Collaborative Technology Development – Design And Operation Of The World's Largest Stirred Mill

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Abstract. Since late 2003, Anglo Platinum has been operating the world's largest stirred mill at their Western Limb Tailings Retreatment Project near Rustenburg in South Africa. The mill is a 2.6 MW, M10,000 IsaMill which was a development of the 1.1 MW M3,000 machine. Only 16 months was required from project kick-off to commissioning – a considerable undertaking in view of the large scale-up step. A novel collaborative development approach was taken between Anglo Platinum and Xstrata as a vehicle for robust technology advancement.

The IsaMill has operated successfully since commissioning in terms of product size, scale-up and mechanical availability. The M10,000 used new designs to reduce internal component wear rates compared to previous IsaMill designs and the relative operating costs of the large IsaMill models (M3,000 and M10,000) are discussed. Laboratory, pilot and full scale operating data is used to validate the success of this installation.

1 INTRODUCTION

Anglo Platinum commissioned the first large scale tailings retreatment facility in the South African platinum industry in December 2003. The facility (known as the Western Limb Tailings Retreatment Project – WLTRP) uses modern concentrator technology to recover PGM's from dormant tailings dams.

Pilot test work demonstrated the need for inert media regrinding of rougher concentrates before cleaning, to produce a smeltable concentrate grade. IsaMill technology was selected to regrind rougher concentrate to 90 per cent passing 25 μm. Due to the scale of the WLTRP, the regrind power requirement was significant at 2.2 MW absorbed. For this duty, Anglo Platinum and Xstrata developed a larger IsaMill; the M10,000.

2 COLLABORATIVE DEVELOPMENT OF TECHNOLOGY

2.1 Introduction

IsaMill Technology was first developed at Mt Isa in the mid 1990's when a major research program was undertaken by MIM as it was then known (now Xstrata) to enable fine grained ore bodies to be economically developed. The first installation of the technology was at the Hilton Concentrator in 1992. This machine was an M500 with a 205 kW motor. The machine that was ultimately developed as an economic full scale machine was an M3000 IsaMill, with a 1.12 MW motor.

Initially, two M3000 IsaMills were installed in the Mount Isa lead/zinc concentrator in 1994. This was then followed with four M3000 IsaMills in the McArthur River concentrator in 1995 [4]. These were required to achieve ultrafine grinding for liberation of fine grained minerals and then achieve good separation of the minerals by flotation, after ultrafine grinding.

The subsequent development of the 2.6 MW M10,000 in late 2002 meant that in just 10 years since the first unit was installed in an operating plant at Hilton Concentrator, the units have increased their capacity 13 fold from 205 kW to 2.6 MW and their volume has increased 20 times.

Further to this, and the focus on this section of the paper, the design, fabrication, installation and commissioning of the project for the capacity increase from 1.12 MW (M3000) to 2.6 MW (M10,000) took only 16 months; an incredibly short time frame.

The project was initiated during a range of meetings between Xstrata Technology (or MIM Process Technologies as it was then) and Anglo Platinum. The scale up was always contemplated by both Netzsch and Xstrata as a future plan, even during the early development of IsaMill at Mt Isa, however it was brought forward as a focused development by a need of Anglo Platinum. The project had an aim to develop a larger IsaMill that has a higher capacity than two M3000 Isamills for a similar capital and operating cost.

2.2 Driving Forces behind the Development

The reasons behind each company being involved in this collaborative development were all different. Anglo Platinum were trying to reduce capital cost for equipment and foresaw potential applications of large scale stirred milling requirements for whole of ore applications in their concentrators in the future. Anglo Platinum also had a current project with a specific application that deemed it necessary for an IsaMill with over 2 MW of grinding power.

Xstrata Technology had considered this development to be a natural expansion of the marketed product range. There were also a number of internal projects that were under consideration at the time which envisaged use of larger scale IsaMills. To have the technology developed in this way under a collaborative development with an external client was clearly seen as bringing benefit to Xstrata. Finally, for Xstrata the application of IsaMills was limited due to the size of the largest existing available machine (1.12 MW). For large concentrators with whole of ore, or high tonnage regrind applications, having a significant number of smaller M3000 machines was not considered desireable from a capital, operating and maintenance perspective.

