

THE USE OF A "WIDE-GAP" PLATE HEAT EXCHANGER ON MIXED JUICE HEATING

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Abstract

The decision to install a plate heat exchanger for primary heating of mixed juice at Union Co-operative Limited is described. The unit installed, an Alfa-Laval AM 20 - TFM with "wide-gap" plates is described and compared with the conventional unit. The cost of the unit and its installation is given and compared with that of a shell and tube heater of equivalent capacity. The performance of the unit, as measured in actual use during the 1985/86 season, in terms of operation, heat transfer, through-put and on-line chemical cleaning is given and commented upon.

Discussion

Union Co-operative Limited has always lacked the heating surface required for all mixed juice heating to be done using vapour 1 as the heating medium. As a result, it was decided to install a heater for commissioning during the 1985/86 season. Since a plate heat exchanger had operated on mixed juice at Union Co-operative during the 1981/82 season, as described by Munsamy¹ in 1982, it was felt that this type of unit would be suitable and should be considered. The advantages of plate heaters were discussed by Munsamy¹ and will not be included in this paper.

Alfa-Laval offered their AM20 - TFM or "wide-gap" unit for this application. It should be noted that Alfa-Laval designed this unit to be used on scalding juice heating for beet diffusers. After consideration, a unit was commissioned during August 1985.

Description

The detailed specification of this unit is given in Table 1. The conventional herringbone pattern was used on the plates but the "wide-gap", which varies from 6 to 16 mm depending on the relationship of the herringbones to one another was applied to the heating surfaces in contact with the juice. The steam side of the plates remain in contact with one another, as would be the case on both surfaces in a conventional unit. The seal between the juice plates is facilitated by a thick gasket and the compression of these on closing up the heater is protected by spacer studs on the outer perimeter of the plates. The widest gap on the juice side of the plates in a conventional heater is approximately 5,4 mm while the herringbones are in contact with one another. Because of the gap in the AM20 - TFM unit, it is important that the juice working pressure be higher than the steam pressure in order to support the plates and prevent deformation and cracking/leaking through buckling of the plates, ie in a conventional plate heater, the plates are basically self-supporting while in this unit, they are not.

The juice passage comprises 4 passes through the heater with entry being on the pressure plate and the exit being at the frame plate. The steam passage consists of a single pass with entry at the top on the frame plate and condensate leaving at the bottom on the frame plate. The flow of steam and juice are normally countercurrent, being co-current during backflushing only.

The steam supply to the unit was piped up for vapour 1 at approximately 35kPa (gauge) and thermometers and pressure gauges were installed on the inlet and outlet pipes to facilitate monitoring of these values constantly.

Table 1
Detailed specification of mixed juice
Plate heat exchanger

TYPE	ALFA LAVAL AM 20-TFM
No. of Plates	65
H.S. of unit	49,22 m ²
H.S. per plate	0,766 m ²
Plate material	AISI 316 SS
Plate thickness	0,8 mm
Gasket material	Resin curved butyl rubber
Juice volume	0,175 m ³
Mass unit (frame + plates)	2200 kg
Maximum juice pressure	600 kPa
Maximum steam pressure	200 kPa
Frame size: height	2135 mm
width	790 mm
length	3515 mm
No. of passes - juice	4
steam	1

Operation and Results

The unit was commissioned during August 1985 and operated without any problems until the end of the season. As a primary juice heater the unit achieved the average results reflected in Table 2 and allowed all mixed juice heating to be carried out on vapour 1. ie primary heating on the plate heater and secondary heating (to 103°C) on 2 shell and tube units in series. The flow path through the heating station at Union Co-operative is given in Figure 1.

The suspended solids in the mixed juice processed through the unit averaged 0,26% and, must have been higher than this due to the suspended solids returned in the filtrate. Initially flow direction was reversed every 4 hours for 4 hours, to prevent blockages but this was later extended to 8 hours reversed flow, for 8 hours without any adverse effects being noted. No changes in the pressure drop or temperature rise were found when flow was reversed.

Table 2
Average results and HTC achieved by the plate heat exchanger

Tons juice per hour	Juice temp (°C)		Press. Drop -juice (kPa)	Vapour 1 pressure (kPa)	Saturated Steam Temp (°C)	HTC (Wm ⁻² C ⁻¹)
	In	Out				
154	69	84	50	32	105	1802

Note: The formulae used to calculate the results are given in Appendix 1.

