IMPROVEMENT OF HEAT BALANCE AT UMFOLOZI FACTORY

by G. ASHE
Umfolozi Co-operative Sugar Planters Ltd.

For years Umfolozi has had "Steam trouble", due to the fact that the factory has been operating with an unfavourable heat balance.

One reason for this steam trouble is the fact that the fibre content of the cane is very low, the average for the last ten years being only 13.6%. With this low fibre content it is essential that highly efficient steam raising and steam usage plant be used in the production of sugar. This was not so at Umfolozi. Exhaust steam was blowing off most of the day while, at the same time, coal at a cost of R5.65 a ton was being burned to produce live steam. There were many reasons for these conditions, the major one being that the type of installed plant was uneconomic in the use of steam. No vapour bleeding of any significance was being used, and if it were used, it meant that more exhaust steam was available for blowing off to atmosphere. Umfolozi also has a high "outside" load consisting of power being supplied for the village and surrounding farmer members, plus pumping of water from the Umfolozi River, a distance of some three miles.

The boilers for raising steam were as follows:

has a high ash content and a low fusion temperature, the operation of the coal fired boilers present a problem.

Five furnaces were fitted with dump grates for coal burning but due to the quality of the coal, very severe clinkering took place on the grate and if not cleaned in time it is impossible to dump the grates and the clinker had to be broken up and raked out of the furnace doors. This caused untold damage to the grates and fire cleaning took over an hour and longer. During this period of cleaning the furnace doors were open and no fuel was being fired and so the boiler being cleaned was virtually off range for the whole period of fire cleaning. This meant that in order to maintain steam pressure the remaining boilers had to be forced.

It was found that on the boilers burning coal, fires had to be cleaned every two hours, and with dump grates the whole fire was dumped into the ash pit with the result that a large proportion of unburnt coal was lost in this way, thus reducing the boiler efficiency.

To overcome this problem one of the C.E. boilers was converted to a chain grate and this improved the efficiency to a certain extent because all the coal was burnt out before falling into the ash hopper.

Unit No.	Make	Capacity	Maximum Working Pressure	Fuel	Year of Manufacture
1	Combustion Engineering	30,000 lb./hr.	250 psig	Coal & Bagasse	1953
2	Babcock & Wilcock	20,000 lb./hr.	160 psig	Bagasse	1926
3	Babcock & Wilcock	30,000 lb./hr.	160 psig	Bagasse	1934
4	Babcock & Wilcock	35,000 lb./hr.	160 psig	Coal & Bagasse	1949
5	Babcock & Wilcock	35,000 lb./hr.	200 psig	Coal & Bagasse	1942
6	Babcock & Wilcock	30,000 lb./hr.	200 psig	Bagasse	1916
7	Babcock & Wilcock	30,000 lb./hr.	200 psig	Bagasse	1918
8	Combustion Engineering	55,000 lb./hr.	250 psig	Coal & Bagasse	1956
9	Combustion Engineering	55,000 lb./hr.	250 psig	Coal & Bagasse	1958
		320,000			

The Boiler Efficiency was of the order of 60% and even lower on occasions due to many reasons, such as low feed water temperature due to excessive make up caused by good water being blown out in the form of exhaust steam, the quantity of make up varying between 50,000 and 100,000 lb./hr. This was partly rectified by injecting exhaust steam into the boiler feed tanks and thus raising the temperature to 200°F.

By having to use so many small boilers their combined losses added together were quite considerable.

The biggest contributor to low boiler efficiency was the fact that coal had to be burnt on certain boilers, together with bagasse. This in itself is no problem but, due to the fact that the coal we receive

CO_2 and O_2 analysers were fitted to the boilers to ensure that they were being operated correctly and this helped to improve the efficiency.

The quality of the bagasse at Umfolozi, due to the abnormal amounts of clay and sand which adhere to the cane, seriously interferes with its burning, and at times tends to put the fires out. This also gives a false idea of the fibre content of the bagasse, a fact which cannot be overlooked.

There are lots of other small faults which all tend to lower the overall efficiency but we will pass on to the usage of the steam.

The live steam was used in the power house to drive three turbines and produce 4000 KW, on the

84" x 39" tandem to drive six steam engines of 450 h.p. each and one multi stage turbine of 600 h.p., and on the 66" x 34" tandem to drive three steam engines of 180 h.p. and one of 260 h.p. plus one single stage turbine of 500 h.p. Live steam was also used to drive the turbines of the Induced Draught and Forced Draught Fans. A small amount was also used in the factory.

