

## MAXIMISING PROCESS PERFORMANCE IN A SUGAR FACTORY: ISSUES OF DESIGN AND MAINTENANCE

NINELA MB<sup>1</sup>, MUZZELL DJ<sup>2</sup> and LOVE DJ<sup>2</sup>

<sup>1</sup>Tongaat Hulett Sugar, Amatikulu Mill, Amatikulu, KwaZulu-Natal, South Africa

<sup>2</sup>Tongaat Hulett Sugar, Technology and Engineering Group, Amanzimnyama,  
KwaZulu-Natal, South Africa

*muzi.ninela@hulett.co.za dave.muzzell@hulett.co.za dave.love@hulett.co.za*

### Abstract

There are always strong incentives for Process Management to achieve high levels of technical performance in a sugar factory. This is particularly so in the South African sugar industry where the 'Division of Proceeds' system accentuates these incentives. The primary route to achieving good technical performance is usually close control of process operations, guided by detailed measures of factory performance.

A critical area that often does not get sufficient attention is that of equipment and process design coupled with the need for proper maintenance. There are many constraints (e.g. financial, mechanical, space and construction) as well as a lack of skill and/or technical knowledge which can contribute to placing limits on the performance that is possible from a particular factory. Identifying and correcting issues of design and maintenance that adversely affect process performance usually requires close attention to detail combined with sufficient technical knowledge. This paper attempts to provide a framework to assist in the process of identifying and correcting issues that affect sucrose loss in final molasses. This is done through a set of simple guidelines that are explained by using anecdotes from the combined experience of the authors to illustrate the type of problems that can be encountered and corrected.

*Keywords:* TPD, process performance, design, maintenance, principles

### Introduction

There are always strong incentives for Process Management to achieve high levels of technical performance in a sugar factory. This is particularly so in the South African Sugar Industry where the 'Division of Proceeds' system accentuates these incentives for raw sugar factories.

The primary means that process management usually uses to maximise technical performance is to ensure that their operating staff are suitably trained and motivated to achieve the highest potential from all the equipment under their control. In general, this means applying the basic principles of sugar technology whilst also adhering to the manufacturer's operating procedures for individual items of equipment.

Because all raw sugar factories within the South African sugar industry operate essentially the same production process, there is a set of standard methods and laboratory analyses for evaluating the entire raw sugar production process (Anon, 2005). Full sets of results are collated and published weekly, monthly and annually by the Sugar Milling Research Institute (SMRI). These figures provide an extremely useful guide for process management to identify

those aspects of their production process that are under-performing, and also enable them to benchmark their operation against others in the industry.

A critical area that often does not get sufficient attention is that of equipment and process design coupled with the need for proper maintenance. Design anomalies and poor maintenance can severely limit the level of technical performance that can be achieved by the operating staff – despite their best efforts. These equipment limits on the potential performance from a particular factory can be the result of a wide range of constraints (e.g. financial, mechanical, space and construction) as well as a lack of skill and/or technical knowledge.

The combined experience of the authors covers numerous practical examples of issues of design and maintenance that have adversely affected process performance. Collections of experiences of this kind run the risk of being like the state of zoology as studied by Samuel Taylor Coleridge, causing him to complain that it was so weighed down and crushed by a profusion of particular information... “without evincing the least promise of systematizing itself by any inward combination of its parts” that it was in danger of falling apart. (Medawar, 1984).

Fortunately a review of the authors’ practical examples indicated a number of common threads that could be summarised into a set of guidelines or principles of good process operations that can be used to identify and correct issues of design and maintenance that adversely affect process performance. Following on the concept embodied in the book, ‘All I really need to know I learned in Kindergarten’ (Fulghum, 1986), the principles have been formulated in simple terms that are concise and memorable. The principles expand in some detail on the obvious prerequisite of a need for close attention to detail combined with sufficient appropriate technical knowledge.

To keep the paper to a manageable length the principles have been illustrated with examples that relate predominantly to sucrose loss in molasses. Sucrose loss in molasses has been chosen because it is normally the primary factor affecting overall process performance, whereas a full analysis would need to cover sucrose loss in bagasse, sucrose loss in filter cake and undetermined sucrose loss. A simple set of three laws that provide a guide to minimising sucrose loss in molasses are outlined in a companion paper (Love and Muzzell, 2009). Using these three laws, correct operating procedures, good maintenance practices and correctly designed plant come into focus to assist with achieving the final goal of low sucrose loss in final molasses.

### **Principles of good process operations**

1. *Look carefully and try to make sense of what you see*  
Careful observation and attention to detail is a prerequisite to identifying issues that can adversely affect process performance. Correct interpretation of these observations requires the logical application of the principles of mathematics, science, engineering and sugar technology. Common sense and an understanding of human nature are also very useful.
2. *You should always know where you are and the way to get back to where you ought to be*  
Accurate measurements are critical to achieving good process performance because they can provide clear indications of when performance is less than ideal. Good measurements

are the best guide on where efforts need to be directed to achieve improved performance. This applies to laboratory sampling and analysis as well as on-line instruments. The measurements that are necessary for the 'mill balance' are particularly important.