After the unit had operated for approximately 72 hours, the temperature rise had decreased to 12°C and the unit was taken off-line for inspection and cleaning. When opened, the steam side of the heating surface was found to be clean; the

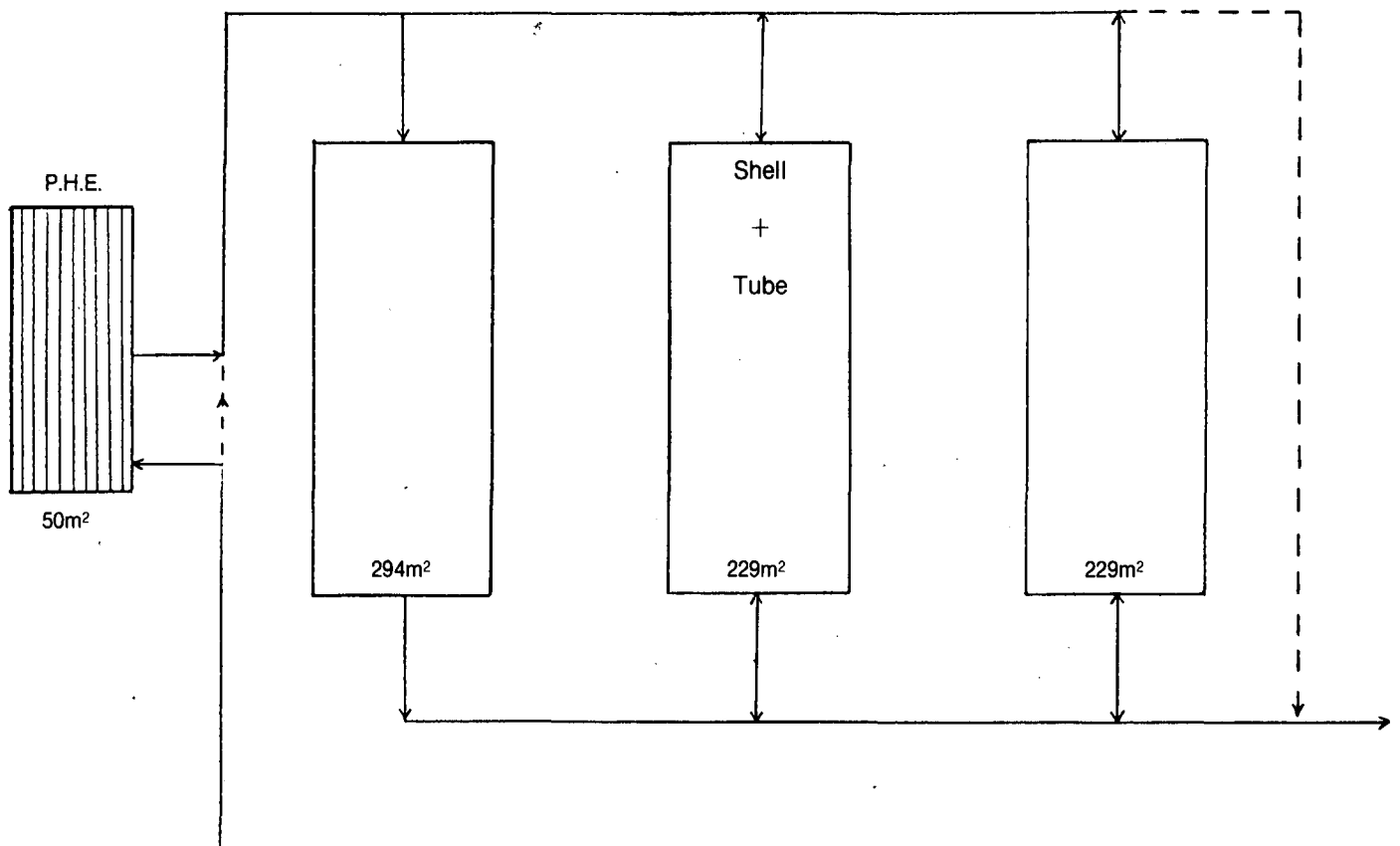


FIGURE 1 Union Co-operative Limited: mixed juice heating – juice flow.

juice side was fouled with a thin, hard black scale directly on the plate with a soft sludge containing sand and bagacillo on top of this. The sludge was hosed off and the scale was manually removed using wire brushes, (no chemical assistance), which took 12 hours to complete. A sample of this scale was subjected to laboratory tests and was found to dissolve in a 3% caustic soda solution at 85°C. On this basis, the unit was piped up to be chemically cleaned and returned to service.