The exhaust steam produced was in excess of what the factory could use, the excess being blown to atmosphere.

Due to the design of the prime movers mentioned above, the exhaust pressure was limited to $\pm$ 6 p.s.i.g. The turbines driving the alternators were using almost 40 lb kWh, and when the back pressure was raised this figure was also raised, and if the live steam pressure dropped the sets became overloaded.

The exhaust steam was used in the Primary Juice Heaters to raise the temperature to 175°F and in the Secondary Juice Heaters to raise the temperature to 220°F.

Two quadruple evaporators were used and the exhaust was fed to the first vessels of each one which was designed for vapour bleeding. This vapour at about $\frac{1}{2}$ p.s.i.g. was used for part of the Primary Juice heating, but this did not help much as there was an excess of exhaust steam most of the time. All the vacuum pans were boiled on exhaust.

Steam Production

From the list of boilers installed it can be seen that with all boilers in operation, 320,000 lbs. of steam should be produced per hour. In theory this is correct, but in practice it is not possible.

Firstly, as Umfolozi crushes seven days a week, the boilers Nos. 2, 3, 6 and 7, have to be cleaned while crushing, which means that for most of the week one of these boilers is off for 24 hours.

Secondly, due to the difficulties experienced with coal firing, boilers Nos. 1, 8 and 9 have to be cleaned every two hours, (see Fig. 1), so that every forty minutes one of these boilers is off range and, depending on the time taken to clean the fires, virtually only two of these boilers are steaming all the time.

All repairs to boilers have to be carried out during crushing operations and consequently yet another boiler may be off range. From this it can be seen that, for most of the time, the rated output of the boilers on line would be approximately 260,000 lb./hr.

The live steam used in Prime Movers (turbo alternators, mill engines and turbines, fans, etc.) amounted to 259,000 lb./hr., which is 66% steam on cane.

This basically was the position we were in up to the 1965/66 season.

In 1964 an investigation was made into the use of extraneous fuel and the steam available for prime movers and processing.

In assessing the steam which could be raised with the fuel available, reference was made to the 39th Annual summary of Chemical Laboratory Reports by C. Perk for the following information. (1963/64 Season).

Heat in fuel per lb. Brix in Proc.	= 8277 Btu
Brix Processed	= 29.72 tons/hr.
Cane Crush	= 745,577 tons
	or 190.55 tons/hr.

Total heat available in bagasse

$$= \frac{29.72 \times 2000 \times 8277 \times 745{,}577}{190.55}$$

$$= 1.92 \times 10^{12} \text{ Btu}$$

Average total heat of steam generated	= 1307 Btu/lb.
Average feed water temperature	= 199°F
∴ heat added to the steam	= 1307 - (199 - 32)
	= 1140 Btu/lb.

100% Boiler Efficiency total amount of steam produced during season would have been

$$\frac{1.92 \times 10^{12}}{1140 \times 2000} = 0.8425 \times 10^{6} \text{ Tons}$$

giving a ratio of steam on cane of

$$\frac{842{,}500 \times 100}{745{,}577} = 113\%$$

At a normal demand of 65% steam on cane the boiler efficiency would have been

$$\frac{65}{113} \times 100 = 57\%$$

which is unusually low.

Process Steam Requirements

The process steam requirements for conditions existing at the time, neglecting the small amount of vapour bleeding, was as follows (1963/64):

Cane Crushed	= 190.55 tons/hr.
Brix % in Clarified Juice	= 13.82%
Brix % Syrup	= 58.74%
A Massecuite per ton Brix	= 35.55 cu. ft.
B ,, ,, ,, ,,	= 9.83 cu. ft.
C ,, ,, ,, ,,	= 8.55 cu. ft.
Exhaustion of B Massecuite	= 57.11%
,, ,, C ,,	= 56.69%
Brix in Mixed Juice % Cane	= 15.60%

Evaporators

As the Brix in the clarified juice was approximately 96% of the brix in the mixed juice, the weight of the clarified juice was:

$$\frac{190.55 \times 15.60 \times 0.96 \times 100}{100 \times 13.82} = 206.54 \text{ tons/hr.}$$

and the amount of water evaporated was:

$$206.54 \times \frac{(58.74 - 13.82)}{(58.74)} = 157.95 \text{ tons/hr.}$$

The amount of steam required for this evaporation in quadruple effect was:

$$\frac{157.95}{4} \times 2000 = 78975 \text{ lb./hr.}$$

Juice Heaters

The juice heating is done in two stages.

