IsaMill™ Technology Used in Efficient Grinding Circuits

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High intensity stirred milling is now an industry accepted method to efficiently grind fine and coarse particles. In particular, the IsaMill™, which was invented for, and transformed the fine grinding industry, is now being included in many new comminution circuits in coarser applications. While comminution has always been regarded as important from a processing perspective, the pressure being applied by environmental concerns on all large scale power users, now make highly energy efficient processes more important than ever.

The advantages that were developed in fine grinding in the early IsaMill™ installations have been carried over into coarse grinding applications. These advantages include a simple grinding circuit that operates in open circuit with a small footprint, the ability to offer sharp product size classification, as well as the use of inert media in a high energy intensive environment.

This paper will examine the use of IsaMill™ technology in fine grinding (P80 below 15 micron), and examine the use of the technology in conventional grinding applications (P80 20 - 150 µm). Recent installations will be examined, including fine and coarse grinding applications, as well as the recent test work that was undertaken using an IsaMill™ in a primary grinding circuit, and the resulting circuit proposal for this site.

While comminution has been relatively unchanged for the last century, the need to install energy efficient technology will promote further growth in IsaMill™ installations, and result in one of the biggest challenges to traditional comminution design.

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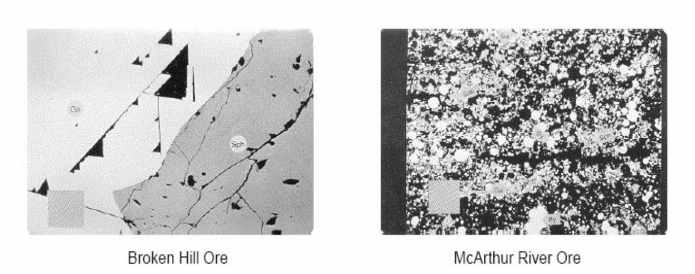
INTRODUCTION and BACKGROUND

The development of IsaMill™ technology was driven by the metallurgical requirements of Lead/Zinc deposits at Mount Isa in Queensland and McArthur River in the Northern Territory, both of which were controlled by Mount Isa Mines Limited (now Xstrata).

The McArthur River deposit was discovered in 1955 but, despite the efforts of numerous mining companies, an economic method for treatment of the fine grained deposit to produce saleable Pb/Zn concentrates was not achieved in 25 years of investigations (Enderle et al, 1997; Pease et al, 2006). In 1989 it was determined that regrinding down to 80% passing 7 µm was necessary to achieve sufficient non sulphide gangue liberation to allow the production of a bulk concentrate. Figure 1 is a comparison of the relative grain sizes of McArthur River and Broken Hill ore and illustrates the complexity of the mineralogy at McArthur River.

Figure 1: Comparison of McArthur River and Broken Hill Ore Grain Size (Grey square is 40 µm)



In the case of Mount Isa, there was a gradual decrease in plant metallurgical performance from the mid 1980's as a result of decreasing liberation size and increased amounts of refractory pyrite in the ore. Concentrate grade targets were reduced to maintain zinc recovery, however plant performance continued to deteriorate to such an extent that by the early 1990's the zinc recovery had decreased from 70% to 50% (Young et al, 1997; Pease et al, 2005; Pease et al, 2006).

Significant work was conducted at Mt Isa on projects investigating finer regrinding using conventional ball and tower mill technology however the power consumptions necessary to achieve the required fine liberation sizes made them uneconomic. Further, the high rate of steel media consumption contaminated the mineral surfaces with iron, resulting in poor flotation response post regrinding.

A real need had arisen for a technology that could grind to ultrafine sizes in metallurgical operations economically and without serious contamination of mineral surfaces and pulp chemistry. However in 1990, there was no generally accepted technology for regrinding economically to such sizes in base metals. So testwork was undertaken at the time into high speed horizontal stirred mill technology, which was used in pigment and other industries. It was shown that such mills could grind down to the ultrafine sizes required for mineral liberation.

Arising from these findings, a program of major mechanical modification of horizontal stirred mill technology was undertaken between Mount Isa Mines Limited and NETZSCH-Feinmahltechnik GmbH (Enderle et al, 1997), the manufacturer of stirred milling technology used for other industries.

After many prototypes of increasing capacities, the first full scale model was developed and installed at the Mount Isa Mines' Lead Zinc Concentrator in 1994. The mill, the M3000 IsaMill™, was quickly installed in other circuits at this concentrator, and was installed in the McArthur River Concentrator in 1995 (Johnson et al, 1998). Later, in 1999, it was commercialised and sold outside of the Xstrata group.

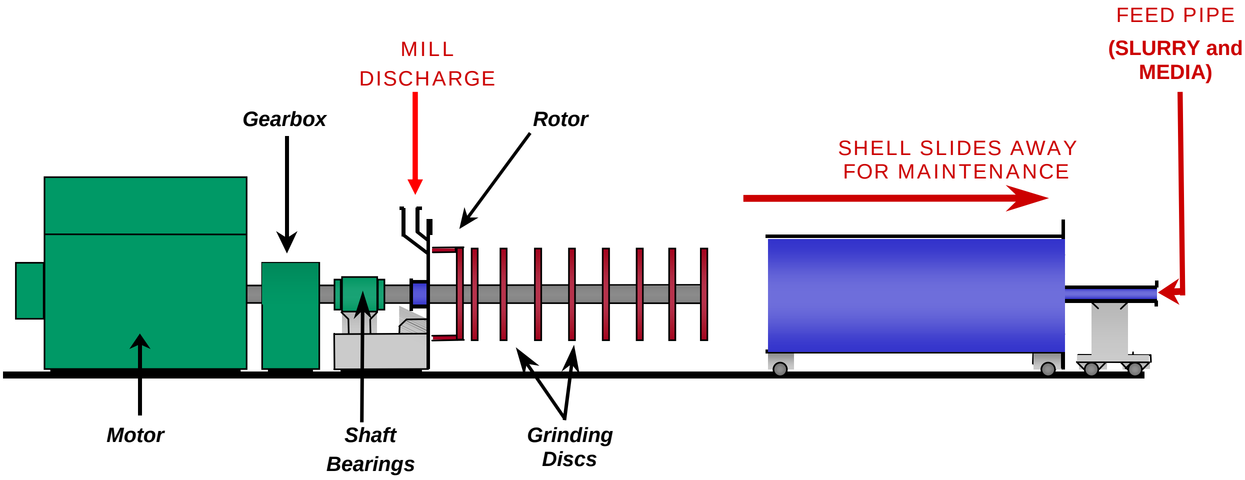
Since commercialisation of the IsaMill™, there are now over 50MW of installed IsaMills™ operating around the world, treating materials including copper/gold, lead/zinc and platinum. While the early installations treated only ultrafine sizes, the current mill installations are treating courser sized materials, once the domain of tower and ball mills. The need for energy efficient grinding circuits will only result in more IsaMill™ circuits being applied in the future.