3. *Always put things back where they belong*  
A basic principle of sugar processing is that streams returned back into the process should match the process stream that they join based on the following criteria: purity, brix, colour (in that order). In exceptional circumstances, it may be necessary to alter the order of the criteria (e.g. to return a stream based on its brix even though there is a better purity match). Sometimes, simply providing the option of returning to the wrong place (to meet some exceptional circumstance) can be extremely dangerous. It can provide an opportunity for inadvertent, ignorant or even subversive diversion of product with detrimental effects on process performance.
4. *Try not to make a mess in the first place*  
Sugar processing is fundamentally about purification and separation, thus it is important to avoid unnecessary contamination of any stream by unwanted components. This applies to a wide range of situations, from allowing air leaks into pans to sugar contamination of condensates and injection water. The obvious need to avoid leaks, spills and overflows of sugar containing streams onto the floor and into drains is particularly important, even where the contents of drains can be returned to the process.
5. *Always clean up after yourself*  
Some contamination is inevitable, so it is important to have processes and equipment designed for clean-up. This applies to operations such as removing air from steam (incondensable gas venting) and sugar from vapour (entrainment separation).
6. *Be in the right place at the right time*  
Optimum process performance is obtained by holding important process conditions at correctly specified values. It is important to know the 'correctly specified values' and how they might vary over time, an obvious example being the boiling profiles for batch pans. Processes must be designed and maintained to ensure that the correct process conditions can be achieved and maintained.
7. *Make sure you know how to balance (and not wobble) particularly in dangerous places*  
Maintaining important process conditions at the correctly specified values with a minimum of variation (oscillation or wobble) requires good quality automatic control systems to achieve this in the face of numerous, varying external factors. This principle of minimising variation has been embraced as a critical factor by the discrete parts manufacturing industry (statistical process control and Six Sigma principles) with a wealth of published information. In contrast, there appears to be very little documented information both on the quality of control that is practically achievable for critical process parameters in sugar manufacturing and the mechanisms to achieve it. This is a complex issue covering process and equipment design, control strategy, measurement, controller tuning and the performance of the final control element.
8. *If you want to get stuff safely from one place to another, carry it carefully and use the right container*  
Correctly designed and maintained piping, pumping and conveying systems are essential for good process performance.

9. *Some things need to be well mixed to be at their best*  
Effective mixing is important both in mechanically mixed vessels (stirred pans, blow-up tanks, remelters) and in vessels that rely on natural circulation (unstirred pans and evaporators). It also has wider implications such as effective water mixing with massecuite to improve centrifugal performance.
10. *It's best if it's not too hot, not too cold, but just right*  
In the design and operation of sugar processing equipment, operating temperature is usually a delicate compromise between numerous conflicting requirements.

Some major benefits of higher temperatures are:

- Higher crystallisation rates
- Higher sucrose solubility (for crystal dissolution in remelters and blow-up tanks)
- Reduced microbial destruction of sugar
- Reduced viscosity with correspondingly lower pressure drops and higher heat transfer coefficients.

Some major benefits of lower temperatures are :

- Lower rates of chemical degradation of sucrose (inversion)
- Lower rates of monosaccharide destruction (Maillard reaction, fructose polymerisation and colour formation)
- Lower sucrose solubility (for cooling crystallisation).

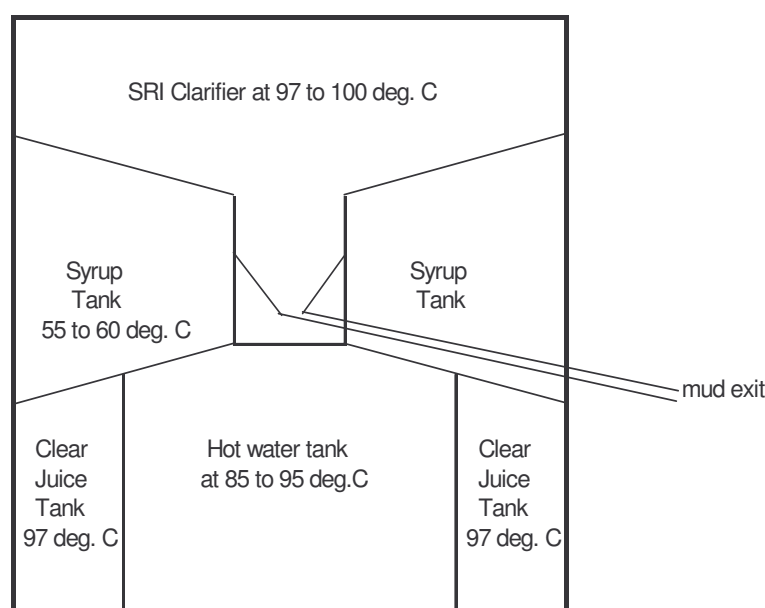
11. *It's best if it's not too big, not too small, but just right*  
Proper sizing of equipment is important and over-sizing equipment (to ensure that it is not too small) can cause its own problems. This can apply to a wide range of equipment, from control valves to clarifiers.
12. *Slow and steady is nearly always better than stop and start*  
A strong driving force behind the move away from batch processing in the sugar industry has been the ability of continuous processes to deliver consistently good performances by steady operation at fixed conditions. For continuous processing equipment to achieve its potential, it needs to be well designed and then operated at as steady a conditions as possible. This often requires adequate sizing and appropriate use of buffer tanks to steady outflow fluctuations.
13. *Don't take it out of the machine until you are sure it is properly finished*  
Many processes require sufficient time to achieve the necessary process result. In batch processing this is usually clearly evident in the time required to complete a batch. In continuous processing the necessary retention time needs to be built into the design of the equipment. Even if continuous processes have sufficient installed volume to provide the necessary retention time, a poor approach to ideal plug flow (resulting from stagnant regions, bypassing and excessive dispersion) can result in insufficient retention time. The flow characteristics of continuous processes (often measured by tracer testing) are thus critical to ensuring that there is sufficient retention time to achieve optimum performance.

