A practical approach to reducing foaming in the C continuous vacuum pan at the Appleton sugar mill in Jamaica

By

D. Foster and R. Bryan

J. Wray & Nephew - Appleton Sugar Estate, St. Elizabeth, Jamaica.

ABSTRACT

During the 2003/04 season, a 50m^3 C continuous vacuum pan was installed at the Appleton factory in Jamaica as part of an ongoing process of factory upgrading. Since its installation, there have been problems with foaming of the massecuite especially at start up resulting in carryover from the condenser. This problem not only represented a loss of sugar and potential earnings to the estate but also presented an environmental threat by contaminating run off streams adjoining the estate's property. In efforts to become and remain environmentally friendly and to comply with the National Environmental Agency's effluent standards, a number of practical measures were taken. These included: a) the reduction of foaming of the massecuite by the initial use of water sprays which were part of the pan design, along with the shock addition of an anti foam agent b) the reduction of the risk of carryover by modifying pan design along with stringent closing down and starting up procedures for the vacuum pan, c) the prevention of sugar material entering the major effluent stream by installing a ditching system on the condenser leg-pipe along with the separation of streams, and d) the reduction of the foaming of massecuite by the continuous addition of anti-foam agent. The result was an elimination of pan carryover, a reduction of the risk of the effluent streams being contaminated with sugar material and a reduction in undetermined loss in the process. It could be concluded that the continuous dosing with the anti-foam agent has allowed a relaxation of some of the stringent procedures that were adopted in starting up and shutting down of the vacuum pan. .

Keywords: foaming, carryover, contamination, anti-foam agent, practical measures

INTRODUCTION

Continuous vacuum pans have become a regular feature of sugar factories that have undergone modernization and also in newly built factories. Once these pans are operated steadily and continuously they have been found to be easier to operate and control than the conventional pans.

The advantages of continuous pans over batch pans include:

1) Better plant utilization since they occupy 50 – 60% less pan space than batch pans for the same heating surface/volume ratio
2) Improved steam economy since the low boiling head allows lower grade second and third vapour to be utilized
3) Continuous pans will stay online for protracted periods (months for C pans) thus reducing the quantity of steaming outs, shutting down, and cutting that are associated with batch pans
4) Reduced risk of carryover because of less cutting and filling up
5) Constant condenser water demand thus, less water needed

In instances where continuous pans are not operated continuously and there are numerous stops and starts, some of these anticipated advantages have actually proven to be headaches. At the Appleton factory, the C continuous pan has operated well during continuous operations. When the pan has had to be shut down and restarted, problems have been encountered with foaming and carryover of sugar material into the ejection stream.

Studies done on foaming in the raw cane sugar process have shown that it was definitely not the result of fermentation thus ruling out the possibility that this was due to the activity of bacteria or other micro-organisms (Meade-Chen[1]). Meade & Chen further stated that when low grade massecuites were boiled at temperatures over 69^{o}C (156^{o}F) they often foamed and overflowed from crystallisers. This could happen immediately or sometimes hours after boiling. This phenomenon was also described as "froth fermentation." The reaction of invert sugars with amino-acids to form carbon dioxide has been shown to be one of the causes for foaming. The carbon dioxide that was formed was thought to have remained in solution and the liberation of the gas, which was catalysed by the crystallisation process, resulted in foaming. Work done by Ambler (Meade- Chen[2]) on beet sugar massecuites showed that the action of amino acids on glucose formed carbon dioxide, melanoidins and other substances that promoted foaming by lowering the surface tension. It was strongly felt that the same conditions that promoted foaming in beet sugar massecuites were probably the cause of foaming in cane sugar massecuites.

Work done more recently on foaming in molasses (Meade-Chen[3]) has also revealed that the reasons are the same as those taking place in the massecuites. It was found that decomposition in molasses in storage could be quite noticeable if heating took place after leaving the centrifugals. A significant evolution of carbon dioxide was associated with heating over 40^{o}C (104^{o}F) and there was no evidence of fermentation.

Work done on foaming components in raw cane sugars (Ito *et al.,* 1980), has shown that saponin is one of the substances causing foaming. It is believed that saponin, as a surface active substance, reduced the surface tension of solutions resulting in foaming (Hallanoro et al., 1990). In white sugars it has been concluded that sugars with more than 0.4mg/kg on saponin always led to foaming (van der Poel et al., 1966)

The use of continuous vacuum pans at the Appleton factory was found to be one of the solutions to the problem of having a marginal capacity in the supply of injection water to pan condensers. It has also facilitated the boiling of the massecuites and especially the low grade at vacuum between 22 and 24” Hg (temperatures of over 79^{o}C, 175^{o}F) in many instances.

