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Towards sustainable energy efficiency and improved throughput: gains made on Anglo Converter Process with the installation of dewatering screens

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The Anglo Platinum Converter Process (ACP) at the Waterval Smelter Complex uses high pressure water granulation to quench and reduce the particle size of the Waterval Converter slag (WACS). The granulated slag is dewatered through a dewatering bin, dried and transferred to a holding WACS silo that feeds the slag cleaning furnace. Processing of the WACS in the three bins follows a programmed sequence of filling, dewatering, discharging, and flushing. Before the installation of the external dewatering screens the dewatering process was effected through a decant valve and an internal filtrate screen situated at the bottom end of the bin. This resulted in discharging of the converter slag with a substantial amount of residual moisture to the LPG-fired dryers. With external screens in place, dewatering continues even during the discharge cycle and this results in reduced moisture content in the WACS.

The benefits of the installation of dewatering screens, underneath the dewatering bins are presented. A comparison of the dryer performance prior to, and after, screen installation is made. This comparison looks at the increased throughput of the dryers as well as the reduction in LPG consumption due to the lower moisture content of the converter slag to the dryer. Conclusions drawn from the comparison will establish the capacity gained in the granulation stream through the installation of the dewatering screens.

Introduction

The ACP situated at the Waterval Smelter Complex in Rustenburg treats all the furnace matte from the three smelters in Anglo Platinum. Polokwane and Union smelters produce cast or crushed matte (PFM and UFM, respectively). This is fed with granulated furnace matte from Waterval smelter and conveyed to ACP by conveyors and pneumatic means into holding silos and roof storage bins. It is at the converter where all platinum streams converge into one for the first time.

The ACP comprises two Ausmelt units, one operational and one standby, one double contact double absorption (DCDA) acid plant treating converter off-gas and one tower plant treating low strength furnace off-gas.

In the converter, furnace matte with high iron content is blown with oxygen-enriched air to reduce the iron to around 3% Fe in the Waterval Anglo Converter Matte (WACM). The iron oxide is fluxed with silica-rich quartz to form a fayalitic slag that contains oxidic nickel based on the following reactions:

$$FeS + \tfrac{3}{2}O_2 \rightarrow FeO + SO_2 \quad [1]$$

$$2FeO + SiO_2 \rightarrow Fe_2SiO_4 \quad [2]$$

During the oxidation of FeS to FeO and SO_2, some nickel is oxidised which then reports to the WACS. This nickel, together with entrained matte in the converter slag, is recovered through treatment in the slag cleaning furnace situated in the Waterval Smelter Complex.

The slag handling facilities prior to treating at the slag cleaning furnace (SCF) are the focus here. The process flow of material at ACP comprises four distinct sections (Figure 1). These are (i) raw materials handling, (ii) converting, (iii) slag handling and (iv) Slow Cool process sections.

Raw materials handling incorporates receiving silos, roof bin and transfer vessels for furnace matte, silica and coal. The converting section is made up of the converter and its auxiliary cooling equipment as well as tapping facilities. The slow cool section is where converter matte is tapped and cast into moulds for the slow cool process.

Slag handling system

The slag handling system comprises three distinct sections: slag granulation, slag dewatering and slag drying. The main aims of this work were to further reduce the amount of moisture in the slag coming out from dewatering bins and improve the throughput of the slag handling section. Slag granulation handles slag tapped from the converter at approximately 3–7 tons per minute. This slag is tapped at a temperature of about 1 280°C to 1 350°C and is directed into a granulation tank via a water-cooled copper launder where a high-pressure water jet hits this stream of molten slag. The water shatters the molten slag into small particles (58.65% retained on 1 mm and 0.52% minus 0.1 mm) which drop to the bottom of the granulation tank where they are further cooled by the water in the tank (Figure 2). The particles that have collected at the bottom of the tank form slurry of 16% solids that is pumped to the dewatering bins for the removal of granulation water.

