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UNDETERMINED LOSS REDUCTION AT MAFAMBISSE SUGAR FACTORY IN MOZAMBIQUE

DUNN NC[1] AND MUZZELL DJ[2]

[1]*Tongaat Hulett Mafambisse, P.O. Box 1121, Beira, Mozambique.*
[2]*Tongaat Hulett Sugar, Technology and Engineering Group, Private Bag 3, Glenashley, 4022, South Africa*
nelson.dunn@mafambisse.co.mz *dave.muzzell@tongaat.com*

Abstract

Undetermined loss, while by name suggesting a measure of 'uncontrollability', is considered by many production managers as a key measure of performance in the raw house. The control and reduction of undetermined loss can present many challenges to operational staff in a raw sugar factory.

Mafambisse (MB) factory is situated in central Mozambique in the Sofala Province. From 2005 through to 2009, undetermined loss averaged 3% at MB. Investigations revealed that the main cause of these sucrose losses was entrainment via the evaporator and Oliver filter condensers. This paper discusses interventions made during 2007 and 2008 to overcome these problems and eventually reduce undetermined loss to an acceptable average of 1.25%.

Keywords: undetermined loss, boiling house recovery, BHR, entrainment, condensers

Introduction

Mafambisse (MB) mill was established in 1972, and the majority of the plant that was installed at that time is still in use. MB uses a pol based mass balance. No sucrose data is available for mass balance calculations. The reduction in undetermined pol loss was achieved over the period of a year in two separate areas, namely the filter and evaporator stations. The cumulative benefit derived from reductions in undetermined loss in both these areas has contributed to the current overall undetermined pol loss of 1.25% on mixed juice, down from 3% in previous seasons.

Filtration

Mafambisse has a six mill extraction tandem. The suspended solids in mixed juice is 0.8-1.0% under normal operating conditions, and can rise during rainy periods to 1.4% or more. The average suspended solids % mixed juice at 0.9% is marginally higher than most milling factories. Harvesting of cane in low lying wet fields often results in soil attachment on the cane and hence the slightly elevated suspended solids in mixed juice.

Filter cake and filtrate tonnages vary in proportion to the suspended solids level in mixed juice. When abnormal pol losses are experienced at the filter station, these losses will be inflated further when suspended solids in mixed juice is high.

Traditionally, undetermined pol losses at the filter station occur when filtrate entrains into the condenser. As the MB cooling water is 'once through' river water and the condenser tailpipe is in an obscure location, entrained pol losses were not easily detected. Process staff at MB suspected that pol losses were taking place through entrainment into the filter condenser. No continuous sampling was undertaken; catch samples of tailpipe water were taken every hour and tested for sucrose. Sucrose contamination was detected in the tailpipe water, and values as high as 500 ppm sucrose were recorded from time to time.

There was insufficient data available to accurately determine filtrate tonnage, therefore an estimate had to be made. Based on reasonable throughput estimates, Process staff calculated the pol entrainment losses that could possibly be taking place.

MB averages 200 tons of mixed juice per hour. At suspended solids values of 0.9% on mixed juice, it is reasonable to assume filtrate % mixed juice of about 15%. Historical data from the Darnall sugar factory in South Africa, which is also a milling tandem, supported this assumption. If 5% of filtrate at 12.5% pol is used as an arbitrary loss through entrainment, then the average hourly pol loss in filtrate will be:

$$200 \times (15/100) \times (5/100) \times (12.5/100) = 0.1875 \text{ tons/hour}$$

Over the period of a normal week, this converts to about 0.9% pol loss on mixed juice.

Although the calculation was theoretical and based on assumptions, the magnitude of the possible loss was enough to spur Process staff at MB to eliminate sucrose entrainment to the filter condenser tailpipe water. It was decided to re-engineer the relevant equipment at the filter station to eliminate this unquantified loss of pol to the cooling water. The modifications undertaken in the 2007/08 offcrop included the installation of new vacuum equipment and refurbishment of filtrate extraction equipment to prevent high liquid levels in the filtrate tanks. Both these changes were designed to reduce the incidence of entrainment.

