PANS VERSUS CRYSTALLISERS: WHAT IS MORE EFFECTIVE?

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Abstract

The A- and B-vacuum pans and crystallisers are compared in terms of crystallisation rate and cost and their influence on process operations is reviewed. The efficacy of crystallisers as standard factory equipment is mentioned.

Introduction

In the sugar industry the crystallisation of sucrose is effected normally in vacuum pans and crystallisers. Although there is universal acceptance of the benefits of C-crystallisers this is not the case for the A- and B-crystallisers. Some countries, like South Africa, have large A- and B-stations while others, Australia being a case in point, have none. This disparity can be explained by the fact that, contrary to the C-molasses which must be fully exhausted prior to leaving the process, the A- and B-molasses are intermediate streams which essentially do not need maximum exhaustion, thus making the use of A- and B-crystallisers optional.

Although crystallisers have the potential to increase the exhaustion of the A- and B-massecuites it is open to debate whether their installation leads to optimal processing conditions in terms of cost and overall sucrose recovery. In a previous paper (Jullienne, 1991) the author came to the conclusion that the B-crystallisers were not a justified investment. In this paper the discussion is extended to the justification for the A-crystallisers, based partly on a comparison with the vacuum pans in aspects such as the rate and cost of crystallisation, sucrose losses and steam economy.

Crystallisation rates of pans and crystallisers

The discussion is based on a raw sugar mill of 300 tch with typical installed capacities as shown in Table 1 and with the average operational conditions detailed in Appendix 1. It is interesting to note that the capacity of the crystalliser station is more than double the pan station. The estimated amount of crystalline sucrose achieved in the installed equipment, under average conditions is given in Table 2. Based on the data in Tables 1 and 2 the rate of sucrose crystallisation per unit capacity of equipment, expressed in mass of sucrose per unit time and unit volume (kg h-1 m-3), can be obtained and is shown in Table 3. It is clear that the rate of crystallisation obtained in the A- and B-crystallisers is of a very low order in comparison with the pans.

Cost of the investment in pans and crystallisers

Based on the costs of recent local projects involving continuous pans and vertical crystallisers (100 m^3 capacity) it is estimated that the cost of the equipment is:

R25 000 per m^3 capacity for the vacuum pan and
R 7 000 per m^3 for the crystalliser.

Using these figures and the rates of crystallisation in Table 3, the investment in pans and crystallisers per unit amount of crystallisation can be calculated and, as shown in Table 4, the crystalliser is found to be a very costly investment.

Table 1

Installed crystallisation equipment

(m^3 capacity for 300 tch)

	Pans	Crystallisers
A-massecuite	186	300
B-massecuite	86	300
Total A and B	272	600

Table 2

Amount of crystallisation in pans and crystallisers for 300 tch (in tons per hour)

	Pans	Crystallisers
A-massecuite	36,0	2,7
B-massecuite	8,1	0,9

Table 3

Rate of crystallisation in pans and crystallisers (in kg h-1 crystal per m^3 installed capacity)

	Pans	Crystallisers
A-massecuite	193	9
B-massecuite	85	3

Table 4

Capital cost of crystallisation in pans and crystallisers (Rand per kg h-1)

	Pan	Crystalliser
A-massecuite	130	800
B-massecuite	300	2 300
C-massecuite*	600	3 500

* The C-massecuite data have been added to the table for the sake of interest and show that even the C-pan, in spite of the well known difficult conditions it operates under locally, is more cost effective than for example, the A-crystalliser.

In summary it can be stated that for the purpose of industrial crystallisation of sucrose, the crystalliser is a large, slow and costly item of equipment. In the A- and B-massecuites it produces a small amount of crystallisation (less than 10%) which the pans could have handled much more effectively. However, in spite of these disadvantages, the A- and B-crystallisers do offer a number of processing benefits, which need to be reviewed when discussing their justification as standard factory equipment.

As already mentioned the issue of the B-crystallisers as an unjustified investment has been covered recently and the next part of the discussion concerns the A-crystallisers only.

Beneficial effect of A-crystallisers

The main influence of A-crystallisers is to be found in the areas of massecuite quantities, molasses purity profile, steam economy and sucrose recycling.

Quantity of massecuite

The proper operation of the A-crystallisers can reduce the volumes of A- and B-massecuite by about 7 and 33% respectively (see Appendix 1). However, especially for a new mill, it is cheaper to instal the required pan capacity to handle these additional quantities rather than build a complete A-crystalliser station. For a 300 tch mill the additional A- and B-pan capacities would cost around R650 000 (based on the installation of bigger pans) while an A-crystalliser station would cost over R2,0 million.