IsaMill™ OPERATION

Grinding Mechanism

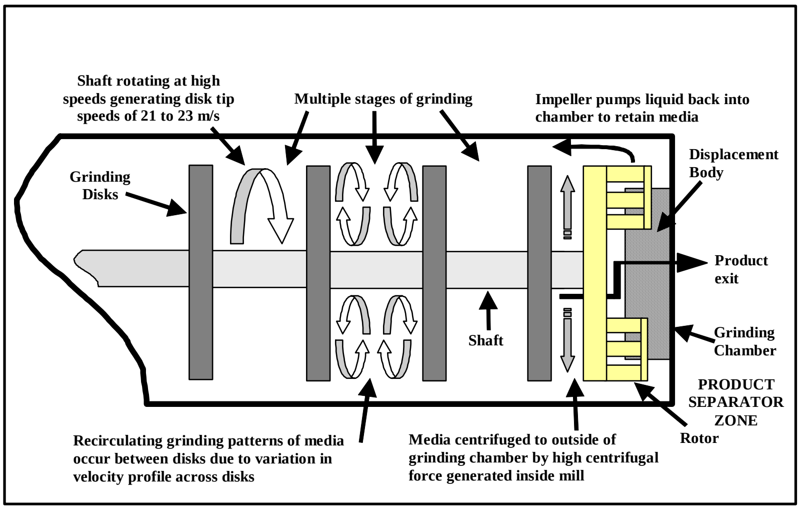
The IsaMill™ is a horizontally stirred mill consisting of a series of 8 discs rotating around a shaft driven through a motor and gearbox. The discs operate at tip speeds of 21-23m/s resulting in high energy intensities of up to 300kW/m3. Figure 2 illustrates the layout of the IsaMill™.

Figure 2: IsaMill™ Layout



The mill is filled with a suitable grinding media and the area between each disc is essentially an individual grinding chamber. As a result the mill is effectively 8 grinding chambers in series. The media is set in motion by the action of the grinding discs which radially accelerate the media towards the shell. Between the discs, where the media is not as subject to the high outwards acceleration of the disc face, the media is forced back in towards the shaft – creating a circulation of media between each set of discs. Minerals are ground as a result of the agitated media, the predominant mechanism being attrition grinding. The mechanism is best illustrated in Figure 3.

Figure 3: IsaMill Grinding Mechanism



As a result of having 8 chambers in series, short circuiting of mill feed to the discharge is virtually impossible. There is a very high probability of media-particle collision as a result of the high energy intensity and the 8 chambers in series.

Media

The key to the efficiency of the IsaMill™ is the ability to use fine media. While tower mills are typically limited to 10-12mm fresh media sizing, the IsaMill™ can use media as small as 1mm. This results in significantly more surface area per unit volume of media in the IsaMill™ than in a Tower Mill – a 2mm charge has 90 times more particles per unit volume compared to 12mm media. As a result, there is a significantly higher chance of media-particle collision, particularly at fine sizes.

The IsaMill™ is able to use a range of media types. Typically, low cost, locally available media such as sand or smelter slag have been used, which provide good grinding performance at acceptable energy efficiency. However, the need for improved energy efficiency at many installations has resulted in the use of high quality, high density ceramics, designed specifically for stirred milling applications, such as Maggotteaux's Keramax MT1.

Media Retention

Grinding media is retained in the mill without the need for screens, which is why IsaMills™ can use fine media. At the end of the mill is a patented product separator consisting of a rotor and displacement body (refer to Figure 3). The close distance between the last disc and the rotor disc centrifuges any coarse particles towards the outside of the mill. Ground product flows into the rotor area where it is essentially pumped back towards the feed end of the mill. This pumping action retains the media in the mill. The balance of the product (equivalent to the feed flowrate) exits the mill through the displacement body. This unique mechanism means that screens or cyclones are not required to retain media in the IsaMill™ which can therefore be operated in open circuit without cyclones, which simplifies the circuit, and reduces capital.

Energy Intensity

The high tip speed of the IsaMill™ results in a high energy intensive environment. Energy intensity of the IsaMill™ is significantly higher than any other commercially available grinding equipment as illustrated in Table 1. Combining the energy intensity and the high grinding efficiency leads to a compact mill, able to be fitted into existing plants where floor space is limited. On the other hand, Tower Mills require a settlement zone at the top to separate the media from the slurry – this limits the agitation speed to a tip speed of 3m/s (compared to IsaMill™ at 21-23m/s) and therefore limits the energy intensity, while ball mills can only have a relatively low amount of ball loading before media empties from the mill.

