PRACTICAL EXPERIENCES OPERATING A FIRST EFFECT FALLING FILM EVAPORATOR UNIT AT PONGOLA

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Abstract

The installation and performance of a 2 000 m² falling-film evaporator unit as part of a raw house evaporator first effect are presented. The decision to install such a unit and the erection and commissioning stages are discussed. Experience relating to the on-line operation, the system reliability and chemical cleaning procedures are highlighted. Several performance parameters were measured and are presented in the paper.

Introduction

In order to process the anticipated additional cane supply at the Pongola mill as well as to compensate for the gradual deterioration in performance of the existing first effect vessels, it was necessary to increase the installed capacity of the raw house evaporator by means of additional heating surface. As the first phase of this expansion, a new 2 000 m² heating surface falling-film evaporator was installed to operate with the existing first effect vessels in the raw house evaporator station.

Choice of vessel design

Previous work undertaken on the application of the principles of process integration for the efficient use of energy ("Pinch Technology") to the cane sugar milling operations demonstrated that evaporators of the falling-film design offered the best operational characteristics to achieve the objective of minimum process energy usage (Seillier and Brouckaert, 1988). The recent development and introduction of the plate evaporator design in the beet sugar industry may offer similar characteristics, although Valentin (1993) has presented some convincing arguments why the former is a better option.

In the case of retrofits to existing cane sugar factories where the application of the energy saving principles is constrained by existing operating conditions, in particular prime mover exhaust steam back pressures, the falling-film design offers the possibility of obtaining the equivalent of two effects within the conventional pressure or temperature differential that exists between the exhaust and vapour 1 steam ranges.

From the application of Rillieux principles, this implies that significant steam or energy saving can be made with little or no change to prime movers and processing equipment operating conditions.

In an attempt to obtain operational experience and sizing criteria, a falling-film pilot-plant evaporator was installed at the old Illovo mill site (FitzGerald *et al.*, 1991) and the opportunity of extending this knowledge on a full-scale unit was a motivation behind the choice of vessel design in the current installation.

It must be conceded from the outset that the process benefits reported here as a result of the installation of the falling-film vessel would have been achieved by means of additional heating surface in any other configuration. Because the new unit is operated in conjunction with vessels of a different design within the first effect and share common steam ranges, it is not operated at its maximum potential in terms of its performance characteristics. The design does, however, have the benefit of a circulating pump that ensures that the heating surface is wet under all conditions including during chemical cleaning.

Description of plant

Previous installation

Prior to this installation, the evaporator station comprised a quintuple effect evaporator consisting of the vessels listed in Table 1. All effects consisting of more than one vessel are operated in parallel in respect of both the juice and steam flows. As a possible result of irreparable tube damage arising from the use of mechanical cleaning methods as well as shell side tube corrosion, the performance of the front end of the evaporator station has deteriorated markedly to the extent that the overall heat transfer coefficients recorded for the first, second and third effects are currently estimated at 70, 85 and 95% of the normal design figures, respectively, after cleaning.

Table 1

Evaporator station vessel design parameters

Effect No.	No. of Vessels	Vessel Type	Tube		Total heating surface m²
			Length (mm)	Diameter (mm)	
1	2	Kestner	7000	50,8	3720
2	1	Roberts	3400	50,8	2400
3	1	Roberts	2450	44,0	930
4	1	Roberts	2375	50,8	1115
5	2	Roberts	1900	44,0	930

Falling-film evaporator installation

The vessel design chosen is a falling-film type with an internal separator and a juice distributor design suitable for handling clarified juice containing small amounts of suspended solids.

The basic plant and the specification for the vessel are given in Figure 1 and Table 2.

The unit is installed to operate in series after the existing first vessel Kestners on the juice side but in parallel on the steam and vapour sides, *viz.* the unit is fed juice from the existing first effect separator but is operated at the same steam and vapour pressures.

As this is the first full scale unit of its kind within the Company, more instrumentation has been specified than would normally be anticipated for this type of unit as seen in Figure 2.

The vessel is fitted with automatic isolating valves on both the steam and juice sides to allow the unit to be taken off-line during normal crushing operations. In addition it is integrated into the existing evaporator chemical cleaning facilities.

On the advice of the supplier, provision is made to flush the heating surface if a condition of "no-flow" in the circulation line is monitored. Due to the height of the installation, this is done by providing an electrically driven water pump powered from the national Eskom grid and drawing hot water from the existing pan-floor supply tank which is maintained at the full level. If such a condition does occur, the unit will be automatically isolated from both the exhaust and vapour 1 ranges and vented to atmosphere at the same time.