## Typical factory installations and examples

### *Integrated clarifier and storage tank installation*

A South African factory had a syrup tank installed between an SRI clarifier and a clear juice/hot water tank (Figure 1). Such a design would make perfect sense if the only goals were to save money and space, and provide a support structure for the SRI clarifier. However, from a process performance perspective it is highly undesirable. The clarifier contents, the clear juice and the hot water will all transfer heat to the stored syrup and increase its temperature. It is well known that the temperature of syrup should be kept low (approximately 60°C – Smith and Taylor 1981) to minimise sucrose destruction (Peacock, 2007). Low temperatures are also necessary to limit the Maillard reaction. The Maillard reaction is normally only considered in relation to lower purity products but it does still occur, although less severely, in syrup (Newell, 1979). There is also the possibility that portions of the complex Maillard reaction may be initiated in the syrup and promote completion of the reaction in the latter stages of massecuite boiling. Products of the Maillard reaction are known to increase massecuite viscosities and make it difficult to achieve low target purity differences (Ninela and Rajoo, 2006).

Another important downside of this installation is the possibility of undetected contamination of products as a result of leaks between the compartments.



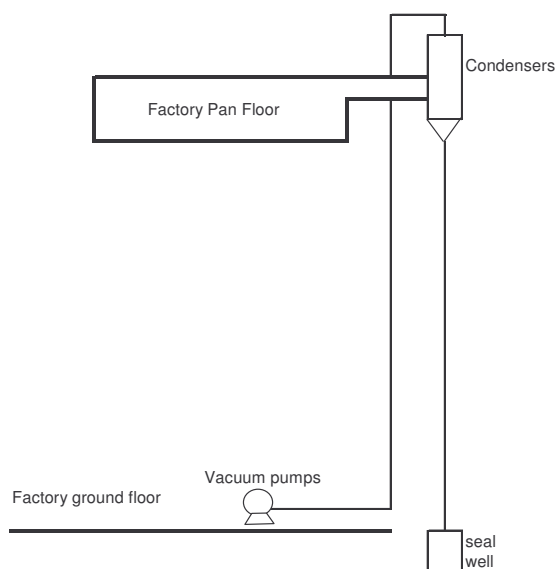
**Figure 1. Syrup tank between SRI clarifier and clear juice/hot water.**

Applicable to principles: 1, 4, 8 and 10.

### *Incondensable gas pipes to vacuum pumps*

Low massecuite boiling temperatures (particularly for C-massecuite) are important to minimise the Maillard reaction and its ultimate negative influence on sucrose loss in molasses. Excessive pressure loss in the incondensable gas lines from the condenser to the vacuum pump can prevent low boiling temperatures. As a rule of thumb, the pressure drop

from the condenser to the vacuum pump should be limited to less than 0.5 kPa. When incondensable gas pipes from the condensers are connected from above the pan floor to vacuum pumps positioned on the ground floor, the long lines create the potential for a high pressure drop along the line (Figure 2). Correct sizing of the incondensable gas line is also important to avoid excessive pressure loss. A C-continuous pan installation was found to have an undersized (100 mm) incondensable gas line. When this was replaced with the correct diameter line (150 mm), it reduced the pressure drop from the pan to the vacuum pump, thus improving the pan operating temperatures.



**Figure 2. Incondensable pipe length.**

Applicable to principles: 1, 8, 10 and 11.

### *Condenser performance*

Pan operating pressure must be accurately controlled at low absolute pressure to maximise exhaustion whilst limiting the Maillard reaction and its resulting negative impact on sucrose loss in molasses. This is achieved by a combination of the condenser, vacuum pump and the control system (Love, 2005). A critical component is an efficiently performing condenser, the design and condition of which ensures good counter-current contact between the condensing vapour and the injection cooling water. Deteriorating condenser performance will initially lead to excessive injection water usage and ultimately to an inability to maintain the desired absolute pressure. Hot incondensable gas lines in combination with excessive injection water usage are an indication of poor contact between vapour and water within the condenser.