Some observations in processing in recent times, have been marked by frothing in syrup, molasses and low grade massecuites. The foaming in C continuous pan especially on starting has become a major concern. Whilst, we have not been able to identify the exact cause, some of the physical operating conditions were typical of those that have been found to cause foaming.

This paper outlines practical steps taken to address the problem of foaming in the C continuous vacuum pan at Appleton.

METHOD

Physical conditions promoting foaming

The physical conditions of temperature and vacuum at which the low grade massecuite was boiled were monitored. Comparisons were made with conditions reported in previous studies.

Measures taken to address the problems

The approach to dealing with the problem was four-fold:

1. Initial Steps taken to reduce the foaming
2. Steps taken to prevent the carryover of sugar material from pan condenser
3. Steps taken to prevent sugar material entering run off streams
4. Continuous use of anti-foam agent to reduce foaming and minimise carryover

Initial steps taken to reduce foaming

The pan is a horizontal type unit with a vertical tube calandria mounted along the shell axis. It is divided into eight compartments with massecuite flowing from one cell to the next. The massecuite flows in series through each compartment and discharges continuously through an overflow box to a receiver with a sealed leg. Each compartment is equipped with sight glasses for feed and cells so that the feed into the pan and the massecuite being boiled can easily be seen. Each sight glass is equipped with a spray nozzle which will allow the use of steam or condensate for cleaning. Along with these nozzles, there are several others that are strategically placed along a division plate that runs centrally down the pan above the top tube plate.

In addition to cleaning the sight glasses and division plate of any build up of sugar, the sprays were designed to apply water to the massecuite in the event of foaming. On those occasions when foaming was observed, water was immediately sprayed on via these nozzles. An anti-foam agent was also applied as follows:

a) 250mL of anti-foam was added to each of the eight compartments via the feed lines during start up of pan
b) The same quantity was added two hours prior to a planned shutdown of the pan.

Steps to prevent carryover

The vapour boiled off from the pan is collected in a steam exit chamber, equipped with an entrainment splash arrestor and then directed to the pan condenser. The initial design, shown in **Fig. 1** was found to be flawed in that the take off point was too low. This was modified to include a save-all with a series of baffle plates spaced 14” inside save-all. The vapour is now drawn off 50 inches higher from the top instead of from the side of the pan, **Fig.2**.

