

PRESS WATER HEATING IN A DIRECT CONTACT HEATER USING SUB-ATMOSPHERIC PRESSURE VAPOUR

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Abstract

In the 1998 season the Malelane Mill implemented a number of energy savings projects. One of these was heating press water from de-watering mills in a direct contact heater. A previously conducted Pinch Study identified that the best matched heating medium was sub-atmospheric pressure Vapour 3 from the mill's quadruple effect evaporator.

This paper discusses the factors considered in the design of the direct contact heater and the barometric seal and swirl tank arrangement. Performance of the heater during the last season is reviewed.

Introduction

During the 1996 season Malelane Mill management undertook a comprehensive Pinch Study to define the energy investment strategy for the mill with a view to reducing process steam usage. The outcome of this study was a project road map identifying the optimum energy saving retrofit path in keeping with funding, operational and technical viability constraints (Singh et al., 1997). One of the 'quick win' projects identified in the Pinch Study was to substitute an even lower pressure vapour from the quadruple effect evaporator station for diffuser heating.

The cane extraction plant at the Malelane Mill comprises a conventional diffuser station followed by a single stage de-watering station. The practice at the time of the study was to heat the inlet of the diffuser bed with recycled scalding juice heated in a shell and tube heat exchanger using Vapour 2 at a pressure of 100 – 105 kPa (a). Supplementary heating at the terminal end of the diffuser was achieved by injecting positive pressure V 1 of 135 – 140 kPa (a) below the diffuser screen. The juice from the Walkers Pressure-fed de-watering mills, referred to as press water is recycled onto the terminal end diffuser bed without any clarification, screening or heating. The press water is typically 58 – 60 °C and therefore, is in effect heated in the diffuser with the directly injected Vapour 1. The bed operating temperature is

kept above 75° C. This temperature has been identified to be the lower limit for good diffuser sucrose extraction and for minimum bio-degradation. (Lionnet, 1989).

Press water characteristics

The quality and quantity of the press water is very variable and is a function of cane quality as well as the extent of droppings from the mill. Mill droppings refers to the bagasse that leaks past the trash plate and falls into the mill juice tray. Droppings increase significantly with a worn trash plate. The table below is a measure of the typical variability experienced.

The heat requirement to raise press water from an average temperature of 58°C to a desired 82°C at the average press water flow rates is calculated to be 5200kW. The best match identified from the Pinch Study for this duty was Vapour 3 at a temperature of 88°C.

Evaporator bleed modification

To maintain the required V 3 pressure for additional bleeding, it was necessary to increase the area of the 3rd Effect evaporator. This was conveniently achieved by converting surplus 2nd Effect area to 3rd Effect duty at relatively low cost. The conversion involved reconfiguring vapour and juice piping on a 740 m² Roberts Vessel. This area was adequate to provide an additional 25 tons/hr V 3 needed for both press water heating and primary mixed juice heating.

Heater selection

Several heater designs were considered, however the nature of the fibrous suspended matter was identified as the major constraint in heater selection. The prerequisite for plate heat exchangers is a relatively clean process stream and therefore this type of heater was ruled out at the outset since screening of the press water was not considered economically viable. Shell and tube heaters with large diameter tubes were considered suitable, however production personnel were still concerned about

Table 1. Press water characteristics.

Parameter	Range	Comment
Purity %	50 - 80	Depends on the incoming cane purity and mill extraction.
Brix %	1.5 – 2.5	Sluicing water is added to the mill juice tray.
Suspended Solids %	2.0 – 15.0	The higher values are encountered during periods of excessive mill droppings and/or high ash in cane
Volume (m ³ /hr)	200 – 260	The addition of sluicing water into the mill juice tray inflates the press water volumes.
Temperature °C	55 - 62	Temperatures fluctuate with ambient conditions.

the likelihood of chokes and this coupled with the high cost of this type of unit eliminated this option. The use of direct contact heaters for mixed juice heating is a well established practice. The advantages of direct contact heaters (Wright, 1979) are:

- Better heat transfer with no efficiency drop off due to fouling;
- No pressure drop;
- The absence of tubes and tube plates as well as lower support requirements reduce construction costs.

