STEAM BALANCE FOR A LOW FIBRE BRAZILIAN SUGAR FACTORY

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Abstract

Two steam balances are given for a low fibre factory, both schemes using exhaust steam from high pressure turbo-alternators to drive mill turbines. The first arrangement uses thermocompressors to achieve a 45% steam/cane ratio and the second, using more extensive bleeding, achieves a 39,5% steam/cane ratio.

The steam balance (energy requirements)

The most important aspect to consider in the design of a sugar factory is, in the words of Oliver Lyle, "the efficient use of steam". In practically all the books on sugar technology this subject is discussed and its importance stressed. However, in the cane sugar industry, little cognisance seems to have been taken of this work. Maybe this is due to the fact that most sugar operations were started many years ago before the time of Oliver Lyle and also started in primitive regions of the world where engineers were afraid to complicate the process by being unconventional. Added to this, it takes a lot of courage and confidence for a local engineer to rearrange an existing evaporator/juice heater system. However, with the present energy crisis and the recent significant rise in the cost of additional fuel, this situation has changed considerably — it now becomes almost obligatory to study this aspect of a proposed sugar factory.

In the case of the Usina Central do Paranã, the milling plant unfortunately was bought before completing careful study of the steam and energy balances and hence there was considerable restriction in deciding on the system to be adopted.

The following expected conditions pertained regarding the extraction plant :

1. The fibre percent cane was expected to be 10%.
2. The sucrose extraction from the cane was to be better than 96%.
3. The crushing rate of the factory was to be 800 metric tons cane per hour.
4. The extraction plant consisted of two tandems of six mills each of Fives-Cail Babcock design.
5. The cane preparation was to be carried out by a DHC/Copersucar set of swing knives followed by a DHC/Copersucar shredder.
6. All drives for the mills and cane preparation equipment were to be Dedini/GHH single stage turbines of 900 kW each.

These turbines have a best specific steam consumption of 23 kg/kWh when supplied with saturated steam of 1,56 MPa and exhausted to a back pressure of 147 kPa (gauge pressures).

From the above data the following estimates were made :—

1. An average of 745 kW was assumed for each of the 16 Dedini turbines in the extraction plant, giving a total estimated steam consumption of 22,8 x 16 x 745 = 272 tons/hour.
2. With a fibre rate of 10% on cane and an extraction rate of 96%, the bagasse quantity works out at 213 kg per ton of cane assuming a moisture content of 50%.
3. Using a production figure of 2 kg of steam per kg of bagasse, the calculation gives the available steam as 213 x 800 x 2 = 340 tons.
4. Power requirements for a modern sugar factory (such as UCP) with water cooling towers, induced draught fans and cane washing plants included among the electricity consumers, run at about 20 kW per ton of cane per hour. This puts the estimate of the (UCP) electric power requirement at 20 x 800 = 16 MW and to produce this power, with 1,56 MPa steam with Dedini single stage turbines, would require a further 365 tons of steam. Multi-stage turbines at these steam conditions could halve this consumption but it was quite clear that there would not be enough bagasse to run the factory.

At this stage the most practical solution was to go for a series scheme, generating the steam at 5,88 MPa and 400°C final temperature and expanding it through turbogenerator sets in the power station to 1,56 MPa, then using it to drive the extraction plant turbines. The water rate of the Brown Boveri turbines ordered for this station was 17 kg steam per kW and so the 16 MW also required 272 tons of steam.

This arrangement made it possible to design a steam balance which gave not only a reasonable surplus of bagasse but also a healthy blow-off margin.

The process steam requirements

The next stage in the programme was to design the process steam usage arrangement and to make sure that these requirements lay within the steam quantity possible from the available bagasse.

A scheme was chosen using a quadruple effect evaporator with a large first effect so that 1st effect vapour could be supplied to the pans, the distillery, the final heaters and a thermocompressor station which not only would put to good use the available blow-off margin but also ensure an excess of condensate for the boiler feed water supply. The second and third effects of the evaporator were also bled for the primary juice heating.

