ASSESSMENT OF A PLATE HEAT EXCHANGER ON PROCESS JUICE HEATING

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Abstract

A plate type heat exchanger was assessed for mixed juice and clear juice heating at the Dalton mill of the Union Co-op. Average heat transfer coefficients of 3 400 W m^{-2} $°C^{-1}$ on clear juice and 3 000 W m^{-2} $°C^{-1}$ on mixed juice were obtained. The pressure drop across the unit ranged from 50 to 100 kPa. The fouling characteristics of the unit together with other data are presented.

Introduction

Plate heat exchangers (PHE) have been tried on juice heating, notably at Noodsberg and Hippo Valley, but were reported to clog up very quickly with bagacillo. A liquid/liquid plate heat exchanger on press water heating/cooling at Dwanga, which was reported to be free from clogging, and the satisfactory performance of these types of units on molasses cooling (Jullienne and Munsamy[1]) were the main reasons behind the decision to run factory scale trials on juice heating.

During the 1981/82 season an Alfa-Laval plate heat exchanger was installed at Union Co-op (UC) and the unit was assessed both for mixed juice and for clear juice heating. The heat transfer coefficient (HTC) was relatively high for both juices, and the pressure drop across the unit was low compared with tubular heaters.

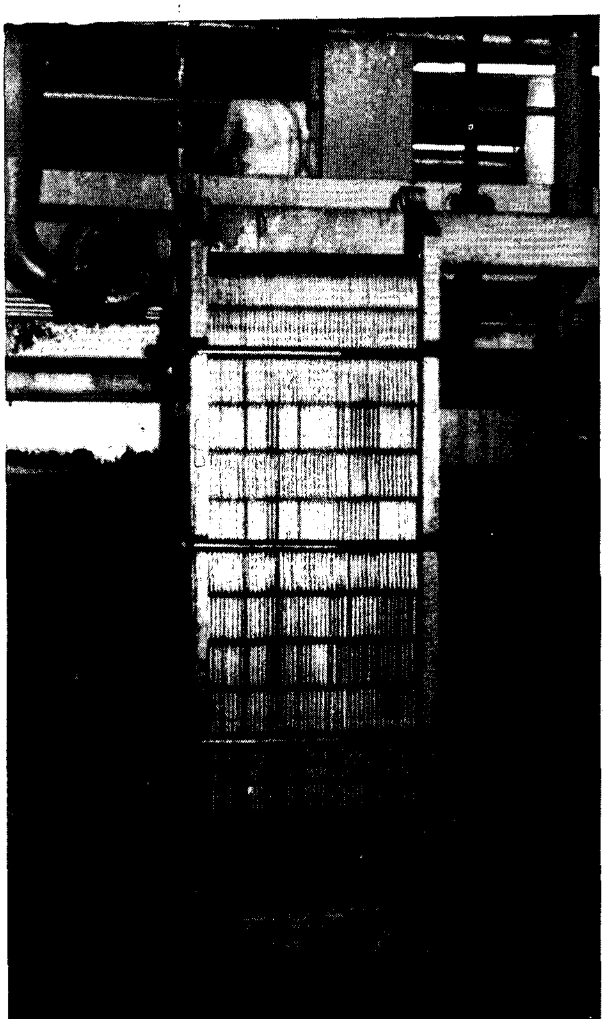

FIGURE 1 A typical plate heat exchanger installation.

Description of the Plate Heat Exchanger

The unit consisted of 44 plates of herringbone design for clear juice heating and an additional 6 plates (total of 50) for mixed juice heating.

The herringbone pattern was arranged to maximise the number of contact points and was clamped together in a frame which could hold a maximum of 174 plates or a plate pack of 1 044 mm. The heating medium (60 kPa gauge exhaust steam) and the process juice were arranged to flow countercurrent to each other. The juice entered at the bottom and climbed up the plate whereas the steam entered at the top and condensed down the other side of the plate. The plates were arranged to form a single pass through the unit. The flow paths of the steam and juice were separated by rubber gaskets, which also formed the seal between the plates. The gaskets also have moulded vents which permit any leaks to vent to atmosphere rather than contaminate the second medium. The piping was arranged so that the unit could be backwashed by reversing the direction of the juice flow. This unit had no incondensible gas outlet.

Detailed specifications of the Alfa-Laval plate heat exchanger are listed in Table 1 and a typical PHE installation is shown in Figure 1. The manufacturers of this unit claim that the opening between the plates was specially designed for sugar juice heating and was relatively large (5, 4 mm). The design, principle of operation and unit selection are reported by Raju and Chand[2], Marriott[3] and various other authors and therefore will be omitted from this paper.

Experimental Procedure

Juice Flow Rate Measurement

The clear juice flow rate was measured by means of an orifice placed in the pipe between the pump and the heater.

Initially, the mixed juice flow rate was also measured using an orifice in the pipe but fouling problems were encountered and a simpler solution was chosen. The flow rate was obtained by taking the mixed juice scale reading with the filters stopped and the filtrate return pump switched off for the period of the tests, which lasted for 1 hour.