The penalty incurred in a direct contact heater by the addition of condensed steam to the process stream would normally be subject to a trade off between additional downstream evaporation requirements versus operational and cost considerations. In the case of press water heating the operational requirement for a non-choking type of unit was considered overriding. The extra water loading was not considered a problem in a diffuser since the quantity of imbibition could be correspondingly reduced to maintain the same imbibition rates. Given these factors, a direct contact heater was considered the optimum choice for press water heating. A survey of the local sugar industry confirmed that direct contact press water heating was already being used albeit with a positive pressure vapour. Using sub atmospheric pressure vapour for the proposed Malelane installation required provision for a barometric sealing leg and tank. The complexity introduced by this requirement meant that special attention had to be paid to the swirl tank design to prevent bagasse particles settling out and causing a choke whilst at the same time providing the necessary barometric seal.

Heater specifications and PFD

The specifications used for the design of the direct contact press water heater and associated sealing leg and swirl tank was as follows:

The process flow diagram showing the integrated press water heater station is shown in Figure 1.

Design considerations

The critical factors that needed to be taken into consideration in the design of the direct contact press water heater were:-

Table 2. Design Specifications for Direct Contact Press Water Heater.

Maximum Press Water flow m ³ /hr	265
Press Water inlet temperature °C	55
Press Water outlet temperature °C	84
Vapour 3 (V3) pressure kPa(a)	60 – 62.5
Vapour 3 (V3) temperature °C	86 - 87
Approach temperature °C	≤ 3
Vapour 3 (V3) mass Flow rate tons/hr	11.5 – 13.8

Prevention of bagasse choking

The potential choking of the heater caused by an accumulation of bagasse hanging up on the internals of the unit was addressed through the introduction of the press water feed via a tangential inlet pipe, at a relatively high entry velocity ($\pm 3\text{m/s}$). This creates a strong swirling effect which, in conjunction with the conical hoods, as shown in Figure 2, assists in washing any bagasse through the unit into the outlet pipe.

Maximisation of liquid – vapour contact

The heater uses a conventional counter current flow pattern for the hot and cold streams. The V 3 enters at the bottom of the vessel and rises while the cold press water enters at the top and cascades downwards over the cones and doughnut trays, which provide an effective liquid curtain and necessary turbulence through which the vapours must flow. This assists the vapours to condense into the liquid stream, thereby increasing the temperature of the press water. Sufficient vessel volume to allow adequate residence time for condensation of the vapour is necessary to ensure efficient operation of the unit in achieving the required approach temperature. The key height and diameter dimensions of the heater unit are given in Figure 2.

Removal of incondensable gases

Adequate sizing and arrangement of the incondensable gas removal assembly is necessary to ensure efficient heating of the press water and minimisation of corrosion and foam formation. Conical caps have been provided over the apex of the cone trays to aid the removal of the incondensable vapours. The main removal nozzles are positioned such that the incidence of entrainment of liquid into the vacuum system is minimised. The incondensable gases are vented into the vapour space of the last evaporator effect.

Factors considered in the design of the barometric sealing leg and swirl tank

Barometric seal leg

Adequate height had to be provided to ensure that the sealing leg could accommodate a vacuum equivalent to that of the last evaporator effect. The maximum vacuum situation arises when the unit is started up using the incondensable vent which evacuates to the last effect of the evaporator. These conditions equate to a potential vacuum of 10kPa(a) and therefore a corresponding barometric sealing leg height of 10 meters provides the necessary safety margin. The diameter of the barometric sealing pipe has been generously sized to allow easy exit of any entrained vapour bubbles at the outlet of the heater vessel as well as reduce the risk of bagasse chokes.

Barometric swirl tank

Due to height constraints set by the location of the heater and its 10 meter barometric sealing leg it was necessary to install the swirl tanks on the ground floor. This necessitated a pumping station to pump press water into the heater and another to return the heated press water onto the diffuser. The general arrangement drawing showing details of the barometric sealing leg and swirl tank is shown in Figure 3. Vertical spindle pumps were selected to eliminate the problems of leaking glands and