Regular inspection of condensers is desirable to ensure that the condenser internals remain intact. A typical incident of a broken rainmaker (of an early Tongaat Hulett design) is shown from Pan 1 at Amatikulu (Figures 3, 4 and 5). This is an 85 m<sup>3</sup> pan wherein poor circulation was witnessed and, in the early part of the boiling cycle, two vacuum pumps were needed to achieve an absolute pressure of around 12 kPa(a). Shading of sections of the condenser by the milk of lime residue in injection cooling water is irregular with a dark section where the rainmaker is broken. This is evidence of vapour bypassing the condenser rainmaker and washing the darkened section of the condenser clean.



Figure 3. AK batch pan 1 rainmaker.



Figure 4. Broken section of the condenser rainmaker.

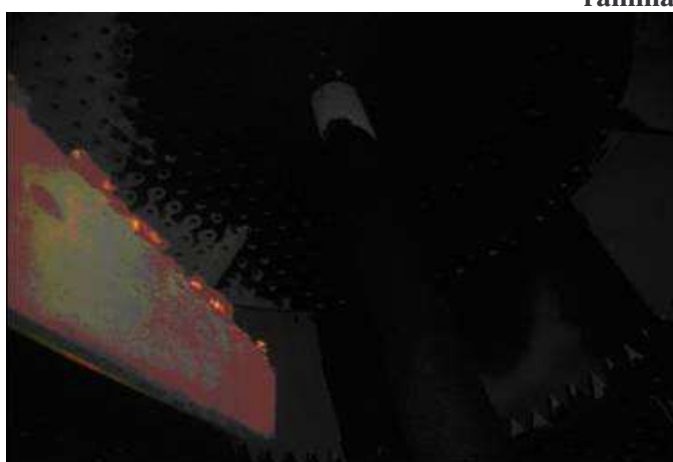


Figure 5. Lime shades on wetted sections of the condenser.

Applicable to principles: 1, 6 and 7.

#### *Injection water cooling*

Cooling tower fans and sprays from the spray ponds should be checked regularly to confirm that they are working optimally. In a factory in Swaziland, immediate improvement to the injection cooling water temperature was witnessed when a number of cooling tower fans that had only two blades were reinstated with four-blade fans. Amatikulu mill TPD figures in the 2007/08 season increased for three weeks (33, 34 and 35) during a time when one of the nine cooling tower cells was down due to a defective fan gearbox. Masseccite temperatures and viscosities increased during this period. In factories with spray ponds, regular checks of sprays for blockages should be done during stop days, and wear on spray nozzles should be assessed every off-crop.

Applicable to principles: 1, 2 and 10.

#### *Control valves*

Correct sizing and installation of control valves is necessary to ensure that process parameters can be effectively controlled at their desired values. An undersized control valve can limit plant capacity or the ability to recover quickly from a process disturbance. An oversized

control valve will be effective only over a small portion of its range (small openings), limiting its ability to achieve effective control. Proper control valve selection and sizing requires an understanding of the complete installation; as a rough guide, the valve must be sized to consume 30% of the total dynamic pressure drop through the system (Sinnott, 1993). It is also important to consider the possibility of 'choked flow' in the control valve and address this by appropriate sizing or positioning of the valve.

Choked flow is common on injection water valves supplying condensers and the resulting cavitation downstream of the valve can cause rapid erosion-corrosion of the piping. A section of stainless steel piping downstream from the injection water valve is an effective remedy to the erosion-corrosion problem but it is preferable to position the valve to eliminate the possibility of cavitation (by placing it sufficiently far below the condenser inlet) or minimise the extent of the cavitation (by placing it at the same elevation as the condenser inlet).

Applicable to principles: 7, 8, 11 and 12.

#### *Air leaks into vessels operating under vacuum*

Vacuum or absolute pressure in a vacuum vessel directly influences the temperature of product in that vessel. Since both sucrose and monosaccharide destruction are reduced considerably at low temperatures, there are huge gains to be had from operating at low absolute pressures. Air leaks into vacuum vessels can have serious adverse effects on the achievement of the desired absolute pressure.

It is essential to undertake vacuum checks on vacuum vessels. This can be done by lowering the absolute pressure to about 30 kPa(a), isolating all pipes connected to the vessel body and then measuring the time for the pressure to increase by 10 kPa. For a new vessel, the pressure should not increase by more than 10 kPa in 60 minutes and for a used vessel time taken should not be less than 30 minutes. If the test falls outside these limits, the leak(s) on the vessel must be found and sealed.