For Netzsch, the long established IsaMill manufacturer, the appeal was more from a challenge to their technical expertise and improved demand for their products.

2.3 Collabarative Development Process

The Process used for the design of the M10000 development was very unique. It was a major departure from all previous technology developments which were performed in house within Xstrata, and given the developments underway within MIM at this time it was quite incredible that it actually happened.

The process used was to first crystallise the need of the customer. Considerable time and effort by both Anglo Platinum and Xstrata Technology was involved examining the application, the requirements for regrinding and the potential of IsaMill to handle the duty. The result from this was the “Defined Application”. The second step was for Xstrata Technology and Netzsch to examine the potential for the M3000 to be scaled up to meet the needs of the “Defined Application”. This was conducted by initially Xstrata and Netzsch to individually review the requirements and then come together for a meeting to discuss and agree on the scale up mechanism, and the recommended machine size.

The final part of the collaboration involved Anglo Platinum undertaking an Engineering Review of IsaMill Technology and this involved a visit and audit of Netzsch’s manufacturing and engineering facilities in Germany.

These three process steps resulted a signing of The Collaborative Development Agreement on October 5th 2002 between Anglo Platinum and Xstrata.

3 DESIGN

3.1 Project Description And Pilot Testing

Anglo Platinum investigated the retreatment of dormant tailings dams in the Rustenburg area in 2000. Given market value of platinum and palladium and US dollar exchange rates at the time, the concentration of PGM minerals in the dams represented a major economic resource. Metallurgical test work identified that a significant proportion of these minerals could be recovered via fine grinding and flotation.

The pilot scale program was developed to confirm concepts previously identified during laboratory scale testing [2]. The laboratory tests suggested that the recovery of PGM’s from the tailings dams was sensitive to the grind size presented to flotation. Pilot tests confirmed this, showing PGM recovery in rougher flotation was 10 % higher with a primary grind of 90 % passing 75 μm, than with 80 % passing 75 μm. Significantly, flotation kinetics increased with the finer grind and the additional liberation of PGM’s and associated base metal sulphides.

