

# A PRACTICAL STEAM BALANCE

By H. J. M. ZONDERLAND

## General

For the design of the new Amatikulu Mill, two steam balances were drawn up. The first one aimed at a high degree of steam economy with a consequent surplus of bagasse, while the second was calculated for a lesser degree of steam economy so as to eliminate an embarrassing excess of bagasse.

As the latter represents the conventional approach to the problem, only the first one will be dealt with.

The scheme to be discussed includes electrically driven mills, a high degree of vapour bleeding, partial heating of cold mixed juice with the aid of condensates and the application of thermo-compression.

The capacity of the new mill will be 250 t.c.h. and 60 per cent imbibition on cane is to be applied.

Provision has been made for the remelting of all B and C sugars with a view to improving the quality of the raw sugar.

## Available Steam

(450 p.s.i.g.—700°F TT)

The Lower Calorific Value of bagasse with a sucrose content of 2 per cent and a moisture content of 51 per cent amounts to:

$$7650 - 18 \times 2 - 86.4 \times 51 = 3208 \text{ B.Th.U./lb.}$$

Although for the modern type of bagasse-fired boiler an efficiency of almost 82 per cent is guaranteed, a value of 77.5 per cent is taken to calculate the B.Th.U.'s transmitted to the boiler feed. This quantity will then be 2486 B.Th.U./lb.

The total heat of steam at 450 p.s.i.g.—700°F TT is equal to 1358 B.Th.U./lb.

For boiler feed water at 228°F, the B.Th.U.'s to be transmitted to generate 1 lb. of steam =  $1358 - (228 - 32) = 1162$  B.Th.U./lb.

Hence,  $2486 : 1162 = 2.14$  lbs. of steam of above specification can be raised from 1 lb. of bagasse.

At 35 per cent bagasse on cane, the available steam will be  $35 \times 2.14 = 74.9\%$  on cane or 374,500 lbs./h for a crushing rate of 250 t.c.h.

## Live Steam to Prime Movers

The total power consumption of the electrically driven milling plant consisting of 2 sets of knives, shredder and seven mills, is estimated at 4610 b.h.p. which will represent 3820 k.w. at the power house switchboard.

A value of 15 k.w./t.c.h. is taken for the power required for all other purposes in mill, factory and village. This will amount to a total of 3750 k.w.

The grand total is, therefore, 7570 k.w. and at a steam consumption of 20 lbs. per k.w. the steam required will be  $7570 \times 20 = 151,400$  lbs./h.

## Process Steam Requirements

The calculations of the process steam requirements for juice heating and evaporation are based on the quantities shown on the flow sheet in Fig. 1.

### I. Mixed juice heating

This heating will be done in 4 stages viz.

(a) primary heating — 1st stage from 80°—118°F in liquid liquid heat exchanger using condensates to be employed as imbibition water.

(b) primary heating — 2nd stage from 118° — 178°F with vapour II.

$$\text{Required are: } \frac{250 \times 2000 \times 151.5 \times 0.9 (178-118)}{100 \times 970}$$

$$= 42,200 \text{ lbs./h.}$$

$$\text{ex flash condensates } \underline{12,200 \text{ lbs./h.}}$$

$$\text{Actual } \underline{\underline{30,000 \text{ lbs./h.}}}$$

(c) Secondary heating from 173° — 198°F with vapour II.

$$\text{Required are: } \frac{250 \times 2000 \times 152.5 \times 0.9 (198-173)}{100 \times 970}$$

$$= 17,700 \text{ lbs./h.}$$

(d) final heating from 198° — 216°F with vapour I.

$$\text{Required are: } \frac{250 \times 2000 \times 152.5 \times 0.9 (216-198)}{100 \times 958}$$

$$= 12,900 \text{ lbs./h.}$$

### II. Clear juice heating

The first stage of this heating will be done with vapour I while for the final stage steam at 15 p.s.i.g. will be used:

$$(a) \text{ first stage: } \frac{250 \times 2000 \times 132 \times 0.9 (218-200)}{100 \times 958}$$

$$= 11,200 \text{ lbs./h.}$$

$$(b) \text{ final stage: } \frac{250 \times 2000 \times 132 \times 0.9 (232-218)}{100 \times 946}$$

$$= 8,800 \text{ lbs./h.}$$

### III. Vacuum Pans

For the J.A. boiling scheme (remelting of all B and C sugars) the required quantity of vapour I will be  $39 \times 1.1 \times 2000 = 86,000$  lbs./h.

### IV. Centrifugals, Sugar dryer and pan steaming

The required quantity of 15 p.s.i.g. steam is estimated at 14,000 lbs./h.

### V. Deaerator

The quantity of 15 p.s.i.g. steam to be available for this purpose has been calculated at 9,000 lbs./h.

VI. Evaporator

A quantity of  $\frac{250 \times 2000 \times 132 \times (1 - 12/65)}{100}$   
 = 538,000 lbs. of water has to be evaporated per hour.