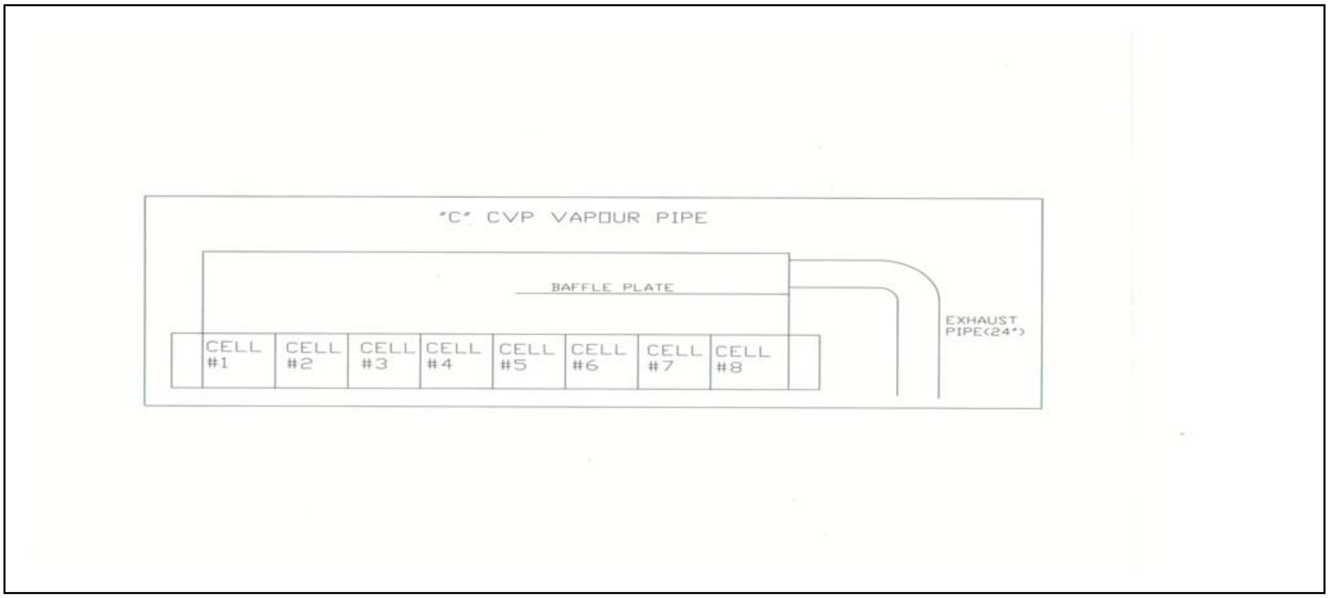

Fig. 1 - Schematic for vapour take-off for continuous C pan – original design

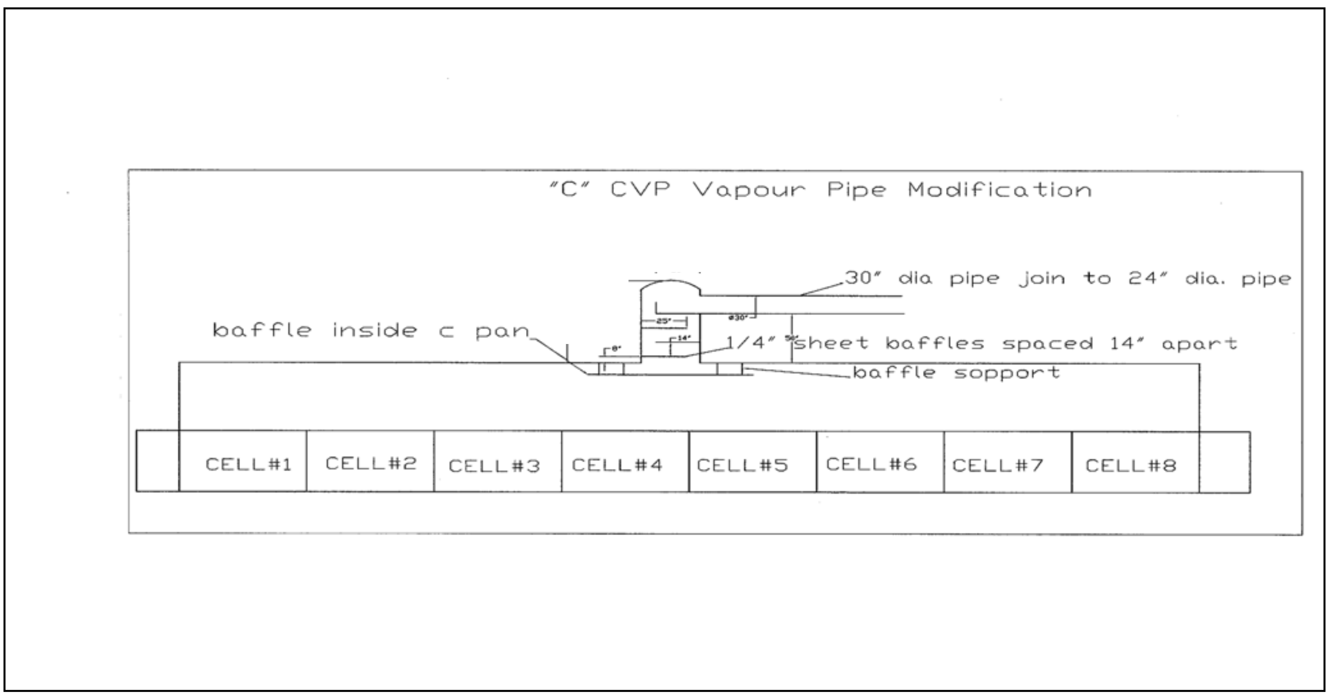

Figure 2 Vapour take-off for continuous C pan - modified

The starting procedures that were implemented were:

a) Vacuum was raised slowly by setting the injection water control valve at 20%
b) There was more vigilance around pan with senior personnel on location

The shutting down procedures implemented were:

a) Lowering the level of massecuite in pan to approximately 9 inches below the top tube plate
b) Based on our experiences, we deviated from the initial recommendation of lightening the pan during prolonged shutdowns by actually maintaining a higher brix.

Steps to prevent sugar material entering run off streams

The injection water is pumped from a nearby river and after exiting the condenser, is returned to the river. Any significant carryover from the pans would have an adverse effect on the quality of water re-entering the river. Over a period of three years the following initiatives were taken:

a) The condenser leg-pipe from the continuous pan was modified to include a ditching well which is the smaller of the two Torri - wells shown in Fig. 3.