Granulated slag in the form of slurry is pumped

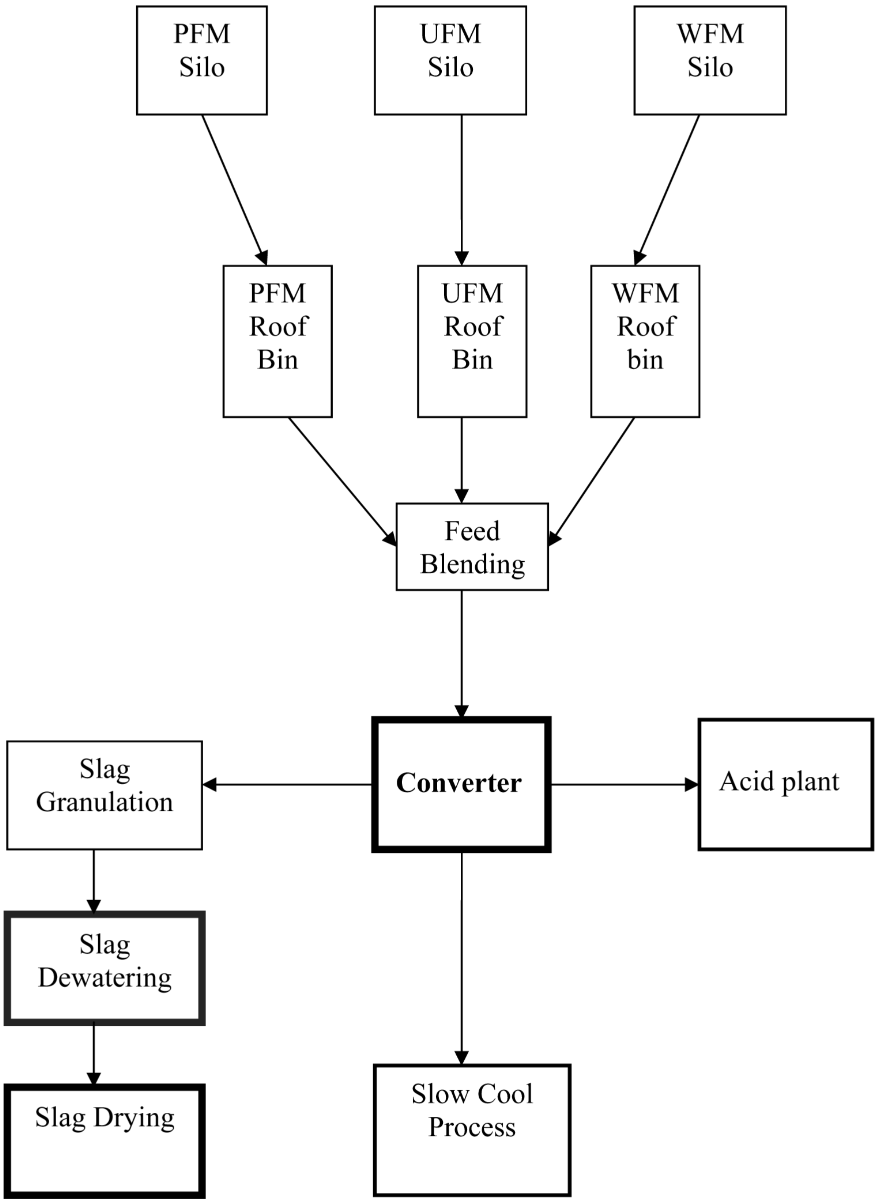

Figure 1. Anglo Platinum converter process flow-sheet

alternately into one of the three dewatering bins each holding on average 720 tons of WACS slurry, of which up to 120 tons is slag. The slurry characteristics are fairly consistent owing to the closely controlled water flow of 1 500 m^3 per hour for a slag flow of 5 tons per min. Each of the bins is fitted with a stainless steel internal screen with 20 mm × 2 mm apertures to effect dewatering of the slag (Figure 3). The bulk surface area of each of the internal screens is about 8.5 m^2. As one bin is dewatering the second is discharging, while the third one is waiting to be filled or is being filled. This sequence is carefully programmed such that there is no delay in slag tapping and that no two bins may be executing a similar sequence at the same time.

Bin sequences

The bin sequence is the order of events taking place in each of the three bins to allow for the transfer of tapped slag from the converter to the dryers. The sequences are defined in Table I and the average period for each sequence was taken from observations in the plant under normal operating conditions.

Each of the three dewatering bins executes all the defined sequences in the order they are given. Filling can only happen to one bin and this is a function of the slag tapping. Once the filling is complete, dewatering automatically starts and takes about 120 minutes. The bulk of the water is decanted from the bin through a valve above the slag layer. As the rate of change slows down, the operators begin to intermittently open the pinch valve at the bottom of the bin to 9% open to release the water below the decant valve just before starting to discharge the dewatered slag. A bin will wait to discharge only when there is another bin that is still discharging, as no two bins can discharge at the same time. Discharging starts as soon as dewatering or waiting finishes and the rate is determined by the dryer feed rate. It takes on average 180 minutes to discharge a 120 ton slag tap. The combined peak feed rate of the two dryers is 48 tons per hour. After the bin completes discharging it goes into a standby sequence waiting for another slag tap and the cycle starts over again.

