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FELIXTON MILL EVAPORATOR STATION: FINAL EFFECT PARTIAL FLASH TANK

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Abstract

Severe spouting in the final effect evaporators at Felixton contributed to high undetermined loss. Tube leaks at the tube sheet interface were identified in the area of the feed pipe nozzles and were suspected of contributing to the spouting. Expansion of leaking tubes was necessary during the weekly shutdown. It was noticed that some of these tubes had to be expanded on a regular basis. Operation of the final effects was accompanied by a persistent banging or percussion. External feed rings had been modified and the banging was initially thought to be as a result of condensate hang-up. This was later identified to be as a result of feed flashing into the 5th effect vessel. A partial flash tank was designed to reduce the flash into these vessels.

Keywords: final effect, spouting, undetermined loss, feed flashing, partial flash tank

Introduction

The Felixton II Mill was commissioned in 1984 and was designed to crush a total of 600 tons of cane per hour. The two separate parallel quintuplet evaporator lines are each able to handle in excess of 390 tons of clear juice per hour (Reid and Rein, 1983).

The two evaporator lines consist of Kestner i.e. first and second effects and Robert third, fourth and fifth effects, as shown in Figure 1.

The Robert vessels were designed with internal feed rings. There are no manholes in the bottom saucers of these vessels – entry into the vessels is via a manhole in the shell above the calandria. Access to the saucers of the vessels for maintenance of the feed rings and tubes is through the calandria down-takes.

The fifth effects are serviced by external condensers and were designed with primary (louvre type) and secondary (knitted mesh type) internally fitted entrainment separators.

Evaporator operation and observations

Observations of the boiling pattern of the Robert vessels during the period 2004 to 2009 generally showed a large degree of spouting occurring above the calandria of the vessels. The spouting was evident in all the Robert type vessels, but particularly in the final effects. The spouting in the final effects resulted in contamination of the injection cooling water circuit and affected the undetermined loss (UDL) at Felixton. The fifth effect vessels also tended to bang often and this was historically attributed to poor condensate removal from the vessels.

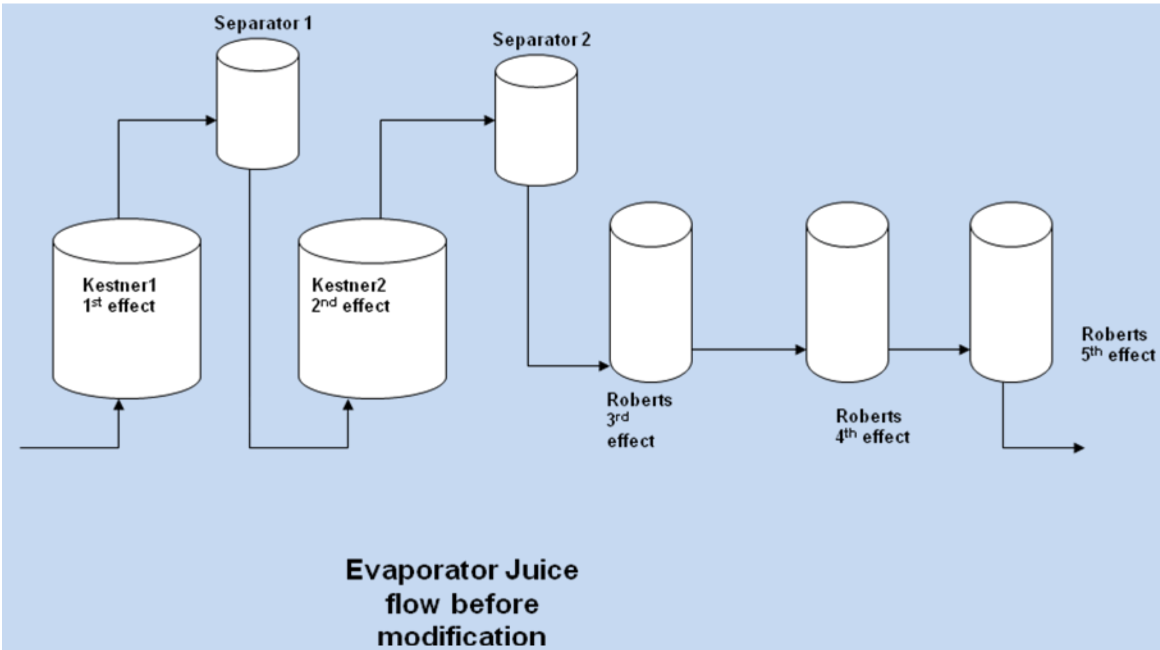

Figure 1. Felixton evaporator configuration.