MB has four rotary drum filters, from which filtrate is drawn into separate high and low vacuum filtrate receiving tanks. The incondensable gases and filtrate vapour flow into the condenser via an entrainment separation tank. Incondensable gases are extracted from the condenser by a single stage vacuum pump. Entrained filtrate is removed in the entrainment separation tank and is returned to the high vacuum filtrate tank through a drain.

Both filtrate tanks have floats inside the tanks themselves. A stem on the float extends through a vent valve located on top of each filtrate tank. When the filtrate level rises above the tank high level mark due to pump cavitation, the float also rises up. The vent opens and air is drawn into the filtrate tank that has the high level. The vacuum in this tank will decrease and the suction head on the filtrate pump will increase. When the suction head increases, the pump will start pumping again and this will reduce the filtrate level in the relevant tank. As the filtrate level drops, the float moves down and the air vent is sealed again. The vacuum is restored to the relevant filtrate tank. A mechanical pressure reducing regulator controls the reduced vacuum in the low vacuum filtrate tank.

There were three filtrate pumps, a pump for each duty and a common standby pump. A balance line connected the pump suction to the filtrate tank above it. The balance lines have not been shown in Figure 1.

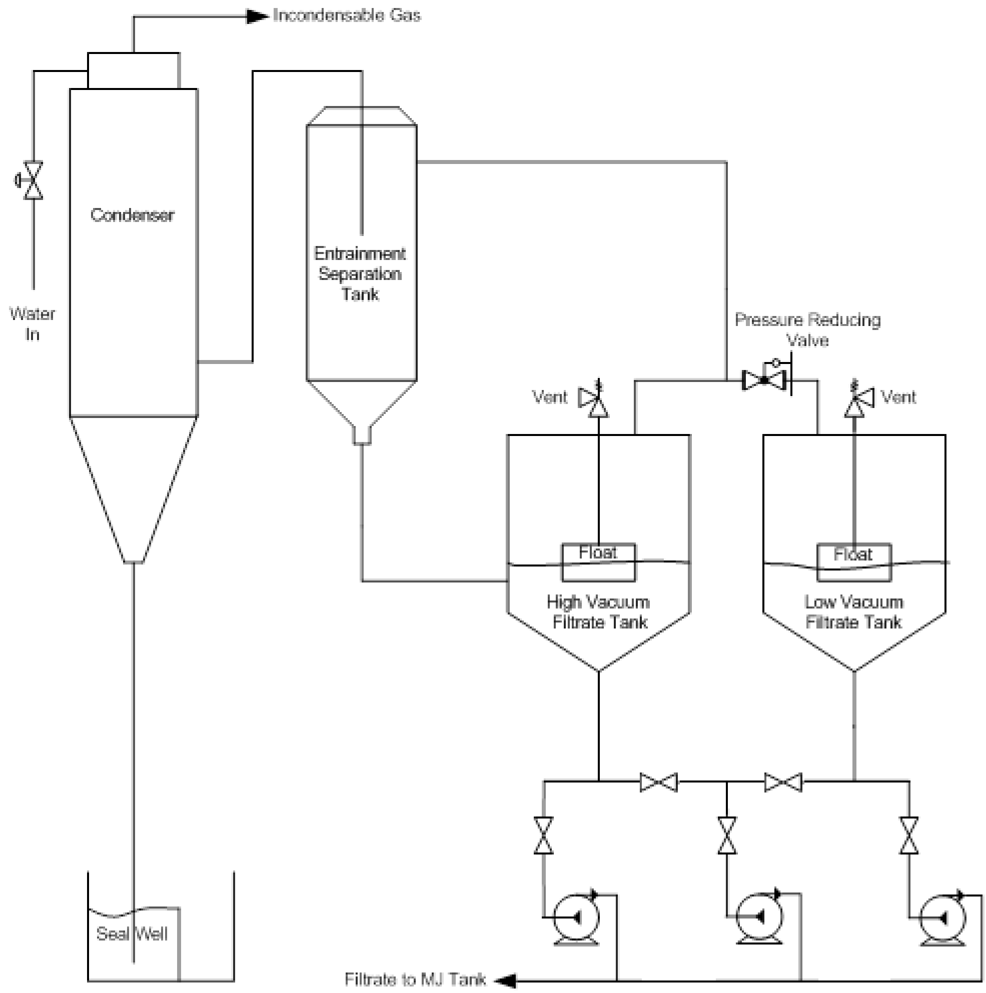

Figure 1. Original filtrate station layout and control before 2008 season.

Modified filtrate station

The original installed system was prone to failure for a number of reasons, including punctured floats, floats sticking and not opening the air vent, and jamming of the counterweight pressure controller. It was decided to convert the old system to a more modern level and vacuum control system for the 2008/09 season.