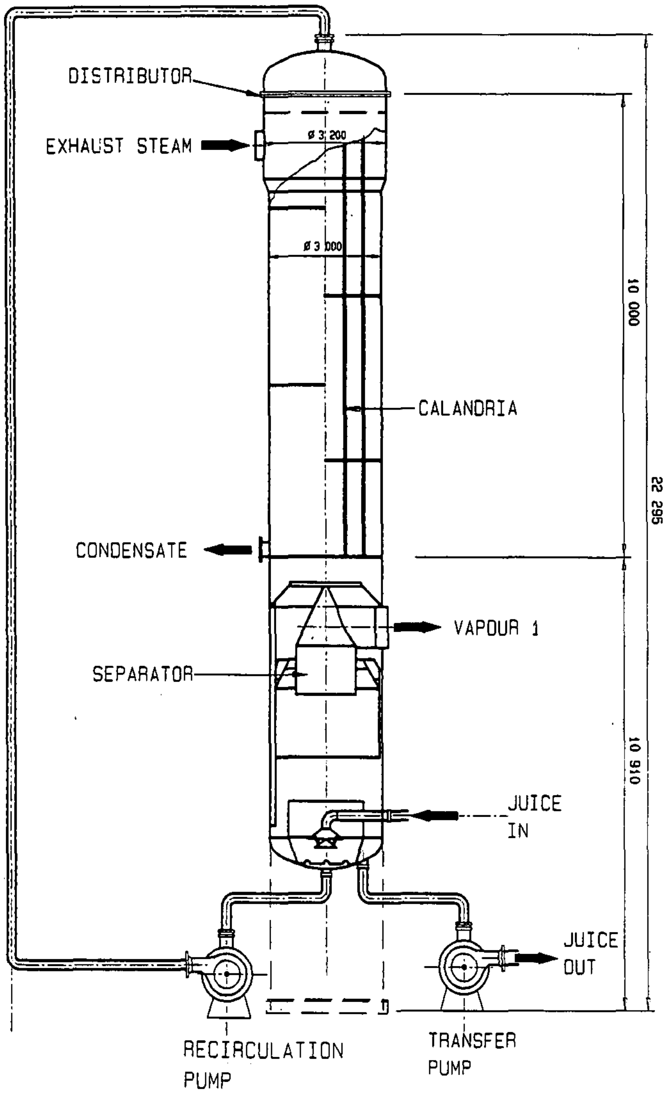

FIGURE 1 Falling film evaporator vessel.

Table 2

Falling film evaporator design parameters

Type	Falling-film
Model	BMA "Beta" type (Baffle-type entrainment separator in base.)
Heating surface (m²)	2 000
Tubes Number O.D. (mm) length (mm) material	1 360 50,8 10 000 ANSI 439 ss

Description of operation

Operation on-line

The evaporator is fed under gravity from the existing Kestner separator to the internal sump in the base of the falling-film evaporator by means of a new line from the existing line feeding the second effect.

From this sump, juice is pumped to the distributor by one of the two circulation pumps at a fixed rate to ensure adequate wetting of the tubes. This flow is not controlled directly but is monitored and can be trimmed by means of a manual control valve. As the juice flows down the inside surface of the tubes, it is heated by exhaust steam on the shell side of the calandria. The resulting two phase juice/vapour mixture is then separated in the cyclonic separator built into the base below the bottom tube-sheet. To ensure adequate wetting of the heating surface, the design allows for juice recycling as required.

Concentrated juice is pumped by means of a transfer pump to the existing second effect vessel through a new line while the vapour is fed into the existing vapour 1 main.

The level in the evaporator sump can be maintained in two ways, viz. during normal operation and reduced flow conditions. Under normal operating conditions, the level is maintained at approximately 70% of the full sump volume using the control valve on the discharge line from the transfer pump feeding the second effect. If the inlet flow is reduced while still maintaining full evaporation, the level will continue to drop even after the outlet valve has closed and once a certain minimum level is reached, this level will be maintained by the addition of hot factory water into the sump.

Chemical cleaning

As the installation can be isolated from the other vessels in the evaporator station, provision is available to clean the vessel chemically at the same time as, or independently of, the other vessels.

This is done by cleaning the unit in a way similar to that practised on the existing Kestner vessels, viz. filling the sump with the cleaning solution at the required strength and circulating using one of the circulation pumps. Allowance is made for water make-up to compensate for any evaporation loss and to control the temperature of the circulating cleaning solution.