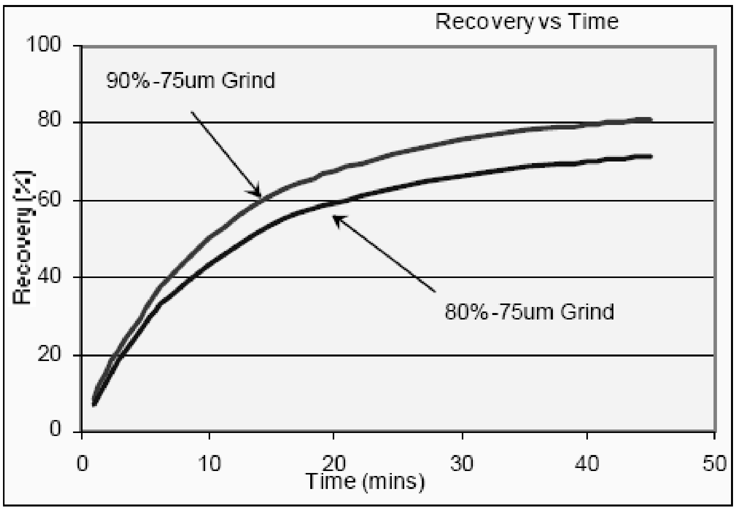

Figure 1: Flotation kinetics as a function of grind size

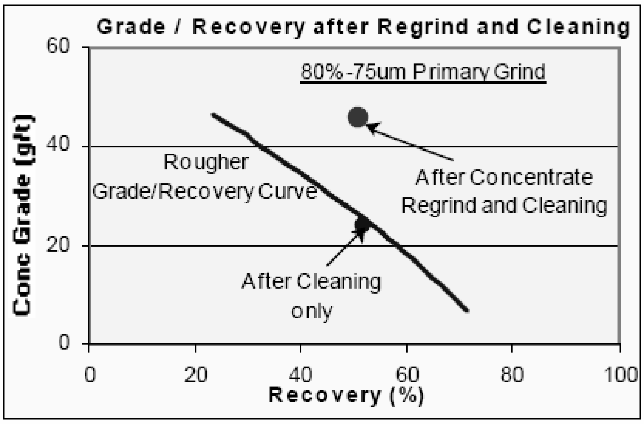

Figure 2: Conventional cleaning vs inert regrind and cleaning

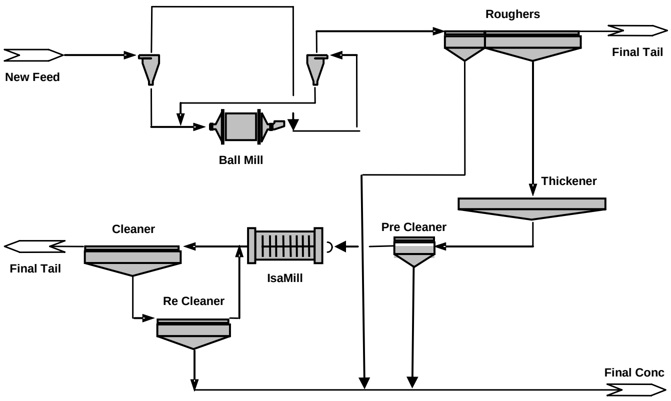

Figure 3: Simplified WLTRP flow sheet

Mineralogical examination showed poor upgrade potential of the rougher concentrate, due to insufficient liberation and oxide coatings on base metal sulphide surfaces. A conventional cleaner /recleaner circuit was not able to shift the grade /recovery curve, so regrinding of the rougher concentrate was employed to improve PGM liberation and freshen-up the heavily weathered mineral surfaces.

The main findings from the pilot plant results were [2]:

- The PGM grade and recovery targets could be met with the use of conventional flotation and IsaMill inert grinding.
- A primary grind of no less than 80 % passing 75 μm, and rougher concentrate regrind of no less than 85 % passing 25 μm is required to meet the grade /recovery targets.

IsaMill technology was enabling for the WLTR project, as smeltable concentrate grades could be produced from the oxidised, slow floating tailings.

3.2 Application

The WLTR concentrator has a capacity of 4.8 Mtpa, and has been designed to easily expand to 10.8 Mtpa. The flow sheet includes recovery of tailings by high pressure water monitoring, ball milling, rougher flotation, rougher concentrate regrinding and cleaner /recleaner flotation [1]. The process design called for an IsaMill nominal feed rate of 53 th^{-1} and maximum 65 th^{-1}. The production of a P_{90} = 25 μm required 35 $kWht^{-1}$ using -5 +3 mm local silica sand. The IsaMill product is fed to a two stage cleaning circuit to produce final concentrate [3].

3.3 IsaMill Design

Phase 2 of the WLTR Project (pending) requires the IsaMill to treat a far coarser feed size. Because of this, and to reduce process risk with the first installation, a variable frequency drive was installed.

The previous method of scale up (to the 1.1 MW M3,000 size) was based on conservation of power intensity. With the larger M10,000, the media agitator (grinding disc) tip velocity would be excessive using this method. A 'constant tip velocity' method was developed which proved more complex than power intensity models, as power does not scale-up linearly with volume.

The larger diameter of the M10,000 required modifications to the design of the Product Separator; a centrifuging /pumping device that classifies the mill product (and retains grinding media). As centripetal acceleration decreases with increasing diameter (at constant tip speed), and pumping efficiency decreases with lower radial velocity, both the centrifuging and pumping actions of the Separator had to be re-designed. The new design focused on improving efficiency of the rotor suction region, rotor pump finger shape and product classification efficiency [1].

Component and materials selection was vital to the operating cost competitiveness of the new mill. A key design aspect was to control disc wear, and the design proposed that the disc surface abrasion rate was within 3 % of the M3,000 mill's rate. As the M10,000 disc design was larger in diameter and thickness, the increased volume of rubber would mean a longer disc life than in the M3,000, as abrasion rates are a function of area and the power density per unit area would be lower.

