THE EFFECT OF TUBE WETTING RATE ON KESTNER PERFORMANCE AT SEZELA FACTORY

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Abstract

Sezela sugar factory uses long tube climbing film evaporators of the Kestner type for first effect evaporation. The plant trial showed that the Kestner specific evaporation rate (kg/m^2/h) and heat transfer coefficient can be improved by increasing the tube wetting rate (kg/min/tube). Increasing the wetting rate by 62% increased the specific evaporation rate by 40%.

Introduction

The climbing film evaporator was patented in 1899 by Paul Kestner. These long tubed vessels, typically 7 m in height, are common in the South African sugar industry and are referred to as Kestners. Kestners are typically used as first and second effect vessels in multiple effect evaporator stations. The authors are not aware of Kestners being used as third, fourth or fifth effects in South Africa.

Although common in the local sugar industry, the performance of Kestners has been inconsistent. However, the Umzimkulu Kestner is viewed as a benchmark by the authors. The Umzimkulu Kestner has good evaporation rates and low fouling rates, and can operate for up to eight weeks without any tube cleaning.

The Sezela Kestners, on the other hand, produce lower evaporation rates and higher fouling rates. The Kestners are cleaned on a two-week cycle. The Kestners also have a history of blocked tubes due to juice drying out in the tubes.

Kestner performance has been studied by a number of South African authors. The studies were mainly on pilot Kestners. James *et al.* (1978) found that the heat transfer coefficient (HTC) increased with feed rate. This paper also quotes a specific evaporation rate of 35 to 40 kg/m^2/h. Walthew and Whitelaw (1996) also studied Kestner performance in a pilot plant and showed that increasing the feedrate increased HTC and decreased the fouling rate.

The Umzimkulu (UK) and Sezela (SZ) Kestner design data, together with the current operating data, are given in Table 1.

The comparison of specific evaporation rates shows that the UK Kestner performs better by approximately 26%. The tube wetting rate is also higher in the UK Kestner. The authors attempted to simulate the UK Kestner wetting rate on one of the SZ Kestners.

Table 1. Umzimkulu and Sezela Kestner data.

Parameter	Umzimkulu	Sezela
Heating surface (m^2)	1 870	9 826
Tube length (m)	7	6.8-7.0
Tube diameter (mm)	51	51
Design cane crush rate (ton/h)	240	450
Current cane crush rate (ton/h)	240	395
Current clear juice rate (ton/h)	360	580
Number of tubes	1 758	9 380
Current wetting rate (kg/min/tube)	3.41	1.03
Typical clear juice brix	10.7	9.5
Typical brix out of Kestner	12.7	16.0
Typical tons evaporation	57	236
Typical specific evaporation rate ($kg/m^2/h$)	30.32	23.98
Typical HTC ($kW/m^2/°C$)	1.50	1.19

HTC = heat transfer coefficient

The trial

The Sezela evaporator station is made up of two separate quintuple effect evaporator sets labelled A and B tails. Each set is made up of two Kestners connected to a common vapour separator. The first Kestner has 2 927 tubes and a heating surface of 3 031 m^2, the second has 1 763 tubes and a heating surface of 1 882 m^2. The juice is fed in parallel with individual clear juice flowmeters. The juice from the separator flows into a Robert type second effect.

As part of the trial, the smaller of the two Kestners in the A tail was blanked off. The trial was conducted for 14 days after cleaning the Kestner. Trial data are given in Table 2, together with data collected 14 days before the trail.

An average of three samples per day were taken for brix analysis, and the flow and pressure measurements were collected on an hourly basis for each day.

The Kestner performance data are summarised in Table 3. The HTC was calculated using the following formula:

$$U = \frac{Q}{A\Delta T_{lm}}$$

where U = Overall heat transfer coefficient ($kW/m^2/°C$)
Q = Heat transferred per unit time (kW) – calculated from juice flow and brix change
A = Heating surface area (m^2) – based on the inside diameter of the tubes
ΔT_{lm} = Log mean temperature difference (°C) – based on exhaust steam temperature, juice inlet and outlet temperatures (taking boiling point elevation into account).

Table 2. Kestner trial data (14 days before and 14 days of the trial).