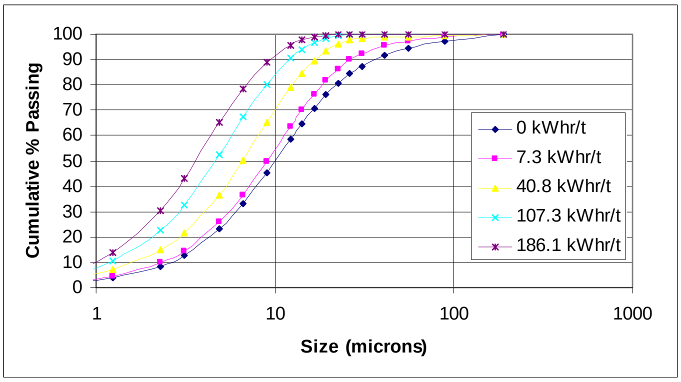
Table 1: Comparative Energy Intensity of Grinding Technologies

	Installed Power (kW)	Mill Volume (m^3)	Power Intensity (kW/m^3)
Autogenous Mill	6400	353	18
Ball Mill	2600	126	21
Regrind Mill	740	39	19
Tower Mill	1000	12	42
IsaMill™	3000	10	300

Product Size Distribution

In open circuit operation, the IsaMill™ is able to produce a sharp product size distribution. Typically the ratio of the P98 to the P80 is around 2.5. This is a direct result of the effect of 8 chambers in series preventing short circuiting and the classification action of the product separator. The ability to operate the mill in open circuit greatly simplifies the operating and maintenance strategies of the circuit. Figure 4 illustrates a typical IsaMill™ product distribution in open circuit at varying power inputs – note the steepness of the curve and the lack of ultra fines that would be expected from a Tower Mill distribution.

Figure 4: Typical IsaMill™ Product Distribution in Open Circuit (South American pyritic gold concentrate)



Inert Grinding

After the initial comminution stages of crushing and/or SAG/AG milling, the following grinding stages is usually carried out using steel charged ball or tower mills. The impact of grinding using steel media can offset any benefits gained by improved liberation, particularly as the target size decreases below 25 µm. Grinding in a steel environment results in the precipitation of metal and iron hydroxides on to the surface of ground particles. These conditions affect flotability, flotation selectivity and lead to higher reagent consumptions to overcome the surface coatings and regain recovery (Trahar, 1984; Pease et al, 2006). The benefits of inert grinding at several locations have been well reported (Pease et al, 2006, 2005, 2004; Young et al, 1997; Grano et al, 1994).

While the negative impacts of steel grinding will be greatest at fine sizings due to the large surface areas and high media consumptions involved, inert grinding has also been shown to produce benefits at coarser sizings (Grano et al, 1994; Greet et al, 2004; Pease et al, 2006). For a long time, chrome media has been offered to, and investigated by, ball and tower mill operators as a means of improving pulp flotation chemistry by reducing the amount of iron released into the grinding pulp and contaminating freshly ground surfaces. Greet and Steiner, 2004, analysed the surface of galena ground in three different environments for the presence of iron. It is clear from Table 2 that while grinding in a high chrome environment reduced the surface iron composition from 16.6% to 10.2%, grinding in a ceramic environment reduced the detectable surface iron to less than 0.1% - a significant improvement over both media types.

Table 2: Composition determined via XPS, of the unetched surfaces of Rapid Bay Galena ground with different media (Greet 2004)

Media Type	Surface Atomic Composition (%)			
	O	Pb	Fe	S
Mild Steel	53.1	15.6	16.6	14.7
High Chrome	50.0	20.6	10.2	19.2
Ceramic	33.6	32.0	<0.1	34.4

IsaMill™ RECENT DEVELOPMENTS

Until recently, inert grinding to coarser sizes (+25µm) was generally impractical in traditional milling equipment due to the high capital investment required to fill the mill. However two recent developments in IsaMill™ technology have allowed coarse grinding in an inert environment to become a reality, namely MT1 ceramic media and the scale up of the IsaMill™ to the M10,000 model.

MT1 Ceramic Media

The development of high intensity stirred mills, such as the IsaMill™, increased energy efficiency by the use of higher agitation speeds and finer media, compared to those associated with tower mills or ball mills. (Gao et al, 1999, 2002). The IsaMill™ has been able to use low cost, cheap media, such as sand, discarded slag, river pebbles, scats etc to obtain very fine grind sizes. However while the mills have been run with low cost media, the low quality media limits the energy efficiency of the mill. Quality issues such as particle shape, grain size, specific gravity etc all constrain the mills energy efficiency as well as the size of feed that can be milled. It is this latter limitation that has constrained the mill to grinding in fine size ranges. Previously available ceramics were of variable quality, high cost, high wearing and low SG which generally made their use uneconomic.

A recent initiative between Magotteaux International and Xstrata Technology brought about the development of a ceramic specifically designed for use in the IsaMill™ to address the limitations of current media. The product, Keramax MT1, was designed to address all the key characteristics for the ideal media, listed by Lichter and Davey, 2002, as:

- Hardness
- High sphericity
- High roundness
- Mechanical Integrity
- SG
- Definite initial charge PSD and top up size
- Chemical composition

Keramax MT1 is a high density, high quality alumina ceramic media. It has been shown to have a consistent hardness when sectioned with no air bubbles or structural defects (Curry et al, 2005). It has been specifically designed for grinding applications, with relatively high SG and low wear characteristics. Keramax MT1 properties are listed in Table 3.

Table 3: Keramax MT1 Properties

Keramax MT1	**Properties**
Composition	79% Al_2O_3 6.5% SiO_2 14.0% ZrO_2
Hardness	1300-1400 HV
Fracture Toughness	5-6
Specific Gravity	3.7
Bulk Density	2.3-2.4

The surface of the media is smooth and ‘pearl-like’ to touch. These surface properties mean that the energy loss in grinding due to friction is minimized, improving the efficiency of grinding. At the same time there is negligible contamination of ground material with deleterious ions.

The true benefits of this material can be seen when it is compared to other media in a lab environment. This was undertaken by Xstrata Technology and Magotteaux separately in 2004 on gold bearing concentrate from the Eastern Gold fields region of WA, using a M4 IsaMill™ (Curry et al, 2005). The results are summarized in Table 4.