Log Mean Temperature Difference

The log mean temperature difference (LMTD) was determined in the same manner as for shell and tube heat exchangers. The exhaust steam at UC was at 60 kPa gauge

TABLE 1
Technical specification of the Alfa-Laval plate heat exchanger at UC

Type	AM 20 — HBM
No. of plates	50
Heat transfer area per plate	0,79 m^2
Heat transfer area of unit	48 × 0,79 m^2
Plate size: length	± 1980 mm
width	± 780 mm
Plate material	A1S1 316 SS
Liquid volume	5,46 litres per channel
Mass of unit (plates + frame)	2 200 kg
Frame designed for	174 plates
Gasket material	Resin cured butyl (rubber)
Maximum gasket temperature	150°C
Maximum working pressure	9 bars
Size of frame: height	2,195 m
width	0,810 m
length	2,440 m
Size of plate pack	50 plates - 300 mm 80 plates - 480 mm 174 plates - 1 044 mm
Price of unit (50 plates)	R10 295 (1981)
Price of one plate	R113

and contained up to 20°C of superheat at times, resulting in a steam temperature of 130°C. The saturated steam temperature corresponding to the above pressure was used to determine the LMTD. The barometric pressure at UC is 90 kPa (1 000 m above sea level) and the saturated steam temperature at 150 kPa absolute is 111°C.

Results

Heat Transfer Coefficient (HTC) and Pressure Drop

The plate heat exchanger was operated for 5 weeks on clear juice without any cleaning of the plates and the average heat transfer coefficient and pressure drop are shown in Table 2. During clear juice heating the steam valve was only partly open, which would reduce the effective steam pressure on the heat exchanger and consequently increase the HTC above the calculated values listed in Table 2.

TABLE 2
Average HTC and pressure drop on clear juice heating

Tons C J per Hour	Juice Temperature (°C)		Pressure Drop (kPa)	Saturated Steam Temperature (°C)	HTC (W m^{-2} °C^{-1})
	In	Out			
130	92	104	75	111	3 400

The unit was also operated on mixed juice for two months and was cleaned every week. UC has a cane diffuser and mixed juice was not screened. The week long evaluation was carried out towards the end of this period. The results are shown in Table 3.

Fouling Characteristics

The plate heat exchanger was opened after 5 weeks of operation on clear juice and the only fouling material found was an accumulation of sludge and a black film on the plates. The sludge was mainly clear juice carry over particles, which were present in the juice at the time of testing. This was easily hosed down with water.

On mixed juice heating the unit was cleaned every week (6 days in operation). The fouling material consisted of sludge which was mainly sand and bagacillo and a thin surface scale similar to the scale found in tubular heaters. The plates were removed, hosed down with water and scrubbed with wire brushes to remove the thin scale.

The plate heat exchanger was backwashed by reversing the direction of juice flow when the pressure drop increased because of accumulation of sludge. The temperature of the juice was not greatly affected by the backwashing provided that the plates were wetted with juice along the whole surface. This could be achieved by throttling the juice outlet valve during backwashing. The unit was backwashed once per shift.

The thin scale on the plates tended to decrease the heat transfer and could not be removed by backwashing. However, the quantity of this type of scale seemed to be less than in tubular heaters.

Advantages of Plate Heat Exchangers

The heat transfer coefficient was high compared with conventional shell-and-tube heaters. Hugot[4] reports HTC values of 261 to 1 310 W m^{-2} °C^{-1} for tubular heaters using exhaust steam. Using an HTC value of 1 310 W m^{-2} °C^{-1}, UC would have needed an 86 m^2 tubular heater for clear juice heating. The surface area of the heater would have been 160% higher than that of the PHE (33,18 m^2). In addition plate heat exchangers do not need insulation, and (for the same duty) can be supported on a less expensive foundation than a shell-and-tube unit. Also less energy is required for pumping juice through a PHE due to the lower pressure drop across the unit.

The unit offers complete accessibility to all parts for easy inspection, cleaning and replacement. At UC the plates were manually cleaned with wire brushes, but a brush could easily be adapted on to an electrical machine for faster cleaning. The unit is well suited for chemical cleaning

TABLE 3
HTC and pressure drop on mixed juice

No. of Days on Range	Pressure Drop (kPa)	Juice Temperature (°C)		Steam Pressure (kPa)	Saturated Steam Temp (°C)	Mixed Juice Flow (t h^{-1})	HTC (W m^{-2} °C^{-1})
		In	Out				
1	50	74	97	60*	111	123	3 380
2	50	76	95	60*	111	133	2 970
3	70	72	96	60*	111	112	3 030
4	100	69	94	52†	109	103	2 900
5	—	—	—	—	—	—	—
6	100	72	94	50†	109	130	3 300

* Exhaust steam manifold pressure † Exhaust steam pressure at the PHE

although this was not tried at UC. The very small holding volume of the unit together with the turbulent flow in the channels makes this type of cleaning very attractive. The rubber gaskets are resistant to cleaning chemicals.

The biggest advantage of the plate heat exchanger is its comparatively low cost. The UC unit costs R10 295 compared with an estimated R30 000 for a shell-and-tube heater for the same duty.

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