THE USE OF POWDERED LIME AT MAIDSTONE

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Abstract

The design and installation of a completely automated powdered lime plant during 1994 is described. This marked the beginning of a major expansion at Maidstone Mill. The conversion from rock lime, a rotary slaker and full time lime plant attendant to a completely automated plant producing milk of lime from powdered or ground unslaked lime was a first within Tongaat-Hulett Sugar. The advantages in lime handling, transport, process control, productivity and safety vastly outweigh the disadvantage of the additional cost of powdered lime. The installation costs are relatively high, however the operating costs show a nett saving in excess of R50 000 per annum. As a process operation, the new plant has proved a great success.

Introduction

Clarification in the South African sugar industry is performed mostly using the defecation process, a vital part of which is the controlled addition of milk of lime. Traditionally its production has been by slaking rock lime, which has a particle size ranging from 19 mm to dust. Maidstone Mill have installed a fully automated plant that produces milk of lime from ground unslaked lime which has a particle size of less than 2,35 mm. It is this ground unslaked lime which is commonly referred to as powdered lime.

The design, operation, installation and commissioning of the plant are described in detail together with the advantages and disadvantages that this plant has to offer. A financial evaluation further reveals the success of this plant.

Why the change

Why would Maidstone want to change their entire milk of lime manufacturing process that had worked successfully for so many years? With the closure of the Mount Edgecombe Mill in 1994 Maidstone embarked on an expansion project which included the replacement of a small milling tandem with a large 300 tons cane/h diffuser. The positioning of the new diffuser meant that the original milk of lime plant had to be relocated. Furthermore, the original lime plant would have required extensive upgrading to automate its operation fully. With this in mind Maidstone's Management team looked at possible alternatives, and decided to change from rock lime to a fully automated powdered lime plant.

Design and specification of the plant

As powdered lime had not been used at any of the Tongaat-Hulett Mills, Maidstone decided to seek expert advice from two of the large bulk material handling companies. Useful information was also obtained from Komati sugar mill regarding the installation and operation of their powdered lime plant. Maidstone specified its required storage and operating conditions and both companies provided individual designs based on the these needs. Both tenders included the design, manufacture, installation and commissioning of their plants.

The plant was selected and installed with the following specifications (indicated diagramatically in Figure 1):

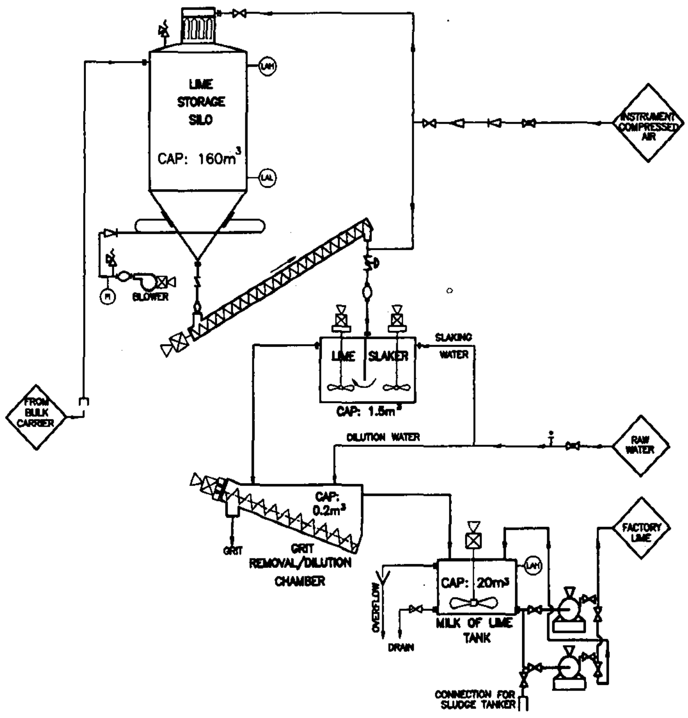

FIGURE 1 The overall process.

- A 160 m^3 cylindrical powdered lime storage silo with a four meter diameter and conical bottom of slope 55°. At 500 tons of cane/h this is sufficient powdered lime storage capacity for a minimum of three weeks. The silo is fitted with a 100 mm diameter filling pipeline and coupling, high and low level indicators, a reverse pulse dust filter and a safety relief valve. A Hibon rotary piston blower supplies air to the six aeration pads fitted to the cone of the silo. The silo discharge pipe is fitted with a 200 mm butterfly valve.
- An enclosed 150 mm diameter variable speed screw conveyor transfers the powdered lime from the storage silo to the slaking unit. The rate of powdered lime delivered to the slaking unit can be adjusted between 200 and 1000 kg/h. The 200 mm diameter discharge pipe from the screw conveyer to the slaker is fitted with a pneumatically activated butterfly valve, together with a clean air supply line and solenoid valve.
- The slaking unit has a capacity of 1,7m^3 and consists of three compartments. The two slaking chambers are each 0,75 m^3 while the grit removal/dilution chamber is 0,2 m^3. Each slaking chamber has an agitator which is belt driven by a 2,2 kW motor.