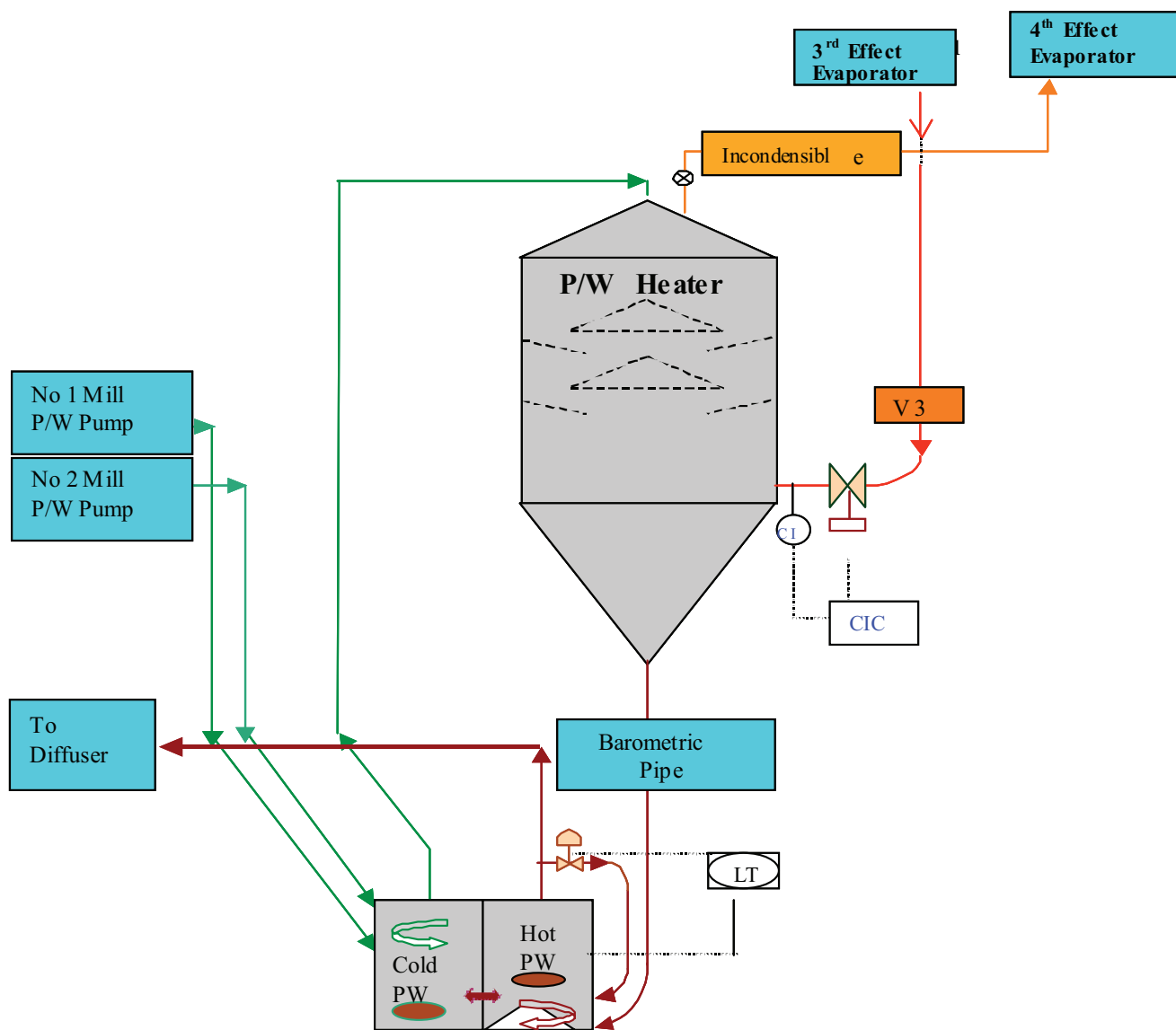


Figure1. Press Water Heater Station PFD.

blocked suction pipes associated with floor mounted pumps. The vertical spindle pumps were installed centrally within the tanks and the press water nozzles were tangentially mounted. This orientation ensured that the incoming liquid would swirl to prevent fibrous particles and sand from settling out. A cone was installed at the base of the tanks to promote swirling by increasing liquid velocity around the periphery of the tank. A recirculation line from the pump delivery was installed to continue the swirling agitation during periods when the mill stopped. The heated press water pump was elevated from the bottom at a height of 500 mm to ensure that the barometric seal volume of 1 m³ was always maintained in the sealing tank. A cut-out has been installed between the tanks so that liquid overflows from the heated press water tank into the cold press water tank to keep the circuit going and thereby prevent a vacuum loss via the heater supply pump delivery line during mill stops.