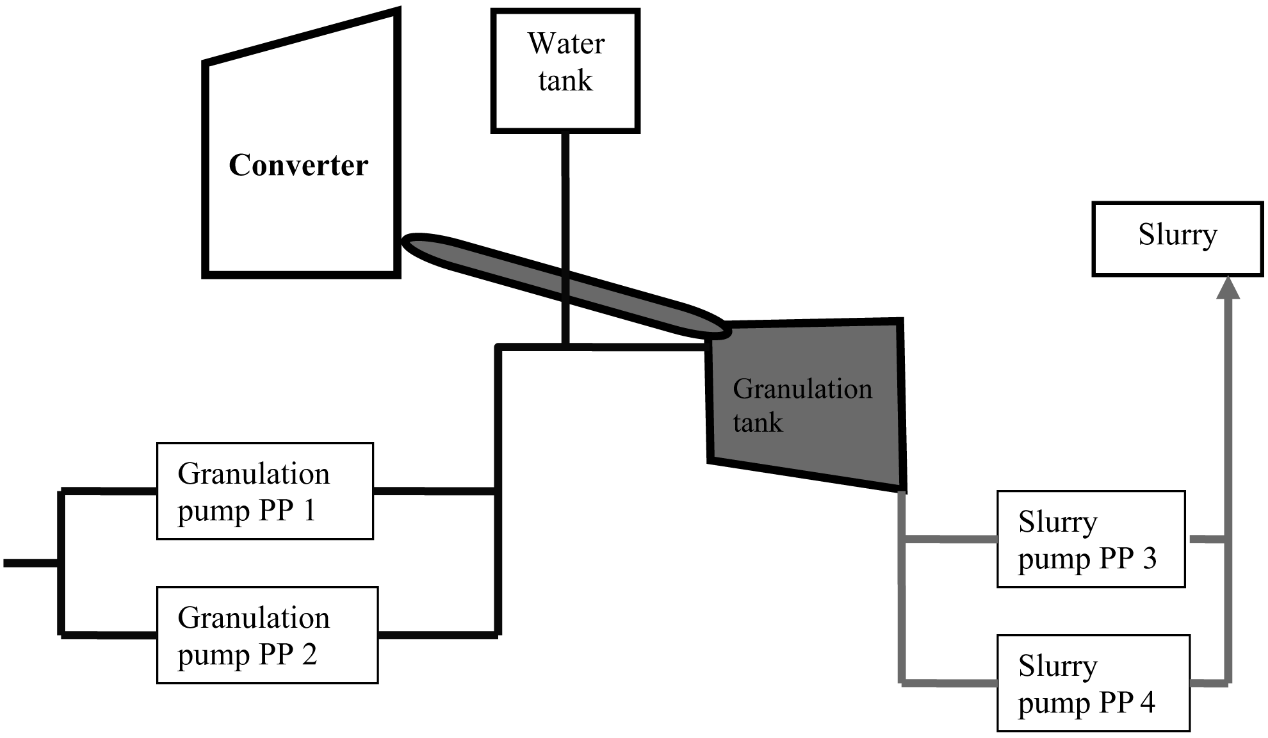

Figure 2. Slag granulation process flow-sheet

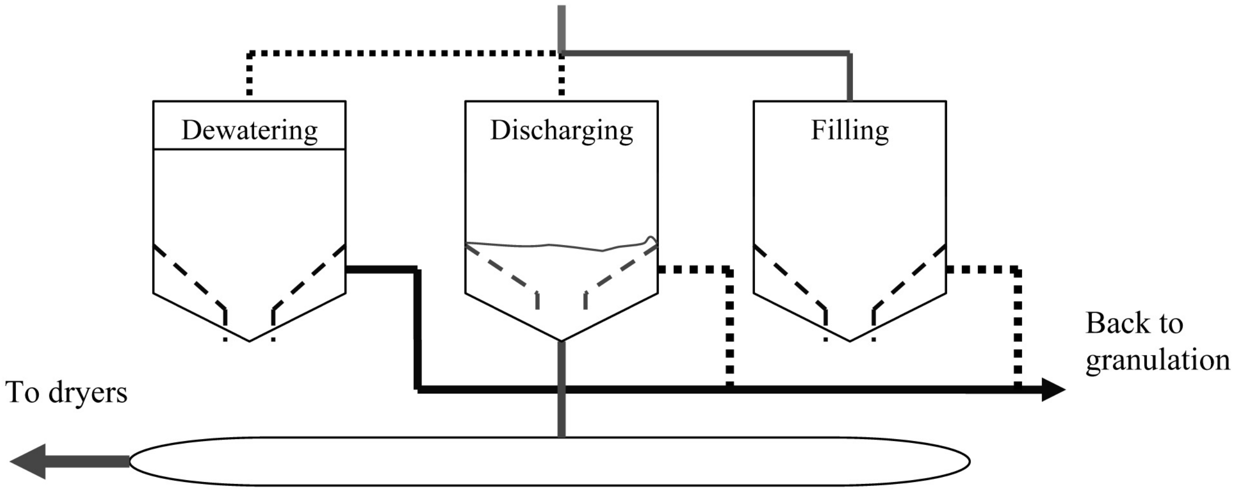

Figure 3. Configuration of dewatering bins

Table I
Definitions and average times of dewatering sequences

Sequence number	Sequence name	Definition	Average time (min)
1	Filling	Filling of bin with slurry	45
2	Dewatering	Filtration of water by means of screens	120
3	Waiting	Waiting to discharge	45
4	Discharging	Discharging of dewatered slag	180
5	Standby	Waiting for filling with slurry	40
	Cycle	Total time to complete all sequences	500

Dewatering modifications

In February 2008, each of the three bins was fitted with a rectangular dewatering screen below the bottom discharge valve (Figure 4). The main purpose was to further remove water from the slag being discharged to the dryers.

The dewatering screen deck measures 3 355 mm × 610 mm, giving a bulk surface area of 2.0 m^2 with apertures of 9 mm × 0.3 mm slotted on poly panels. Each screen deck is fitted with two 3.5 kW vibrating motors with a 4.3 mm stroke. The purpose of the screens is to separate water from the slag discharged during pulsing and further remove water from the slag during the discharge sequence. The external vibrating screens have an added advantage to the dewatering circuit in that vibrations are more effective in removing capillary water than stationary screens.

Samples taken from point Bn (Figure 4) represented the moisture content of the slag before installation of the screens while those taken at point Sc indicated the moisture content after the new screens. Sampling was done by using a spade sampler which was pushed into the stream to cut a sample of mass 1 500 g to 2 000 g taken at times 0, 30, 90, 180 min after dewatering finish. This exercise was performed for a short period between March 2008 and May 2008 after the January shutdown when conditions were close to normal operating conditions. When the slag was not discharging to the dryers, samples were not taken.