1. Low vacuum pressure is set on the pressure indicator controller (PIC). The pressure is regulated by a butterfly control valve.
2. In the event of a high level in one of the filtrate tanks, the Mobrey switch float will rise, activating and opening a solenoid valve to bleed air into the relevant filtrate tank. The increased pressure in the tank will increase the suction head on the filtrate pump, resulting in rapid removal of filtrate.
3. When the filtrate level drops, the Mobrey switch float will drop down, deactivating and closing the solenoid valve. Vacuum will be re-established in the filtrate tank.
4. To visually monitor possible entrainment, a 120 mm diameter sightglass was installed on the vapour/incondensable gas pipe leading from the filtrate tanks to the entrainment separator and condenser. Entrainment is normally observed when large droplets travel up the pipe to the entrainment separator.

5. The entrainment return pipe from the entrainment separator to the filtrate tank was also equipped with a sightglass for the same purpose. Any flow of filtrate in this pipe indicates that filtrate has managed to reach the separator and corrective action is required.
6. A conductivity probe is installed in the vapour/incondensable gas pipe to notify operators when there is any entrainment up this pipe. Notification takes place through an audible alarm. The conductivity output is also trended for management inspection and evaluation on a daily basis.
7. Filtrate pump inspection is undertaken regularly during the season to ensure that casing and impeller erosion has not taken place. Mechanical erosion will adversely affect pump efficiency and contribute to high filtrate tank levels and possible entrainment.
8. The low and high vacuum filtrate pump duties were totally separated, with both a dedicated pump and standby pump for each duty.

The layout of the modified station is illustrated in Figure 2.