Undetermined loss and trace sugar contamination

The season to-date UDL and injection water contamination for the period 2005 to 2012 are shown in Figure 2. Prior to 2005, the UDL at Felixton was generally below 2.0%. The UDL increased over a four-year period from 2005, and during the 2007/08 season it reached a high of 3.0%. The loss in this particular season was attributed to poorly fitted and damaged metex screens in the final effects. Lionnet (1984) showed that entrainment from evaporators correlated fairly well with the vapour velocity according to the relationship:

$$\text{Entrainment} = 18.5 * V^{1.2} \text{ (mg/s)}$$

where V = vapour velocity (m/s).

Wright (1988) highlighted that the Cattle Creek type louvre separator could operate efficiently up to a face velocity of 21.5 m/s on final effect vapour with a pressure drop of 625 Pa across the separator. These figures were based on the use of the simplified Souders-Brown expression for limiting face velocity to avoid re-entrainment. A calculation of the vapour velocities occurring in the louvre separator at Felixton highlighted that the maximum face velocity that could be expected was 10 m/s. The expected entrainment of sucrose into the injection water system at this velocity based on the assessment of Lionnet (1984) was 24 kg/day. These calculations showed that the metex screens could be removed from the vessels with little or no additional entrainment expected. The metex screens were removed during the 2008 off-crop and no large increase in entrainment of sucrose into the injection water was observed during the following crush. The UDL in fact dropped marginally to 2.90% in the 2008/09 season with the metex screens removed. UDL did not, however, return to the previous lows of <2.0% recorded in the years prior to and including 2005/06, and in 2009 again increased and peaked at a season to-date loss of 3.2%.

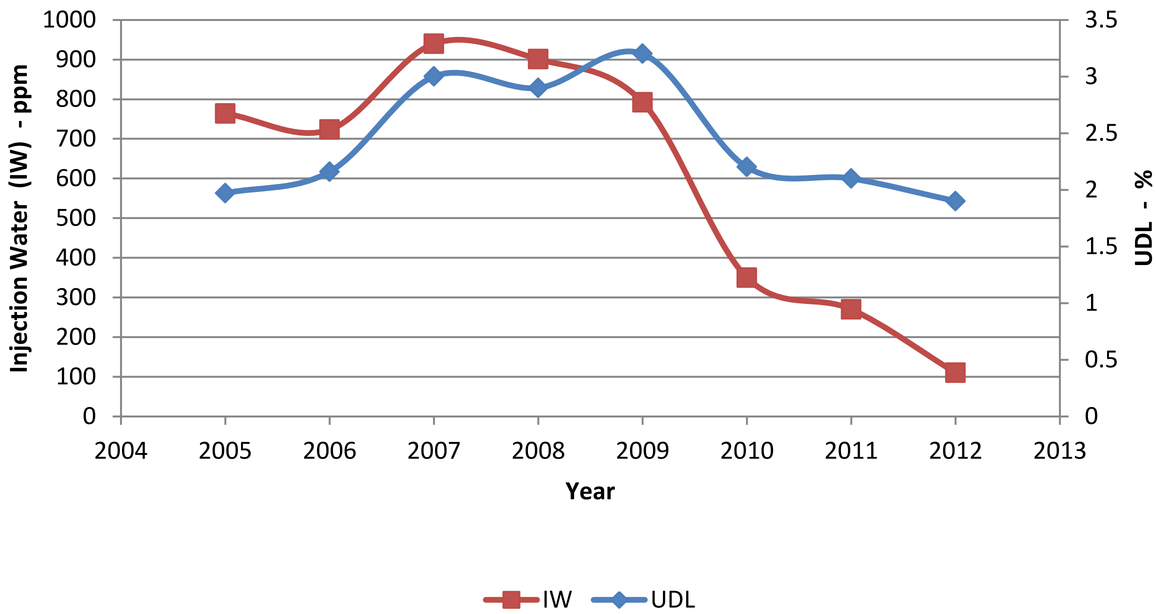

Figure 2. Undetermined loss and injection water trace sugar ppm from 2005 to 2012.