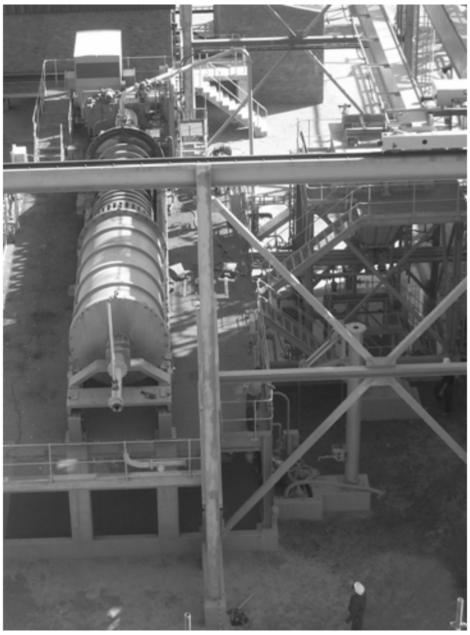

Figure 4: 22 x 11 m footprint of WLTR M10,000 IsaMill grinding circuit

4 OPERATION

4.1 Scale Up

The theoretical power draw can be calculated for a given volume, media filling and disc tip speed. With a fixed speed mill, the accuracy of the power calculation can only be verified at a single point. The power based scale up calculations could be verified over a wider range than usually possible, due to the use of a variable speed drive with the WLTRP M10,000. At the time of testing the power scale up, the IsaMill power draw had been reduced by operating at a lower media volumetric filling of 56 % (calculated). The IsaMill feed tonnage was well below design, so the mill was turned down to avoid over grinding. This explains why the motor power draw in Figure 5 is lower than normal. The actual motor power draw at different mill speeds is within a 2 % error band of the scale up calculation.

Test work on similar Anglo Platinum Merensky tailings material was conducted at laboratory scale in 2001. A range of tests were performed, at varying feed sizes and energy inputs. The grinding data for a laboratory test is compared to survey data of the M10,000 at similar energy input (Table 1). Allowing for minor differences in the ore samples, the milled products should exhibit similar particle size distributions as the mineralogy is broadly consistent and the same grinding media (-5 +3 mm local crushed silica sand) and specific energy were used.

The M10,000 exhibits marginally better top size control, and a narrower overall product PSD. The CSI (Coarse end Size Index - or P_{98} : P_{80} ratio) is 2.6 for the M10,000 whereas the CSI for the laboratory mill is 3.0.

The M10,000 scaled up accurately, both in terms of power and product PSD. Power efficiency appears equal to the laboratory mill, with control of the product PSD marginally better.

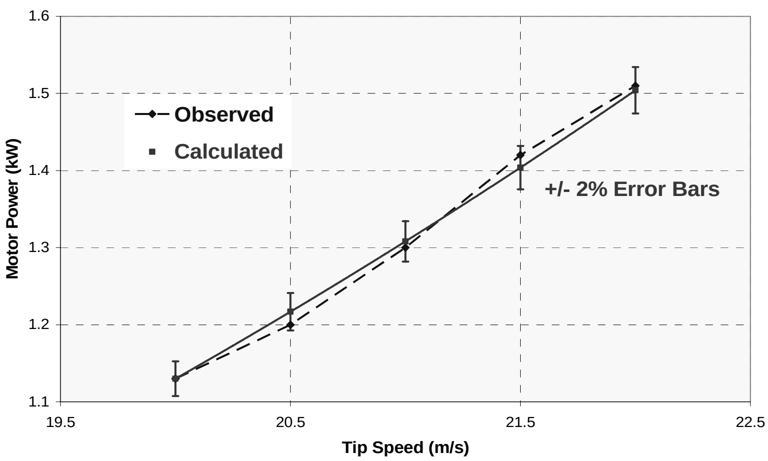

Figure 5: Theoretical vs actual motor power at varying disc tip speed

Table 1: Laboratory vs Full Scale Grinding Efficiency

IsaMill Model	Installed Power (kW)	Chamber Volume (L)	Specific Energy (kWh/t)	Pulp % Solids	P_{98} (μm)	P_{80} (μm)
M4	4	3.5	37	39	47.5	16.0
M10,000	2,600	10,000	37	42	42.5	16.5