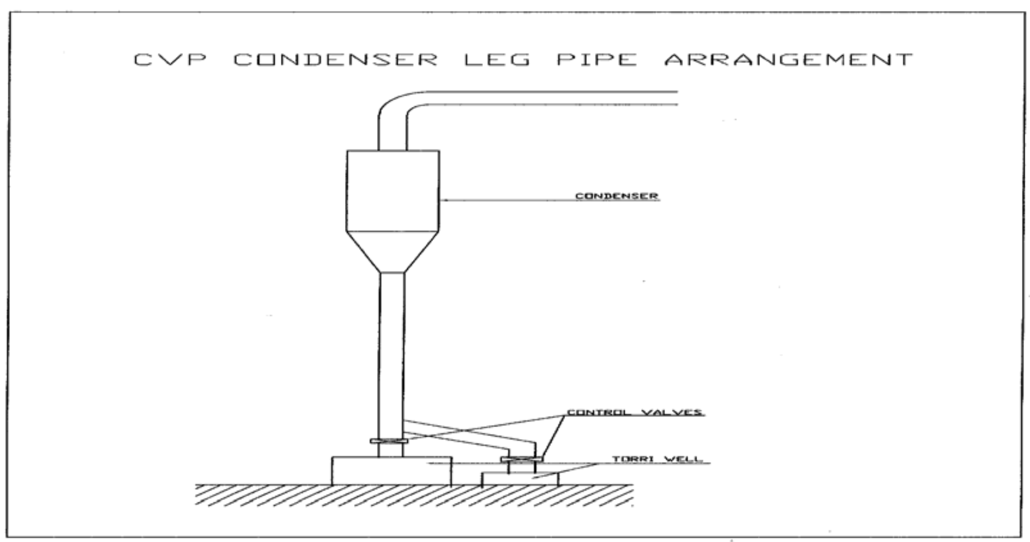

Figure 3 Continuous vacuum pans condenser leg - pipe arrangement

b) The drains from the Torri-wells were separated so that, in the event of a carryover of sugar material from the condenser, this would not end up in the main run off stream.

c) At start up, the water exiting the condenser was diverted to the ditching well. Control valves installed on the leg-pipes, were connected to signal lights on the pan floor to clearly indicate whether the system was in the ditched or operational position.
d) A conductivity probe was installed in the ejection water return to the river to detect any elevated readings that could be attributed to the presence of sugar material. An alarm was set up on a computer page along with a buzzer that would be triggered if conductivity readings went above established level.

Continuous use of anti-foam agent

The B molasses leaving the centrifugal is pumped either to storage or to a header tank where it is conditioned before being fed to the C continuous pan in order to boil the C massecutite (**Fig. 4**). Conditioning of molasses involved diluting to 65^{o} brix, continuous mixing along with controlled heating to 55^{o}C (131^{o}F).