Figure 1 shows this arrangement and the various flows are indicated also on the chart, showing how the balance is arrived at.

The actual system used is a little more complicated than is shown on the chart as a condensate flash recovery system was incorporated, flashing the condensate from the first effect vapour to the third effect calandria and the second effect condensate to the fourth effect calandria.

Condensate and the boiler feed system

The condensate steam from the first effects of the evaporator is pumped directly to the de-aerator vessel at the boiler feed water station and arrives there at approximately 120°C, corresponding to the pressure in the first effect calandria. This was considered the best way to recover both the heat in the flash and the water for the boilers.

The thermocompressors were designed to compress first effect vapour which was passed first through a mist eliminator, then through an impingement baffle scrubber using second body condensate as a scrubbing medium and then, finally, through a second mist eliminator to take out entrained second effect condensate.

The thermocompressor should, in theory, produce an excess of pure make-up water for the boilers. However, there existed doubt among the consultants as to whether this condensate would be pure enough to feed 5,88 MPa boilers and so every effort was made to conserve steam condensate in case the thermocompressors had to be abandoned.

In actual operation, the thermocompressors have given trouble with the condensate supply for the boilers. The thermocompressors are at present being used only to make feed water make-up by boiling treated river water in one vessel of the spare evaporator set and compressing steam back into the exhaust range.

Naturally, this modification upsets the economy of the system but, as the factory, to date, has not crushed more than 15 000 tons of cane in one day due to present restrictions on production in Brazil, this situation has not proved serious.

For a final crushing rate of 20 000 tons of cane per day, the lack of thermocompressors will mean a shortfall of steam from the boilers of about 30 tons per hour. A scheme has been drawn up in the light of experience gained with the present installation to change the system of process steam usage to compensate for this shortfall.

Figure 2 shows the proposed changes and the corresponding steam flows are shown in their appropriate places.

Appendix I and II show the simplified calculations relating to the sheets.

Appendix III shows the calculation of the available steam from the bagasse.

Conclusion

Due to the healthy blow-off margin designed into the basic power requirement scheme of the factory, it is possible to make economies in the process requirements to meet the shortfall from the boilers. The cost of a few juice heaters and tubes to increase the heating surfaces of the evaporator bodies is far less than the installation of another boiler with is fuel consumption.

The modifications proposed for the process steam usage to make up for the shortfall from the non use of the thermocompressors are the following :—

1. Mechanical stirrers are to be fitted to the vacuum pans to make their operation possible on high brix feed without requiring the addition of movement water and so reducing their steam requirements to correspond more closely to the theoretical steam consumption.
2. The lengths of the tubes are to be increased in some of the evaporator bodies to supply the extra heating surface required in the new scheme.
3. One more juice heating stage will be installed to make use of some of the waste heat going to the condensor.