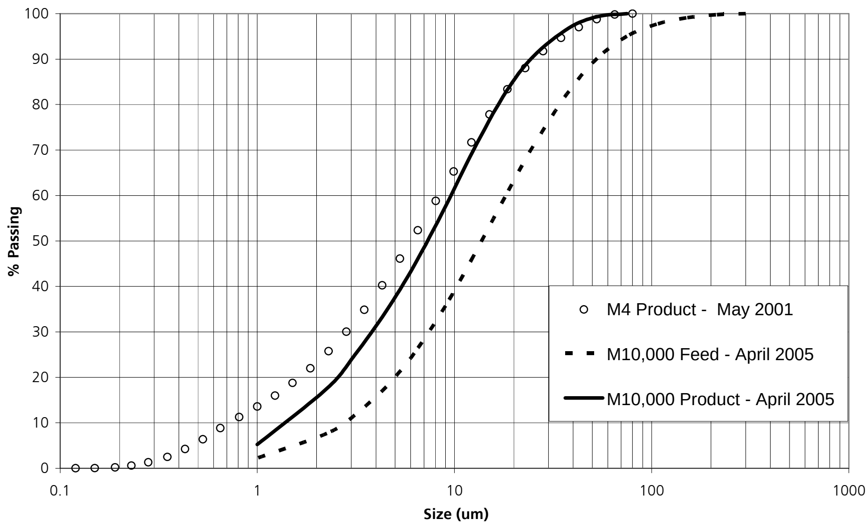

Figure 6: M4 vs M10,000 Product PSD

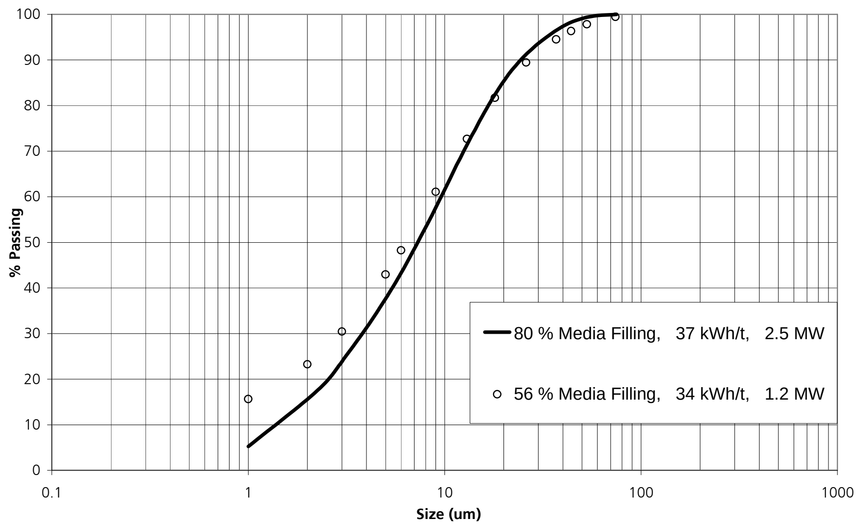

Figure 7: M10,000 turn down capability

4.2 Turn Down

Section 4.1 describes the M10,000 operating at low power (< 50% of installed motor capacity) by reducing the media load in the grinding chamber. This method of power control is common to all IsaMills. Decreasing power by reducing media load, or 'turn down' is necessary in single mill grinding lines to avoid over grinding (and over heating) during periods of low feed tonnage. Turn down would be important to the WLTRP, as the rougher flotation mass pull would fluctuate with head grade. Figure 7 shows the M10,000 operating at similar energy inputs, but greatly different power draws. Despite these extreme operating situations, the IsaMill produces the same P_{80} in both cases.