It is estimated that the higher quantities of massecuite would not entail additional centrifugals because the hotter products would cure at a faster rate which would more than compensate for the additional quantities. This was confirmed by recent trials on B-massecuite at the Noodsberg mill (Getaz, personal communication).

Steam consumption

The steam consumption, without A-crystallisers, would increase by about 1% on cane (see Appendix 1). For a 300 tch mill, this shortfall, if it has to be made up in supplementary fuel, represents an additional fuel consumption worth about R200 000 per season (based on local coal prices). Theoretically, additional boiler capacity, estimated at R150 000, would be required although in most cases minor changes to process steam usage could be advantageously introduced to compensate for the extra pan floor steam consumption. Even when allowing for the additional boiler capacity (and additional pan capacity) the extra fuel costs are small compared with a net capital saving of about R1,3 million.

Molasses purity profile

The elimination of the A-crystallisers would result in higher A- and B-molasses purities (see Appendix 1). This would generally be considered a disadvantage but may be a blessing in disguise in the sense that the higher purity profile has the potential to reduce the sucrose degradation losses in the back-end. Under average conditions the higher molasses purities would not affect the C-massecuite purity. On the occasions when the B-molasses purity may tend to become excessively high the recycling of B-molasses on the B-massecuite can be practised in order to attain the desired C-massecuite purity. It is worth noting that, contrary to a commonly held belief, there is no change in the loading of the C-station (as long as the C-massecuite purity remains the same) irrespective of the purity level of the A- and B-molasses.

Sucrose recycling

It is also a fashionable belief, not totally supported by the author, that the level of overall sucrose recovery performance is directly linked to the achievement of high A-massecuite exhaustion. This is borne out by the many statements made by local technologists in the last few years (Jullienne, 1976; Lamusse, 1989; Singh, 1989; Dale, 1990). It is generally perceived that increased exhaustion 'puts sugar in the bag' and in so doing reduces the level of sucrose degradation caused by recirculation. Although there is no doubt that, everything else remaining the same, high exhaustion can be beneficial, it is felt that its importance is grossly overvalued. In fact an analysis of data for the last few seasons from selected mills shows no statistically significant correlation between A-exhaustion and, for example, Corrected Boiling House Recovery (5 year data) or Undetermined Losses (8 year data). Note: The data (see Appendix 2) used in the statistical analysis are those of AK, MS, IL, SZ and UK.

These mills have been chosen for their relatively constant operating conditions as raw sugar producers over the period under consideration. Furthermore, it can be debated that the installation of crystallisers, even when improving the massecuite exhaustion, does more harm than good on the sucrose degradation front, by effectively increasing the overall retention time of soluble sucrose in the factory. This is confirmed in Appendix 3 in which a model was used to calculate inversion losses for continuous A- and B-stations with and without crystallisers. The model takes account of changes in the material balance and purity, and quantity of sucrose in solution for a typical set of pH and temperature conditions. The sucrose losses calculated by Vukov's and Schäffler's equations (Schäffler, 1992) are summarised in Table 5.

Table 5

Sucrose losses due to inversion in a 300 tch mill with and without A- and B-crystallisers

	Tons sucrose inverted per season	
	Based on Vukov's equation	Based on Schäffler's equation
With A- and B-crystallisers	144	491
With A- and without B-crystallisers	122	389
Without A- or B-crystallisers	116	375

In passing, it is worth noting that other measures like the elimination of the breakage and unnecessary dissolution of the B-sugar and the reduction of the retention time of factory products in tanks are considered to hold more potential for reducing sucrose degradation in process than A-crystallisers.

Conclusions

Crystallisers are costly items of equipment which effect relatively small amounts of crystallisation. They compare poorly with vacuum pans in terms of crystallisation rate and cost. They are, of course, essential on the C-massecuite but there is no clear evidence to suggest that they are necessarily beneficial for the A- and B-massecuites. This does not imply that massecuite exhaustion is considered irrelevant to process operations but rather that the installation of crystallisers to obtain the incremental exhaustion in the A- and B-massecuites may be unjustified. In spite of this, it is stressed that the maximisation of overall exhaustion of the A- and B-massecuites through better pan and centrifugal operation is still considered to be an essential part of sound process management.

Admittedly, this paper is of limited practical importance to the local industry as all the mills are already equipped with A- and B-crystallisers but it could be of interest when planning new installations and mill expansions.