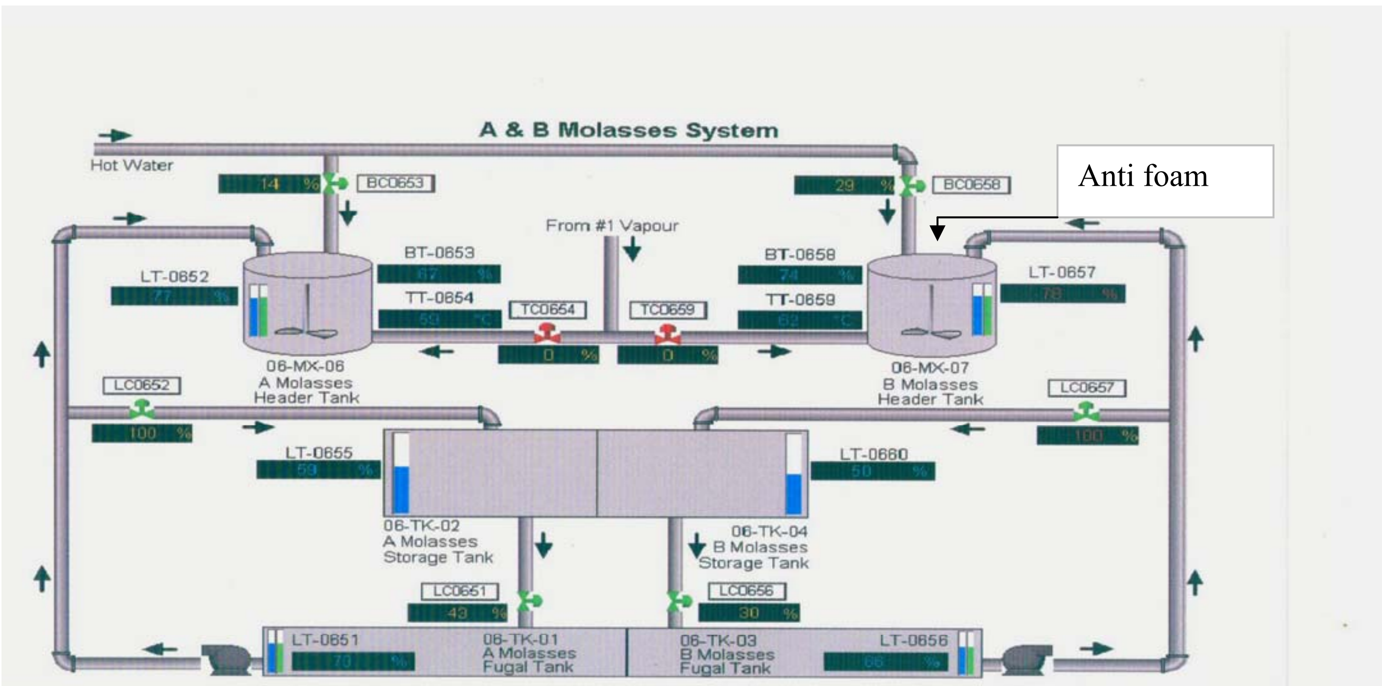

Figure 4 Anti-foam addition to B molasses header tank

Header tank at an average rate of between 33 and 51 ppm/B molasses depending on the extent of foaming, over a period of 45 days. During the period of dosing with the anti-foam, the following was done:

a. The daily dosing was monitored and weekly averages calculated.

b. The undetermined losses were monitored and comparisons made with the previous period of 24 days when no anti-foam was added.
c. Comparisons were made with the operating time efficiency during and before the period anti-foam was used.
d. The number of stops and starts of continuous C pan were noted during and before the use of the antifoam.
e. The following stringent measures were relaxed in order to observe the effectiveness of continuous addition of the antifoam.
    i. Vacuum was quickly raised instead of being done slowly
    ii. The practice of spraying water on massecuite when foaming was observed, was discontinued.
    iii. The level to which massecuite was lowered in the pan was varied with the view of reducing same.

The anti-foam agent used was a specially formulated, concentrated inhibitor for controlling foaming in sugar factories and alcohol fermentation processes. It has no inhibiting effect on micro-organisms used in fermentation process and is chemically, very stable. The recommended dosing was between 20-100ppm according to the severity of the foaming problem. The chemical can be diluted to as low as 1-2% with water. The concentrated chemical was used during experiments due to the unavailability of a batch tank and agitator that were recommended for preparing the dilutions.

RESULTS AND DISCUSSIONS

The results of monitoring of the physical conditions during the boiling of the C massecuite are shown in **Table 3**. The two conditions indicated were the ones that were more typical of the operating condition in the pan.

Table 1 – Physical conditions during boiling of the C massecuite

Calandria pressure (psia)	Body pressure (“Hg)	Massecuite temp (^oF) Cell 2	Massecuite temp (^oF) Cell 4	Massecuite temp (^oF) Cell 5	Massecuite temp (^oF) Cell 7	Massecuite temp(^oF) Recommended
16	23	162	165	172	172	<156
13	25	154	152	164	162	<156

During the routine operations, it was felt that the foaming observed in the molasses may have been as a result of the heating done for conditioning, prior to its use for low grade boiling.

The pan would normally be operated at a vacuum below 25” Hg, and at calandria pressures between 14 and 16psia. It was evident that, under this condition with massecuite temperatures in the range that are known to promote foaming, foaming would indeed occur.

Initial action to reduce foaming

The following observations were made to initial actions taken to reduce foaming:

a. Spraying water via the designed nozzles did not yield the expected results. Whilst, there was a small reduction in foaming, it was occurring to the extent where sugar material was still being carried over from the condenser.
b. The spray nozzles were often blocked with sugar or rust deposits.

The shock addition of the anti-foam prior to shutdown also, did not produce the desired result, probably due to the continuous discharge of the material from the pan during operations.

Actions to prevent carryover

With the installation of the save-all, it was observed that, there was some reduction in the quantity being carried over. The fact that carryover was still taking place, remained a cause for concern.

The start up and shut down procedures that were implemented were noted to have resulted in a significant reduction in the incidence of carryover. The following adverse effects were however observed:

a. Reduction of the massecuite level to nine inches below the top tube plate was somewhat too low and resulted in some delays before massecuite discharge on start up. There were also occasions when receiver space was limited and it was not possible to achieve these levels of reduction.
b. Massecuite had to be discharged from all cells and this resulted in higher than targeted purity material being pumped to crystalliser. The end result was spikes in final molasses purities.
c. The need to have senior personnel attending to the pan start up was not always practical since this sometimes occurred at odd hours.

d. There were instances when shutdown was impromptu and steam was not available to tighten the massecuite.

Actions to prevent sugar material entering run off streams

The system of diverting injection water in the event of carryover worked satisfactorily. There was however an occasion when the control valves malfunctioned due to a faulty solenoid causing both valves to remain open. This prompted the installation of signal lights to indicate valve positions. Despite continued incidence of foaming, there has been no further carryover of sugar material to the river from the continuous C pan since this incident.

