td>
<td><strong>15.22</strong></td>
<td><strong>13.05</strong></td>
</tr>
<tr>
<td><strong>Uba Cane</strong></td>
<td><strong>13.79</strong></td>
<td><strong>14.33</strong></td>
</tr>
<tr>
<td>Difference in Soft Canes</td>
<td>+ 1.43</td>
<td>— 1.28</td>
</tr>
<tr>
<td>Difference as per cent. on Uba</td>
<td>10.35%</td>
<td>8.9% decrease</td>
</tr>
</tbody>
</table>

Thus we have 10.35% increase in juice to be dealt with and a reduction of nearly 9% in fuel available for production of steam—a very disturbing set of conditions indeed!

Let us see what this actually means to the factory.

It is reasonable to assume practically the same mill extraction ratio and the same boiling house recovery, consequently for the same output of sugar per season less cane will be crushed, viz., 10.35%. This means that 10.35% less bagasse will be available for the generation of steam. But the fibre content has gone down at the same time to the extent of 8.9% of cane (say 9%). and thus we are faced with a fuel shortage totalling 19% to 19½%. How is the required steam to be generated under such conditions?

If there is any value in the suggestions put forward in this paper, the problem should not be difficult, for, as pointed out, a conservative estimate of 25% fuel saving is possible, which will more than meet the new set of conditions.

**Financial Equivalent of Fuel Saving.**

Let us estimate the value of this fuel saving apart from the necessity to meet the new conditions brought about by the advent of soft canes.

It is necessary in the first place to evaluate the calorific value of Bagasse Fuel for varying moisture content and the following tabulation is that which was used for construction of the fourth quadrant of Figure 1, sheet 1.

<table>
<thead>
<tr>
<th>Moisture % Bagasse</th>
<th>Gross Calorific Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>48%</td>
<td>4,300 B.T.U's</td>
</tr>
<tr>
<td>50%</td>
<td>4,130 B.T.U's</td>
</tr>
<tr>
<td>52%</td>
<td>3,970 B.T.U's</td>
</tr>
<tr>
<td>54%</td>
<td>3,800 B.T.U's</td>
</tr>
</tbody>
</table>
Relating Bagasse to Coal value:

1. 1 lb. of coal of 12,700 B.T.U.s. at 85% gross Thermal efficiency imparts to water in Boiler 10,600 B.T.U.s.

2. 1 lb. of Bagasse (see Heat Balance above) imparts to water in Boiler at 64% gross Thermal efficiency 2,631 B.T.U.s.

3. Bagasse per Unit of coal = 10,600 / 2,631 = 4.00

Taking this ratio of 4 tons of Bagasse to 1 ton of 12,700 B.T.U.s coal which will cost 15/- at Durban F.O.R., it will be evident that 1 ton of Bagasse will have an equivalent cost of ½ shillings = 3.75/- i.e. 3d. per ton for the service of delivering from rail to Bunkers as in the case of coal and so we get 1 ton of Bagasse worth 4/- at Boiler Furnace.

The annual Fuel delivered to Boilers based on a 4,000 hour season will weigh 100 x .35 x 4,000 tons = 140,000 tons.

Since we make a 25% Fuel Saving this will equal 35,000 tons which at a cost of 4/- = £7,000 per annum.

If it is the case that say 20% of this fuel (given as 19 to 19½ in text) is necessary to produce the steam required for soft cane operation then we can capitalise £5,600 of the above saving at say 8%, which indicates that a Factory of the size considered can afford to spend £70,000 in carrying through the recommendations made such as the installation of Air Heaters, Superheaters, Insulation of Steam and feed water piping and Process Plant, establishment of a closed feed system of feed water, etc.

There would still be 5% saving namely £1,400 per annum from the additional fuel saved out of the total of 25%: Multiply these figures by the number of Factories which can definitely effect such savings and consider what it means to the whole Industry in Natal. It is a problem worthy of the most serious consideration.

It is possible to dwell on the problem still further by discussing improvements in process plant and equipment, but the foregoing notes must suffice on this occasion.

Conclusion.

Given sympathy and proper treatment, the problem, though vital and serious for the Industry, is easily capable of solution by the proper applications of the arts of engineering.

Each factory no doubt requires treatment on its merits, but with expert guidance, many seemingly impossible things can be achieved.

In this conclusion the Author, wishing to strike a personal note, feels that it is only right and appropriate to make an appeal to the powers-that-be to study the engineer's problems closely, to listen to his pleas, and not to dismiss lightly, as of no account, his schemes for improvement, which, in all good faith he continues to put forward, in spite of many rebuffs in the past. His task is always an onerous one, and he operates under difficulties which look as if they may be added to with soft canes coming along.

If these notes prove to be of assistance in appreciating the Engineer's problems, the Author will be glad, and his end will be served, for he has always received courteous and helpful treatment from Sugar Factory Staffs, and feels that an acknowledgment, publicly, is due to the many friends whom he has met from time to time in the course of his movements about the sugar belt in Natal and Zululand.

Bibliography.

"Cane Sugar" by Noel Deerr.