The grit removal/dilution chamber is inclined at a 30° angle with a submerged screw conveyor discharging into a 200 mm diameter down pipe.

Opposite the grit removal discharge pipe is the milk of lime overflow weir and discharge pipe. The final dilution water is added above the overflow weir via a 40 mm water line.

The slaking unit is supplied with a vent and two large hatches for easy inspection. The operating face of the slaker is fitted with the water supply piping including two pneumatically activated butterfly valves, two rotameters and five solenoid valves. The slaker is fully automated and requires no operator attention after commissioning.

- A 20 m^3 cylindrical milk of lime storage tank is located on ground level just below the slaker. This tank has a large four blade agitator driven by a 2,2 kW motor. There is a series of baffles on the tank wall that are spaced at regular intervals to ensure that thorough mixing is achieved. A high level indicator, an overflow pipe and drain valve are all standard on the storage tank.

  Two 7,5 kW motors power the centrifugal pumps that are mounted on the ground alongside the tank and are used to transfer milk of lime into the factory supply and distribution tank.
- The electrical panel stands under the silo and houses all electrical switch-gear and the Siemens PLC. Although the panel has an IP65 rating it has been enclosed in a fibreglass housing with transparent front. All the stop/start buttons and indicator lights on the panel door are thus clearly visible and easily accessible.

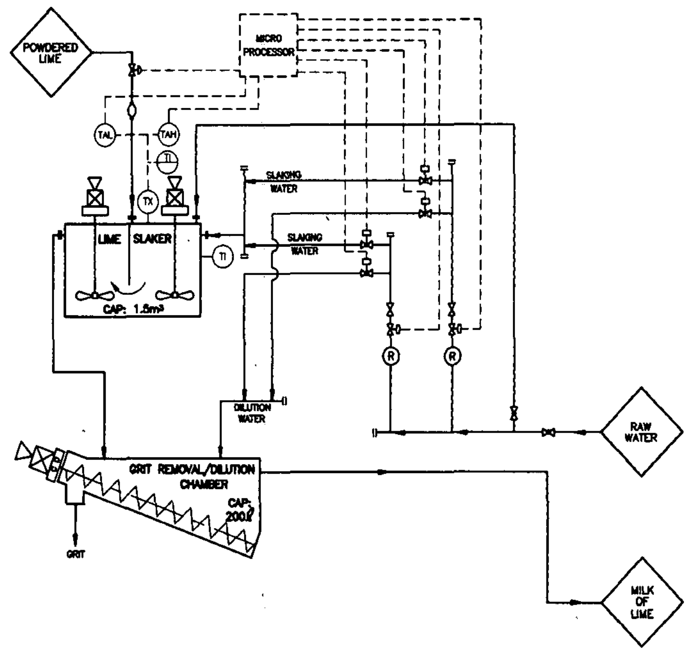

FIGURE 2 The slaking unit.

Plant operations

There are two separate operations.

Off-loading and storage of powdered lime

Powdered lime is delivered to the mill either by rail or road tanker and is then pneumatically off-loaded. If the powdered lime is delivered by rail tanker then a compressor is required to deliver air at 200 kPag and 17 m^3/min. The cost of purchasing a compressor for this operation is expensive and unnecessary if road tankers with on-board compressors are used to deliver powdered lime to the mill.

The off-loading procedure is a simple operation that is performed by the driver. The road tanker is parked as close as possible to the silo and the flexible hose from the tanker is coupled to the silo filling pipe. The compressor is then started and the tanker is pressurised to 200 kPag. The reverse pulse dust filter on the top of the silo is switched on and off-loading then begins by opening up the discharge valve from the tanker. The powdered lime is blown up the filling pipe and into the silo while the air is drawn through the filter bags and out to atmosphere. The lime dust which collects on the filter bags is shaken off by periodic pneumatic pulses at 25 second intervals. Off-loading usually takes between one and one and a half hours.

Once off-loading is complete the filter is switched off and the flexible hose is uncoupled. It is then a mill responsibility to check physically that all the lime has been off-loaded, and to record the lime tonnage from the suppliers' weighbridge delivery document.