Primary Heating—the cold mixed juice + 20% returned filtrate is heated from 100°F to 175°F.

Secondary Heating—(after liming) from 170°F to 215°F. As the juice leaving the clarifiers is at 195°F this juice will have to be heated in the first vessel of the evaporator to 212°F before evaporation takes place.

Taking the specific heat of mixed juice as 0.9 and the mixed juice weight of 204.68 tons/hr., the amount of steam used for heating is:

$$\frac{0.9 \times 1.2 \times 204.68 \times (175 - 100 + 215 - 170)}{961} \times 2000 + \frac{0.9 \times 206.54 \times 2000 (212 - 195)}{961}$$

$$= 61772 \text{ lb./hr.}$$

Vacuum Pans

The steam consumed by vacuum pans can vary considerably and depends on the amount of wash water, diluted molasses, etc. Average figures show that for a brix of 65°, the steam required to evaporate the water from the syrup is equal to twice the weight of the water.

Additional steam will be required for remelting purposes and for evaporating water from syrup with a brix of less than 65.

Brix in clarified juice $= 0.1382 \times 206.54$
$= 28.66$ tons/hr.

Water in syrup at 65° Brix $= \frac{35}{65} \times 28.66$
$= 15.43$ tons/hr.

Syrup of 58.74° Brix contains $= \frac{41.26}{58.74} \times 28.66$
$= 20.13$ tons/hr.

A difference of (20.13 − 15.43) 4.7 tons/hr.
Therefore steam consumption including remelt
$= 2000 \times (4.70 + 2 \times 15.43)$
$= 71120$ lb./hr.

Steam will also be required for remelting Quantity of "B" Massecuite
$= 29.72 \times 9.83$
$= 292.1$ cu.ft./hr.
$= 292.1 \times 94.7$ lbs./hr.
$= 27662$ lb./hr.

$$\text{Sugar \% massecuite} = \frac{100 \text{ bm } (J - M)}{\text{bs } (S - M)} \ *$$

where bm = Brix massecuite
bs = Brix Sugar
J = Massecuite purity
M = Molasses purity
S = Sugar purity

$$= \frac{100 \times 95.83 (73.87 - 54.80)}{99 (98 - 54.80)}$$

$= 42.7\%$

and the weight of sugar $= 0.427 \times 27662$
$= 11{,}812$ lb./hr

The same calculation for C Sugar will give 11260 lb./hr. after single curing and $0.7 \times 11260 = 7888$ lb./hr after double curing. Thus the total amount of sugar to be remelted is

$$11{,}812 + 7888 = 19{,}700 \text{ lb./hr.}$$

This sugar requires $\frac{19{,}700}{2} = 9850$ lb. water/hr.

and the steam consumed is $= 1.5 \times 9850$
$= 14775$ lb./hr.

Other Steam Consumers

Into this category fall sugar drying, steaming out centrifugals, pans, etc., which may be done with exhaust steam.

At $1\frac{1}{2}\%$ steam on cane this gives

$$\frac{1.5 \times 2000 \times 190.55}{100} = 5717 \text{ lb./hr.}$$

Total steam requirements without vapour bleeding

Plant	*lb./hr.*	*% on Cane*
Evaporators	78,975	20.7
Juice Heaters	61,772	16.2
Pans	71,120	18.7
Remelting	14,775	3.9
Sundry	5,717	1.5
Total	232,359	61.0

Thus without vapour bleeding to produce a syrup of 58.74° Brix and remelt all B- and double-cured C-sugar requires 61% steam on cane.

Allowing a reduction for vapour bleeding and additions for losses from radiation, leaks, etc., the factory should require about 65% on cane for processing, which is 254,000 lb/hr.

As was shown earlier on the steam used by prime movers amounted to 259,200 lb./hr. and therefore an excess of some 5,000 lb./hr. was being blown to atmosphere.

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*Hulla-Suchomel formula.