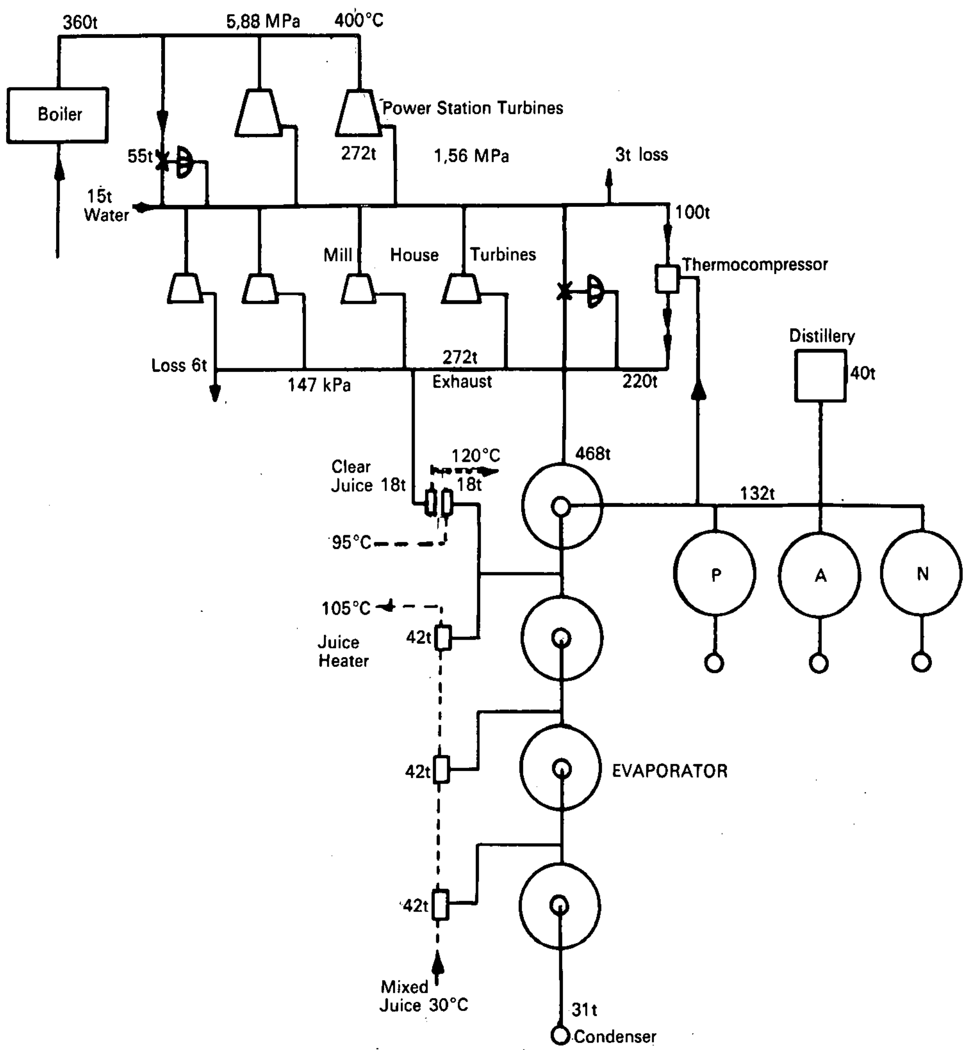

FIGURE 1 Steam flow Diagram at 800 tch Usina Central da Pavana.

With the above proposed modifications, it will be seen that the overall steam consumption of the plant can be reduced from the present 360 tons per hour i.e., the full output of the six 60 ton boilers, to 316 tons per hour, more than compensating for the loss of the thermocompressor economies.

APPENDIX I

	Use
Mixed juice on cane	110%
Clear juice brix	14°
Syrup brix	65°
Filtrate return	15%
Mixed juice inlet temperature	30°C
Mixed juice outlet temperature	105°C
Specific heat of juice	3,768 J/g/°C
Latent heat of evaporation of water	2 257 kJ/kg
Vacuum pan steam requirements	165 kg/ton of cane
Distillery steam requirements	50 kg/ton of cane
Thermocompressor recycle	120 tons of vapour with 100 tons of steam

$$= \frac{120\,000}{800} = 150 \text{ kg/ton cane.}$$

Mixed juice heating steam requirements.

Steam required to heat mixed juice per ton of cane.

$$\frac{1\,000 \times 1{,}10 \times 1{,}15 \times 3{,}768 \times (105-30)}{2\,257}$$

$$= 158 \text{ kg/ton of cane.}$$

Assuming equal heating in each stage gives ± 53 kg per stage.

Evaporation equation $\frac{65 - 14}{65} \times 100$ gives 78,5%.

Total water to be evaporated 0,785 x 1 100

= 863 kg per ton.