The slaking process

The slaking process is most easily understood with an initial overview of the entire slaking operation shown in Figure 1, followed by a detailed description of the slaking reaction and controls shown in Figure 2.

A one button start is all that is required to initiate the operation. The rotary blower supplies air to the aeration pads which serves to fluidise the lime in the cone of the silo and ensures a consistent feed to the screw conveyor. Set at a fixed rate, the screw then feeds a fixed amount of lime into the first slaking chamber. Water is added to the first chamber where the initial reaction takes place.

The partially reacted product then flows under the baffle separating the two slaking chambers into the second chamber. No water is added to the second chamber, which provides sufficient retention time for complete slaking.

The milk of lime then overflows from the second slaking chamber to the grit removal/dilution chamber. The grit settles out and is removed by the grit screw while final dilution water is added to ensure that the required milk of lime Baumé is achieved. The milk of lime then overflows to the storage tank until a high level is reached, at which point the plant shuts down. The milk of lime is now ready to be pumped into the factory distribution system for use in several processes.

The slaking unit operation is based on the simple slaking reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2 + 63{,}6KJ$$

Calcium oxide + Water → Calcium hydroxide + Heat

The Baumé is determined by preset lime/water ratios that are calculated using data from Hugot (1960) as shown in Table 1. This data has been plotted in Figure 3 to allow easy calculation for any Baumé that is required.

Table 1

Lime/water ratios calculated using data from Hugot (1960)

LIME				
Baume'	Density	g CaO per litre	% CaO by mass	kg H^{2}O per kg CaO
1	1.007	7.5	0.745	133.0
2	1.014	16.5	1.640	60.0
3	1.021	26.0	2.540	38.0
5	1.036	46.0	4.430	21.6
10	1.074	94.0	8.740	10.4
15	1.117	148.0	13.260	6.5
20	1.161	206.0	17.720	4.6

(Data as per Hugot)

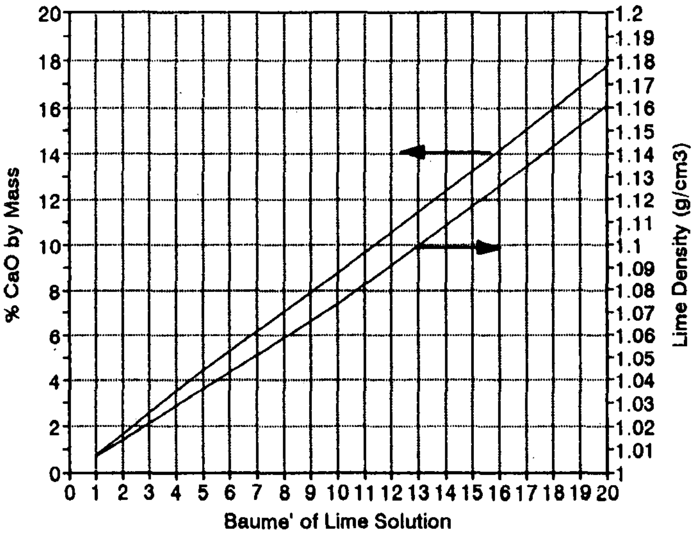

FIGURE 3 Baumé of lime solution.

At Maidstone a 10° Baumé milk of lime slurry is required to be pumped to the factory distribution tank. The juice operator then manually dilutes the milk of lime to 7° Baumé for process use. Using the last column in Table 1, a preset lime to water mass ratio of 1: 10,4 for the new plant will ensure a product of 10° Baumé.

Thus for a fixed powdered lime rate of 600 kg/h a total water flowrate of 6240 kg/h was required. After commissioning a split of 4000 kg/h to the first slaking chamber and 2240 kg/h to the dilution chamber was found to be most suitable, under normal operating conditions.

As the reaction is exothermic, temperature is used as the reaction control variable to ensure effective slaking. The slaker has four temperature limit set points that are governed by a master controller. The master set point is set at 67°C while the four temperature limit set points are set as follows:

- Very High 77°C
- High 72°C
- Very Low 58°C
- Low 62°C

Under normal reaction conditions between 62 and 72°C the water flow rates to the slaking chamber and the dilution chamber remain as set during commissioning and will do so until the temperature deviates from normal conditions. When the temperature falls below 62°C this implies that the reaction temperature is too low and the slaking water is diverted to the dilution chamber. This effectively allows more lime to mix with less water and hence the reaction temperature starts to climb until normal conditions are reached. If the temperature falls below 58°C an audible alarm sounds and the plant should be checked. During start-up this very low temperature alarm is only activated after a set time period, thus allowing the reaction sufficient time to generate enough heat.