Table 4: Media Type vs Energy, Consumption and Net Power for 250t/hr Treatment Rate

Media Type	Consumtion Rate (g/kWhr)	Specific Energy (kWhr/t)	Consumption Rate (Kg/t)	Net Power (MW) for 250 t/hr example
MT1 (-4 +3mm)	15	7.6	0.11	1.9
Alumina 1 (-4 +3mm)	128	13.1	1.68	3.3
Alumina 2 (-4 +3mm)	295	12.4	3.66	3.1
Australian River Pebble (-4 +3mm)	200	27.9	5.58	7.0
Australian Silica Sand (-6 +3mm)	781	11.2	8.77	2.8
Ni Slag (-4 +1mm)	1305	17.8	23.23	4.4

Keramax MT1 was found to be more efficient than the other ceramics or sands tested. This has big implications to grinding circuit design, as it requires less installed power for an application on MT1 compared a to much larger installed power that would be required if sand was used. This is highlighted in the final column of Table 4, where for a hypothetical throughput of 250tph, 1.9MW is required to do the grinding duty using MT1, compared to 7.0MW on River Pebble (-4mm to +3mm).

Keramax MT1 has all the attributes of inert media that has been in use in IsaMills™ over the last decade, but has the toughness and high SG to make it a more efficient and harder wearing media than slags and sand, while at the same time being able to handle coarser feed size distributions.

M10,000 IsaMill™

In late 2002, Xstrata Technology, in collaboration with Netzsch and Anglo Platinum, developed the M10,000 IsaMill™ ; the worlds largest stirred mill. The mill was developed for Anglo's Western Limb Tailings Retreatment Project near Rustenburg in South Africa. The project involved the retreatment of dormant platinum containing tailings, which represented a major economic resource. Fine grinding testwork had established that the PGMs could be recovered from the tailings. Pilot scale work resulted in the circuit needing to produce a primary grind, no less than 80% passing 75 µm, and a rougher concentrate regrind of no less than 85% passing 25 µm, which would enable good recovery of PGM's. The tonnage required for the regrind circuit was 53tph (max 65tph), to produce a P90 of 25 µm, requiring 35kWh/t. This duty could not be performed in a single M3000 IsaMill™. To maximize the economics of the project, a larger mill was required leading to the development of the 2.6MW, M10,000 IsaMill™, (Curry et al 2005).

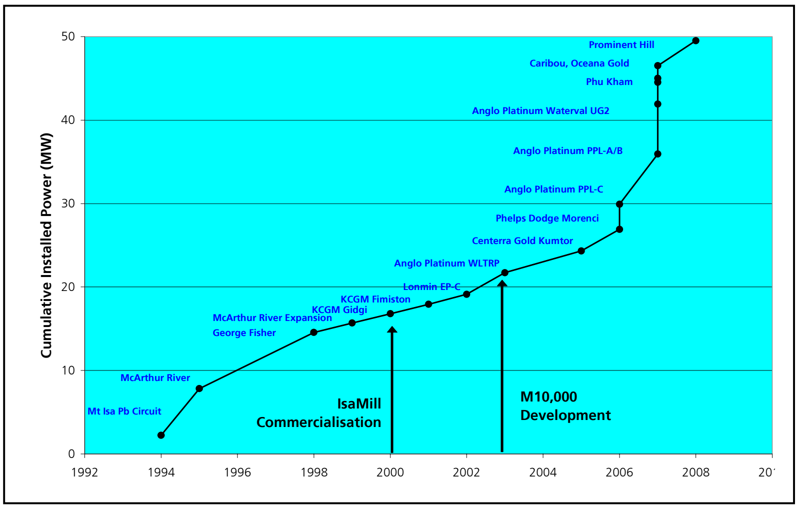
Results from the Western Limb Tailings Retreatment Project have confirmed the accuracy of the scale up from the lab scale M4 IsaMill™ and pilot plant IsaMill™ testwork to the full scale unit, Table 5.

Table 5 Laboratory versus Full Scale Grinding Efficiency

IsaMill™ Model	Installed Power (kW)	Chamber Volume	Specific Energy (kWh/t)	Pulp Solids	P98 (µm)	P98 (µm)
M4	4	3.5	37	39	47.5	16.0
M10,000	2,600	10,000	37	42	42.5	16.5

Since Anglo's Western Limb Tailings Retreatment Project, there have been 9 other M10,000 IsaMills ™ either installed or designed at the time of writing. They are either installed with 2.6MW or 3.0MW motors, and all use ceramic media. The rapid growth of IsaMill™ technology is shown in Figure 5.

Figure 5 – Time versus Cumulative Power for IsaMill™ Installations



Today, large scale coarse grinding using inert media is both practical and economic, due to the development of large scale IsaMill™ technology and MT1 ceramic media. The use of the IsaMill™ with inert media in coarse grinding applications not only has significantly improved energy efficiency, but also has improved downstream separation processes due to the production of minerals with clean, iron free surfaces.

The following Case Studies describe IsaMill™ installations being applied to coarse grinding duties.

CASE STUDY 1 - KUMTOR M10,000 INSTALLATION

The M10,000 IsaMill™ installation at the Kumtor gold mine in the Kyrgyz Republic, is one of the largest gold mines operating in Central Asia, producing over 500,000 ounces of gold per annum. It is based 4000m above sea level in the Tien Shan Mountains, and is owned by the Kumtor Operating Company, a fully-owned subsidiary of the Canadian company Centerra Gold Inc.

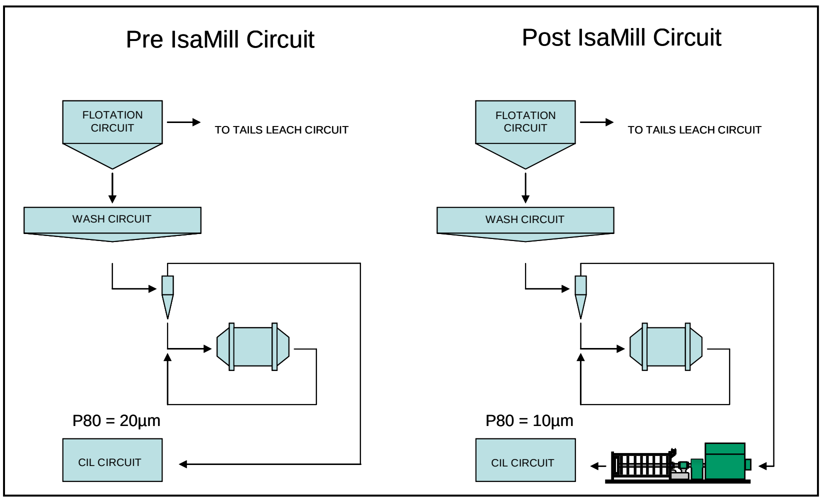
The Kumtor installation treats a hard refractory orebody of finely disseminated gold linked with significant quantities of pyrite. The flowsheet is conventional crushing, SAG and ball mill circuits, before the ball mill cyclone overflow is floated. The tailings are thickened and then undergo CIL before passing to the tails disposal circuit. The concentrate is also thickened, and is then reground in a conventional ball mill, prior to CIL, before stripping, electro winning and refining to doré. The regrind ball mill, operates in closed circuit with 25 mm diameter balls and very high recirculation loads (~600 %), to produce a product with a P80 of ~20 µm. Liberation studies undertaken by Kumtor established the gold recovery benefits of grinding finer, with an optimal P80 sizing of 10 µm selected for the design.