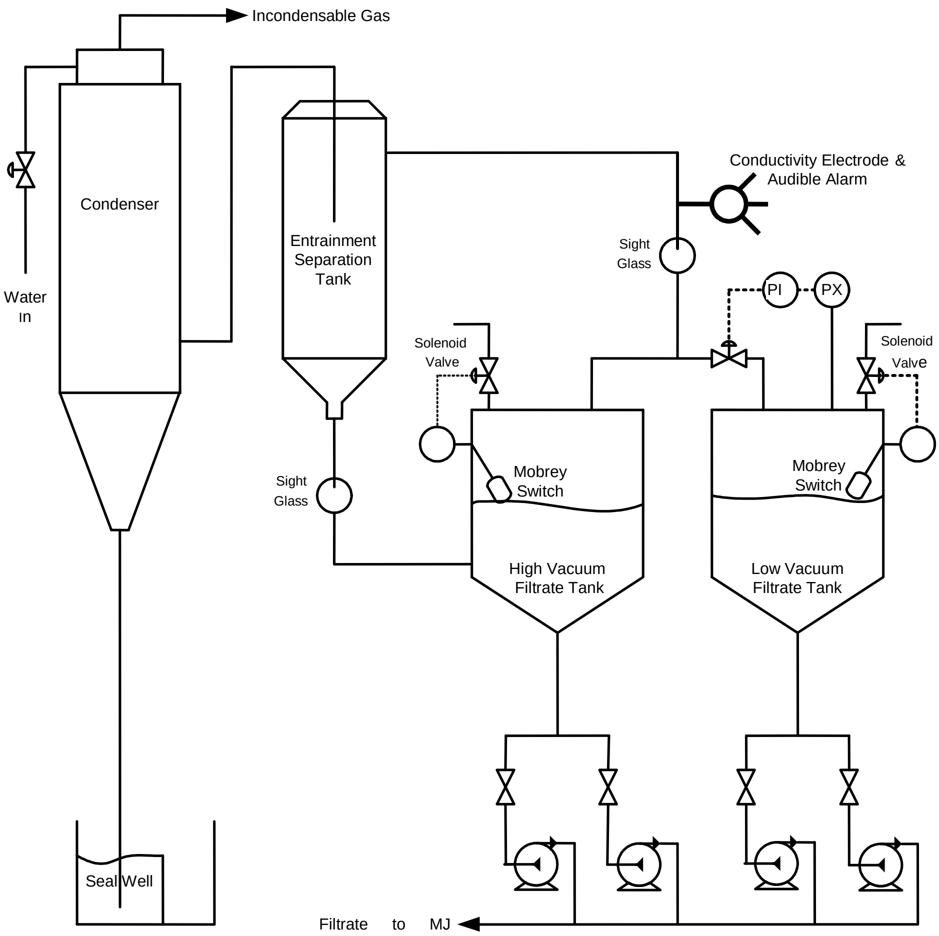

Figure 2. Modified filtrate station.

Results and Discussion

Apart from trending injection water conductivity measurement, sampling of filter condenser tailpipe water was initiated at short 15 minute intervals for a 24 hour period over a number of days. No sugar traces were detected. Monitoring of this area has become a normal management function to ensure that no sucrose entrainment occurs.

Evaporator entrainment separators

During the 2005 season a decision was made to replace the corroded Sugar Milling Research Institute (SMRI) vane type save-alls in all the evaporator vessels with vertical chevron plate (VCP) entrainment separators. The decision was based on the knowledge that the VCP entrainment separator is a new generation design that had yielded good results. The undetermined loss (UDL) for the 2005 season was 2.6%. Drawings were made for the VCP installations and an engineering firm was contracted to manufacture and install the VCPs on a phased basis over a period of three years.

In the 2005/06 offcrop three evaporator vessels including the two last effects were fitted with VCP entrainment separators. The UDL for the following 2006/07 season increased to 3.63%. During the next offcrop, a further four vessels were completed. UDL remained high at 3.12%. In the 2007/08 offcrop the remaining two 3rd effect vessels were completed. All the evaporator vessels now had VCP entrainment separators. It was after the fabrication of the last two sets of VCPs but prior to their installation that the two sets were examined by Process staff and an alarming discovery made.

Around the periphery of the VCP packs large gaps of up to 50 mm were identified, together with some areas between the louvres where the gaps were large enough to allow uninterrupted sucrose entrainment to take place. After this discovery the other evaporator vessels were also inspected as these had not been done at the time of installation during the previous two offcrops. The same problems were identified in all the other vessels. MB removed all the VCP packs and refabricated them according to design, sealing off all the gaps.

Evaporator syrup extraction pumps

Mafambisse has two sets of quadruple effect evaporators. The layout before 2008 is illustrated in Figure 3.