If the temperature rises above 72°C this implies that the reaction temperature is too high and the dilution water is diverted to the first slaking chamber. This effectively allows more water to mix with less lime and hence reduces the reaction temperature. If the temperature does exceed the very high limit of 77°C then the screw feeder that supplies lime to the slaker stops until the temperature reaches normal operating conditions. This is essential as it prevents excess lime being added and choking up the slaking unit with a thick sludge.The temperature control of the slaking unit is used to direct the water to where it is best utilised, thus ensuring that the slaking reaction is well controlled to produce a consistent milk of lime product.

Installation and commissioning

The support steel work, the silo, the slaking unit and the storage tank were erected within two days, using a 60 ton crane. The mechanical and electrical installations were slightly delayed by supply and manufacturing errors and were only completed eight days later. The three days necessary for commissioning meant that the entire plant was installed and commissioned within two weeks.

Commissioning involved testing the start-up and shutdown sequences and adjusting these to suit local conditions.

Advantages

Having described the operations of the powdered lime plant, a comparison can be made with the original plant and the advantages can be highlighted.

- The off-loading of the lime is faster, safer and requires no labour. With the original plant eight labourers wearing dust masks and other protective clothing took six hours to off-load a 30 ton load. The driver of the tanker requires just one and a half hours to blow 30 tons of lime into the new silo.
- The transport costs by road tanker, including the off-loading, are 2% or R3.00/ton less than the railage costs.
- No demurrage costs are incurred at the rail siding and the delivery times for a consignment of lime have been reduced from three weeks to one week.
- The entire process is fully automated and therefore a full time lime plant operator is not necessary.
- The slaking process is temperature controlled which ensures that most of the calcium oxide is converted to calcium hydroxide, and that the milk of lime is at a consistent Baumé.

Disadvantages

There are a few disadvantages:

- The capital cost of installing a new plant.
- Powdered lime is 6,1% or R10.00/ton more expensive than rock lime.
- Although the plant is automated routine checks are required when slaking is in progress.

Is the plant cost effective?

The annual operating costs of the new powdered lime plant are compared with the original plant. These figures are based on a normal Maidstone crush budget of two million tons of cane. At 0,7 kg calcium oxide/ton of cane, this reveals a total lime requirement of 1400 tons of calcium oxide or 1550 tons of powdered or rock lime (± 90% CaO).

The additional costs of the new plant are:

- Powdered lime is R10.00/ton more expensive than the rock lime.

The savings of the new plant are:

- The lime plant attendant is no longer required. The saving in salary, medical aid, pension etc amounts to a total of R25 000/annum.
- The labour costs for off-loading the rock lime total R17 000/annum. This is based on eight labourers for six hours every week, which equates to 48 hrs/week or one full time labourer.

- The new plant contains far less equipment with no bucket elevators, two screw conveyors in place of four, two stirred tanks in place of four, one silo in place of three storage bins and far fewer motors. Thus there is a maintenance cost saving estimated at R20 000/annum.
- The transport costs of powdered lime are three rand per ton less expensive than rock lime.
- Due to the fact that powdered lime is delivered by road tanker and not by rail, there is no chance of being charged for demurrage in the event of a delay.
- The personal protective equipment used by the labourers and potential hazards such as being burnt whilst off-loading are issues that no longer need consideration by managers or supervisors. This saving is enormous but difficult to quantify.

An overall analysis shows a nett annual saving of:

Lime attendant	R25 000	
Off-loading labour	R17 000	
Maintenance reduction	R20 000	
Transport saving	R4 650	(R3 × 1550)
Less: Extra cost of powdered lime	R15 500	(R10 × 1550)
Nett Annual Saving	R51 150	

Reviewing the plant in terms of annual operating costs it is quite obvious that there is a tremendous saving which exceeds R50 000/annum. Therefore in terms of operating costs the plant is definitely cost effective.

However, is it feasible to replace an existing plant with a fully automated powdered lime plant?

The capital cost of installing the powdered lime plant at Maidstone was R540 000. Given that the nett annual saving of the plant is R51 150, the pay back period is:

Pay Back Period: R540 000 / R51 150 = 10,5 years.

A pay back period of ten and a half years shows that to replace an existing plant is not justifiable. However if a new factory was being built then a powdered lime plant would definitely be attractive.

Conclusions

The need to relocate the original lime plant to accommodate Maidstone's expansion encouraged a fresh look at an alternative. The installation of the powdered lime plant has significant advantages from both operational and financial points of view with annual savings exceeding R50 000. This particular installation has fitted in exceptionally well with the productivity improvement plan which has allowed a reduction in staff complement without sacrificing performance. Thus far the plant has proved to be a great success.

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REFERENCES

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