Amatikulu mill evaporator station developed several leaks over a number of years. However, because the evaporator system was over capacity, syrup brix did not suffer initially and a flag for immediate attention was not raised. Over time this resulted in syrup temperatures drifting from an acceptable 55-60°C range to 68°C and above. This resulted in Maillard reactions starting early in the factory, making processing difficult downstream, and high sucrose losses in molasses were incurred. Pressure testing of the evaporator train during boil-off revealed a number of leaks that needed attention. Pressure testing of the evaporator train every stop day has now been adopted as a normal operating procedure and continues to reveal new leaks that develop during the crushing periods.

Applicable to principles: 1, 2, 4 and 10.

#### *Installation of absolute pressure transmitters*

Absolute pressure transmitters are preferred to vacuum transmitters on vacuum vessels as they give a direct measure of the operating pressure rather than a measurement that is relative to the (normally unmeasured) external ambient atmospheric pressures. The full value of the absolute pressure reading is lost if the transmitter is not installed correctly.

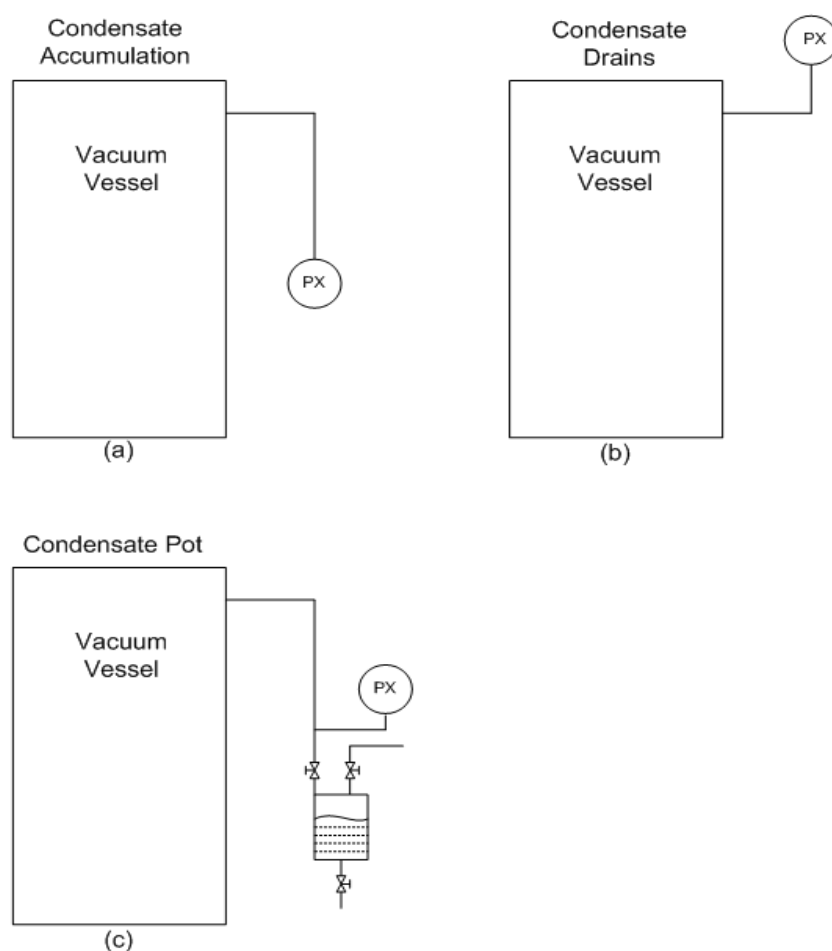
A very common fault is to locate the transmitter below the tapping point on the vacuum vessel and not provide a means of draining condensed vapour that will inevitably accumulate in the

pipe above the transmitter (Figure 7a). When boiling a C-massecuite, the tolerances on absolute pressure are very tight to achieve the desired low massecuite temperature. An accumulation of 1000 mm of condensate in the pipe above the transmitter will increase the absolute pressure measurement by 10 kPa above the actual pressure within the vessel. Under automatic control the offset caused by this accumulation of condensate will cause a drift in the actual operating pressure, eventually causing an in and out of control situation, with maximum injection water usage. The feed control set-point will become increasingly inappropriate as the operating pressure drifts.

To overcome this problem, the absolute pressure transmitter must be installed above the tapping point so that any condensation runs back into the vacuum vessel (Figure 7b). If this is not possible, then a condensate collection pot must be installed to facilitate manual draining of the accumulated condensate, while at the same time not affecting the pressure measurement cycle (Figure 7c). On batch pans it is possible to automate the draining of the pot between each cycle. A more complex automatic drainage system is required for continuously operating vessels, to ensure that the quality of control is not disrupted.

Applicable to principles: 2, 4, 5, 6, 8 and 10.

#### Absolute Pressure Transmitter Installation



**Figure 7. Installation of a pressure transmitter or pressure gauge on a vacuum vessel.**

### *Product diversion to final molasses*

Other than deteriorated floor washings, final molasses purity is the lowest purity product in a raw sugar factory. Therefore, if any product other than deteriorated floor washings is mixed with final molasses prior to sampling and weighing, it will register as an increase in sucrose lost in final molasses. Many factories have an emergency facility to divert B molasses to final molasses when the factory back end fills up. When this is not in use, the B molasses line must be completely isolated with a blank flange to prevent 'accidental' diversions taking place.