It was obvious from the above that in order to reduce extraneous fuel being burnt it would be necessary to reduce the usage of exhaust steam for process, as well as the live steam consumption by the prime movers.

In order to get exhaust steam at 15 psig it would be necessary to install an efficient turbo alternator to produce about 5MW at about 20 lb. of steam per kW. (Existing Turbines use 40 lb./kW). This turbo alternator would require 100,000 lb. of steam per hour at full load and would have to operate at 450 psig 750°F. This meant that a new boiler would also be required.

A comparison is now made to see what advantage would accrue by installing a pre-evaporator operating at 15 psig and producing vapour at 5 psig.

Steam requirements under these new proposed conditions would be:

Juice Heating

Primary Heating (100°F to 175°F) will use vapour from the first vessel of the quad at about ½ psig and require:

$$\frac{204.68 \times 0.9 \times 1.2\ (175 - 100) \times 2000}{971}$$

= 34184 lb./hr.

Secondary Heating (170 to 215°) will use exhaust steam at 5 psig

$$\frac{204.68 \times 0.9 \times 1.2\ (215 - 170) \times 2000}{961}$$

= 20702 lb./hr.

The heating of the clarified juice in the pre-evaporator using steam at 15 psig will be

$$\frac{206.54 \times 0.9 \times 2000\ (227 - 195)}{946}$$

= 12576 lb./hr.

The amount of water to be evaporated to produce a brix of 65° will be

$$\frac{206.54 \times (65 - 13.82) \times 2000}{65}$$

= 325253 lb./hr.

The steam requirements of the pans will be
2000 × 2 × 15.43
= 61720 lb./hr.

Assuming the turbine will use 4,000 kW at 20 lb./hr then 80,000 lb./hr. of 15 psig steam will be available
∴ Exhaust steam at 15 psig available for pre-evaporator will be
80,000 − 12,576
= 67,424 lb./hr.
Water to be evaporated in normal quadruple effect
= 325253 − 67424
= 257,829 lb./hr.
less the vapour to the primary heaters
= 257,829 − 34184
= 223645 lb./hr.

Steam for first vessel

$$= \frac{223645}{4}$$

= 55911 lb./hr.
Total in first vessel
= 55911 + 34184
= 90095 lb./hr. in first vessel

Therefore total steam requirements will be

Pre-evaporator (15 psig)	... ...	12576
Evaporator (5 psig)	... ...	90095
Juice Heaters	„	20702
Pans	„	61720
Remelt	„	14775
Sundry	„	5717
Total		205585

This represents

$$\frac{205585}{381100} \times 100$$

= 54% on cane

As before, allowing for losses, radiation, etc., we get approximately 58% steam on cane, which is 228,000 lb./hr.

This constitutes a considerable saving over the prevailing condition of 65% steam on cane.

Therefore 26,000 lb./hr. less steam would now have to be produced and as 1 lb. of coal produces 7 lbs. of steam this would mean a saving of 208 tons of coal per week, and although the scheme would not eliminate the use of coal completely, it was decided to go ahead with the additions.

Subsequently it was decided to increase the crushing rate of 250 tons/hr. and the following plant was installed during the 1966 off-season:

One Combustion Engineering boiler having an evaporation rate of 125,000 lb./hr. at 450 psig and at 750°F.

A 6,000 kW A.E.G. turbo alternator of the back pressure type operating at 450 psig and 750°F and back pressure of 15 psig.

A 9,000 sq./ft. (Dorman Long) Semi-Kestner pre-evaporator was first installed to take all the exhaust from the turbine and later it was decided to increase the back pressure from the mill engines to the same as that of the turbine, i.e. 15 psig and install another pre-evaporator of 20,000 sq. ft. (Elgin) thus passing all available exhaust steam at 5 psig through pre-evaporators and producing vapour at 5 psig for Secondary Juice heating and Pan Boiling. Primary heating would be done with vapour II from the first vessel of the Quad Evaporator.

Two Juice Heaters to heat clear juice to 235°F.

This scheme was not finished at the start of the 1966/67 season but was completed during the season and, therefore, the final figures for this past season do not show the full benefit obtained from the additions but nevertheless show a marked improvement over previous years.

Evaporation rates of over 12 lb./sq. ft. of heating surface have been obtained on the Semi-Kestners and the operation of this plant is a subject on its own.

The installation of the new boiler made it possible to dispense with some of the older low efficiency boilers and thus raised the boiler efficiency to over 70%.