In late 2005, a 2.6MW M10,000 IsaMill™ was commissioned at Kumtor, treating the regrind ball mill discharge to a product sizing of 80% passing ~10 µm. Figure 6 illustrates the before and after flowsheets. This installation represented the first commercial application of the Magotteaux MT1 media. The decision to use the MT1 media was based on several key factors:

- Low wear rates resulted in less media required to be transported to the remote site.
- High SG ceramic media translates into more efficient power usage compared to sand, enabling 1 x M10,000 IsaMill™ operating in open circuit to do the work equivalent to 2 x M3000 IsaMills™ operating on sand, reducing capital cost and simplifying the circuit.
- Cyanide consumption would be reduced

Soon after commissioning the IsaMill™ was treating on average 72 tph, compared to the design tonnage of 65 tph. The current power draw was approximately 1950 KW, which equates to 23 KWhr/t specific grinding energy. Shortly after commissioning, metallurgical results had seen a drop in the gold tailings grade by 30%, (which represents an extra 20,000 ounces of gold per annum being recovered).

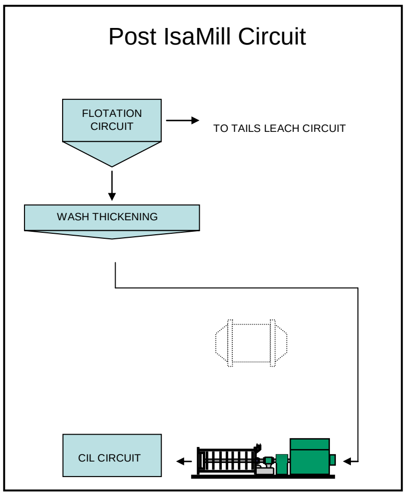
Figure 6: Pre and Post IsaMill Circuits at Kumtor



Replacement of Kumtor Ball Mill with IsaMill™ During Ball Mill Maintenance

While the Kumtor IsaMill™ is designed as an ultra fine grinding application, it was noted by Kumtor management that the IsaMill™ would be required from time to time to operate without the ball mill, when the ball mill required maintenance, Figure 7. This would allow the Kumtor operation to continue without any lost production from the maintenance. In this operation the mill would be expected to produce a coarser product, although it was hoped to match the ball mill discharge.

Figure 7: Circuit Configuration during Ball Mill Maintenance



Testwork was conducted on samples of rougher concentrate, which predicted that a coarse charge of ceramic media could produce a similar output to the ball mill, i.e. a P80 of 20 to 25um.

In March 2006, shortly after the IsaMill™ was installed for fine grind duty, the ball mill was relined for a 4 week campaign, and the IsaMill™ feed was coarsened from 20 um to 150um. However during the relining of the ball mill, a much finer ball charge was actually used in the IsaMill™ than used during the testwork, while the IsaMill™ was also operated with a non optimized feed density and rotor selection. The 4 week timeframe did not permit these key variables to be optimized, which, along with the fine media, impacted on the power draw, which was only 1885 KW (average) throughout the trial.

The key findings of the trial were

- IsaMill™ has reduced the feed from F80 of 130µm to 150µm to P80 of 60µm to 65µm
- Size reduction has been undertaken by finer media than used in the testwork
- Media consumption has been good at 17.5g/KWhr
- IsaMill™ operated continuously during the 4 week ball mill shutdown enabling full scale production to be achieved, with no breakdowns
- No significant wear issues were noticed during the trial, with the same mill liner and disc used throughout and after the trial
- Coarser media, optimal density and the use of a high flow rotor could have improved the power draw and further reduced the discharge sizings

CASE STUDY 2 - NEW INSTALLATIONS USING IsaMill™ in COARSE DUTIES

Phu Kham Project

The Phu Kham deposit is located approximately 100km north of the Laos capital Vientiane. It is owned by Pan Australian, an Australian listed mining company. The Phu Kham deposit hosts two distinct styles of mineralisation: an oxide gold cap and beneath this transitional/primary copper-gold. The Phu Kham oxide gold cap is the principal deposit for the Phu Bia heap leach gold mine, the first phase of the development of the Phu Kham deposit, which entered into production in 2005. The Phu Kham Copper-Gold operation is planned for start-up in mid 2008. Feed to the concentrator will consist of 12MT on average, with planned annual output from this mine being over 200,000 dry metric tonnes (dmt) of concentrate (grading 25% copper), containing 50,000 tonnes copper, 40,000 ounces gold and 400,000 ounces silver, (on average). The concentrate will be exported for further treatment and refining by custom smelters in the Asia Pacific region.

Process technology employed for Phu Kham Copper-Gold is conventional comminution at the head of the circuit, followed by flotation to produce a copper-precious metal concentrate, (Pan Australian, 2006)

Rougher concentrate will be treated through a M10,000 IsaMill™, powered by a 2.6MW motor, treating approximately 168 tph and reducing the feed size from a F80 of 106um to a P80um of 38um, before further flotation. The grinding media for the operation will be MT1.

Prominent Hill Project

Oxiana Limited owns 100% of the Prominent Hill copper-gold project located 650 kilometers north west of Adelaide, and130 kilometers north west of BHP Billiton's Olympic Dam in South Australia, Australia.