"Insulation data" by Newalls.
taint extent, but he has pointed them out very clearly. I think that the case is very clearly made out for the savings in fuel, but Mr. Porteous has not mentioned the saving to be made through improved furnace design.

Mr. PORTEOUS: The length of the paper rather astonished me, and I was careful not to enlarge too much on it, because you might become bored by the time I reached the end. Mr. Murray mentioned the question of furnace design. I frankly admit that I missed that more or less purposely. I don't want to excuse myself. I did miss purposely emphasising the fact that with improvements in the design of furnaces, more fuel could be saved — much greater than 25%. Mr. Murray mentioned this morning 40%, I think.

Mr. P. MURRAY: 40% more steam.

Mr. PORTEOUS: That is rather high, but you have had the experience, and no doubt have some valuable figures stored away somewhere. I need hardly say that it has been impossible for me to use the figures which I have collected from time to time. This paper is perfectly general; it is typical but hypothetical.

Mr. BECHARD: We have here, indeed, a very valuable paper. Mr. Porteous has taken it from the point of view of the steam producer. I would like to take the view of the steam consumer, of the sugar maker. With the water treatment we have, I have been able to gauge the quantity of water which goes through the boilers per hour. I don't know what our steam moisture is. I do know that on the average we are pushing through the boilers approximately 90,000 lbs. of steam per hour. We are crushing between 60 and 70 tons of cane per hour. And I come to the remarkable conclusion that we are using between 22 and 26% of make-up water. Mr. Porteous tells us here that we should use the figures which I have collected from time to time. This paper is perfectly general; it is typical but hypothetical.

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The heaters have approximately two thousand square feet of surface. On rough measurement, I come to the rather high figure of 1,000 gallons (10,000 lbs.) of hot water per hour being run to waste. We have got to make it up with cold river water. Also having this in view—that whereas, with this water, there is only a trace of solids, river water goes as high as ten to eleven grains per gallon. That also raises concentration in our boilers, therefore produces wet steam. I look at it this way—that for quite a considerable time a day 10,000 lbs. of water are going to waste, thus approximately 1,600,000 B.T.U's, per hour are wasted. We are wasting, therefore, on that figure, approximately 800 lbs. of bagasse per hour, which is 16% of our total bagasse production. This will give you in actual practice what has happened.

I want to stress this view:—if you have not got steam, you have got to rush your process, you have got to rush your evaporation. That means you are going to use more steam at the pan, and the whole work is going to suffer just through the steam not having been saved in the first place—the operator simply has not got it to use.

The PRESIDENT: There is another point. There is the heating. Quite a lot of direct heating is done. You cannot possibly get that back into the feed tank.

Mr. PORTEOUS: I think I understood Mr. Bechard to say that he used vapour compression.

Mr. BECHARD: No, we use the vapour as it is, two or three pounds pressure.

Mr. PORTEOUS: I definitely state in the paper that 6% make-up is a very good condition indeed. I am not at all surprised to hear of 26%. That is one of the most serious losses in the factory. I don't know why the technicians of the Industry have not tumbled to this before. I don't want to appear a carping critic at all, but I think Mr. Bechard has definitely the cure in his own hands; he ought to alter his heating problem entirely, raise his heaters to a point where he can get his condensate back, or pump the condensate from the existing station. Mr. Wilson mentioned heating in blow-ups. I want to make it clear—as I have indicated in Diagram No. 3—that there is steam used in process in my calculations from which condensate is irrecoverable and this was given on page 35 as 4.3% on cane, a very good figure judging by what I have seen in some factories. That is, I have taken account of direct heating operations.

Mr. Bechard emphasised a particular problem that has got to be faced very, very soon. I have not mentioned it in this paper. He referred to the
consumer's aspect—that is the consumer of steam, not so much the steam producer—it is an important one. There is apparatus available, namely, Thermal Storage, which will get him out of his difficulty. I think a paper on that has, as a matter of fact been given in Natal, which I would ask Mr. Bechard to read. Mr. Bechard could speak with knowledge on the subject. Have I answered your point, Mr. Bechard?

Mr. BECHARD: The main point I want to draw was that very few factories—I am in a position to know—know what the actual make-up water is, and it would be very interesting, or perhaps it would give them a very big surprise to see what actually is the quantity of make-up water.

Mr. PORTEOUS: Yes, I thought I had emphasised that. I have a case in mind. It was amazing to me to discover that the amount of make-up came to something like 15 to 20%. It is quite unnecessary. You can collect all your pure condensate and get it back.

Mr. JOHN MURRAY: Regarding Mr. Bechard's remarks, the greatest crime, to my mind, in a sugar factory, is the exhaust steam blowing through the roof. I should say that a good sugar factory should have a thermal efficiency of 60%.

If you put ten pounds pressure on top of that simple engine to turn that steam into atmosphere, I don't think you get a thermal efficiency of half of one per cent. One moment you are asking the boilers to deal with 60% efficiency, and the next moment you are asking them to deal with a half per cent. efficiency. Naturally you have a problem.

The PRESIDENT: I would like you to join me in a hearty vote of thanks to Mr. Porteous for a very splendid paper, which will pass into your Proceedings and be a splendid record. (Applause).