Contamination of the injection cooling water system was evident in the years with high UDL, with average sugar trace levels of between 700 and 940 ppm recorded during these crush periods.

Feed rings

The removal of the evaporator feed rings for cleaning and maintenance in the off-crop was always extremely difficult and required experienced rigging crews to rig the 250 mm diameter flanged and rolled feed ring piping sections out through the calandria down-takes. The need to simplify the task from a safety aspect initiated a capital request in 2008 for external feed rings to be fitted to the Robert vessels. The external feed rings and nozzles were designed to give a specific pressure drop across the feed nozzle in each effect. The number and size of nozzle holes used for each Robert vessel and the pressure drop associated are tabulated in Table 1. The external feed rings were installed during the off-crop prior to the start of the 2009 season. The feed rings are now easy to remove for descaling and can be cleaned on the run with a high pressure water jet when required.

The low value of 3.3 kPa selected for the pressure drop across the feed orifice for the design of the fifth effect feed ring was expected to reduce any problems associated with the flashing of feed in these vessels.

Table 1. Feed ring orifice details.

Evaporator Number	**3**	**4**	**5**
Temperature of Juice In (°C)	107.9	96.9	82.8
Brix of Juice In (%)	41.6	46.2	53.3
Tons/h of Juice In	79.8	71.8	62.3
Pressure drop across orifice (kPa)	3.7	3.4	3.3
Number of orifices	8	8	8
Orifice diameter (mm)	45	43	40

Re-tubing of the fifth effects

In the 2004 and 2005 seasons a large number of tube failures occurred, especially at the tube sheet interface. These failures were caused by thinning and belling of the tube as a result of mechanical cleaning. Capital was applied for and approved in 2006 to replace all old/damaged tubes from both fifth effects. Re-tubing took place in the 2007 off crop. The condition of the tube plate was checked by the relevant certified authorities during the re-tube and was found to be generally in good condition.

During the 2009/10 season there were numerous complaints from operational staff concerning leaking of the recently installed tubes in the final effects, especially in the area immediately above the new external feed ring nozzles. These leaking tubes were routinely either plugged or expanded during the Monday maintenance stop; some of these expanded tubes would only last a week before requiring re-expanding. The continuous re-expanding of tubes resulted in distortion of some of the tube holes, as seen in Figure 3. The tubes in severely damaged holes that would not seal were removed and the tube sheet plugged. In some instances, the plugs also did not seal adequately, and these were welded.

Figure 3. Tube sheet with distorted tube hole.

The operation of the evaporator station during this period as a result of the above was extremely difficult, especially with regards to throughput and brix control.
Inspection of the bottom tube plates showed less scale build-up in the vicinity of the feed nozzles. Significant spouting was evident when observing the boiling syrup through the vessel sight glasses – this spouting was initially attributed to leaking tubes. The UDL increased over the course of the 2009 season, the final to-date UDL being recorded was 3.2%.

Further investigation

Often while walking past or working in the vicinity of the evaporator station there would be a banging noise coming from the last effects. The banging was intermittent in nature (i.e. it would come and go) but, when present, was very persistent. Factory operational staff claimed that the fifth effects were known to bang and had done so for 25 years, and attributed it to a cyclical build-up of condensate in the calandria of the vessels. Staff maintained that banging/percussion was to be expected when the fifth effect vessels were operated for any length of time.

The increase in the number of leaking tubes that had to be replaced on a weekly basis in 2009 when compared to previous seasons was attributed to the condensate hammer in the vessels, which factory staff now claimed was occurring more frequently. An extensive investigation was therefore undertaken around the condensate system to address the problem of condensate hammer. Love (2010) highlighted problems associated with two phase systems when the phases are in close proximity to each other.

An early observation that was made when considering the fifth effect condensate removal system was that the datum of the fifth effect bottom tube sheet was below the top level of the reject condensate tank. The hang-up of condensate in the vessels was found to be as a result of too high an operating level in the single reject condensate tank. Two issues were highlighted:

(i) A level control set point set too high, resulting in high condensate levels.