Due to the risk of mill stoppages if the press water system stopped e.g. due to a choke, it was decided to leave the de-watering mill standby press water pumps un-modified i.e. re-

main pumping to the diffuser. In the event of heavy mill droppings the press water heater station is shut down and the standby pumps are operated, pumping unheated press water to the diffuser. This practice is reserved for problem periods only.

Operating results

The unit ran for the complete 1999 season. Press water outlet temperatures of 78 – 84°C have been recorded for most of the season. Approach temperatures of 2– 4°C have been achieved with V3 pressures of 50 – 63 kPa (a). There have been a few incidents of chokes in the heated press water swirl tank and pump delivery line. These instances have been traced back to heavy droppings from the mills. Inspections of the heater internals has shown only a negligible amount of fibrous residue hanging up on the cone and doughnut tray support struts.

Incidences of press water entrainment in the V3 condensate occurred during the commissioning period. This was traced to operator error resulting from opening the V3 valve before the unit was evacuated using the incondensable gas line. The op-

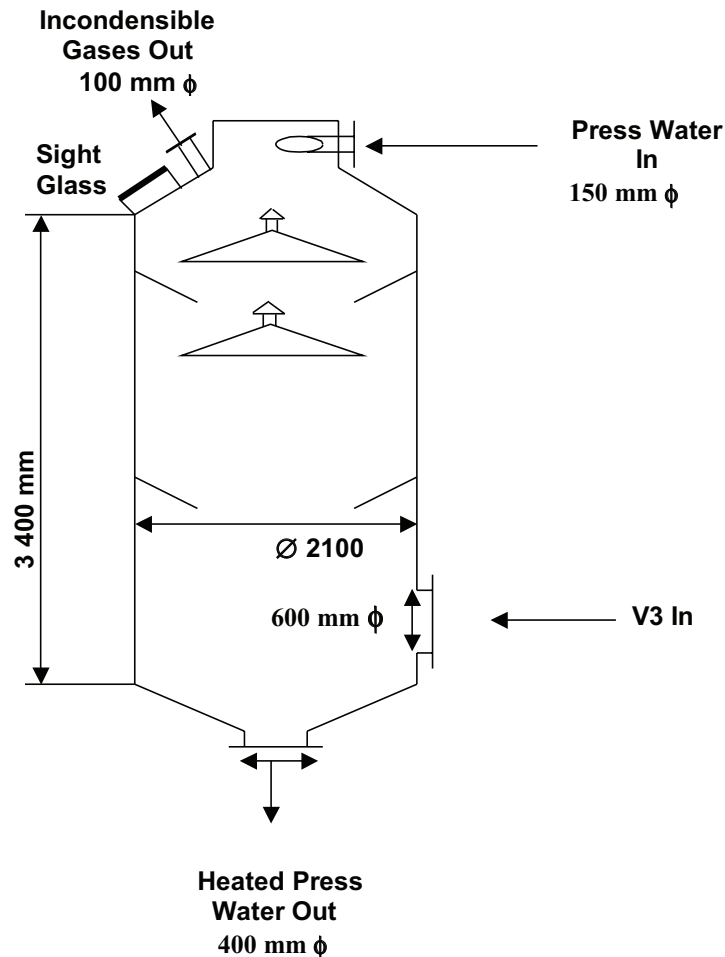


Figure 2. Direct Contact Vapour Heater.

erating procedure was reinforced with more intensive training and in addition a capacitance probe was installed in the V3 line. An automatic interlock was configured on the Distributed Control System such that if the probe detected entrainment the steam valve would close immediately.

The press water station was installed as a prototype unit and for this reason all equipment was constructed out of mild steel. The heater and tanks show some degree of erosive wear, but this was anticipated with the high sand levels in press water. The material of construction will be reviewed at the end of the current station's life span.