The chemical solutions are pumped by means of an existing supply pump into the sump until the required level is reached. The solution is circulated around the vessel while

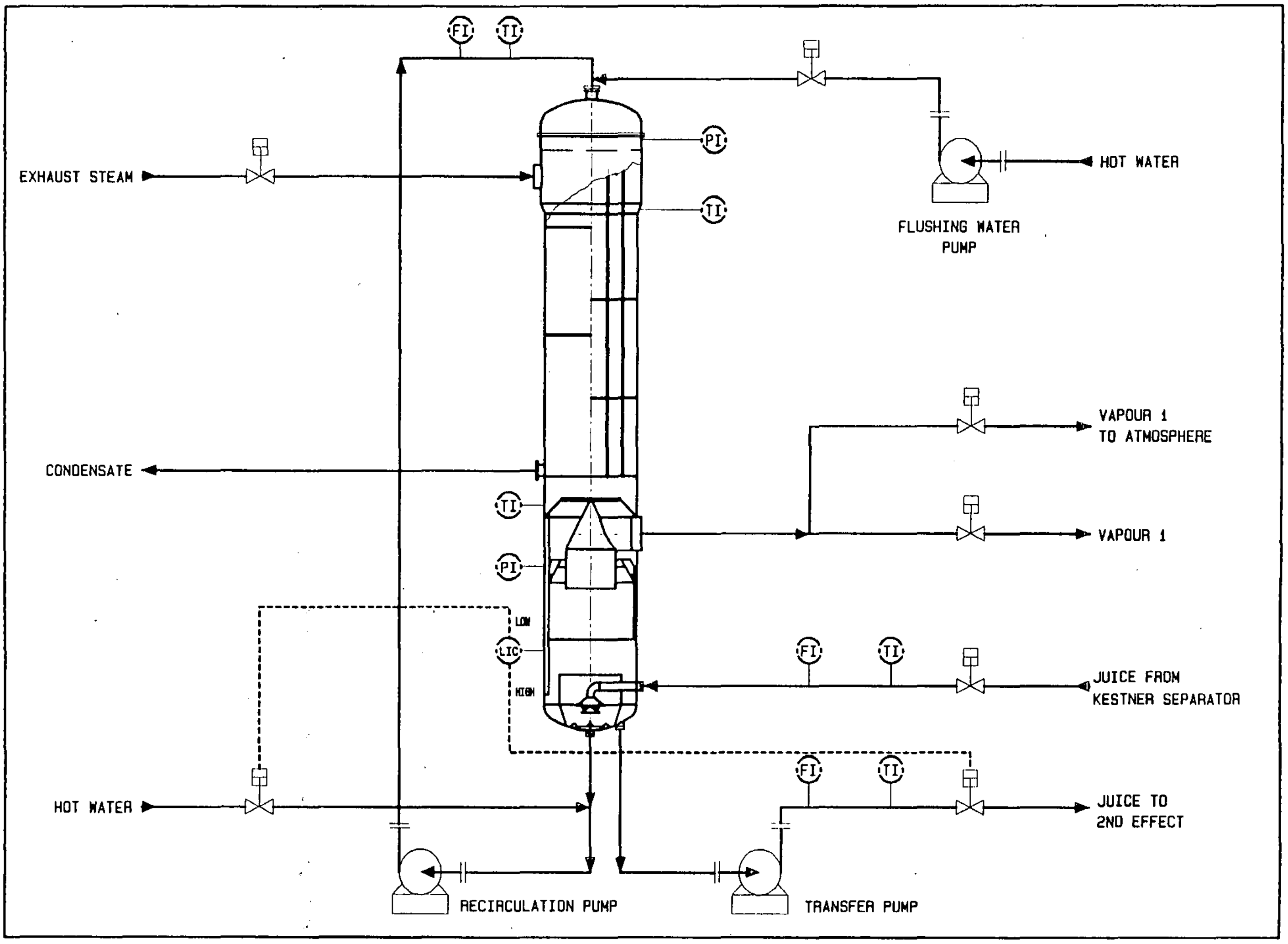

FIGURE 2 Simplified instrumentation diagram.

the exhaust steam addition is controlled at the required operating temperature. On completion, the spent solution is pumped back to a dilution tank or dumped, and the unit is flushed with water.