Day	Clear juice	Brix		Exhaust		Vapour		Wetting rate	Evap rate	HTC
	t/h	in	out	kPa	°C	kPa	°C	kg/min/tube	kg/m²/h	kW/m²/°C
14 Days before the trial										
1	266	10.79	16.89	217	123	138	109	0.95	19.56	0.88
2	314	9.10	15.45	222	124	148	111	1.12	26.28	1.23
3	317	10.63	17.62	221	123	147	111	1.13	25.59	1.19
4	314	11.11	18.08	220	123	147	111	1.12	24.62	1.16
5	300	9.07	15.09	219	123	147	111	1.07	24.39	1.16
6	282	10.71	20.06	222	124	147	111	1.00	26.71	1.24
7	273	10.49	18.30	219	123	147	111	0.97	23.73	1.13
8	286	9.86	17.69	220	123	144	110	1.02	25.79	1.19
9	289	9.16	14.25	221	123	146	111	1.03	21.05	0.97
10	290	9.71	13.51	222	124	145	110	1.03	16.61	0.75
11	297	9.73	15.59	220	123	146	111	1.06	22.74	1.06
12	291	10.02	16.42	221	123	147	111	1.03	23.05	1.08
13	288	10.10	16.06	219	123	145	110	1.02	21.77	1.02
14	307	9.56	14.50	218	123	139	109	1.09	21.27	0.96
Average	294	10.01	16.39	220	123	145	110	1.04	23.08	1.07
14 Days of the trial										
1	319	10.77	17.05	219	123	135	108	1.82	38.74	1.67
2	317	11.34	16.26	218	123	140	109	1.81	31.69	1.44
3	327	10.67	15.34	218	123	138	109	1.86	32.89	1.47
4	304	8.94	14.92	218	123	131	107	1.73	40.24	1.68
5	287	7.71	12.77	209	122	124	106	1.63	37.47	1.63
6	271	9.07	14.21	219	123	141	110	1.54	32.37	1.47
7	252	8.61	13.16	202	121	131	107	1.43	28.73	1.44
8	260	8.53	13.08	214	122	133	108	1.48	29.83	1.33
9	298	8.44	13.65	215	123	134	108	1.69	37.48	1.67
10	287	8.80	12.73	219	123	141	110	1.63	29.21	1.33
11	281	8.31	12.65	224	124	147	111	1.60	31.81	1.44
12	297	8.71	12.06	220	123	137	109	1.69	27.24	1.17
13	312	9.80	13.49	221	123	141	110	1.78	28.19	1.24
14	306	9.19	12.63	218	123	139	109	1.74	27.46	1.23
Average	294	9.21	13.86	217	123	137	109	1.68	32.38	1.44

HTC = heat transfer coefficient

Table 3. Summary of Kestner performance data.

Parameter	Before the trial	During the trial
Heating surface (m²)	4 913	3 031
Number of tubes	4 690	2 927
Average clear juice flow (ton/h)	294	294
Average wetting rate (kg/min/tube)	1.04	1.68
Average juice brix in	10.01	9.21
Average juice brix out	16.39	13.86
Average evaporation (ton/h)	114	98
Average specific evaporation (kg/m²/h)	23.08	32.38
Average HTC (kW/m²/°C)	1.07	1.44

HTC = heat transfer coefficient

The HTC and the specific evaporation rate for each day are shown in Figures 1, 2 and 3.