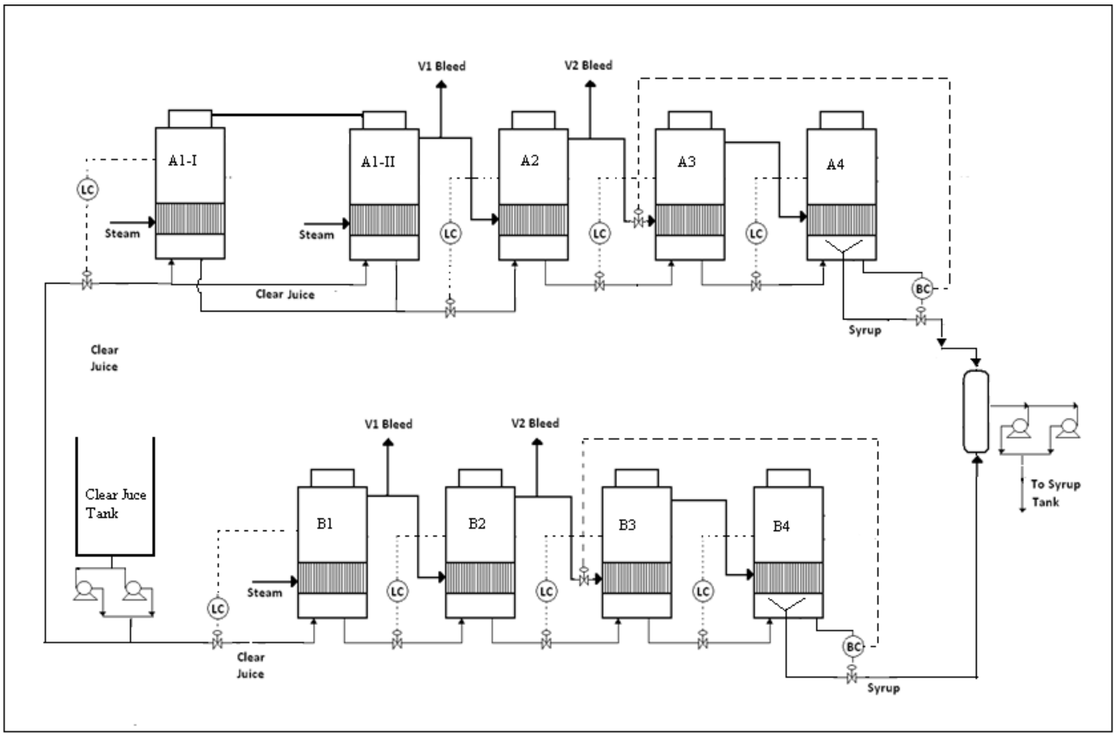

Figure 3. Evaporator layout before 2008 season with one set of syrup extraction pumps.

The following were included in the evaporator arrangement:

1. The A-line evaporators had two 1st effects in parallel followed by single 2nd, 3rd and 4th effects.
2. The B-line consisted of four individual vessels arranged in a quad layout.
3. Each evaporator line had individual water ejector condensers to generate vacuum. This is not shown in Figure 3.
4. Syrup from each of the A and B-line final effects combined into a common syrup manifold on the suction side of the syrup extraction pumps.
5. Syrup from the evaporators was pumped to the syrup storage tank on the pan floor.

Observations and Modifications

Level control

Syrup level in the A and B-line last effects was extremely difficult to control. Although the absolute pressures in both lines varied slightly on occasion, the pressure differences were small and had no measurable effect on the syrup level. However syrup levels in the two last effects were seldom the same. When the syrup level in one of the last effects increased, it created a higher suction head on the single syrup extraction pump than the line with a low syrup level. As a result, syrup was extracted from the line with the higher syrup level in the last effect vessel. The syrup level now started to fall in the vessel where syrup was being extracted, while the syrup level in the other last effect continued to rise. When the syrup level rose to a critical suction head, the syrup extraction changed from the last effect where the level was dropping to the last effect where the syrup level was rising. In this way, the syrup was extracted from the last effects in batches and the batching process was dependent upon the rate at which the levels in the last effect changed. There was preferential extraction of syrup from one line where the syrup level was high, while there was no syrup flow from the other line.

Periodically, the absolute pressure increased suddenly. When that happened in the last effect where the syrup level was rising, it triggered an increase in suction head on the syrup extraction pump, which forced a change in syrup removal to this vessel. The reverse applied when the absolute pressure dropped suddenly and the suction head decreased on the syrup extraction pump.