Conclusion

The Malelane Mill has installed and successfully commissioned a press water station utilising V3 from the quadruple effect evaporator. The unit has been in operation for the last one and a half crushing seasons. The unit has achieved the design heating requirements. Choking in the swirl tanks has occurred on occasion, however this has been traced to excessive droppings from the mills. The installed cost of this project was approximately R300 000. Based on a season's operation this unit has paid for it self within the first 8 months of the campaign. In keeping with the overall objective to reduce process steam usage, the resultant savings in reduced coal burning is estimated to be R350 000 per annum.

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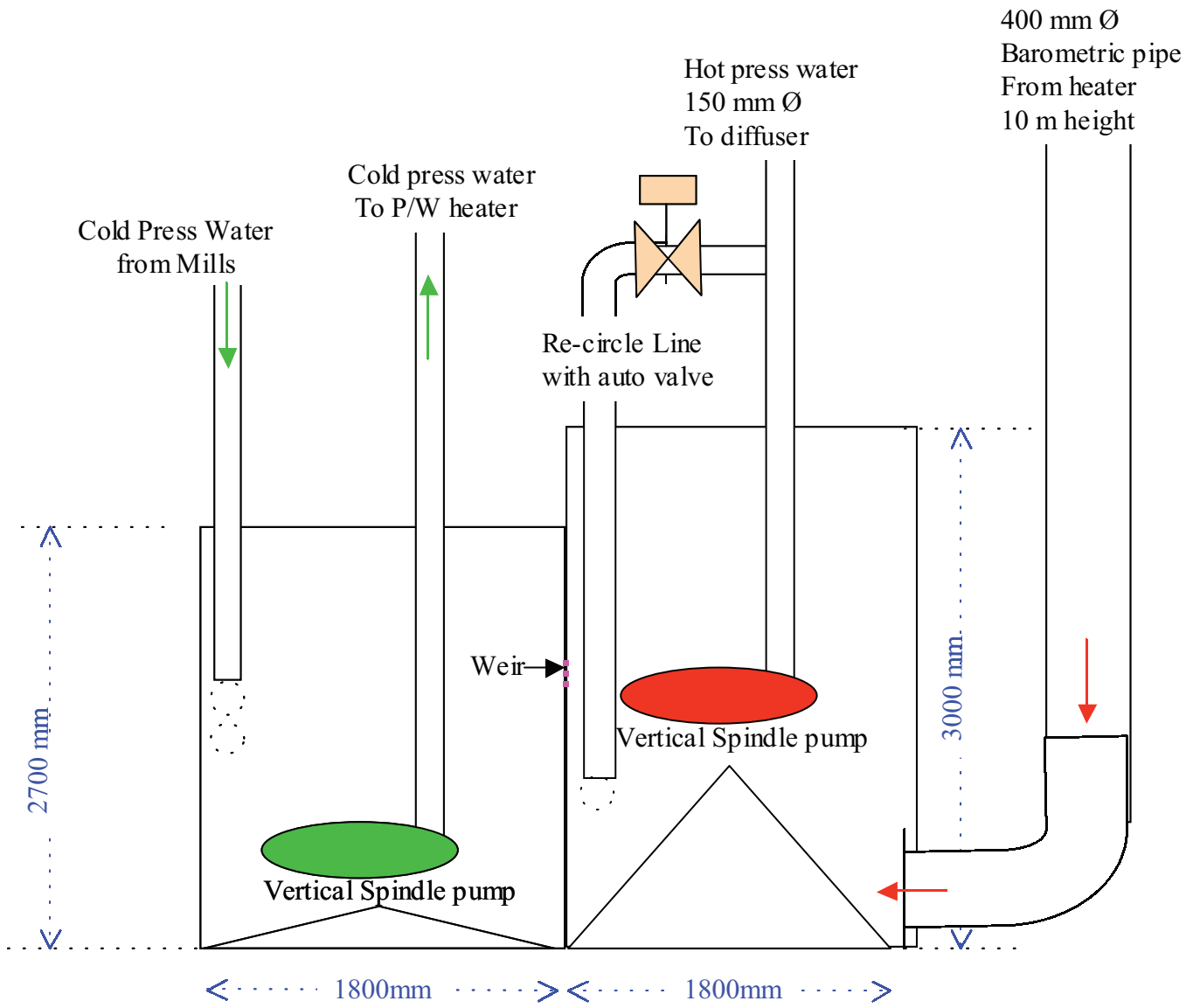


Figure 3. Swirl tank and barometric sealing leg G/A.