The conductivity and buzzer system have allowed the quicker detection of any carryover and this has facilitated prompt action to limit sugar material entering the river. The graph in Fig. 5 showed normal conductivity readings at just over 400µS/cm. In the presence of sugar material resulting from carryover, the conductivity was elevated to over 900µS/cm. The graph also showed that the sugar material was present in elevated quantities for approximately nine minutes.

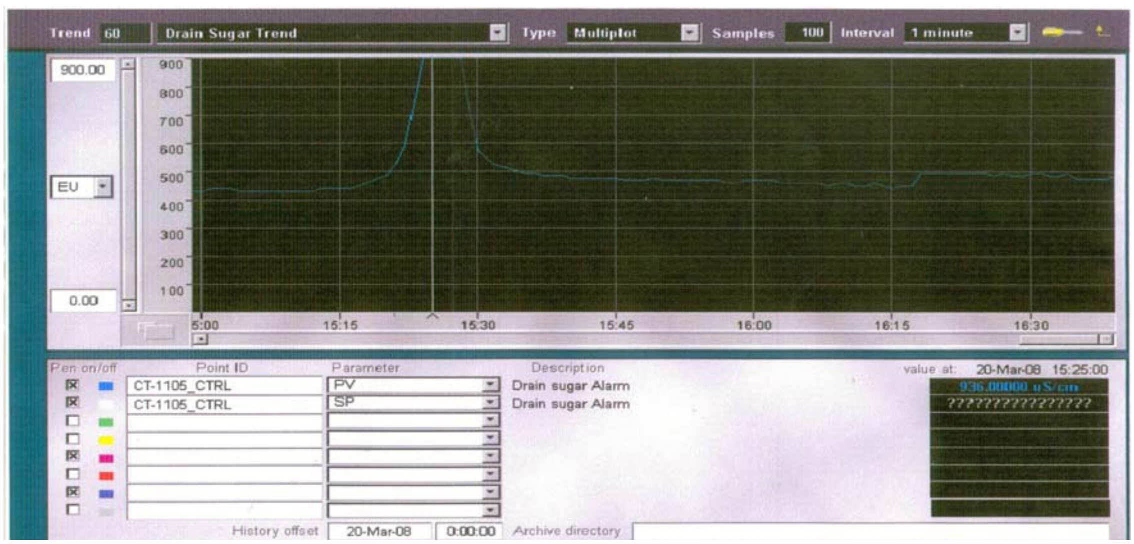

Fig. 5 – Detection of sugar material using conductivity – Absence of buzzer system

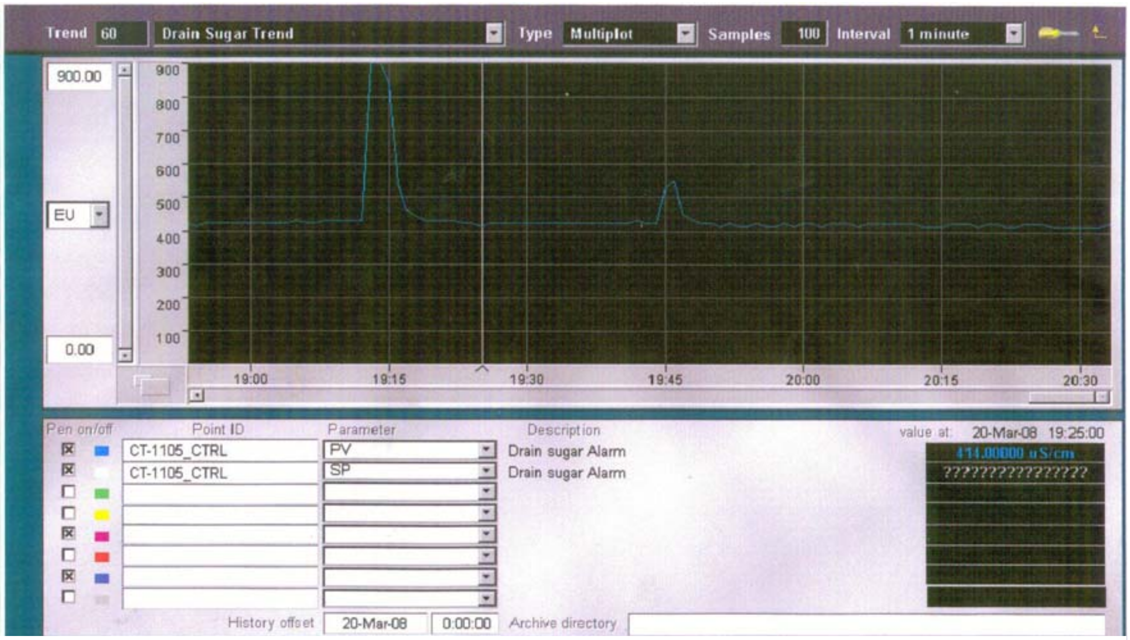

Fig. 6 – Detection of sugar material using conductivity – Buzzer system installed

The graph in figure 6 showed that sugar material was present for just over four minutes.