With the application of thermo-compression i.e. vapour II with the aid of live steam (450 p.s.i.g.—700°F TT) recompressed to 15 p.s.i.g. the following will be the total evaporation achieved by the quin-truple effect:

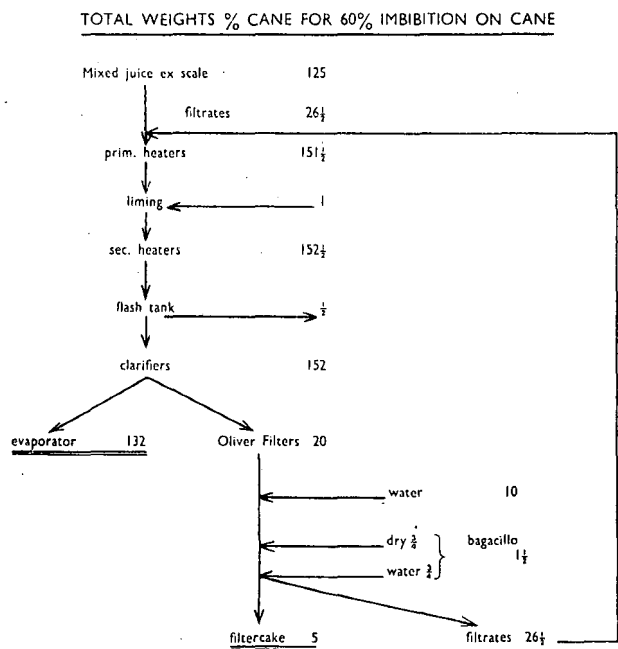
5th effect: x  
 4th ,, x  
 3rd ,, x  
 2nd ,, x + 30,000 + 17,700 + Vap,II for T.C.  
 1st ,, x + 30,000 + 17,700 + Vap,II for T.C. +  
 + 12,900 + 11,200 + 86,000

$$538,000 = 5x + 205,500 + 2x \text{ Vap,II for T.C.}$$

$$x = 66,500 - 0.4 x \text{ Vap,II for T.C.}$$

Fig. 1.

**FLOW SHEET JUICE CLARIFICATION  
 DEFECCATION PROCESS**



Let E.S. be the quantity of available exhaust steam and L.S. the quantity of live steam required for thermo-compression.

Equating the weight of the heating steam to the weight of vapour produced in the first vessel:  
 $E.S. + L.S. + \text{Vap,II for T.C.} = x + 30,000 + 17,700 +$   
 $+ \text{Vap,II for T.C.} + 12,900 + 11,200 + 86,000$   
 or  $E.S. + L.S. = x + 157,800$

When x is now substituted by above value:

$$E.S. + L.S. = 224,300 - 0.4 x \text{ Vap,II for T.C.}$$

As for our conditions 1.2 lbs. of live steam are required to recompress 1 lb. of Vapour II, the "live steam to T.C." can be replaced by the value of 1.2 x Vap,II for T.C. or : E.S. = 224,300 - 1.6 Vap,II for T.C.

The quantity of available exhaust steam is equal to the quantity of live steam to prime-movers reduced by radiation losses and exhaust steam required for other purposes

$$151,400 - 4,600 - 8,800 - 14,000 - 9,000 = 115,000 \text{ lbs./h.}$$

When this value is substituted in above formula it appears that the quantity of Vapour II for T.C. amounts to 68,310 lbs./h. and the live steam for thermo-compression will consequently be 1.2 x 68,310 = 81,975 lbs./h.

The steam balance can now be drawn up as in Table 1.

Expressed in terms of the thermal equivalent bagasse weight the surplus steam amounts to 29.2 tons per hour or 700 tons per day.

**Conclusions**

This apparently embarrassing surplus of bagasse could be used for following purposes:

1. For paper and board manufacturing.
2. An amount of approximately 13,400 k.W.h. of power could be made available to either the Electricity Supply Commission or for local irrigation. In this case no thermo-compression would be applied, the shortfall in 15 p.s.i.g. process steam to be supplied by a self governing back pressure set.
3. For remelting of additional sugar. The calculated surplus bagasse alone would be sufficient to remelt an hourly quantity of approximately 120 tons of sugar.

**Summary**

Of the two steam balances drawn up for the new Amatikulu Mill, the one aiming at a high degree of steam economy has been discussed. With 60 per cent imbibition on cane and remelting of all B and C Sugars, the steam consumption amounts to 50 per cent on cane. This consumption is equal to 11 per cent fibre on cane. The surplus bagasse in this scheme will be 700 tons per day which is, in itself, an impractical amount of fuel saving. However, this surplus could be used for other purposes as suggested.