The impact of the dewatering screens was determined by the difference in the moisture content of sample taken between points Bn and Sc. The whole basis for the moisture reduction and saving on LPG consumption comes from calculation based on the figures measured from the two points.

Drying of dewatered slag

The slag is conveyed to the surge bin which feeds into two hoppers feeding two LPG-fired dryers operated in parallel. Control philosophy of the dryers is such that air at 550°C in the burner is used to drive out moisture as well as pneumatically convey the dried slag into a holding silo. The exit temperature of the air and slag is controlled to between 80°C and 120°C. If the temperature falls below 80°C, the feed rate of wet slag into dryer is reduced to maintain a minimum of 80°C. If the exit temperature goes beyond 120°C, the feed rate is increased so as to maintain the temperature below 120°C. This temperature control is a function of moisture level variation in the feed dewatered slag.

Energy calculation assumptions

The energy required for drying the slag is calculated from the assumption that preheated air at 550°C imparts heat to capillary water on the slag particle surface until the water is evaporated. During the process, part of the heat is used as enthalpy to heat up the solid slag from 25°C to about 120°C. Coupled with enthalpy required to heat water from 25°C to 100°C, change state of water from liquid to gas and heat steam from 100°C to 120°C, the total enthalpy of the system is equivalent to energy required for drying a specific mass of slag of specific moisture content.

Results

The two response parameters which were monitored after the installation of the dewatering screens were:

- Moisture content
- Dryer specific LPG consumption.

The moisture content as measured at the point Bn (Figure 4) on all the three bins was compared with moisture content measured at point Sc.

Moisture content

The average moisture content of the slag as it feeds into the external dewatering screen drops with time. The weighted average moisture content for the bin samples which represented moisture before installation of screens was 6.3% (Table II and Figure 5).