When the syrup level in one of the last effects increased, the disengagement height decreased and sucrose entrainment increased. The rise and fall of syrup level in the last effects repeated in a continuous cycle. Sucrose entrainment took place each time the syrup level increased and reached a critical height in the last effect vessel.

Solution

The interactive effects of conditions in the last effects had to be removed.

During the 2007/08 offcrop changes were made to the syrup extraction system for both evaporator lines. Each evaporator line was equipped with two syrup extraction pumps as in Figure 4. The suction head condition on the pump was now affected only by the last effect vessel to which it was assigned.

At the same time, the water ejector condensers (water jet condensers) from both lines were replaced with a single standard Tongaat Hulett design condenser to service both the A and B-evaporator lines. The last two effects were linked with a common vapour pipe that connected to the common condenser. The condenser was equipped with liquid ring vacuum pumps. The problem with variations in the absolute pressure in both last effect vessels was removed.

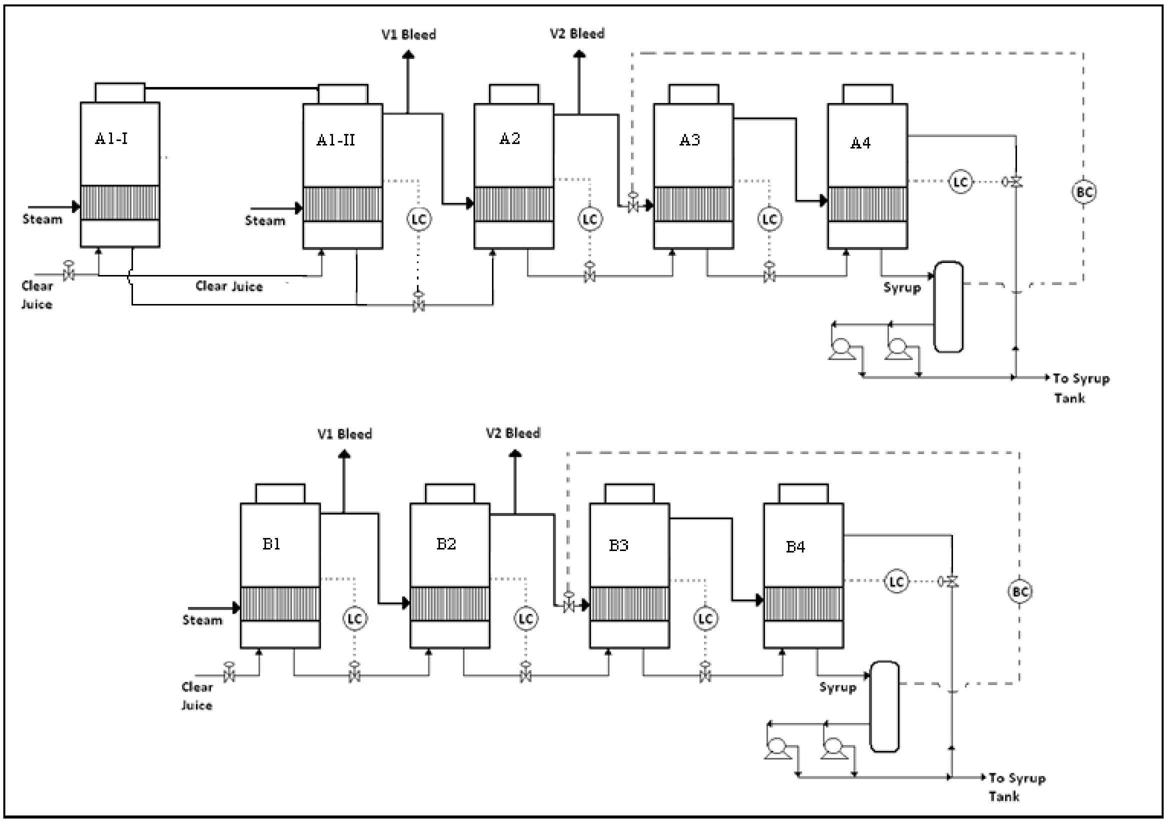

Figure 4. Modified evaporator layout from 2008 season to include two sets of syrup extraction pumps.