Applicable to principles: 3, 4 and 8.

### *Low purity floor washing*

It is normal practice to recover floor washings back into the process stream to reduce undetermined loss. If the floor washings are excessive and the purity has deteriorated, an abnormal amount of non-sucrose will be introduced into the system. The inflated non-sucrose will result in increased sucrose losses in final molasses, as virtually all the non-sucrose leaves the factory in final molasses (Love and Muzzell, 2009).

To avoid this situation, it is essential to stop all leaks and overflow of product onto the floor. If this is minimised, then the small volume of floor washing must be recovered quickly to minimise inversion of sucrose. Recovered products should be returned back to the process to achieve the closest match in terms of purity, brix and colour (in that order).

Applicable to principles: 2, 3, 4, 10 and 13.

### *Juice Retention Times in Evaporators*

Long juice retention times in evaporators contribute to increased sucrose destruction and Maillard reaction. At one time, the Mount Edgecombe mill (closed  $\pm$ 1993/94) had a first effect of the evaporator train provided by seven Robert design vessels (of differing sizes), all operating in parallel. When the evaporator station was refurbished, a single Kestner design evaporator was installed to provide the first effect of evaporation. This substantially reduced the juice retention time in the first effect with an associated reduction in sucrose destruction. Over-sizing of evaporators will also result in long juice retention times. Design and sizing of evaporators may need reviewing, especially in times when cane crops are shrinking and evaporator systems become increasingly over-capacity.

Applicable to principles: 10 and 11.

### *Venting of incondensable gas from vessels heated with steam or vapour*

All steam and vapour streams inevitably contain some air or other incondensable gases. When these streams are condensed in the calandrias of pans and evaporators, the concentration of the incondensable gasses will consequently increase. The concentration of incondensable gas will be further increased by air leakage into vessels operating under vacuum. It is important to ensure that the concentration of incondensable gas (at any point within the calandria) does not rise to the critical level where it creates a practically discernable reduction in heat transfer. This is achieved by venting steam/vapour that contains the concentrated incondensable gasses at a concentration below the critical level. The gases are normally vented separately from the bottom and top of the calandria at the end of the natural flow path of vapour through the tube bank. These are normally referred to as 'heavy' and 'light' incondensable gas vents although there is no evidence to support the implication that there is a separation based on the density

of particular incondensable gasses. It is, however, important to ensure that both vents operate effectively so that there is no accumulation of incondensable gas at either the top or the bottom of the calandria. Inadequate venting can result in massecuite or juice/syrup circulation stopping completely (Zulu *et al*, 2008).

Three common problems with gas venting include:

- ‘Heavy’ and ‘light’ incondensable gases are vented through a common pipe, with a single isolation valve on the common pipe. In this arrangement, there is no way of ensuring that one vent does not operate preferentially at the expense of the other – with a consequent reduction of heat transfer in the area serviced by the under-performing vent. To overcome this problem, the ‘heavy’ and ‘light’ incondensable gas vents must each have their own isolation valve and the vent pipes should be separated to allow independent free flow of both gases from the calandria.
- The ‘heavy’ incondensable gas extraction manifold inside the calandria is located too close to the bottom tube plate and the holes are on the underside of the extraction pipe. Since a small level of condensate is required in the calandria to provide the necessary head for the condensate to flow, the incondensable gas outlet holes can become flooded with condensate and the ‘heavy’ gas cannot escape. This configuration must be changed so that the holes are on the top of the pipe and the pipe should be about 100 mm above the bottom tube plate.
- A single perforated pipe is inserted vertically into the centre of the calandria and the incondensable gasses are removed from the top of this pipe. The assumption is that all the gases will vent equally through the holes in the vertical pipe. Unless the perforations are carefully sized to ensure even withdrawal of gasses from the full length of the pipe (similar to proper sparger design) the majority of the venting will take place from the top of the calandria with little or no venting from the bottom of the calandria. This problem can be particularly severe in evaporators with long tubes such as Kestner and semi-Kestner types of vessels. An effective solution is to provide incondensable vents on the condensate outlets of this type of vessel where the steam flow is predominantly longitudinal rather than radial.

Applicable to principles: 5 and 8.

#### *Distribution and circulation in vacuum vessels*

Even distribution of feed and jigger steam in a pan will promote circulation of massecuite in the pan. Good circulation will promote increased sucrose crystallisation and improved final molasses exhaustions. Poor circulation and localised over-heating of massecuite that does not circulate will introduce a Maillard reaction and increase glucose destruction in particular.