Table I. LIVE STEAM AND 15 p.s.i.g. PROCESS STEAM BALANCE

I. LIVE STEAM			
Available steam		to prime movers .. .. .	151,400 lbs./h.
at 450 p.s.i.g. — 700°F T.T.	.. .. 374,500 lbs./h.	for thermo-compression .. .. .	81,975 "
		radiation losses:	
		3% of above total .. .. .	7,000 "
		for steaming out Oliver Filters — reduced	
		live steam equal to .. .. .	500 "
		bagasse to storage for mill stops, week-end	
		boil off and start up — 2 tons bagasse/h.	
		equal to .. .. .	8,625 "
		Surplus steam .. .. .	125,000 "
	<b>TOTAL ..</b>	<b>TOTAL ..</b>	<b>374,500 lbs./h.</b>
II. 15 p.s.i.g. PROCESS STEAM			
ex prime movers .. .. .	151,400 lbs./h.	for evaporation .. .. .	265,285 lbs./h.
Vapour II.. .. .	58,310 "	clear juice heating .. .. .	8,800 "
live steam .. .. .	81,975 "	centrifugals, sugar dryer and pan steaming	14,000 "
		deaerator .. .. .	9,000 "
		radiation losses .. .. .	4,600 "
	<b>TOTAL ..</b>	<b>TOTAL ..</b>	<b>301,685 lbs./h.</b>

**Mr. Thumann:** On page 1 — "Mixed Juice Heating (a) primary heating — 1st stage by liquid heating", — is there any allowance made for the possible acidity of the water?

**Mr. Zonderland:** I think they provide stainless steel heat exchangers if there is any chance of corrosion.

**Mr. Thumann:** On page 2 — "Conclusions, No. 3 — For remelting of additional sugar. The calculated surplus bagasse alone would be sufficient to remelt an hourly quantity of approximately 120 tons of sugar". Have you also allowed for the reprocessing of that remelt?

**Mr. Zonderland:** Yes, that is included.

**Mr. Thumann:** You are working on a consumption of 35 per cent. bagasse on cane. Is that the average for the year, or is that continuous throughout the season?

**Mr. Zonderland:** It is actually slightly higher over the last five years.

**Mr. Thumann:** From the beginning to the end of the season?

**Mr. Zonderland:** The average figure for the season is over 35 per cent., so I took 35 per cent. so as not to be too optimistic.

**Mr. Renton:** We have just installed a liquid exchanger at Darnall. The problem of corrosion is a serious one on the juice side of the heater because the juice has not been limed. The water side is easy as the pH will only be slightly off.

**Mr. Thumann:** When we talk about the juice side we think about the inside of the tubes. On the heating side the shell is most important, and this is made of very corrosive material, as are the baffles in a steam heater, and perhaps in a liquid heater too.

**Mr. Phipson:** Mr. Zonderland, what condensate do you propose using for heating the juice?

**Mr. Zonderland:** We shall use the condensate from the last three vessels.

**Mr. Phipson:** I do not think you will have much trouble using this condensate, because it is alkaline. I have done a lot of tests, and you get a little ammonia distilled off your evaporator, and the pH of the condensate is between 8.5 and 8.8. You should not get corrosion.

**Dr. Douwes Dekker (in the chair):** What is the pH of the clarified juice from which you get the alkaline steam?

**Mr. Phipson:** It is about 7. Our steam is alkaline right through the factory due to the ammonia that is distilled off in the evaporators.

**Mr. Chiazzari:** Is not the juice heating station going to be rather complicated? I see that there are six stages of heating. Do you contemplate interconnecting these, and are they interchangeable?

**Mr. Zonderland:** It is rather complicated but it is the only way to achieve the purpose of steam economy. At Triangle where we are introducing this system, we separate groups of heaters. They are completely independent of each other. It has been worked out in such a way that if something happens to one of the heaters, we can still get the final temperatures we require. We are not going in for spare heaters and valves, and the danger of getting the juice through the wrong heater. It has been designed in such a way that there is a bit of heating surface in hand on each particular group of heaters, so that we can afford to take one juice heater out of the line, and still get our required final temperature.

**Mr. Chiazzari:** It must be a very complicated valve system.

**Mr. Zonderland:** It is not at all complicated. There is one valve on each heater and that is all. It is like a juice line supplying the heaters, going through a batch of three and then moving to the next.

**Mr. Fourmond:** I see that the primary heating in the first stage is in the liquid heat exchanger, and that condensate will be used for imbibition water, which will consequently have a high pH. Are you not going to dissolve more impurities from the fibre of the cane? I believe that when Mr. Wagner was at Illovo he had trouble when using condensate as imbibition water.

**Mr. Wagner:** That is quite true. At one stage Illovo was using water from the evaporators. At that time

Illovo was running a refinery and during that period we had a lot of filtration trouble in the refinery. After we changed over again to cold water the trouble seemed to disappear. We put it down to the fact that the temperature of the water may have been too high.

**Dr. Douwes Dekker:** You mean it would not filter properly because of the high temperature of the water, not the high pH?

**Mr. Wagner:** Yes.

**Mr. Zonderland:** The condensate from the last three vessels is going to be used for heating the cold mixed juice, and the temperature of the water arriving at the mill will not be more than 130° F.