The spread of the moisture content from 14 % to 47% in

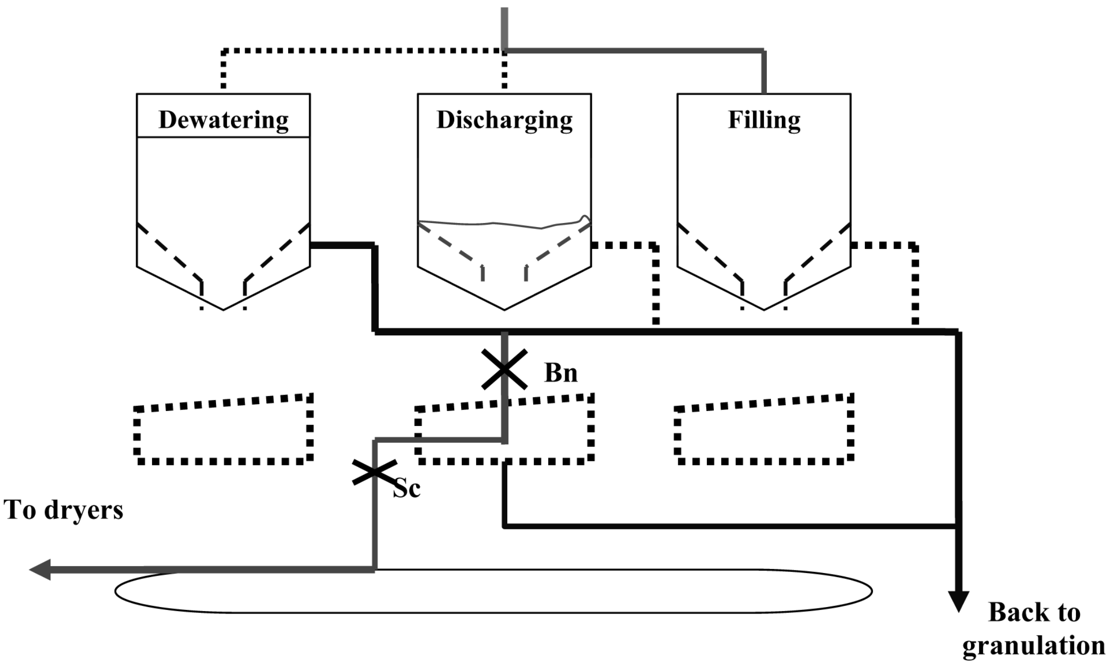

Figure 4. Position of external dewatering screens relative to original setup

Table II
Moisture content (mass %) from three bins before installation of screens

Time (min)	Bin 1 moisture (%)	Bin 2 moisture (%)	Bin 3 moisture (%)	Average moisture (%)
0	27.7	46.8	13.1	29.2
30	4.9	11.3	7.1	7.8
90	3.2	7.3	5.2	5.2
180	2.8	2.7	5.2	3.5
Weighted average moisture content				6.3