Continuous use of anti-foam agent

Table 2 – Dosage levels for anti-foam agent

Week#	Anti-foam (ppm/cane)	Anti-foam (ppm/B molasses)
1	2.33	41
2	2.13	33
3	1.56	33
4	2.35	39
5	2.20	40
6	3.23	51
7	2.85	50
Average	**2.34**	**41**

The actual dosages of anti-foam shown in **Table 2**, were ascertained by physically observing the conditioned molasses to see the application for which there was no foaming or frothing. (**Fig. 7** & 8)

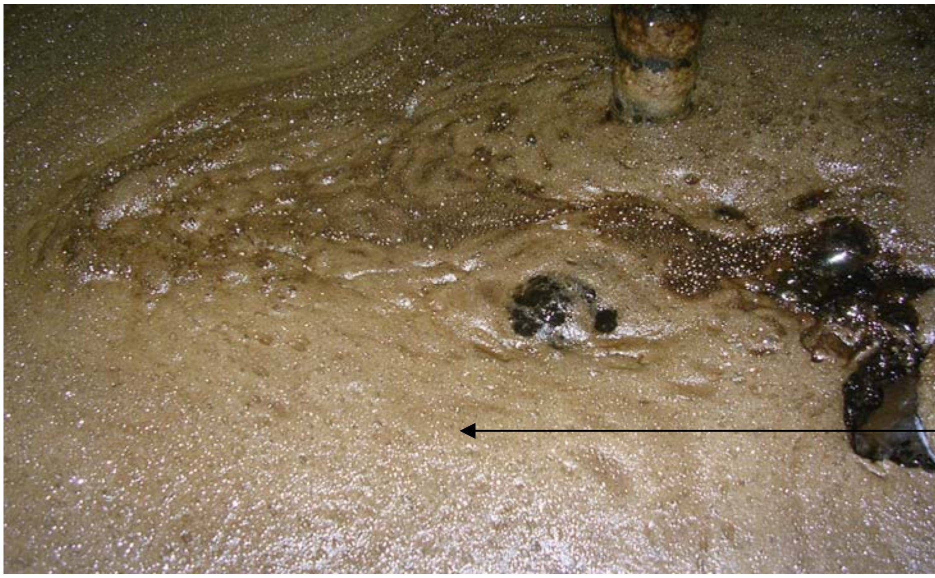

Fig. 7 – Pictorial view of foaming on molasses surface – no anti-foam added

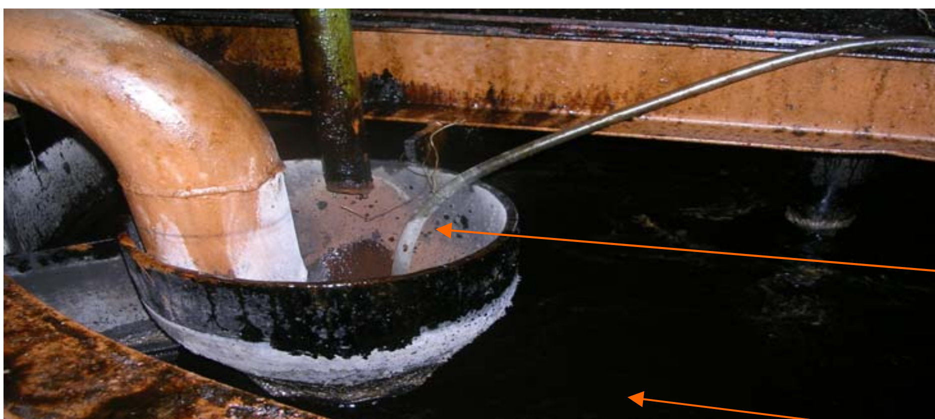

Fig. 8 – Pictorial view of absence of foaming in molasses header tank after

Rate of between 33 and 51ppm/B molasses was found to be adequate for the conditions and compared favourably with the recommended values of between 20 and 100ppm.

Whilst, we have not been able to quantify the exact amount that was attributed to sugar loss as a result of the foaming, there was a reduction in undetermined losses during the period when anti-foam was used as compared to the initial period when no antifoam was used (**Fig. 9**). These results were achieved despite the fact that operating time efficiency for the factory was much lower during the period of anti-foam usage (**Fig.10**).