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APPENDIX 1

Average operational data for a 300 tch mill with and without A- and B-crystallisers

	With A- With B-	With A- Without B-	Without A- Without B-
Tons brix/h syrup	45,0	45,0	45,0
Purity syrup	85,3	85,3	85,3
m³/h A-massecuite	46,3	46,3	49,4
B-massecuite	14,4	16,0	20,9
C-massecuite	11,6	11,6	11,6
Purity A-molasses	66,7	66,7	70,0
B-molasses	43,7	47,2	50,4
C-massecuite	53,0	53,0	53,0
A-Exhaustion	66,5	66,5	62,0
B-Exhaustion	61,2	56,3	56,3
Curing temperature (°C)			
A-massecuite	50	50	65
B-massecuite	54	65	65
Design capacity (m³)			
A-pans	186	186	198
B-pans	86	96	125
C-pans	104	104	104
A-crystallisers	300	300	0
B-crystallisers	300	0	0
Nominal retention time (h)			
A-pans	4,0	4,0	4,0
B-pans	6,0	6,0	6,0
A-crystallisers	6,5	6,5	0
B-crystallisers	20,8	0	0
Quantity (m³) A and B massecuite in process*	872	582	423
Vapour 1 (t/h)			
Pan floor	39,1	39,9	43,8
Ancillaries b-end	2,4	2,2	2,0
Exhaust steam % cane b-end	11,1	11,2	12,2

* It is assumed that the pans and crystallisers are of the continuous type and run at design capacity.

APPENDIX 2

A-Exhaustion, undetermined losses (UL) and corrected boiling house (CRB) figures for AK, MS, IL, SZ and UK for the period 1984-1991 (as reported by Sugar Milling Research Institute, Durban)

	Season							
	84	85	86	87	88	89	90	91
	AK (Amatikulu)							
A-Exhaustion	64,9	64,1	64,9	66,7	68,2	68,9	68,6	68,2
CRB				87,4	87,7	87,7	88,2	88,3
UL	1,23	1,19	1,98	1,48	1,65	1,73	1,56	1,48
	MS (Maidstone)							
A-Exhaustion	62,4	64,9	64,7	62,4	63,2	65,7	68,0	68,5
CRB				86,8	86,7	86,1	86,9	87,2
UL	0,79	1,11	1,52	1,39	1,70	1,80	1,70	1,40
	IL (Illovo)							
A-Exhaustion	67,1	65,3	67,0	67,5	67,6	64,7	64,1	68,8
CRB				86,3	86,3	87,1	86,3	86,9
UL	1,50	1,90	1,91	1,57	1,69	1,46	1,76	1,35
	SZ (Sezela)							
A-Exhaustion	66,0	66,0	65,7	63,6	63,5	67,1	68,7	67,5
CRB				87,3	87,6	86,9	87,1	87,3
UL	1,18	1,48	1,99	1,80	1,67	1,89	1,68	1,52
	UK (Umzimkulu)							
A-Exhaustion	65,5	64,7	64,5	66,0	65,8	65,9	67,0	67,6
CRB				86,9	86,9	86,2	86,8	87,6
UL	1,29	1,38	1,94	1,56	1,60	1,50	1,74	0,93