(ii) Pressure variations around the single reject condensate tank which receives condensate from multiple sources (evaporators, pans, heaters) within the factory. It was surmised that the pressure variations that occurred inside the reject condensate tank were able to cause fluctuations in the operating level of the vessel.

An operational guideline was proposed and the operating level of the reject tank was set at a maximum of 30% of the tank level. This operational philosophy reduced the frequency of the banging, but did not eliminate it altogether, highlighting that there was an additional problem. Spouting of syrup was also still evident when observed through the vessel sight glasses. The spouting could have been as a result of leaking tubes, as this problem had still not been resolved.

Flashing of feed

Love (2010) listed various scenarios where condensing vapour/steam had resulted in hammer and failure of pipes and tanks. Feed flashing into the vessel and then condensing was highlighted as a possible cause of the banging.

Kirsner (1999) highlighted that condensation induced water hammer can be 100 times more powerful than steam flow driven hammer. Based on this statement, it was argued that it was possible that the shock wave as a result of the percussion taking place in the fifth effects was having an adverse effect on the tube sheet and tubes in these vessels.

A simple test was devised to evaluate the possibility of the feed flashing and condensing as the cause of the problem. The vessels were brought on line and once the banging was evident the manual juice feed isolation valve to the fifth effect was closed. On closing the valve, the banging stopped and when the valve was opened the banging resumed. This test was repeated a number of times, with each test resulting in a positive response. The manual opening and closing of the isolation valve highlighted that the banging was now occurring inside the vessel and was not related to a condensate removal problem. This banging was a result of the feed flashing on entering the vessel and then partially condensing when mixing with the colder re-circulating syrup that moves down the down-take of the vessel into the saucer. In an evaporator train the phenomenon of feed flashing and then partially condensing is exacerbated in the final effect. The quantity of flash as a percentage of the feed into the individual effects at Felixton was calculated, and varied between 1.0 and 1.5% in the second, third and fourth effects and is 3.0% in the final effect. In addition, at the lower vapour pressures in the final effect, the volume of flash vapour is substantially greater than in the earlier vessels. A comparison of the volumetric flow rate of the flash occurring in each of the vessels is shown in Figure 4.

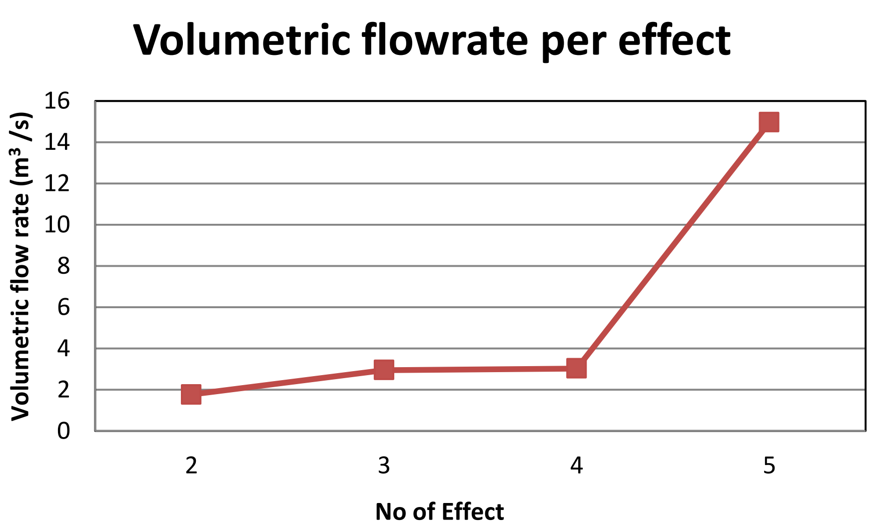

Figure 4. Volumetric flow rate of flash (m^3/s).

Partial flash tank

The pressure drop between the fourth and fifth effects at Felixton was 36 kPa. In order to reduce the effect of this and eliminate the problem associated with the flashing of feed, a partial flash vessel was designed for each of the fifth effects as shown in Figure 5. The flash vessel accepts all the feed from the fourth effect, which is then partially flashed prior to it entering the fifth effect. The flash from the flash vessel is directed into the vapour space of the fifth effect. The pressure in the flash vessel is measured and a throttle valve situated in the vapour line is controlled to obtain a delta P between the flash vessel and the final effect allowing regulation of the quantity of flash produced. Some flash is required into the saucer of the evaporator to promote thorough mixing of the vessel contents and to enhance heat transfer. The partial flash vessels were installed during the 2010 off-crop and were commissioned at the start of the 2010/11 crushing season.