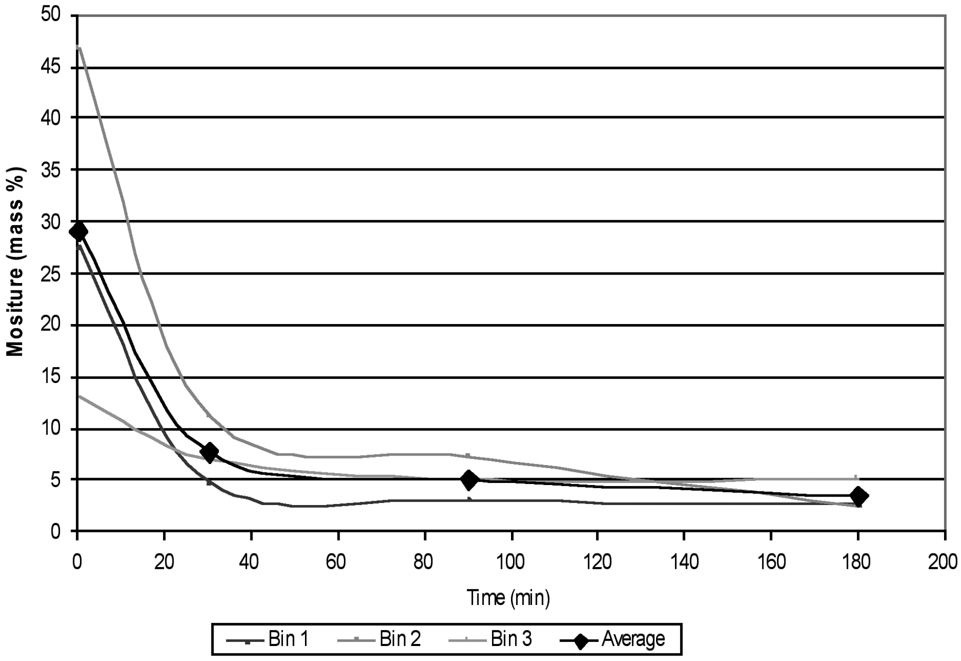

Figure 5. Reduction in moisture levels with time before installation of dewatering screens

Table III
Moisture content (mass %) of slag after installation of screens

Time (min)	Screen 1 moisture (%)	Screen 2 moisture (%)	Screen 3 moisture (%)	Average screen moisture (%)
0	8.54	11.9	8.08	9.51
30	4.64	5.68	5.37	5.23
90	2.81	4.55	4.73	4.03
180	2.4	2.28	3.85	2.84
Weighted average moisture content				4.1

the slag as measured from the three bins indicates the state and performance of the internal screens as well as control and judgement by the operators. This also indicates different effectiveness of the internal dewatering screens between the three bins (Figure 5).

Moisture content measurement of the samples taken at the discharge end of the dewatering screens (Table III and Figure 6) show a lower initial value compared to those in Table II. This indicates that most of the water released from dewatering bin during pulsing is separated from slag by the screens. Before installation of the screens, this water could have reported to the dryers and exert a significant thermal load on the dryers.

The maximum moisture content of screen discharge at time 0 min. was shown to be 12% (Table III and Figure 6). This is a very significant reduction in moisture from 45% when the slag was discharged from the bin 2. The weighted average moisture content of the screen discharge was calculated to be 4.1%.

The moisture content of samples taken from dewatering bins and screens show a sharp decrease in the first 40 minutes. Thereafter the moisture decreases slowly to levels just under 5%. Average moisture contents of the bin and screen samples are shown in Figure 7. The average bin samples contained 30% moisture while the screen samples contained about 10% at the beginning of the discharge at time 0.

Combination of results before and after installation of the dewatering screen clearly brings out the impact of dewatering screens on moisture reduction (Figure 7). The widening of the range between two moisture contents from time 40 min, back to time 0 justifies the installing of the external screens to capture water discharged at pulsing and initial stages of dewatering. The 2.2% difference in

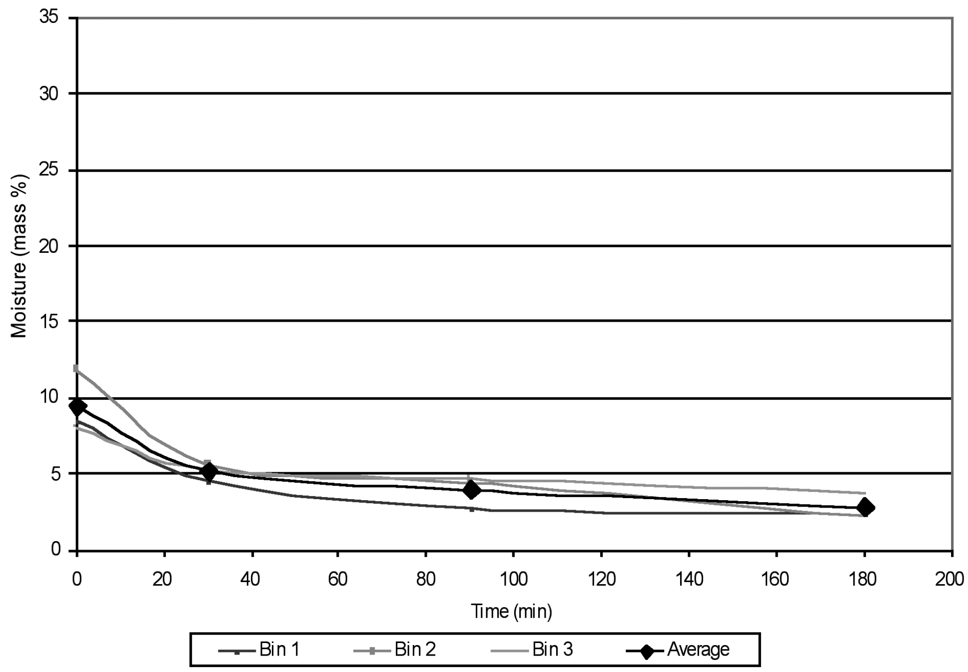

Figure 6. Reduction in moisture levels with time after installation of dewatering screens