The ore body consist of copper gold breccia, and will be mined via an open pit. The ore will be treated through a conventional grinding and flotation processing plant, with a designed capacity of 8MTPa. The initial planned concentrate production will be on average 187,000 dry t/a peaking at 230,000t in 2009, with average concentrate grades of 45% copper, 19g/t gold, 57g/t silver. The high grade concentrate will be sold to smelters in Australia and in Asia. (Oxiana, 2007)

One M10,000 IsaMill™, powered by a 3.0MW motor, has been selected to treat the rougher concentrate. It will treat approximately 138 tph, reducing the feed size from a F80 of 125um to P80um of 24um for further flotation. The planned commissioning of the mill will be mid to late 2008. The grinding media for the operation will be MT1

Anglo Platinum Installations

Anglo Platinum installed the first M10,000 in 2003, in their Western Limb Tailings Retreatment Project, after working with Xstrata Technology to scale up the existing M3000 IsaMill™. The resulting mill, the M10000, was a powered by a 2.6MW motor, which had a variable speed drive (this was a precautionary measure, as it was the first M10,000 to be built).

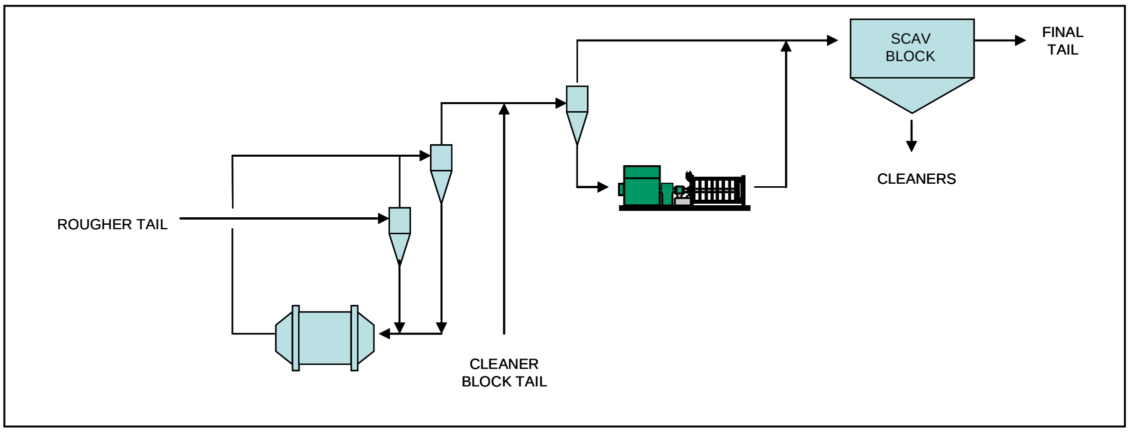
The mill treats oxidized PGM's from a tailings dam in a precleaner tail stream, and reduces feed from 75um to 25um.

Four years later, in 2007, Anglo Platinum has ordered another five, M10,000 IsaMills™. This time the mills come with fixed speed drives, and are powered by 3MW motors. The high energy efficiency demanded by the sites have called for ceramic media, and the duty of the mills will be similar, i.e. typical duty from 75-100 um feed size down to 53 um product size.

To date, the first IsaMill™ has been successfully commissioned at Potgietersrust Platinum mine (C-Section), and there are mills being manufactured/installed at Potgietersrust A and B Sections (2 mills), followed by two more at the Rustenburg Watervaal UG2 operation in late 2007.

The Potgietersrust Platinum mine (C-Section) mill is designed to operate with a 3MW motor and use MT1 media, treating scats from A and B section primary milling circuits, with the ore having a Bond Work Index, BWi, over 30 kWh/t. Figure 8 illustrates the simplified C section flowsheet with an IsaMill™.

Figure 8: Simplified PPL C Section Flowsheet with a M10,000 IsaMill™



The rougher tail is milled in closed circuit with a ball mill. Cyclone overflow, at a nominal P80 of 75 µm, proceeds to the IsaMill™ predensifying cyclone which increases the percent solids for efficient IsaMill™ operation, while sending the fines to the scavenger flotation circuit. The IsaMill™ then treats the predensifying cyclone underflow, before the product enters the scavenger flotation circuit.

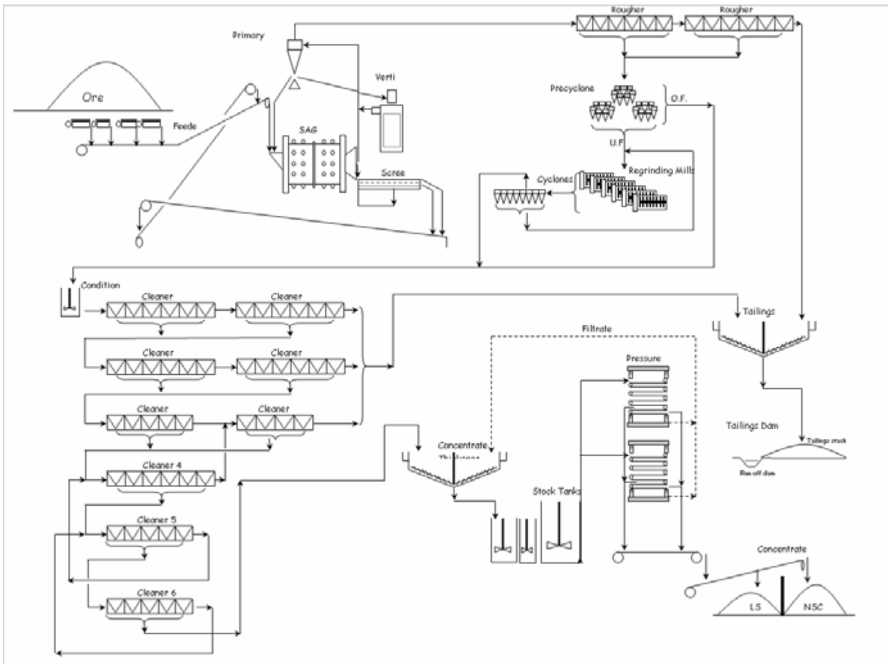
The IsaMill™ circuit is based on testwork which found very favourable flotation results after IsaMilling™ the cyclone overflow from an F80 of 75 µm down to a product sizing P80 of 53 µm. The circuit is designed to treat 162t/hr (nominally) through the IsaMill™, which is then rejoined with the predensifying cyclone overflow, before it passes to the scavenger flotation circuit. Design energy consumption grinding from F80 75µm to P80 53µm is 9 kWhr/t. The IsaMill will operate with top size 3.5mm MT1 ceramic media.

