

ENERGY CONSEQUENCES OF DIFFUSION VERSUS MILLING

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Abstract

The energy requirements for a diffuser versus a milling factory are compared by means of a computer simulation program. Generally, the diffuser option requires more steam, except for the case of low pressure boilers. The diffuser option gains strongly when export power is to be maximised. When Vapour 2 instead of Vapour 1 is used for diffuser heating and pan operation, there is little difference in the total high pressure (HP) steam consumption.

Introduction

The object is to compare the effects on energy usage of the two alternative methods of extraction, namely milling versus diffusion. Authors such as Van Hengel (1989) and Idehara (1995) have already written on this subject. This contribution draws considerably from a paper by Rein and Hoekstra (1994), but some variations and modifications have been included.

Four cases will be discussed: the base case; running at a lower boiler pressure; aiming at maximum export power output; and using Vapour 1 instead of Vapour 2 for pan and diffuser vapour supply. The calculations were done on the in-house developed Steam Load Overall Balance (SLOB) steady-state simulation program, which was described by Rein and Hoekstra (1994). The outputs of the various cases, for milling versus diffusion, are summarised in Table 1.

Assumed operating conditions

The following general operating conditions apply:

Cane throughput rate	: 300 t/h
Cane analysis	: 15,5% brix; 13,0% sucrose; 15,0% fibre
Imbibition	: 300% on fibre
Bagasse moisture	: 50%
Boiler pressure	: 3200 kPa abs
Temperature of HP steam	: 400°C
Boiler efficiency, based on net calorific value (NCV)	: 78%

Prime mover energy requirements (MW):

	Milling	Diffusion
Direct drive turbines	3,05	0,90
Turbo-alternators	8,65	9,00
Total	11,70	9,90

Direct drive turbine efficiency	: 40%
Turbo-alternator efficiency	: 63%
Hours/crush week	: 148
Hours on standby/week	: 14
Steam consumption during standby	: 88,5 t/h

Table 1
Comparison of operating data for milling versus diffusion

Case No	1 Base case		2 Lower HP steam pressure		3 Max power generations		4 Use V2 for process heating		
	Mills	diffuser	Mills	diffuser	Mills	diffuser	Mills	diffuser	
HP Steam									
Pressure (kPa abs)	3 200	3 200	1 480	1 480	3 200	3 200	3 200	3 200	
Temperature (°C)	400	400	285	285	400	400	400	400	
Flow rate (t/h)	142,8	153,0	192,4	165,3	145,0	161,4	136,4	140,8	
Steam % cane (instantaneous)	47,6	51,0	64,2	57,9	48,3	53,8	48,3	49,7	
HP - LP Steam Balance									
Steam to turbines & TA's (t/h)	(+)	123,1	95,3	186,4	144,3	138,8	154,8	123,2	95,4
Steam let-down (t/h)	(+)	13,8	51,8	0,0	14,8	0,3	0,6	7,1	39,4
Steam blow-off (t/h)	(-)	0,0	0,0	41,8	0,0	0,0	0,0	0,0	0,0
Desuperheating water (t/h)	(-)	12,1	17,1	4,4	4,9	9,9	8,7	10,7	14,4
LP steam (t/h)	(=)	149,0	164,1	149,0	164,1	149,0	164,1	141,1	149,6
V1 bleed (t/h)		54,4	86,8	54,4	86,8	54,4	86,8	15,4	15,4
V2 bleed (t/h)		43,8	25,0	43,8	25,0	43,8	25,0	82,7	96,2
Bagasse balance									
Bagasse production rate (t/h)	(+)	87,5	91,5	87,5	91,5	87,5	91,5	87,5	91,5
Bagassed used for fuel (t/h)	(-)	68,3	76,1	84,6	75,6	69,3	80,2	65,2	70,0
Bagacillo usage (t/h)	(-)	3,0	1,5	3,0	1,5	3,0	1,5	3,0	1,5
Bagasse surplus rate (t/h)	(=)	16,2	13,9	-0,2	14,4	15,1	9,8	19,3	20,0
Weekly bagasse surplus, t/wk		1 806	1 447	-4 270	1 568	1 650	834	2 261	2 346
				(as coal)					
Power used by factory (MW)		11,7	9,9	11,7	9,9	11,7	9,9	11,7	9,9
Electric power export (MW)		0,0	0,0	0,0	0,0	1,7	6,5	0,0	0,0
Exhaust pressure at evaporators (kPa abs)		194,1	194,4	194,1	194,4	194,1	194,4	195,5	195,4

Case 1: (base case)

Diagrams of the steam flow arrangement for the base cases of diffusion and for milling are shown in Figures 1 and 2, respectively. The main difference is the absence of diffuser direct vapour injection and diffuser juice heating for the option of milling. Some aspects of diffuser and mixed juice heating are summarised in Table 2.