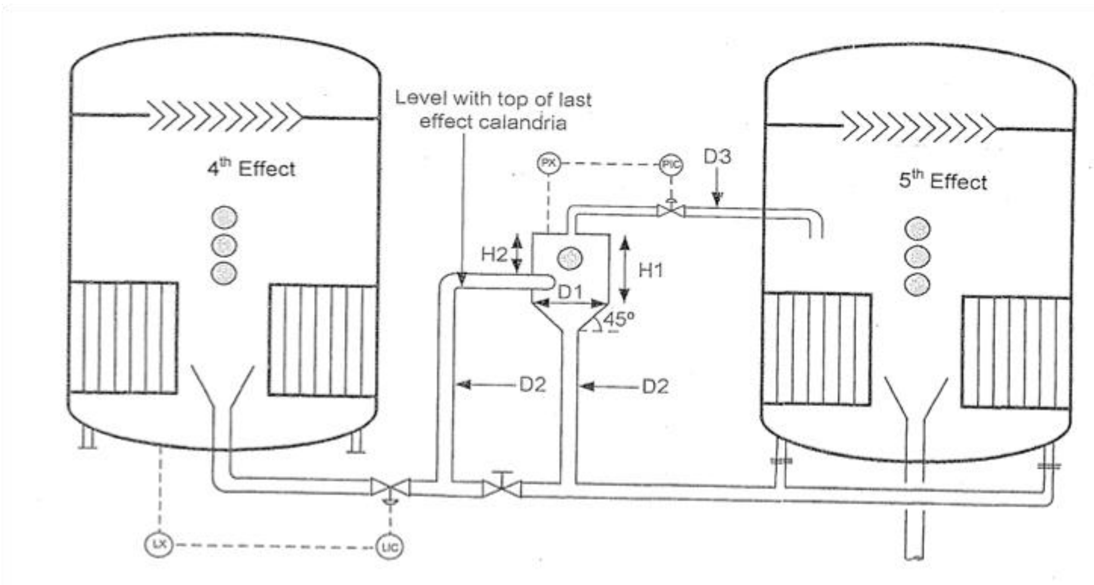

Figure 4. Diagram showing juice partial flash tank installed.

Tube sheet repairs

The fifth effect tube sheets required extensive maintenance to re-sleeve damaged holes, particularly where the tube sheet had been drawn as a result of a tube leak, or where the hole was distorted as a result of over-expanding. The tube hole was machined and the sleeve inserted such that, after it had been fitted and the tube expanded, it folded over the tube plate to ensure that a proper seal between tube plate and sleeve was obtained. It was also easy to remove the sleeve without damaging the tube plate if there was a tube leak. A section of the sleeved tube sheet is shown in Figure 6.

Figure 6. Tube plate holes after sleeving.

Results

The installation of the flash vessels has completely eliminated the persistent banging that was associated with the flashing of feed. The banging from condensate build-up has been eliminated by maintaining a low operating level in the condensate reject tank.

Where previously 20-30 tubes had to be expanded on a weekly basis, there is now on occasion a requirement to expand only one or two tubes. The spouting in the vessel is more constrained, with very little contamination of injection cooling water occurring. The sugar trace in injection water shown in Figure 2 highlighted the reduction in cooling tower contamination after the installation of the partial flash vessels. The UDL highlighted in Figure 2 also showed an improved trend after the partial flash tanks were installed.

Since flash tanks were installed the vacuum control has also become more stable and has resulted in an improvement in the throughput and brix profile across the evaporator station in line with the original design.

Conclusion

The problems associated with operating the Felixton evaporator train in the 2009 season, together with the high UDL, were identified as being caused by tube leaks in the final effects. The leaking tubes were as a result of inefficient condensate removal and feed flashing on entering the vessel. The damaged tube sheet has been repaired by re-machining the tube holes and installing sleeves to accommodate the standard evaporator tube.

The partial flash tank has eliminated the problem of the vessel banging and any associated damage that might have occurred as result of the percussion shock wave.

Acknowledgements

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