Before the implementation of the IsaMill™, it was calculated that a 8MW conventional ball mill operated in closed circuit, would be needed to do this duty. However with the M10,000 IsaMill™, less than half the power is required due to open circuit operation and the use of ceramic.

CASE STUDY 3 – IsaMills™ in McARTHUR RIVER SAG CIRCUIT

McArthur River Mine (MRM) is part of Xstrata Zinc, an operating subsidiary of Xstrata PLC. It is a zinc/lead mine, operating in Northern Territory, Australia, and was commissioned in 1995. The development of the IsaMill™ for regrinding down to a P80 of 7 µm was the enabling technology that allowed the mine to be developed. Initially there were 4 x M3000, 1.1MW IsaMills™ in the regrind duty. This has since been expanded to 6 with a combined installed power of 6.7MW. The current plant flowsheet is shown in Figure 9.

Figure 9: McArthur River Flowsheet

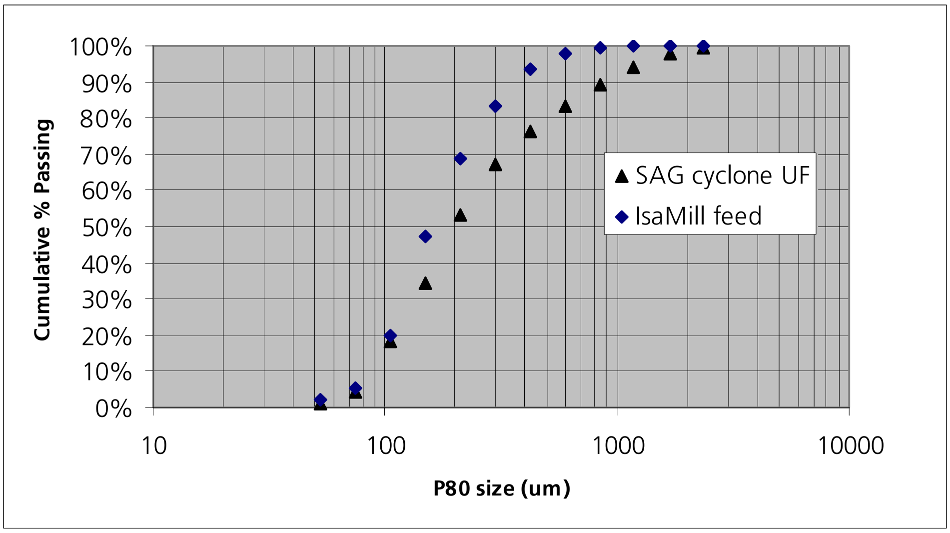


The grinding circuit consists of a primary SAG mill, closed by a double deck screen and cyclones. All screen oversize is returned to the SAG Mill. Cyclone overflow (currently at P80 of 70µm) feeds flotation, while cyclone underflow is split between a Tower Mill or returned to the SAG Mill. The Tower Mill product is returned to the SAG sump where it is pumped with the SAG screen underflow to the primary cyclones.

MRM have a need to increase milling capacity to account for decreased head grades as the operation shifts from underground to open cut. At the same time there was a desire to reduce downtime and reduce operating cost by eliminating the Tower Mill from the circuit, hence MRM have been keen to explore the effectiveness of a M10,000 IsaMill™ in the primary grinding circuit. In the primary grinding circuit, the IsaMill™ will be treating material of the order of 300 to 350um, the coarsest any IsaMill™ has been designed for. The IsaMill™ in the primary grinding circuit will be operating in open circuit, producing a P80 of 40µm product that could be pumped directly to flotation, with the SAG cyclone overflow. The Tower Mill will be decommissioned.

Testwork has been undertaken using a M4 and M20 IsaMills™ and reported by Anderson and Burford (2006). The findings from this work indicated that while the IsaMill™ could treat the screened cyclone underflow feed at 623um, the presence of SAG mill scats also in the underflow caused blockages of the small scale mill. The feed to the IsaMill™ can be summarised by the Figure 10.

Figure 10: McArthur River SAG Cyclone Underflow and IsaMill M20 Feed Distribution

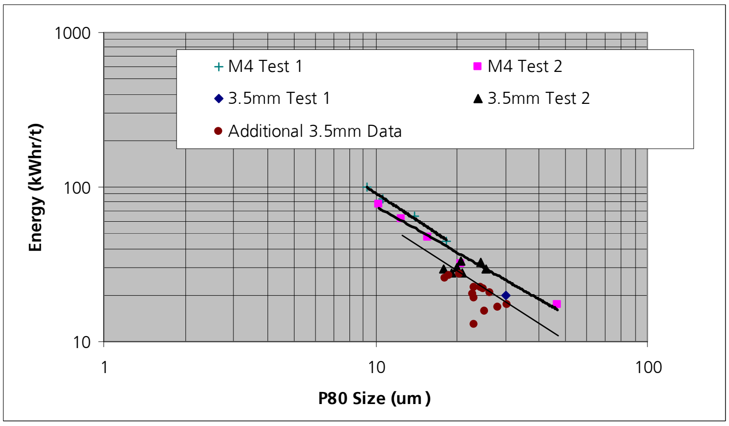


The average results from the two site test conducted with the M20 IsaMill™ indicted that the mill could reduce an average feed size of F80 of 350um, to a product with a P80 of 20 to 30 um, using MT1 as media (3.5mm in diameter). The testwork also indicated that an energy input of 10-15kWhr/t was required to reduce the feed, screened at a top size of 623µm, to a product P80 of 40µm. The data is shown in Figure 11, marked as "3.5mm Test 1" and "3.5mm Test 2".