4.3 Flotation

A series of IsaMill on /off tests were performed between August and October 2004, to confirm the effect of fine grinding on flotation [5]. Figure 8 shows the impact of fine grinding on final concentrate grade, by plotting the IsaMill on /off data pairs over time. Only data pairs that represent a full 24 hour period (of

Table 2: Mean final concentrate and cleaner flotation tail grades

IsaMill Status	Final Conc (g/t)	% Change	Cleaner Tail (g/t)	% Change
On	57.3	+ 42 %	3.05	- 28 %
Off	40.4		4.26	

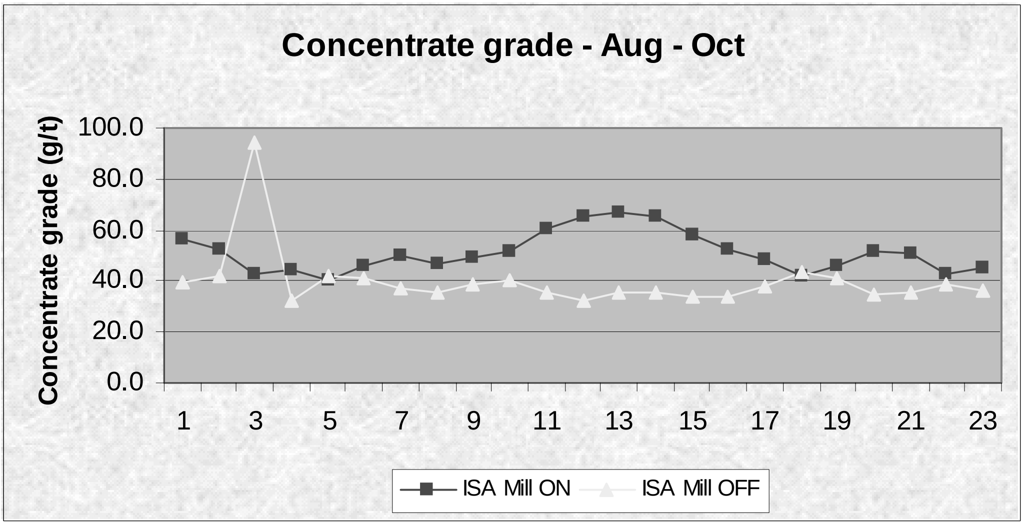

Figure 8: Impact of IsaMill on final concentrate grade

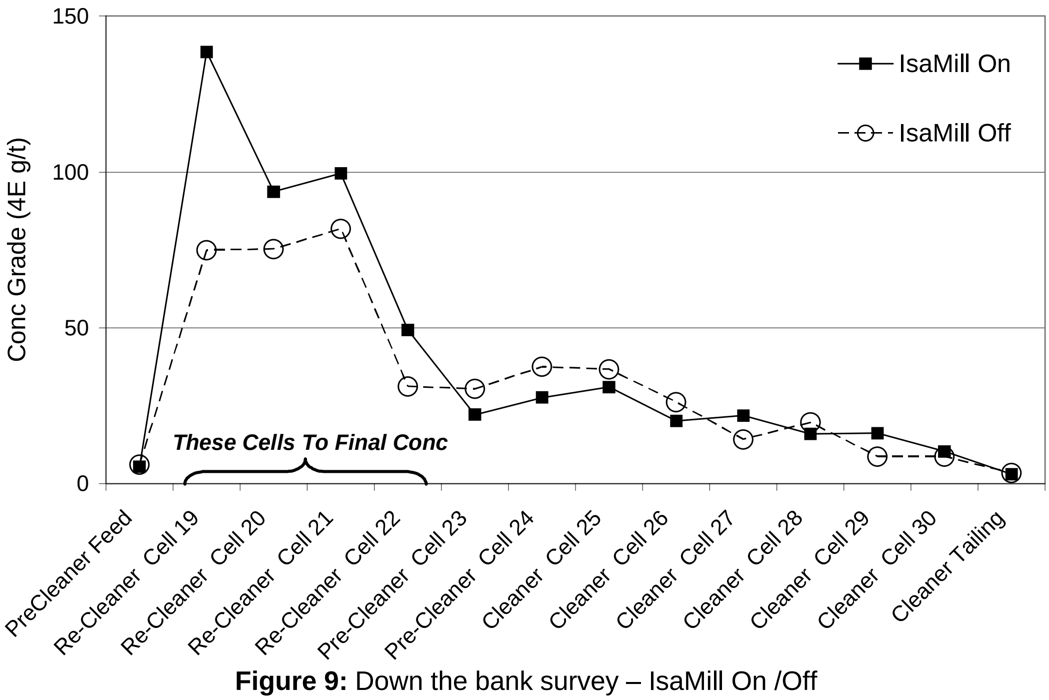

Figure 9: Down the bank survey – IsaMill On /Off

either on or off) are used. Table 2 lists the mean data from the test period, for final concentrate and cleaner tail grade. All PGM grades are built up 4E assays (Pt + Pd + Rd + Au). The effect of regrinding the rougher concentrate was in line with pilot plant findings as the IsaMill had to be operating for the plant to achieve target final concentrate grade (50 g/t 4E).