Table 2
Comparison of heating duties for milling versus diffusion

	Milling	Diffusion
Mixed juice temperatures		
Initial (°C)	35	67
Final (°C)	103	103
Mixed juice heater areas		
1st stage (m ²)	530	530
2nd stage (m ²)	800	530
Vapour consumptions		
Diffuser heating (t/h V1)	0,0	32,7
1st stage mixed juice heaters (t/h V1)	5,9	5,4
2nd stage mixed juice heaters (t/h V2)	33,8	15,0
Total	39,7	53,1

Comments

- The diffuser needs heating vapour for the scalding juice and for direct vapour injection, which the mill does not, but because this is taken from the evaporator bleed, the HP steam requirement from the boilers will not increase by the same amount.
- Because the mixed juice for the milling factory is at a lower temperature (35°C) than the draft juice (67°C) from the diffuser, it needs more vapour to heat it to the temperature for flashing ahead of clarification (103°C), and will require somewhat larger mixed juice heaters. This can be seen in Table 2. However, because the initial mixed juice temperature from the milling factory is lower, all the additional heat can be obtained from Vapour 2, which will have a relatively lower effect on the amount of HP steam required.
- In spite of the above give-and-take for the two alternatives, the total amount of heating vapour for the diffuser factory is significantly larger. This can be seen from Table 2. Reasons are the estimated heat losses of 2,4 MW by radiation from the diffuser, which runs at about 80°C and, more important, the evaporation which takes place from the hot diffuser juice at the de-watering mill (assumed to be 4% of cane feed) which absorbs latent heat.
- The diffuser produces slightly more bagasse than the milling train, firstly because of lower loss of suspended solids in mixed juice (typically 0,1% versus 0,7%) and secondly because of the lower bagacillo requirement (0,5% versus 1,0% on cane).
- Due to the higher ash content of the diffuser compared with milling, (typically 3,5% versus 2,0%), the diffuser bagasse has a slightly lower heating value (7205 versus 7500 MJ/t NCV), per formula of Don *et al.* (1977). However, the combined effect of all this is that the total bagasse from a diffuser has a slightly higher heat content.
- Because the injection vapour used in the diffuser cannot be recovered as condensate, a diffuser factory is likely to require a larger amount of boiler make-up water. This restriction could be overcome by using heat exchangers.