APPENDIX 3

Estimate of Inversion Losses for a 300TCH Continuous Boiling House

									LOSS ESTIMATE USING VUKO/SCHAFFLER CALCULATION							SUCROSE INVERTED			LOSS ESTIMATE USING SMRI REGRESSION {log (k) = 17.92–6548/T–0.71pH}			SUCROSE INVERTED		
EQUIPMENT	WORK VOL. M^3	TONS PRODUCT HELD	AVG BX OF PROD	PUR	CRYST % SUC	TEMP	pH	BRIX M.Liq	DENS. M.Liq	BX CORR pH	dpH/dT	OPER. pH	(K)	% LOSS	SUC. EXP.	HOUR	WEEK	SEASON	SMRI LOG (K)	SMRI (K)	HOURLY SUC LOSS	HOUR	WEEK	SEASON
CASE 1: A AND B CRYSTALLISERS IN USE (A EXH: 66.5 BEXH:61.2)																								
A PANS	186	273	89.0	85.7	65.6	67	5.8	78.0	1.40	5.53	-3E-03	5.40	2E-06	0.012	71.76	0.009	1.50	49.5	-5.176	7E-06	0.040	0.029	4.83	159.2
A CRYSTS	300	447	92.0	85.7	73.5	58	5.7	81.0	1.42	5.42	-3E-03	5.33	8E-07	0.005	93.52	0.004	0.71	23.4	-5.649	2E-06	0.013	0.013	2.12	69.8
A MOL TANKS	60	89	76.0	66.7	0.0	60	5.7	76.0	1.38	5.43	-3E-03	5.34	1E-06	0.007	45.31	0.003	0.53	17.3	-5.537	3E-06	0.017	0.008	1.32	43.7
B PANS	86	126	89.0	66.7	59.5	68	5.6	83.0	1.43	5.31	-2E-03	5.22	3E-06	0.017	30.41	0.005	0.87	28.7	-4.985	1E-05	0.062	0.019	3.17	104.5
B CRYSTS	300	450	94.0	66.7	70.9	60	5.5	89.2	1.47	5.19	-2E-03	5.12	9E-07	0.005	82.06	0.004	0.76	24.9	-5.381	4E-06	0.025	0.020	3.44	113.4
B MOL TANKS	40	60	78.0	43.7	0.0	60	5.5	78.0	1.40	5.23	-2E-03	5.16	2E-06	0.010	20.32	0.002	0.33	11.0	-5.407	4E-06	0.024	0.005	0.80	26.5
														TOTAL:	323	0.026	4.36	143.8				0.089	14.87	490.7
CASE 2: A CRYSTALLISERS; NO B CRYSTALLISERS (A EXH: 66.5 BEXH:56.3)																								
A PANS	186	273	89.0	87.5	65.6	67	5.8	78.0	1.40	5.53	-3E-03	5.40	2E-06	0.012	71.76	0.009	1.50	49.5	-5.176	7E-06	0.040	0.029	4.83	159.2
A CRYSTS	300	447	92.0	85.7	73.5	58	5.7	81.0	1.42	5.42	-3E-03	5.33	8E-07	0.005	93.52	0.004	0.71	23.4	-5.649	2E-06	0.013	0.013	2.12	69.8
A MOL TANKS	60	89	76.0	66.7	0.0	60	5.7	76.0	1.38	5.43	-3E-03	5.34	1E-06	0.007	45.31	0.003	0.53	17.3	-5.537	3E-06	0.017	0.008	1.32	43.7
B PANS	96	141	89.0	66.7	59.5	68	5.6	83.0	1.43	5.31	-2E-03	5.22	3E-06	0.017	33.94	0.006	0.97	32.0	-4.985	1E-05	0.062	0.021	3.54	116.7
B MOL TANKS	40	60	78.0	46.7	0.0	60	5.5	78.0	1.40	5.23	-2E-03	5.16	2E-06	0.010	21.71	0.002	0.36	11.7	-5.407	4E-06	0.024	0.005	0.86	28.3
														TOTAL:	245	0.022	3.70	122				0.070	11.80	389
CASE 3: NO A CRYSTALLISERS; NO B CRYSTALLISERS (A EXH: 62 BEXH:56.3)																								
A PANS	198	291	89.0	86.0	65.6	67	5.8	77.9	1.40	5.53	-3E-03	5.40	2E-06	0.012	76.69	0.010	1.61	53.0	-5.176	7E-06	0.040	0.031	5.15	170.1
A MOL TANKS	60	89	76.0	70.0	0.0	60	5.7	76.0	1.38	5.43	-3E-03	5.34	1E-06	0.007	47.56	0.003	0.55	18.2	-5.537	3E-06	0.017	0.008	1.39	45.9
B PANS	125	184	89.0	70.0	59.5	68	5.6	82.5	1.43	5.31	-2E-03	5.22	3E-06	0.017	46.39	0.008	1.35	44.7	-4.987	1E-05	0.062	0.029	4.82	159.1
B MOL TANKS	40	60	78.0	50.5	0.0	60	5.5	78.0	1.40	5.23	-2E-03	5.16	2E-06	0.010	23.48	0.002	0.38	12.7	-5.407	4E-06	0.024	0.006	0.93	30.6
														TOTAL:	171	0.021	3.51	116				0.068	11.37	375

CALCULATIONS:

DENSITY = 0.998 + (.00372*BX) + (.00001778*BBBX^2)
BRIX CORRECTED pH = MEASURED pH –(0.007*BX/2)
dpH/dT = (0.015*BX CORRECTED pH) – (0.0017*pH^2) – (0.0339)
OPERATING pH = (T–25)*dpH/dT) + BX CORRECTED pH
VUKOVEQUATION (K) = 16.91 + log(W) – 5670/T – pH
Where W = Water concentration in g/ML
% SUCROSE LOSS PER HR = (1-e^(k*60))*100