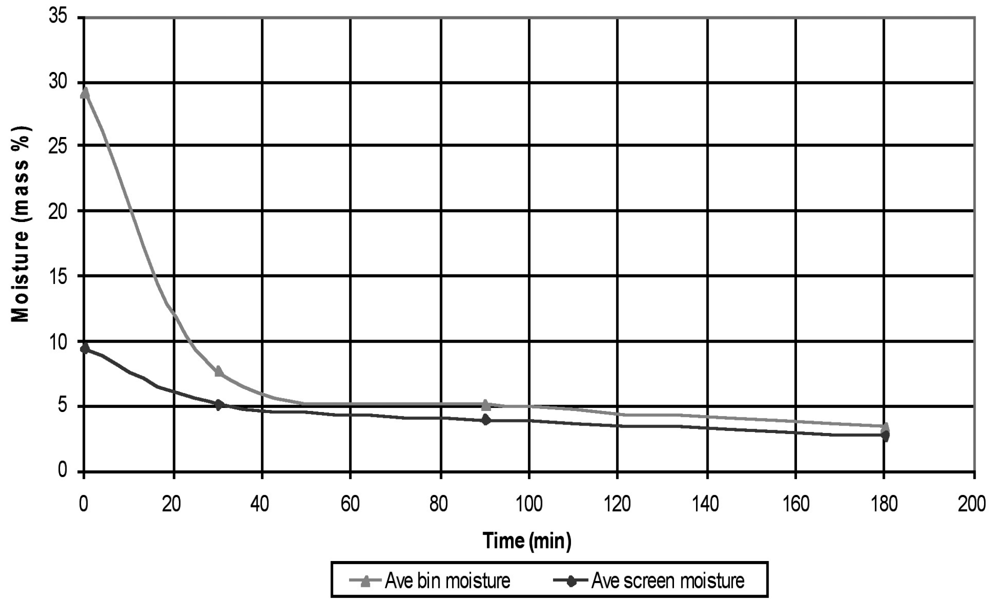

Figure 7. Moisture level reductions with time after dewatering screen installation

weighted average moisture content between bin and screen samples translates to a 34.9% reduction in moisture.

LPG consumption

A comparison of LPG consumption before and after installation of the dewatering screens is shown in Figure 8. There is a slight noticeable reduction in specific LPG consumption from February to May which is the period after the installation of the dewatering screens. The average LPG specific consumption for September 2007 to January 2008 was 6.1 kg per ton slag dried while that for February to May 2008 was 5.6 kg per ton of slag dried. This translated to a 0.5 kg per ton saving in LPG consumption.

Theoretical specific LPG consumption was calculated by comparing energy requirements for drying two slag samples at 6.3% and 4.1% moisture assuming the same conditions of burner settings and slag feed rate as explained previously. The calculation showed that a 1.2 kg per ton LPG saving was realised by reducing moisture content from 6.3% to 4.1%. This saving on LPG consumption translated to a R1.5 million per year cost saving, assuming a 40 ton per hour average feed rate through the two dryers.

Capacity improvement

The installation of new external dewatering screens added a further benefit over the primary moisture reduction of increased capacity to the slag handling system. Detailed optimization work on the capacity improvement is not part