Combined results of four changes at MB

When MB started the 2008/09 season, four important changes had been made to the plant to minimise sucrose entrainment into the cooling water system.

- The filtrate station was automated.
- VCP entrainment separation packs replaced the SMRI vane type save-alls in all evaporator vessels.
- Additional syrup extraction pumps were installed to provide separate syrup extraction facilities for each evaporator line.
- Absolute pressure variations between the A and B-lines were nullified by the installation of a single condenser catering for both lines of evaporators.

All four of these changes were made to reduce sucrose entrainment from both the filter station and the evaporator station. MB did not attempt to quantify the reduction in entrainment from each of the individual changes. The end results reported here have been attributed to the combined input from all four changes.

At the start of the 2008/09 season an immediate reduction in UDL was reported. For the first eight weeks of the season, the UDL was below 1% on average. This was a massive improvement when compared with the first four weeks of the 2007/08 season, where the UDL was in the order of 4%. The results are shown in Figure 5. In the middle of the 2008/09 season the UDL drifted out due to very low time efficiencies. A number of A-centrifugal breakdowns were experienced. In weeks 12 and 13 overall time efficiencies (OTEs) were 22% and 47.7% respectively, and the UDL for these weeks was 5.26% and 6.49%. The high UDL in the last two weeks of the season can also be attributed to very low OTE. The adverse effects of low OTE are clearly illustrated in Figure 5 trends.