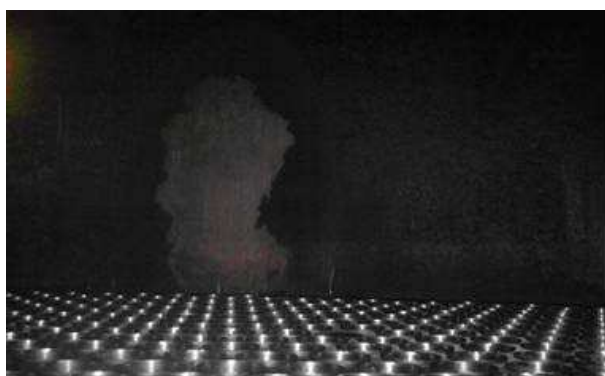
It is essential that the distribution of feed and jigger steam (when used) in a vacuum pan is symmetrical and is directed to the correct area under the calandria. An even distribution through the feed and jigger steam orifices can be achieved by proper sparger design to specify the correct size and number of orifices and the appropriate pipe size for the feed ring. In principle, the feed should be distributed close to the periphery of the pan. If an internal feed ring is installed it should not obstruct the massecuite circulation, particularly towards the periphery of the pan underneath the calandria. If there is an obstruction, then the feed horn must be located outside the pan with risers installed to feed into the pan saucer.

Similar principles apply to the design of feed rings for evaporators, although the sizing of feed holes is also influenced by the need to minimise the possibility of blockage by pieces of evaporator scale. In evaporators a benefit can be obtained by positioning the feed ring to promote a degree of plug flow within the vessel, whilst in pans a fully mixed system is preferable to achieve effective control of crystallisation conditions.

Applicable to principles: 1 and 9.

*Circulation marks in vacuum pans - feed trails*

Erosion marks on the wall of No. 1 batch pan at Amatikulu showed signs of increased circulation of massecuite in that area. On close inspection, the pan saucer also had marks of condensate in the form of a rusting trail exactly below the erosion mark on the pan wall (Figures 8 and 9). On pressure testing the pan, leaking tubes were found around the same area.



**Figure 8. Erosion marks on AK batch pan 1 wall.**



**Figure 9: Condensate trail on AK batch pan 1 saucer.**

There were also zones in the same pan where there were no erosion marks on the wall of the pan above the feed orifice, proving poor circulation during boiling at that zone. On close inspection of the feed orifice, it was found to be choked with massecuite. A white trail mark of deteriorated syrup/massecuite mix had come out and remained on the pan saucer (Figure 10).

Applicable to principles: 1 and 9.



**Figure 10. White trail of syrup/massecuite on AK batch pan 1 saucer.**

### *Continuous centrifugal maintenance*

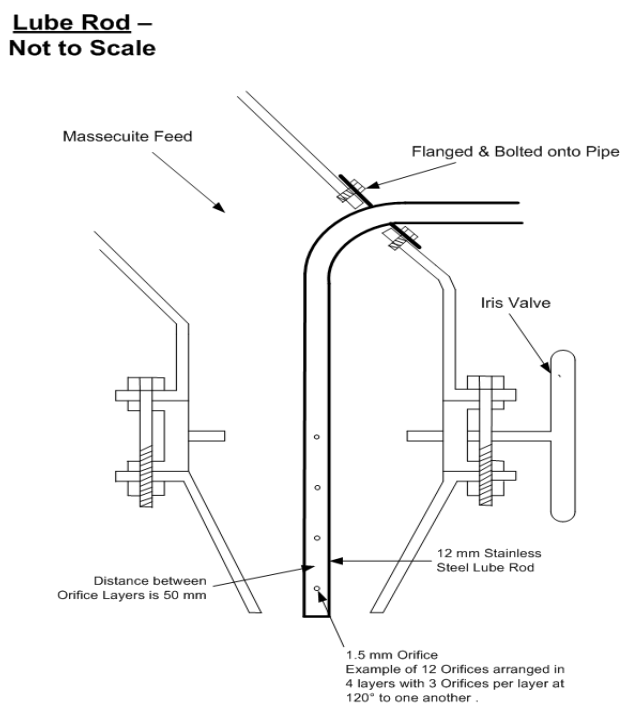
Molasses is conveyed from the centre area of the continuous centrifugal to the outside via a pipe that passes through the sugar chamber in the outer section of the centrifugal. If the conveying pipe is made of mild steel, it is susceptible to corrosion and, if a hole develops on the top of the pipe, sugar will enter the molasses pipe and increase the final molasses purity substantially. It is advisable to replace the mild steel pipe with stainless steel.

Applicable to principles: 4 and 8.

### *Lube rods in continuous centrifugal feeds*

Installation of lube rods in the massecuite feed to continuous centrifugals improves mixing of wash water into the massecuite, resulting in a reduced volume of water required for curing. Traditionally, water is added from a perforated ring located around the periphery of the feed cone on the centrifugal. Wash water added in this manner does not penetrate the massecuite and when the massecuite and wash water arrive in the mixing cup of the centrifugal, most of the water will be 'thrown out' of the cup before effective mixing takes place. Poor mixing of wash water and massecuite will produce inefficient washing of the sugar crystals. However, if water is introduced into the body of the massecuite using a lube rod (Figure 11), the water will have to escape through the massecuite before the mixture is expelled from the mixing cup and will therefore improve the sugar crystal washing efficiency. Over-washing of massecuites will result in increased purity of molasses and an increased volume of lower brix molasses. The use of lube rods therefore mitigates the effect of over-washing (McEvoy and Archibald, 1975).