Erection and commissioning

Due to the overall height of the installation, the evaporator vessel was manufactured in three sections and trial assembled on the shop floor with locating lugs. The sections were transported to the site and erected on a prepared foundation using a 90 ton long reach crane. Due to limited site access, the loads were limited to 5 tons each. The vapour separator internals and juice distributor were manufactured and supplied directly from Germany for installation locally. In order to match the thermal expansion of the mild steel shell, the vessel was fitted with imported ANSI 439Ti welded unannealed ferritic stainless steel tubes which exhibit a similar expansion coefficient. To facilitate erection during the season, tie-ins were made during the preceding off-crop.

The installation was initially commissioned on water during which time minor problems with the circulation pumps and the in-line flow meters heightened awareness of the importance of minimum wetting rate to this type of design. Once resolved, the unit was brought on-line and has proven remarkably stable and the only problems subsequently encountered were due to pump failures when handling the caustic soda cleaning solutions.

Operational experiences

Impact

The immediate impact of the additional heating surface on the process was dramatic with the vapour 1 range pressure climbing to levels never experienced before at Pongola. For a relatively low exhaust pressure of 85 kPag, a vapour 1 pressure of 45-50 kPag was readily achieved as is shown in Figure 3.

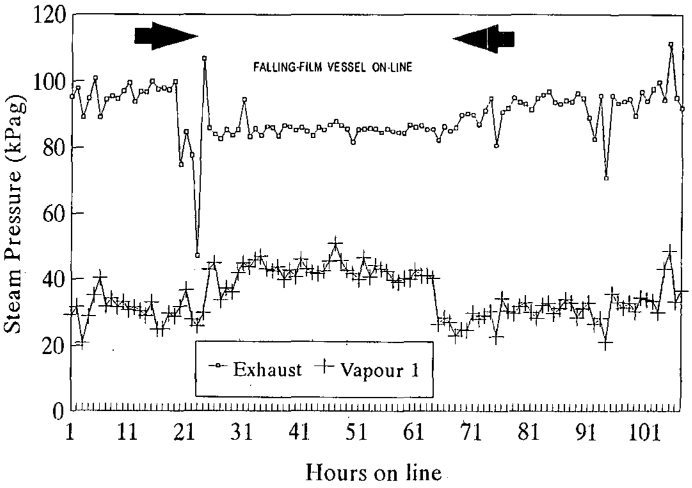

FIGURE 3 Impact of additional area on pressure ranges.

The higher vapour 1 pressures and the resulting higher brixes obtained from the falling-film vessel assisted the pan floor in coping with higher crush rates of up to 230 tons/hour of cane when necessary. The vapour 2 pressure also increased to between 20 and 35 kPag which helped in preheating of limed juice to temperatures which ensured proper flashing.

The dependence on the circulation pump and the control strategy adopted ensures that the falling-film evaporator operates almost independently of any variation or disturbance to either the juice or the steam supplies. Once on-line, the unit has proved stable, reliable, and easy to control with a minimum amount of operator attention being required. In less than 5 minutes from being brought on-line, the vessel can be placed under full automatic control, all desired operating conditions being easily maintained. The cyclonic separator performed well with sugar trace levels of less than 2 ppm being found in the condensed vapour.

Chemical cleaning

The evaporator proved easy to clean, no operator attention being required after the cleaning solution starts to circulate and the level is set on automatic for water addition. The unit is chemically cleaned with 20% m/m caustic soda solution at 102°C for about 8 hours, followed by flushing with water.

An inspection of the tubes after the first cleaning indicated some scale on the tube walls reaching down approximately 300 mm, but no further scale was evident below this point. This scale, in the shape of a "V", appeared to occur in those areas furthest from the points where the juice is fed onto the tube sheet by the distributor. This may be symptomatic of the lower wetting rate being achieved due to the higher density of the caustic soda cleaning solution. After the cleaning, a large amount of soft scale was removed through the bottom drain while the distributor also accumulated scale deposits from the tubes which had to be flushed out with water.

Further chemical cleanings were just as successful although there was some concern when five tubes were found to be blocked partially. It is believed that this is a direct result of the accumulation of sludge on the distributor after chemical cleaning which resulted in some maldistribution of juice over the tube sheet. These blockages were easily removed by means of a high pressure water jet.

Operational results

Overall heat transfer coefficients

Using process data recorded by the operating staff and juice samples analysed by the laboratory staff on an hourly basis, average performance figures were obtained on a shift basis. The evaporation rates for the first effect and the various vessels within the effect were estimated from brix balances based on brix measurements taken across these vessels and the recorded clear juice flow rate. The overall heat transfer coefficients (OHTC) were then calculated using the exhaust steam and vapour pressures assuming saturated steam conditions and the juice temperatures were recorded for the various streams in the first effect. The results are shown in Figure 4.