Again after 72 hours use, the temperature rise decreased to 12°C and the unit was taken off-line, flushed with water, cleaned by circulating 3% caustic soda at 85°C through the unit for 3 hours, again flushed with water and opened for inspection. The steam side showed a slight, “dusty” fouling which was probably carbonised product entrained in the vapour while the juice sides were bright and shiny, showing that the chemical cleaning had worked satisfactorily and could be used routinely.

The unit was returned to service and not opened again until the end of the season. Chemical cleaning was carried out every 72 hours and the unit returned to service immediately after each cleaning. The advantages of this method of cleaning, on this type of unit, compared with the mechanical method of cleaning a shell and tube heater, are obvious and need not be elaborated on. The stock solution of caustic was titrated after use and made up to strength before the next clean.

The usage and cost of caustic soda consumed is given in table 3 below.

Table 3
Average chemical consumption and cost per cleaning cycle

Consumption of caustic soda kg	Cost of caustic soda c/kg	Cost per chemical clean R
15	86,2	12,94

Discussion

The heat transfer coefficient achieved was more than twice that which would be achieved by a shell and tube heater operating under the same conditions. Hugot³ quotes values of 817Wm⁻²C⁻¹ for a shell and tube heater working under these conditions. This indicates the efficiency of the plate heat exchanger. The average measured pressure drop, which includes reverse flow periods, at 50kPa is extremely low and is lower than that measured by Munsamy¹ on the conventional plate heat exchanger.

The cost of the unit and its installation was R42 500; the unit and its delivery costs comprising R35 302 of this, the balance being structural steel, piping and valves. A shell and tube heater of the same capacity was quoted at approximately R55 000 at the time, before considering structural steel requirements, lagging and space.

This plate heat exchanger can be modified by changing and extending the plate pack to carry out the total juice

heating duty on vapour 1 at a current cost of R47 000 (exclusive of tax) and a new unit for this total duty would cost R88 100 at current rates. If Union Co-operative, were considering a new juice heater station the unit costs of the equivalent shell and tube heaters would total approximately R220 000 while two plate heat exchangers would cost R176 200; the economics and advantages described would obviously dictate the choice.

Conclusion

As a result of the success of the two plate heat exchangers applied to sugar processing at Union Co-operative, with their resultant savings and advantages as well as the success of those applied to molasses cooling elsewhere in the industry, it can be stated that plate heat exchangers can and should be used in future installations in this field. Future development could mean that diffuser scalding juice is screened prior to heating it in plate heat exchangers.

Acknowledgements

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2. Jullienne, LMSA and Munsamy, SS (1981). Assessment of Final Molasses Coolers. *Proc S Afr Sug Technol Ass* 55: 83-84.
3. Hugot, E (1970). *La Sucrierie de Cannes*: p 426.

APPENDIX 1

Formulae used for calculation of results

- (i) Log mean temperature difference was calculated according to the formula:

$$\Delta t = \frac{T_e - T_i}{2,3 \log \frac{T_s - T_i}{T_s - T_e}}$$

where

T_s = saturated steam temperature at 90 kPa barometric pressure (°C)

T_e = temperature of the juice at exit of the heater (°C).

T_i = temperature of the juice at inlet of the heater (°C).

Δt = log mean temperature difference.

- (ii) Heat transfer coefficient was calculated from the formulae:

$$Q = k A \Delta t \text{ and } Q = mC (T_e - T_i)$$

where

Q = quantity of heat transferred in W and kW respectively.

k = Co-efficient of heat transfer ($Wm^{-2}C^{-1}$)

A = Heating surface (m^2)

Δt = Log mean temperature difference (°C)

m = mass of juice processed ($kg \text{ sec}^{-1}$)

C = Specific heat of juice ($kJkg^{-1}C^{-1}$)

T_e = Exit juice temperature (°C)

T_i = Inlet juice temperature (°C)

- (iii) Specific heat of juice was calculated from the formula:

$$C = (1 - 0,006B) 4,187$$

where C = Specific heat of juice ($kJkg^{-1}C^{-1}$)

B = Brix of juice

- (iv) Pressure drop was obtained from the difference between inlet and outlet juice pressures as measured. (kPa).

- (v) Mass of juice was calculated from factory mass balance figures of cane and mixed juice for the period during which the unit operated and from a filter station mass balance for the mass of filtrate. From these masses, the mass of "total" juice per hour was obtained and the brix of the juice was also calculated.