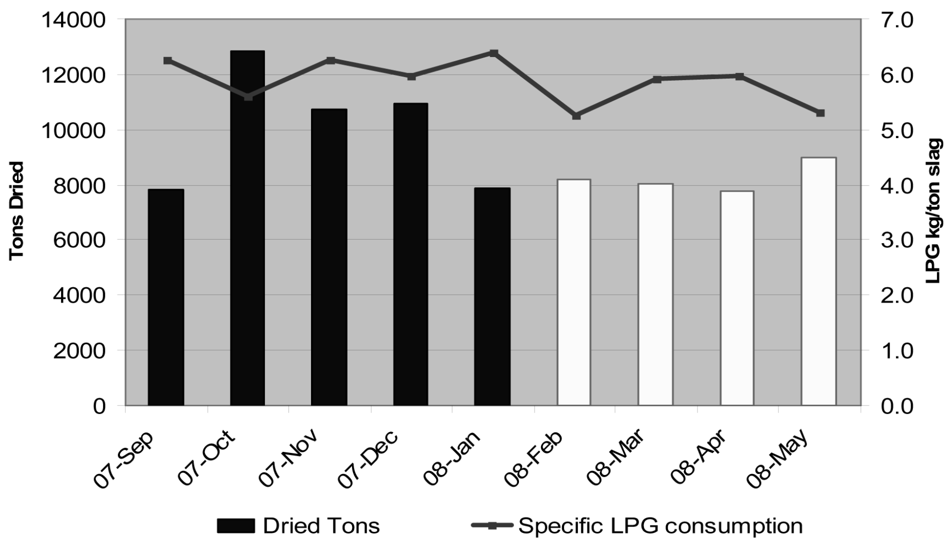

Figure 8. Comparison of Dryer LPG consumption for periods before and after dewatering screens installation

of this report but preliminary analysis of the flexibility of dewatering controls has shown some capacity increase of the dewatering circuit.

The original operating philosophy of the dewatering bins was that operators had to wait for the dewatering stage to complete and for the bin sequence to step into the 'waiting' stage before the bin could be pulsed (pinch valve intermittently opens to 9% for 30 seconds). The bin could only be discharged once the operator visually confirmed that no water flowed through the discharge pinch valve at the bottom of the bin during pulsing.

Since the installation of the external screens, the bin sequences have been changed so that the bins are pulsed automatically in the dewatering stage once the rate of change of the bin weight slows to indicate completion of the dewatering sequence. This means that the slag is discharged earlier even if the dewatering sequence has not completely finished due to the fact that excess water in the slag will be removed by the external dewatering screens as observed in Figure 7. The sequence now also does not have to wait for operator intervention to be manually moved into the discharge mode as this step can now be automated. This decision was informed by the observation of different moisture content between bin and screen samples (Figures 5–7).

Discussion of results

The installation of the external dewatering has resulted in significant benefits being realized. It has also opened new opportunities for the study of the slag handling system capacity.

Moisture reduction

A clear moisture reduction due to the installation of dewatering screens is demonstrated (Figures 5–7). The biggest benefit is realized during the first 40 minutes of discharging where water released during pulsing and at initial stages is captured by the newly installed screens. From 40 minutes until the end of discharging there is a consistent moisture reduction across the screens. The performance of the three dewatering bins showed some apparent difference in internal screen performance. This is due to the fact that the internal screens sometimes get blinded and the level of water reaching the external screens is therefore excessive. The inefficiencies of the internal screens make the installation of the external screens a worthwhile investment realising a 34.9% reduction in moisture content in the slag.

LPG consumption

The measured specific LPG consumption from September 2007 to May 2008 showed a 0.5 kg per ton savings due to external screen installation. This is compared with a 1.2 kg per ton saving from a theoretical calculation. The difference between the two figures can be explained by the inherent equipment-related inefficiencies that are always experienced in real life.

In terms of financial savings, the observed specific LPG consumption savings translates to over R0.5 million per year while the theoretical calculation suggested a R1.5 million per year saving.

Capacity study

The new operating philosophy of the dewatering bins has benefited from the installation of the screens, in that dewatering times are shorter and discharging of the bins can start earlier. The overall effect is shortening of bin cycle times with the resultant effect that the converter can tap slag more frequently than before. This significantly decreases the dewatering time of the bins by about 30 min. on average, thereby shortening the combined cycle times of the dewatering bins by about 90 min., translating to extra capacity on the slag handling system.

Conclusions

The installation of the external dewatering screens has achieved its intended purpose of moisture reduction to the dryers. The secondary benefit of lower specific LPG consumption has been demonstrated, but the measured saving remains lower than predicted. Installation of screens has improved the flexibility in the handling of the interface between dewatering and discharging sequences since discharging may begin before dewatering is fully complete. Extra capacity of the slag handling facility has been achieved with the aid of the dewatering screens.

Recommendations

Benefits due to the installation of the dewatering screens can be accurately quantified if the burner efficiencies of the burners and dryers are improved so that energy is used predominantly to dry the slag.

Further work on the burner control needs to be done so as to realize the full benefits attributable to installation of the dewatering screens. This must start with the installation of accurate LPG flow-meters which will be used to determine accurate quantities of LPG consumed per time period.

A weightometer needs to be installed on the conveyor to the feed bins so that an accurate mass of slag fed to the dryers is measured.

Regular flushing of the internal screens improves the efficiency of the whole dewatering circuit.

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