The higher flotation kinetics and improved PGM liberation that come with regrinding the rougher concentrate, resulted in higher concentrate grades in the recleaner circuit. As the recleaner concentrates report to final concentrate, the ability to maximise the grade in these cells is vital to meeting overall concentrate specification. The difference in recleaner concentrate grades with the IsaMill on or off is detailed in Figure 9 which shows a down-the-bank survey. Cleaner flotation grade and recovery is improved with IsaMilling.

4.4 Maintenance, Availability and Operating Cost

Being a completely new machine, the focus placed on commissioning activities was great. Representatives from Xstrata (Technology (Brisbane), Zinc (Mount Isa) and South Africa business units), Netzsch (Germany) and Siemens (Germany and Australia) were involved in the commissioning process. Despite having built contingencies upon contingencies in the planning stage, the end result was an uneventful and simple commissioning. Hot commissioning commenced on 15th December 2003, and was complete by the 18th December. The mill was then 'stood down' until the tailings dam reclaim mining and main plant ramp up were complete.

Following several brief shut downs in the first month of operation to inspect the mill internals, the M10,000 was put into a normal PM cycle of an 8 hour shut down every 8 weeks (or 1300 hours mill run time). These shut downs are used to rotate and /or shuffle the grinding discs to maximise their life. The disc life is 6000 hours, or 38 weeks (at current circuit availability). The first-fill shell liner is still in use, and was 30 % worn at the July 2005 shut down.

Down time for the IsaMill grinding circuit in the months June and July 2005 is shown below, and separated into stoppages related only to the IsaMill, and stoppages related to ancillary equipment in the circuit. Examples of the most common stoppages of ancillary equipment include pump trips and bypass events due to upstream disturbances that require the IsaMill feed thickener to be placed in recycle. The overall grinding circuit availability is greater than 95 %, with the IsaMill machine availability above 99 %. The month of July included a planned 8 hour IsaMill maintenance shut down.

As the M10,000 design was able to take advantage of hindsight and adjust several parameters from the M3,000 design, it was expected that the larger IsaMill would have a lower operating cost. Another platinum producer operates an M3,000 IsaMill only kilometres from the WLTR site, and uses the same grinding media, with similar feed and product sizes. This allows for the most accurate comparison in spares cost between the two machines. Table 4 shows that the smaller IsaMill spares cost is three times the cost per tonne milled and almost double the cost per kilowatt hour of the larger machine.

5 CONCLUSION

The use of a novel technology development method has been beneficial for Anglo Platinum and Xstrata. The design process was rapid, exhaustive in detail, transparent and above all successful. The M10,000 IsaMill has scaled up accurately and is operating below forecast cost and above budget availability. Most importantly, the down stream cleaner flotation results are matching those seen in pilot testing, whilst plant tests have confirmed the need for regrinding with the IsaMill prior to cleaning to achieve final concentrate grade.

Table 3: Down time analysis for June and July 2005

		June 2005	**July 2005**
A	Hours in month	720 h	744 h
B	Main plant running	711 h	744 h
C	IsaMill planned maintenance	0 h	8 h
D	IsaMill break down	0.5 h	3.1 h
E	Total IsaMill down time = (C + D)	0.5 h	11.1 h
F	Ancillary break down	28.2 h	27.9 h
G	IsaMill Availability = (B – E) ÷ B x 100	99.9 %	98.5 %
H	Overall Circuit Availability = (B - E - F) ÷ B x 100	96.0 %	94.8 %

Table 4: Normalised operating cost of M10,000 and M3,000 IsaMills

IsaMill Model	**Normalised Unit Cost**	
	/t milled	/kWh
M3,000 (with 1,100 kW motor)	1	1
M10,000 (with 2,600 kW motor)	0.33	0.55

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