The steam produced when crushing 250 tons/hr. was 275,000 lb./hr., or 55% on cane, which is better than the 58% on cane calculated in 1964 and shown above.

The reason for this is the fact that all the exhaust steam produced was passed through the pre-evaporator at 15 psig and produced vapour at 5 psig.

Extraneous Fuel

The following example is worked out to show if and when Umfolozi will have to burn coal to produce 275,000 lbs. of steam per hour:

Moisture % Bagasse = 52.5%
Sucrose % Bagasse = 2.2%
Purity of Last Mill Juice = 70%

$$\text{Brix \% Bgse.} = \frac{2.2}{70} \times 100 = 3.17$$

$$\text{Fibre \% Bagasse} = 100 - 52.5 - 3.17 = 44.33$$

With a fibre % Cane of 12

$$\text{Bagasse \% Cane} = \frac{\text{Fibre \% Cane}}{\text{Fibre \% Bgse.}} \times 100 = \frac{12}{44.33} \times 100 = 27.1\%$$

Tons of bagasse per hour at 12 Fibre % Cane at 250 tons/hr.

$$= \frac{27.1 \times 250}{100} = 67.6 \text{ tons bagasse/hr}$$

For 13 Fibre % Cane = 73.2 tons bagasse/hr
For 14 Fibre % Cane = 78.9 tons bagasse/hr

Amount of bagasse required to produce 275,000 lb./hr. of steam with bagasse having a L C V of 3140 BTU/lb. and steam of 1160 BTU/lb.

$$\text{Tons Bagasse} = \frac{275{,}000 \times 1160}{3140 \times 2000} = 51 \text{ tons}$$

With a boiler efficiency of 70% we will require

$$\frac{51}{70} \times 100 = 73 \text{ tons/hr.}$$

Therefore when the Fibre % Cane is only 12 we will be (73 - 67.6) tons = 5.4 tons short and coal will have to be burnt. At 13 Fibre % Cane we will be just square. At 14 Fibre % Cane we will have (78.9 — 73) tons = 5.9 tons surplus.

A surplus bagasse store is essential to be able to store excess bagasse when available and feed this back in times of low fibre.

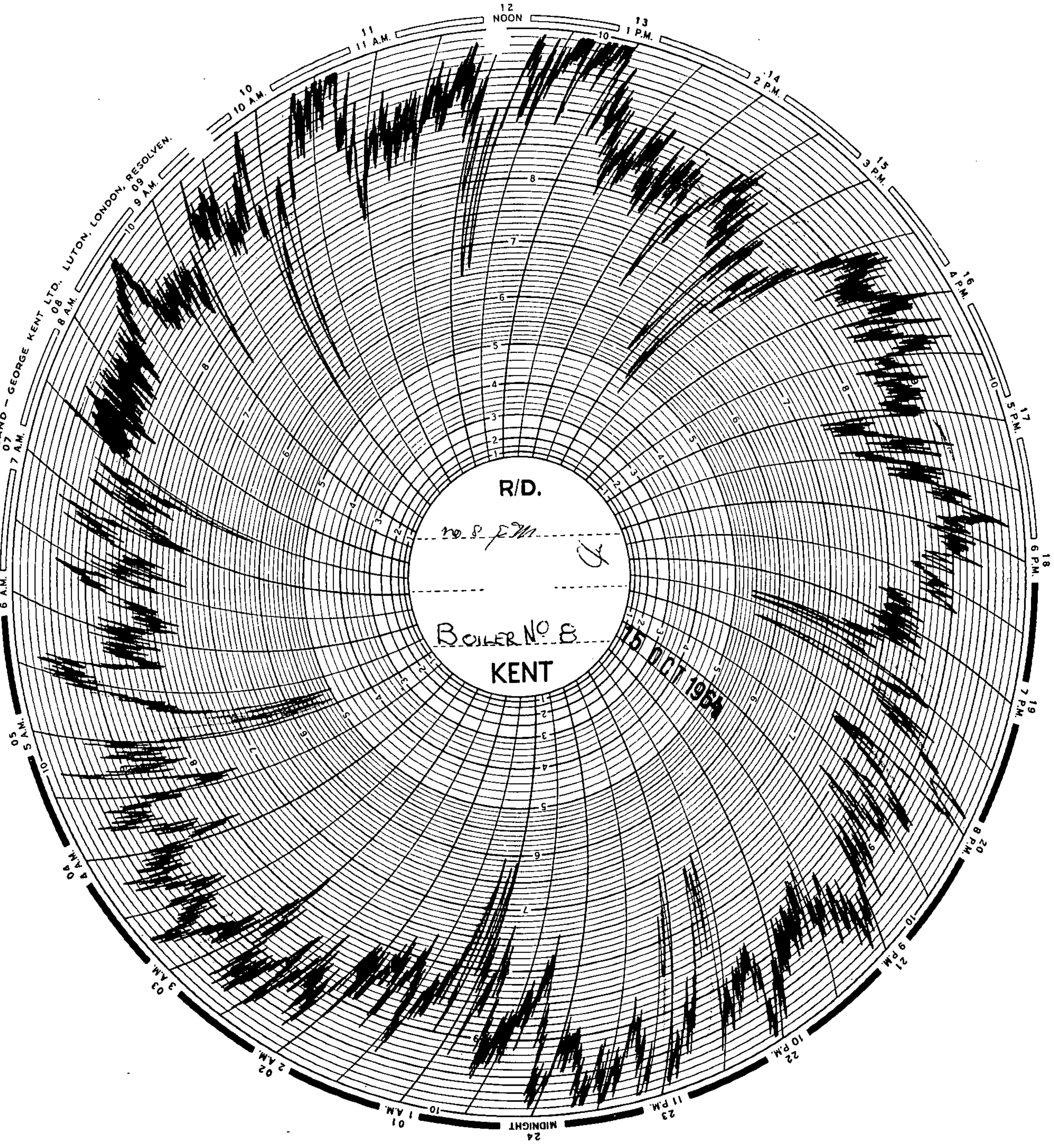
A time efficiency of over 95% is essential if extraneous fuels have to be saved, because mill stoppages are the major cause of surplus fuel and extraneous fuels being used.