Apart from the variability of the results, the most notable feature of the results achieved to-date is that the coefficient for the falling-film evaporator did not match the magnitude of the values obtained previously on the pilot plant where coefficients of over 3,0 kW/m^2°C were recorded (FitzGerald *et al.*, 1991). While this is not unexpected as pilot plants tend to perform better than full scale units (Walthew, personal communication)*, they are still disappointingly lower than anticipated. The operational coefficients ranged from 2,4 kW/m^2°C immediately after the caustic soda cleaning to a low of 1,0 kW/m^2°C after three weeks of operation. The rate of fouling is also significantly faster than that reported for the pilot plant.

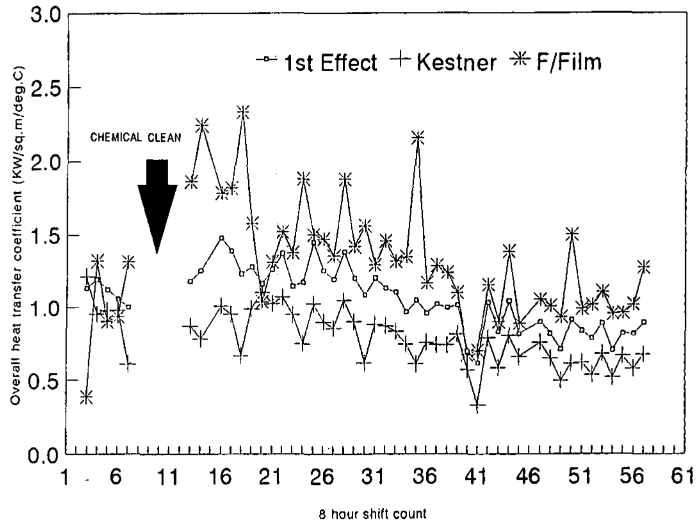

FIGURE 4 Overall heat transfer coefficients.

The variation in results obtained is probably as a result of both catch sampling and spot measurements and further work will be undertaken in the coming season using continuous samplers and, if available, an on-line data logging facility to be mounted on the centralised process control system.

Figure 5 also demonstrates the rate of fouling by plotting the difference between the exhaust and vapour 1 range pressures between two chemical cleanings. The data show that with time, fouling of the tubes resulted in a higher pressure difference as a result of a lower heat transfer coefficient.

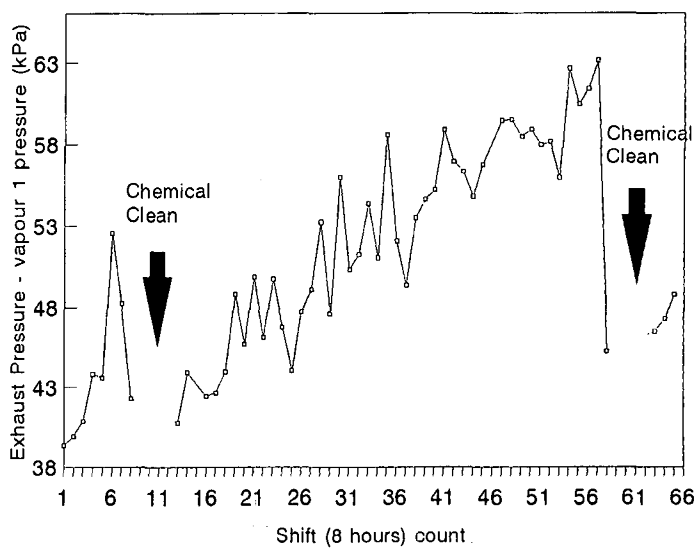

FIGURE 5 Effect of fouling on exhaust – vapour 1 pressure differential.

Inversion

One of the main characteristics of a falling-film evaporator is its short retention time. Pending resident time distribution tests to be conducted next season, juice samples from clear juice through to second effect juice were analysed by the SMRI (Schaffler, 1994) to determine the level of inversion, if any, that is taking place within the vessel. Although only one series of samples was analysed, no inversion was detected. Further tests will be undertaken to confirm these initial findings.

Conclusions

The commissioning and operation of a falling film evaporator vessel operated in conjunction with climbing film vessels in the first effect of a raw house evaporator station has proven simple, successful and generally trouble free. The design principle and control philosophy adopted tend to insulate the unit from fluctuations and variation in both the juice or the steam sides making the installation very simple to control, operate and clean chemically. Further work is required to confirm its performance characteristics and is planned for next season.

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