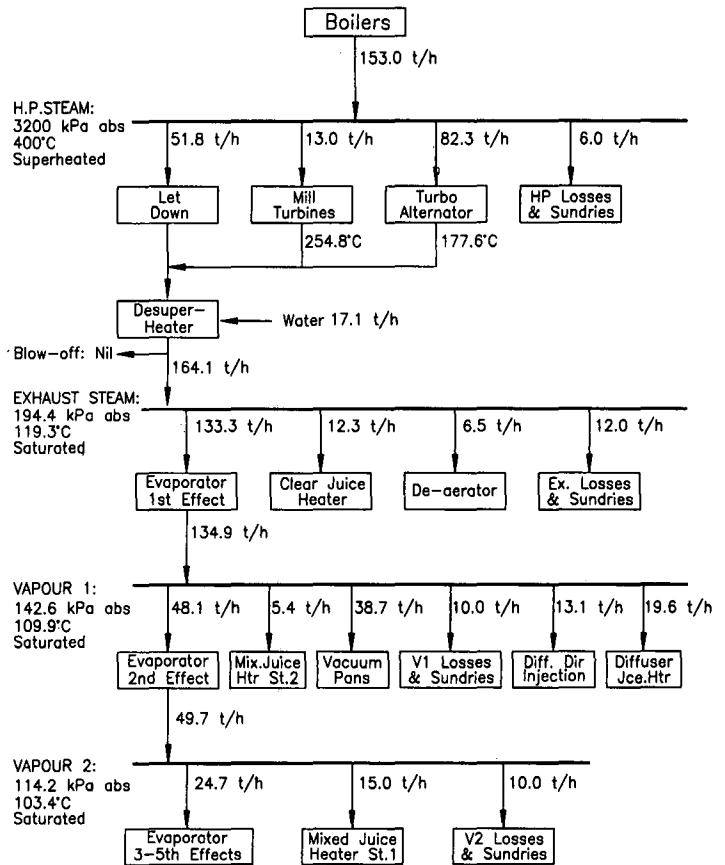


FIGURE 1 Base case of steam flows - diffusion

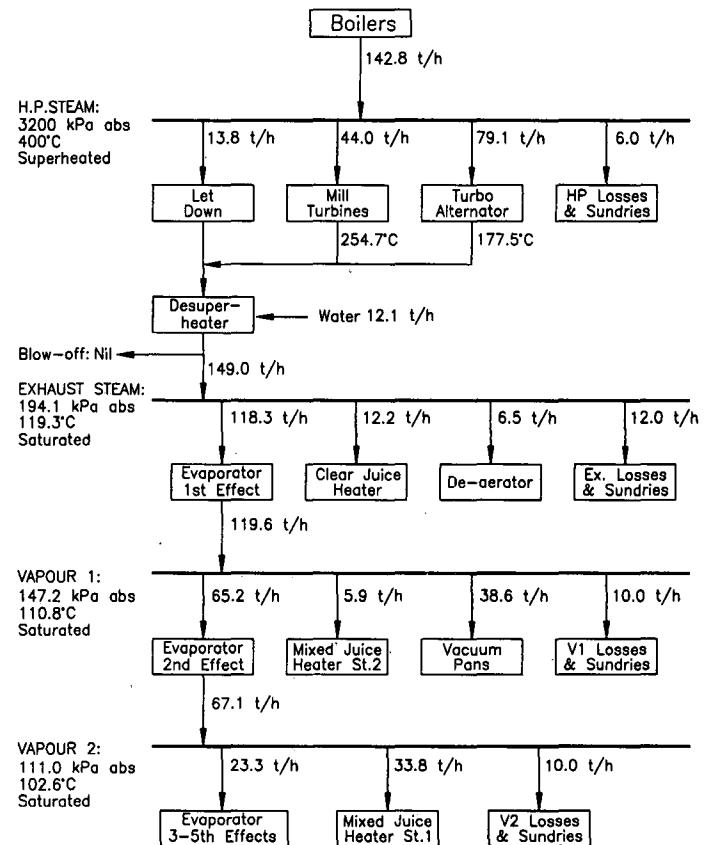


FIGURE 2 Base case of steam flows - milling

- Because of the large amount of evaporation which takes place with a diffuser, such a factory will require more service make-up water, which might be significant when water is in short supply.

Case 2: boilers operate at a lower pressure

In this case, the boilers which supply the "high pressure" steam operate at 1480 kPa absolute, with a steam temperature of 285°C. The results are shown in Table 1.

Comments:

- Although the thermodynamic efficiencies for the turbines and turbo-alternators are assumed to be the same as at the higher pressure, the steam consumptions have increased considerably, simply due to the lower enthalpy drop from the lower boiler steam pressure to the exhaust steam pressure.
- For the milling factory, the amount of "high pressure" steam required to drive the turbines and turbo-alternators is considerably more than the exhaust steam required for the process, so that much steam has to be blown off, with consequent waste of energy and potential condensate. The factory gets into the situation of having to burn coal, because the bagasse fuel is not sufficient.
- To counteract such wastefulness, part of the electric power requirement could be generated by a condensing turbo-alternator, so that the back-pressure turbo-alternators will produce exhaust vapour sufficient to require only a nominal amount of let-down vapour to make up the necessary amount of low pressure (LP) steam for process. This would require about 3,05 MW from the condensing turbo-alternator, with the nett effect of reducing the boiler steam production from 192,5 to 170,0 t/h.
- With the diffuser option, the turbine steam requirement remains lower than the process steam requirement, so that the balance is again made up by letting down boiler steam and adding the de-superheating water. The total boiler steam requirement is however higher than in the base case. The reason for this is that the let-down and the exhaust steam have lower enthalpies, which require less water for de-superheating. Because boiler steam + de-superheating water = process steam + HP steam losses, it follows that, for a lower de-superheating water requirement, the boiler steam needs to be correspondingly higher.
- Because the diffuser factory is still self-sufficient in its energy requirements, there would be economies in capital cost when constructing a new diffuser factory to run at lower boiler pressures, provided there is no likelihood of power for export or bagasse for by-products being needed in the future.

Case 3: aim for maximum power export

In both options, sufficient turbo-alternator generating capacity is added to provide exhaust steam to the point that only a nominal amount of let-down steam from the boiler is required.

Comments:

- Although these alternatives require the same amount of process vapour as in the respective base cases, the respective high pressure steam requirements will be higher.

This is because there will be more exhaust vapour from the turbines and practically no let-down steam, and this resulting mixture of lower enthalpy will require less de-superheating water and corresponding more steam from the boilers via the turbines.

- In spite of the higher steam productions, both options still show a bagasse surplus. To increase the export power further, one could conceivably burn the remaining surplus and use the additional HP steam in condensing turbo-alternators. However, calculations show this would only produce an additional 0,9 and 0,5 MW for the milling and the diffusion factories respectively, which hardly seems worthwhile.
- The export power produced by back pressure turbo-alternators is very economical: only 1,3 t/h HP steam per MW is required, compared with 6,2 t/h per MW for a condensing turbo-alternator.

Case 4: use Vapour 2 for the vacuum pans and diffuser heating

In this case, Vapour 2 instead of Vapour 1 would be used for these purposes.

Comments:

- Because the diffuser factory has a higher process steam requirement than the milling factory, it gains relatively more from this change to lower grade vapour, but still requires slightly more HP steam than the corresponding milling factory.
- In spite of that, the diffuser factory shows a slightly higher bagasse surplus because of its higher total bagasse heating value, as previously described.

Conclusions

If one ignores the very important considerations of cost and maintenance, whereby the diffuser factory scores, and looks purely at energy and fuel considerations, one could generalise as follows:

- If power export is not an issue, only Vapour 1 is used for process requirements, and the bagasse is considered a valuable raw material for by-products, a milling factory using high pressure steam has the advantage.
- If there is no intention to export power or use bagasse for by-products, a diffuser factory operating at the lower boiler pressure would be preferable.
- If it is the intention to maximise the export of power, a diffuser factory is the obvious choice.
- If Vapour 2 is used for process requirements, there is little to choose between the two alternatives.

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