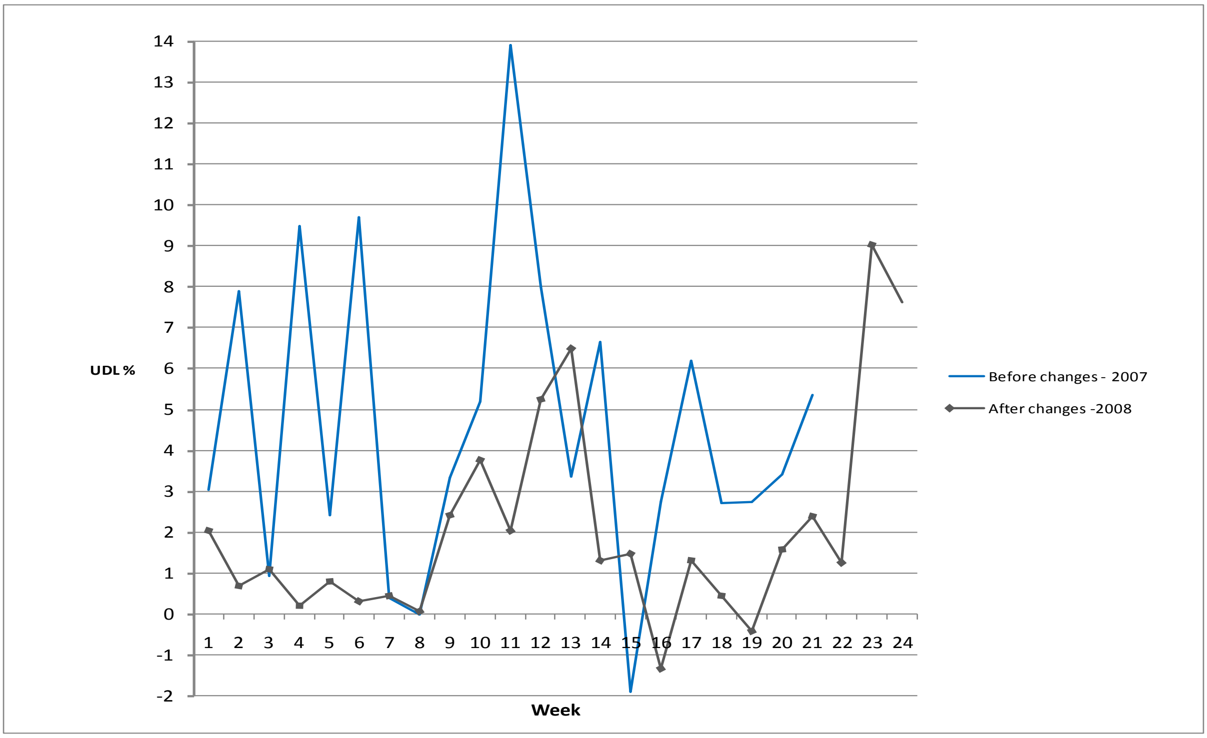

Figure 5. Undetermined loss (UDL) before and after the four changes made at the Mafambisse mill.

Except for 2009, the average UDL continued to drop after the changes to the filtrate system, the installation of the VCP entrainment separator packs, the changes to the evaporator syrup extraction pump configuration and the common vacuum system for both evaporator lines. The UDL trends from 2005 to 2012 are illustrated in Figure 6. In 2009 a few weeks of very low OTE, coupled with delivery of stale cane, resulted in a large quantity of mixed juice being dumped. The UDL for the season was understandably high, but MB recovered from this poor performance season to register excellent UDL figures for the following three seasons. No further changes were made to the filtrate and evaporator stations during this period.

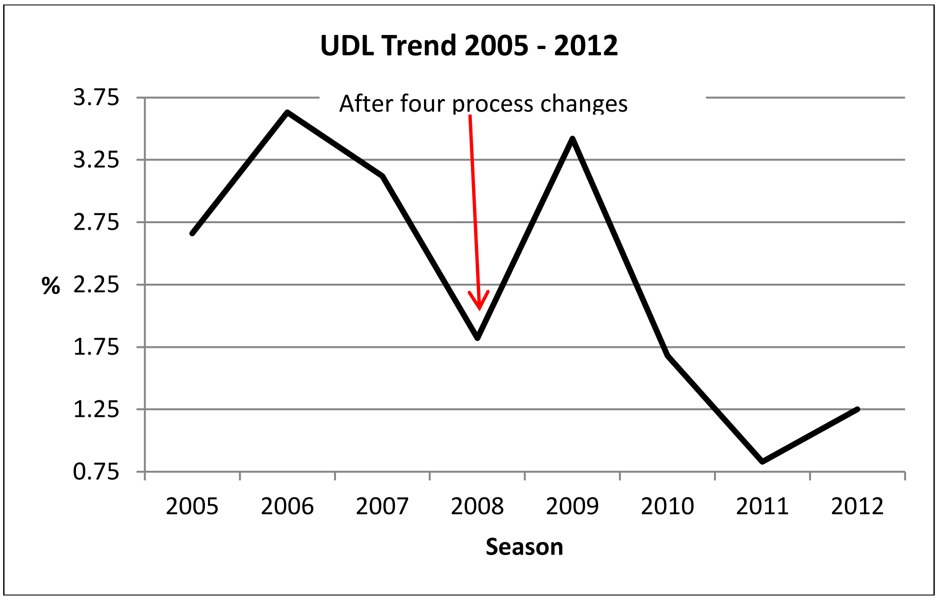

Figure 6. Undetermined loss (UDL) trends at Mafambisse mill from 2005 to 2012.

Conclusion

Process staff at Mafambisse mill recognised that there was scope to reduce the average UDL from a value of more than 3% to less than 1%. The route to success was attention to detail. This involved questioning all aspects of design and operation that could contribute to high UDL. Automation at the filter station, the correction of the VCP pack installation in the evaporators, the separation of the syrup extraction system for both evaporator lines, and a common evaporator vacuum system for both evaporator lines all contributed in some way to the reduction in UDL.