Applicable to principle 9.



**Figure 11. Introducing wash water to massecuite using a lube rod.**

### *Steam addition in continuous centrifugals*

A perforated steam jacket is common on the feed pipe of many continuous centrifugals. The addition of steam or vapour at this point rapidly increases the temperature of the feed and, in particular, the temperature of the molasses in the feed. The increase in temperature reduces the molasses viscosity, which promotes easy and rapid separation from the sugar crystal. Since the holes in the steam jacket are very small, they are prone to blockage by scale. The result is increased molasses viscosity requiring excessive wash water to remove the molasses from the crystal, with a resultant increase in purity rise on curing and an increase in the final molasses purity.

On a shut down, connect water to the steam inlet of the jacket and check that water squirts out of all the holes.

Applicable to principles: 8, 9 and 10.

### *Retention times in continuous crystallisers*

The last opportunity for recovering sucrose that would otherwise be lost in final molasses is during the cooling crystallisation that takes place in the C-crystallisers. This is achieved by providing sufficient retention time and an appropriate cooling profile. Generally, a retention time of 48 hours or greater is sufficient, with a final temperature of about 45°C. Banks of horizontal batch crystallisers that were converted to continuous operation were found to perform poorly, even though the nominal retention time was sufficient. Tracer tests showed that there were effectively two flow paths, with a substantial portion of the massecuite short-circuiting the majority of the installed volume and spending insufficient time in the crystallisers for proper exhaustion. The major route for the bypassing massecuite was across the top of the free surface of the massecuite where it remained hotter and less viscous than the rest of the massecuite that was being stirred and cooled within the vessel. This problem was solved, and a much closer approach to plug flow achieved, by ensuring that massecuite entering the top of a vessel (or pair of vessels) was forced to leave via the bottom of the vessel (or pair of vessels), thus ensuring that the entering massecuite was mixed with the contents of the vessel. This 'top to bottom' flow path was then followed by a 'bottom to top' flow path, and so on, by using alternating top and bottom connecting gutters. In situations where all the connecting gutters are located at the top of the horizontal crystallisers, a vertical plate that extends down from the surface of the massecuite to the stirrer shaft can be installed in the middle of each crystalliser to prevent the bypassing.

Applicable to principle 13.

## **Conclusion**

The examples given above can never be exhaustive. However, using the given principles as a guide, Process Engineers or Technologists can continue this search for anomalies in sugar factories to maximise each factory's technical performance and profits.

## **Acknowledgements**

The authors would like to acknowledge Tongaat Hulett management for allowing the information contained in this paper to be made public, and process staff at different factories who were willing to share some of their experiences, even where it seemed career-threatening.

## REFERENCES

- Anon (2005). South African Sugar Technologists' Association Laboratory Manual. 4th Edition, July, ISBN: 1-874903-32-8, published in electronic format.
- Fulghum RL (1986). *All I really need to know I learned in kindergarten*. Random House, New York, USA.
- Love DJ (2005). Achieving and controlling vacuum in process vessels using condensers and vacuum pumps. *Proc S Afr Sug Technol Ass* 79: 286-300.
- Love DJ and Muzzell DJ (2009). Minimising sucrose loss in molasses – the three laws of molasses loss. *Proc S Afr Sug Technol Ass* 83 (in press).
- Medawar PB (1984). *The Limits of Science*. Oxford University Press, Oxford, UK.
- McEvoy MAJ and Archibald RD (1975). Increased capacity of continuous centrifugals on low-grade massecuites. *Proc S Afr Sug Technol Ass* 49: 80-85.
- Newell GM (1979). A preliminary investigation into factors affecting gas formation in massecuite and molasses. *Proc S Afr Sug Technol Ass* 53: 62-65.
- Ninela MB and Rajoo N (2006). Practical steps taken at Tongaat Hulett Sugar factories to achieve low target purity differences. *Proc S Afr Sug Technol Ass* 80: 448-461.
- Peacock SD (2007). The effect of final effect operating pressure on sucrose degradation in evaporator stations. *Proc Int Soc Sug Cane Technol* 26: 1445-1459.
- Sinnott RK (1993) *Coulson and Richardson's Chemical Engineering*. Volume 6, Second Edition, Butterworth-Heinemann, Oxford, UK.
- Smith IA and Taylor LAW (1981). Some data on heat transfer in multiple effect evaporators. *Proc S Afr Sug Technol Ass* 55: 51-55.
- Zulu MI, Ninela MB, Muzzell DJ and Mncube FS (2008). Panfloor modifications that improved performance at Amatikulu mill. *Proc S Afr Sug Technol Ass* 81: 190-197.