Clear juice heating requirements 95° to 120°C.

$$\frac{1\,100 \times (120 - 95) \times 3{,}768}{2\,257}$$

= 46 kg/ton of cane

i.e. = 23 kg of steam in each stage

Overall evaporation equation (in kg steam/ton of cane).

Thermocompressor	150
Vacuum pans	165
Distillery	50 1st effect vapour
Final juice heating	53
Clear juice heating	23
Secondary juice heating	2 x 53
Primary juice heating	3 x 53
To the condenser	4 x X
	706 + 4X
=	863
or X =	39

Steam consumption of the first body is in kg steam per ton of cane.

Thermocompressor	150
Vacuum pans	165
Distillery	50
Final juice heating	53
Clear juice heating	23
Secondary juice heating	53
Primary juice heating	53
Condenser	39
	586 kg

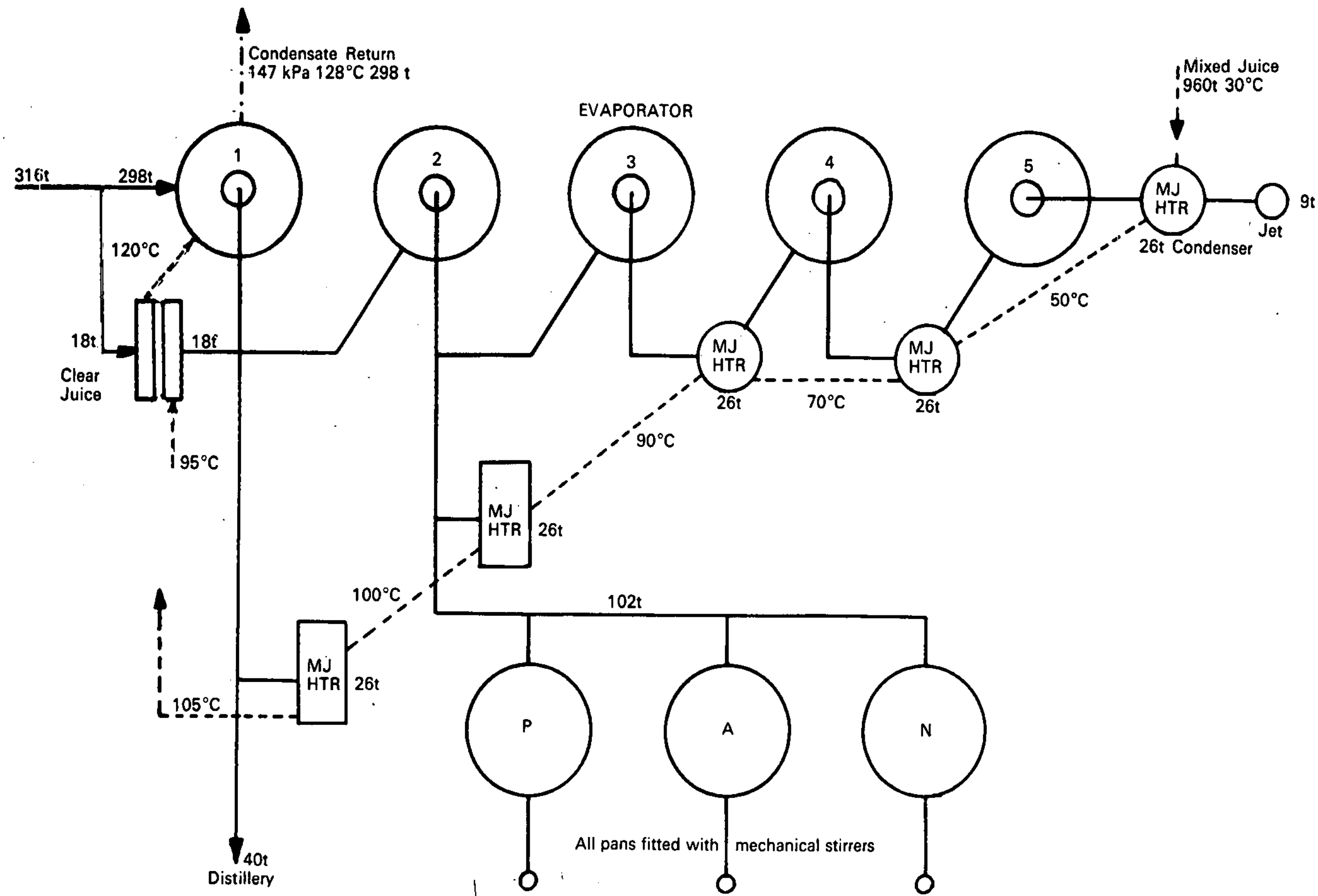

FIGURE 2 Improved steam balance. Usina Central da Pavana.

Net steam consumption of the factory is in kg steam/ton of cane.

Evaporator first body	586
Less Thermocompressor recycle	150
Plus Clear juice 2nd stage body	23
	459 kg steam per ton of cane

APPENDIX II

Theoretical pan floor steam consumption

(Pans fitted with mechanical stirrers)

A Strike.

Evaporation $= \frac{92 - 65}{92} \times 100$
$= 29\%$

Feed = Clear juice — evaporation
= 1 100 — 863
= 237 kg/ton of cane

Steam for "A" Pan = Pan factor x evaporation
= 1,1 x 0,29 x 237
= 76 kg/ton of cane

B Strike.

Assuming a yield of 55%.

B strike has (0,14 x 1 100) x (100 — 55) ÷ 100 solids.
= 69,3 kg/ton at 70° brix
= 99 kg of feed

B Strike steam $= \frac{1{,}1 \times 92 - 70}{92} \times \frac{69{,}3}{0{,}7}$