The average ratio for the previous six years was 4.14 tons sugar/ton coal. On this basis, during the last season, when we made a record of 169,711 tons of sugar, if no changes had been made we would have used 42,250 tons of coal whereas we used only 12,080 tons giving a ratio of 14.12 ton sugar/ton coal.

Most of the new plant was installed by the end of August and from August to the end of the season the ratio was 23 tons sugar/ton coal.

Conclusion

With the price of coal landed at Umfolozi approximately R6.00 per ton it can be seen from the above that a considerable saving has been effected due to the improved heat balance made possible by the additional plant, despite a one per cent lower fibre in cane than the previous season.


12 NOON
13 1 P.M.
14 2 P.M.
15 3 P.M.
16 4 P.M.
17 5 P.M.
18 6 P.M.
19 7 P.M.
20 8 P.M.
21 9 P.M.
22 10 P.M.
23 11 P.M.
24 MIDNIGHT
01 1 A.M.
02 2 A.M.
03 3 A.M.
04 4 A.M.
05 5 A.M.
06 6 A.M.
07 7 A.M.
08 8 A.M.
09 9 A.M.
10 10 A.M.
11 11 A.M.
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R/D.
BOILER No 8
KENT
15 OCT 1964

FIGURE 1

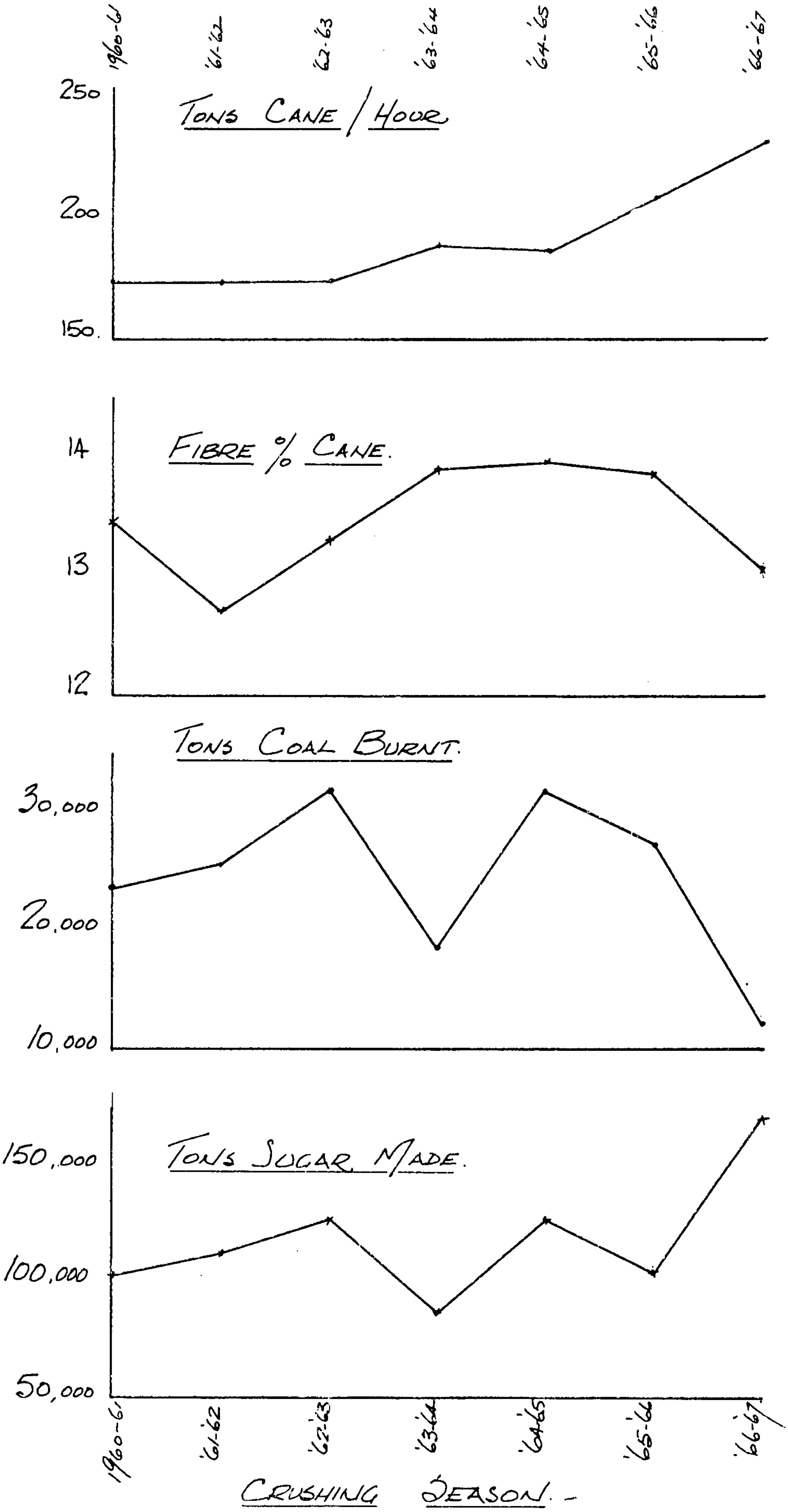
Tons Cane / Hour
Fibre % Cane.
Tons Coal Burnt.
Tons Sugar Made.
250
200
150
14
13
12
30,000
20,000
10,000
150,000
100,000
50,000
1960-61
'61-'62
'62-'63
'63-'64
'64-'65
'65-'66
'66-'67
Crushing Season.

FIGURE 2

Discussion

Mr. Steffen: What is the maximum period at Umfolozi between boiler cleaning?

Mr. Ashe: There are three types of boilers. Those with chain grates and dump grates hardly ever require cleaning. The conventional hearth furnace of the Babcock boilers require cleaning about every six days. This is due to ash accumulation behind the bridge wall.

Mr. Calder: Was it an expensive and a long job to convert from a dump grate to continuous stokers?

Mr. Ashe: It can be done during an off-season. The cost of conversion was R70,000 on a boiler producing 55,000 lb/hr. The saving in fuel paid for the conversion in a short time. This cost is almost halved if the grate is installed at the same time as the boiler.

Mr. Renton: I think one reason for your unfortunate experiences with a dump grate was the fact that you were burning coal in it.

Mr. Main: How do you calculate the steam efficiency of your boiler?

Mr. Ashe: We are given tons of bagasse figures from the laboratory daily and also tons of coal used. The total heat put into the boiler house is compared with total steam produced, every steam pipe being metered. Boiler feed water is also metered and from these figures we work out a daily efficiency figure, using both higher and lower calorific values of the fuel, and then taking an average.