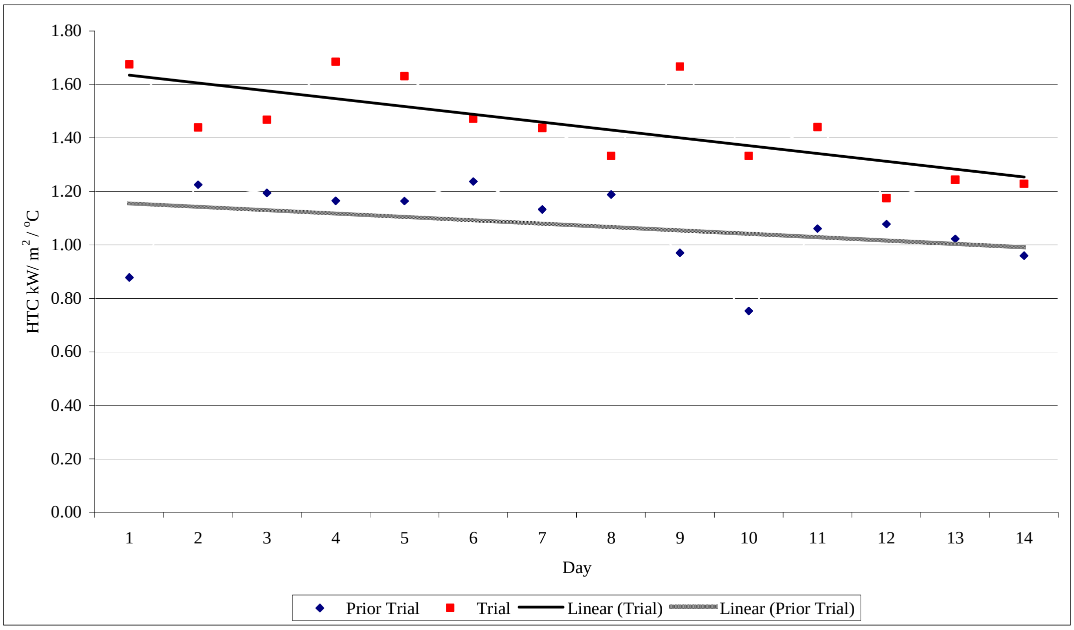

Figure 1. HTC 14 days prior to and 14 days during the trial.

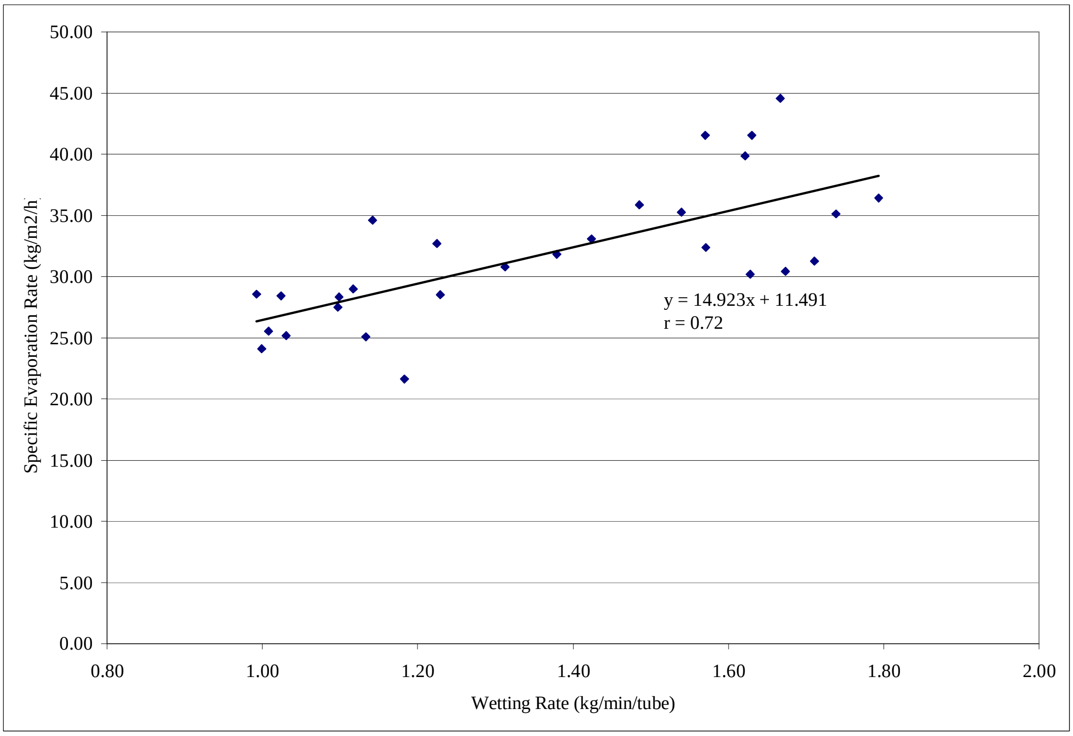

Figure 2. Specific evaporation rate versus wetting rate prior to and during the the trial.