= 26 kg/ton of cane

Assuming a "B" sugar yield of 50% leaves 35 kg of solids for "C" strike and gives a feed of 35 ÷ 0,7 = 50 kg of feed at 70° Bx.

"C" Strike.

"C" strike steam requirements are $\frac{92 - 70}{92} \times 50 \times 1{,}1$.
= 13 kg/ton of cane.

Assuming "C" sugar remelted to 70° Bx.

Total steam for the vacuum Pans = 76 + 26 + 13 x 2.
= 128 kg/ton of cane.

Overall evaporation equation for the future scheme :—

Distillery	50
Clear juice heating	23
5th Stage mixed juice heating	32
4th Stage mixed juice heating	2 x 32
3rd Stage mixed juice heating	3 x 32
2nd Stage mixed juice heating	4 x 32
1st Stage mixed juice heating	5 x 32
Vacuum pans	2 x 128
To the condenser	5X

863 = 809 + 5X
and X = 11

Steam consumption.

Distillery	50
Clear juice	23
5th Stage mixed juice heating	32
4th Stage mixed juice heating	32
3rd Stage mixed juice heating	32
2nd Stage mixed juice heating	32
1st Stage mixed juice heating	32
Vacuum pans	128
Condenser	11
Final clear juice heating	23
	395 kg/ton of cane

APPENDIX III

Steam from the available bagasse.

Bagasse analysis was assumed as follows :

Fibre 47%; pol 2%; brix 3°; moisture 50%.

LCV = 7 650 — 18 pol — 84,6 x moisture % bagasse.
= 3 384 BTU/lb
= 7 871 kJ/kg

Total heat of steam at 5,88 MPa and 400° is 3 174 kJ/kg

Heat added to feed in the boiler per kg of water is 3 174 — 502 kJ/kg

Guaranteed efficiency of the boiler is 80% on LCV.

Ratio of steam to bagasse $= \frac{7\,871 \times 0{,}8}{3\,174 - 502}$
= 2,36 kg of steam per kg of bagasse.