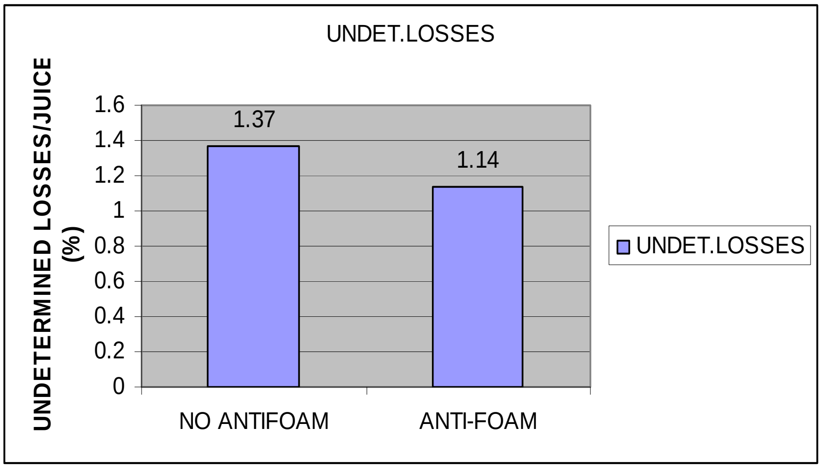

Fig. 9 - Undetermined losses during and prior to anti-foam usage

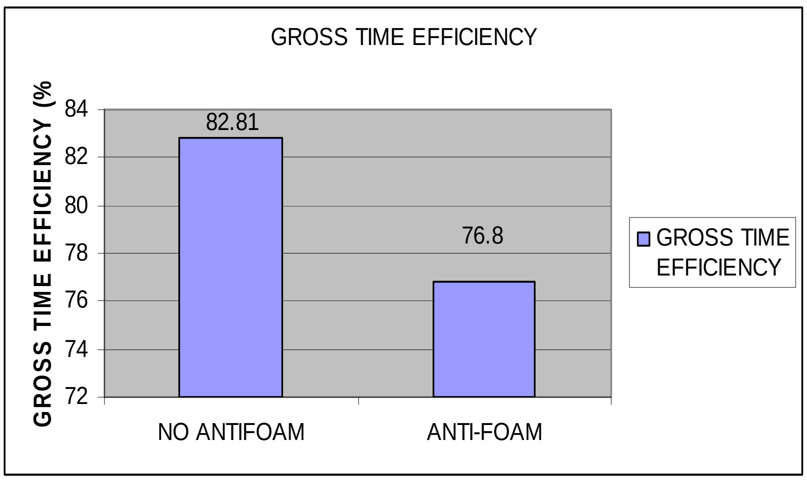

Fig. 10 - Factory gross operating time efficiency during and prior to anti-foam usage

Prior to the commencement of the anti-foam usage during the 2007/08 season, there were six recorded stops and starts of the continuous vacuum pan over a period of 24 days. There were also three incidents of carryover of sugar material from the pan due to foaming during this period. Following the continuous use of the anti-foam, there have been nine stops and starts of the pan, with no recorded carryover as a result of foaming.

The extent of foaming in the pan was also, noticeably much less and this facilitated the relaxing of some of the stringent measures that were earlier enforced during starts and stops of the pan. These include:

a. The vacuum could now be raised quickly without any carryover
b. It was no longer necessary to use spray nozzles to prevent foaming.
c. It was no longer necessary to reduce pan levels to as much as nine inches below top tube plate. Massecuite levels were now only reduced to between four and six inches below tube plate.
d. It was no longer necessary to have senior persons attending to the C continuous pan on start up. Operating personnel were reporting greater ease in starting pan without the same fear of carryover

CONCLUSIONS

The practical strategies employed to cope with the problem of foaming in the continuous C pan, carryover of sugar material and the prevention of this material from entering effluent streams have given positive results with the incidence of these events being curtailed.

Modification to vapour take off, lowering of massecuite levels along with tightening of material appeared to have made a major contribution to the prevention of carryover.

Whilst the continuous addition of the anti-foam did not completely eliminate the foaming, the occurrence was reduced to such an extent where stringent measures could have been relaxed during the starts and stops of pan, also, the fear of carryover was lessened.

Despite the fact that there were no chemical analyses to ascertain the levels of any foaming components, it was evident that some of the physical operating conditions such as high pan temperatures and low vacuum would have promoted foaming. As part of our future efforts, it is our intention to try and identify any chemical components that may be promoting foaming in the materials being processed.

During the next off season, similar modifications will also be done to condenser leg pipes on batch pans as we strive to eliminate the possibility of carryover of sugar material to effluent streams from any source and make our operations as environmentally friendly as possible.

Finally it must be stressed that the results achieved were the combined efforts of the practical measures employed along with the continuous dosing of the anti-foam agent.

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