Results were also presented on Figure 11 showing two trials that were also conducted using the 4 litre laboratory IsaMill™, ("M4 test 1" was conducted with unscreened SAG cyclone underflow; "M4 test 2" was conducted with SAG cyclone underflow top screened at 1.7mm).

Data from the M20 site tests shows higher efficiency for a given target size compared to the M4 IsaMill™. Some of the increased efficiency may have been due to the decreased feed size distribution of the site test, but it is unknown what is the impact of this difference, if any. Also the variability and accuracy of the data is affected by the fact that the mill was filling up with steel during the trials, which indicated further testwork was required to confirm the initial results...

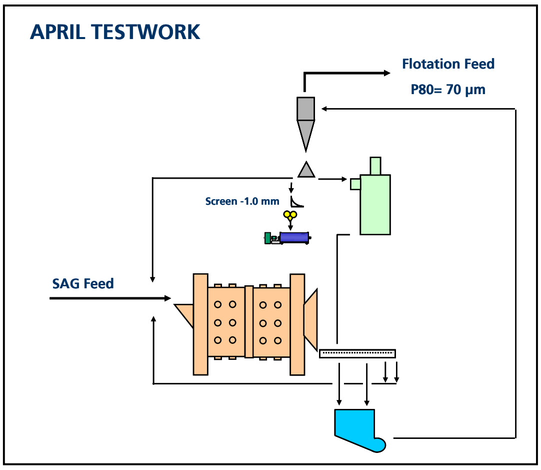
Figure 11: Product Size - Energy Relationship for 3.5mm MT1



Continuing Testwork

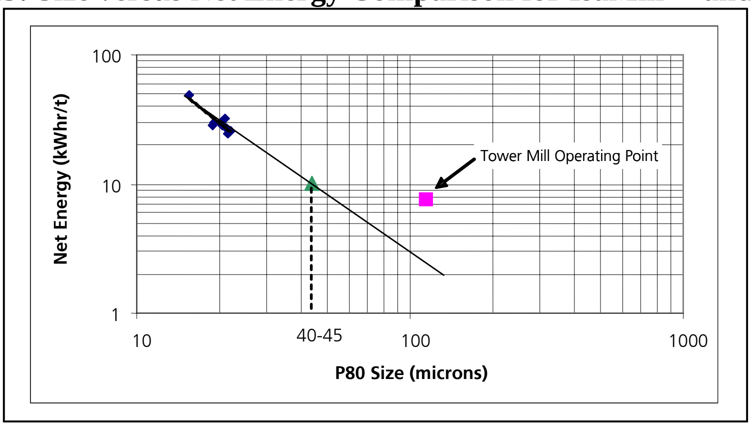
Further testwork was conducted later in 2006 to support the initial testwork, as well as overcome the presence of scats in the feed stream that lead to blockages in the M20 IsaMill™. Figure 12 displays the flowsheet that was used in this testwork that incorporated a magnetic separator to remove steel scats in the cyclone underflow. Aso the feed was screened this time at 1mm (previous screening was at 623um).

Figure 12: Site Testwork at MRM Using M20 IsaMill™ with a Magnetic Separator on Feed



The M20 IsaMill™ was able to treat material, that was slightly finer than the previous work, from a feed sizing of 300um, down to a product sizing of 20 to 25 um, (finer than the 40um target). The data was able to permit a size energy relationship to be established, as shown in Figure 13, compared with the current Tower Mill operation in that circuit.

Figure 13: Size versus Net Energy Comparison for IsaMill™ and Tower Mill



Using the energy data from the M20 IsaMill™ testwork, and the current energy use for the Tower Mill in the primary circuit, it has been conservatively estimated that the IsaMill™ could do the same duty as the Tower Mill for a third of the energy, a saving of 5KWhr/T less energy, i.e. Tower Mill uses 7 to 8 KWHr/T for a P80 of 100um, while the IsaMill™ achieves same sizing for 2 to 3 KWHr/T.

McArthur River Mine Future Circuit

McArthur River Mine has included two M10,000 IsaMills™ in the upgrade of the concentrator to cope with the increased tonnage as the mine goes from underground to open cut. As at March 2007, the concentrator has been planned to increase throughput from 1.8MTpa to 2.5MTPa, with a resulting increase in concentrate production from 320,000T of zinc lead concentrate to 430,000T of zinc lead concentrate. It is planned that the circuit will be ready for commissioning in mid 2008, (Xstrata Zinc, 2007). The IsaMills™ will take 1 year to be manufactured before they are delivered to site. They will take between 1 to 2 weeks to be installed.

McArthur River Mine managements' selection of IsaMills™ technology for their upgrade was due to the higher efficiency of the mills compared to existing technology. This overcome the need to increase the number of power generators at the remote mine site, while the small footprint of the mills enabled them to fit into the existing concentrator.

Final design parameters are still to be finalised at the time of writing, but the new circuit will have the cyclone underflow from the SAG mill reporting to magnetic separators and oversize screens to ensure all iron scats are taken from the stream before treatment by the two M10,000 IsaMills™.

Further testwork will also be undertaken during 2007 to trial one of the M3000 IsaMills™ in the fine grinding circuit to undertake the coarser duty. The first trial is planned for May, 2007.

CONCLUSION

IsaMill™ technology is becoming the preferred technology in efficient coarse grinding circuits. The development of reliable ceramic media, such as MT1, as well as the development of high capacity M10,000 IsaMills™, have lead to the IsaMill™ being a realistic alternative in coarse grinding applications.

IsaMills™ in coarse grinding applications have all the advantages of fine grinding applications, such as simple circuit design, small footprint and iron free contamination when used with ceramic media, which has profound beneficial impact on metallurgy, recirculating loads and reagent use. However the biggest advantage of IsaMills™ is its high energy efficiency, as a result of its high speed stirring action in a packed bed.

With the pressure being applied to all industries today for improved sustainability and the need for increased energy efficiency, the adoption of IsaMill technology in coarse applications is good news for operators, as the development of the IsaMills™ allows for significant energy and capital savings for the application.

IsaMill™ technology is a true alternative to ball mill and tower mill circuits.

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