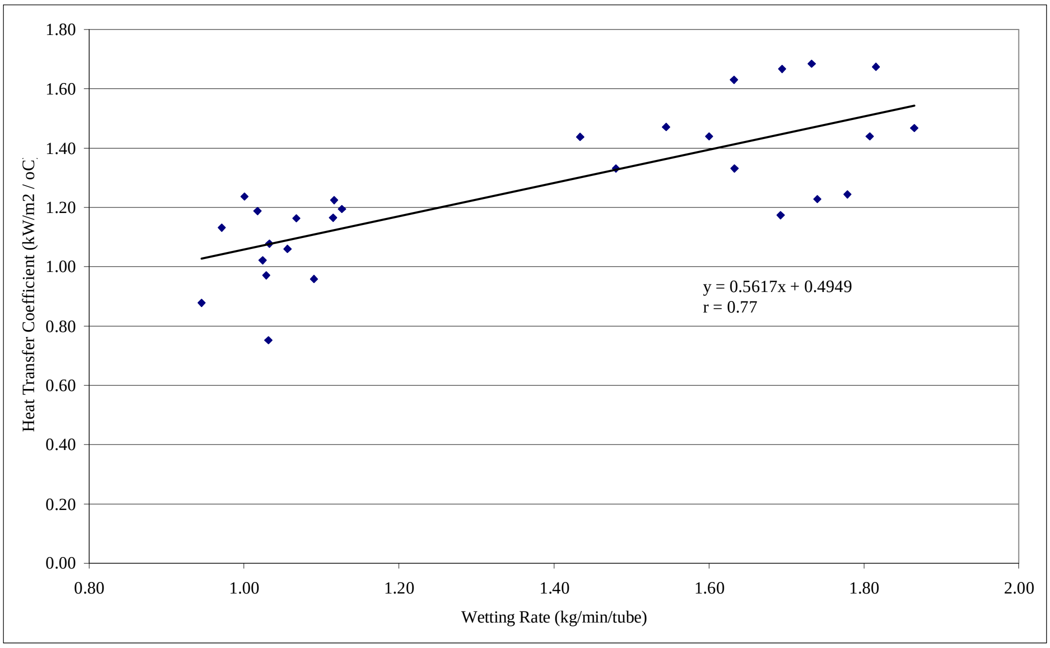

Figure 3. HTC versus wetting rate prior to and during the trial.

Discussion

Although the Sezela wetting rate during the trial did not reach that of Umzimkulu there was a significant increase in Kestner performance, measured by specific evaporation rate (kg/m^2/h) and HTC (kW/ m^2/°C), as the tube wetting rate increased.

These plant level trial results are in line with the findings of James *et al.* (1978) and Walthew and Whitelaw (1996) in pilot plant work.

By increasing the wetting rate from 1.04 to 1.68 kg/min/tube, an increase of 62%, the specific evaporation rate increased from 23.08 to 32.38 kg/m^2/h, an increase of 40%. Within the range tested, the HTC did not flatten out with increasing wetting rate (see Figure 3). This is in line with James *et al.* (1978). Walthew and Whitelaw (1996) showed that the HTC flattens out around 1.3 kg/min/tube.

Figure 3 shows a steeper HTC drop per day during the trial compared with prior to the trial, which may indicate a faster fouling rate. This may, however, be due to other factors and cannot therefore be linked directly to the trial. There was no evidence of excessive fouling during post-trial cleaning. Faster flow rates would tend to reduce fouling rates.

The reader must be cautioned that these were plant level trials, and thermocouples, pressure transmitters and flowmeters were not calibrated specifically for the test; the measuring equipment is calibrated during the off-crop period. Accurate sampling of the juice after the Kestner is not easy, due to flashing. However, a proper sampling device was fitted with two valves, and the sampler was instructed to cool the sample in the sampling device before collecting the sample.

During the trial the Kestner showed signs of condensate logging. The level of condensate inside the calandria was not visible but the bottom incondensable gas vent kept spouting condensate and the condensate drain had to be opened on occasions. The authors feel that with proper condensate drainage the evaporation rate could have been even better.

Conclusions

In conclusion, the trials showed that Kestner performance measured by HTC and specific evaporation rate can be improved by increasing the wetting rate. Kestners must be designed and operated with high wetting rates. Within the wetting range tested (0.9-1.8 kg/min/tube) the performance improvement was almost linear.

In new installations where two Kestners are being installed with parallel juice feed, consideration should be given to feeding of the juice in series. This will increase the wetting rate and improve performance. However, a proper model needs to be developed.

Acknowledgement

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