Comparing Energy Efficiency in Grinding Mills

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ABSTRACT

The IsaMill™ is challenging the way that plants are designed and operated. This paper challenges existing designs of concentrator flow sheets, particularly focusing on magnetite circuits.

From what has started out as a small scale ultra fine grinding mill in the pharmaceutical and pigment industries, it has been redesigned and improved upon for mineral processing, and has been the mainstay of fine grinding applications for over 10 years. These applications have required energy efficient grinding to succeed, and have been predominately in the base metals industry.

Further development of the IsaMill™ has now resulted in the machines being able to treat larger tonnages, with higher capacity motors. This development, along with the introduction of purpose designed ceramic media, has allowed the mill to treat courser feed sizes. At the same time, the mill still offers highly efficient grinding, and has enabled it to be operated in coarser tertiary and secondary grinding applications.

The acceptance of the mill in coarser applications, predominately in base metals and PGM applications, has enabled the IsaMill™ to be a serious contender for beneficiation in other minerals. One such application is the potential for IsaMills™ to be part of magnetite flowsheets, which are being considered in Australia to meet the growing iron demand of China. The high energy efficiency of the IsaMill™ compared to conventional technologies, as well as the smaller infrastructure requirements, provides a great opportunity to reduce the power intensity of magnetite circuits.

This paper will examine the use of IsaMill™ technology in conventional grinding applications, including recent testwork in a primary grinding base metal circuit, as well as testwork on magnetite ore comparing a lab scale IsaMill™ with a lab scale Tower Mill.

The growing demand for minerals over the next decade, coupled with higher energy cost, will result in energy efficient technology, such as the IsaMill™, being included in standard circuit design.

INTRODUCTION and BACKGROUND

The development of IsaMill™ technology was driven by the metallurgical requirements of fine grained 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 complex nature of both deposits required ultra fine grinding to sizes that were not possible to do economically with the technology that was available in the early 90's.

McArthur River orebodies were mineralogically complex, and required regrinding down to 7 µm to achieve sufficient liberation to allow the production of a bulk concentrate (Enderle et al, 1997; Pease et al, 2006). In the case of the Mount Isa orebodies, 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 that saw recovery decrease from 70% to 50% (Young et al, 1997; Pease et al, 2005; Pease et al, 2006). However using conventional ball and tower mill technology to achieve finer grinding for mineral liberation was uneconomic, as well as resulting in a high rate of steel media consumption which contaminated the mineral surfaces with iron deposits, resulting in poor flotation response post regrinding.

In both of these orebodies, a need had arisen for a technology that could grind to ultra fine sizes in metallurgical operations economically without serious contamination of mineral surfaces and pulp chemistry. Testwork was undertaken in the early 90's at Mount Isa Mines into high speed horizontal stirred mill technology, which was used in pigment and other industries. It was shown at pilot scale that such mills could grind down to the ultra fine 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 the stirred milling technology, to make the technology more applicable for the mining industry.

After many prototypes, 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 is now over 70 MW of installed IsaMill™ power operating around the world, treating materials such as copper/gold, lead/zinc and platinum. While the early installations were applied to ultra fine duties, the IsaMill™ today is being applied to coarser grinding applications, once the domain of tower and ball mills. The application to coarser duties, means all the advantages of the IsaMill™ that was developed for ultra fine grinding can now be applied to the coarser applications.

IsaMill™ OPERATION

The IsaMill™ is a horizontally stirred mill consisting of a series of discs rotating around a shaft driven through a motor and gearbox, at speeds ranging from 21-23m/s, with energy intensities up to 300kW/m^3. The general layout of the IsaMill™ is displayed in Figure 1, while the grinding mechanism is displayed in Figure 2.

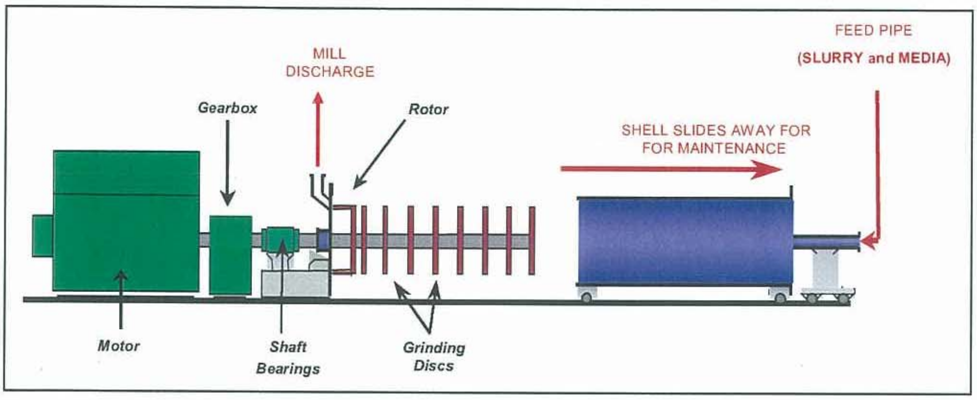

Figure 1: IsaMill™ Layout

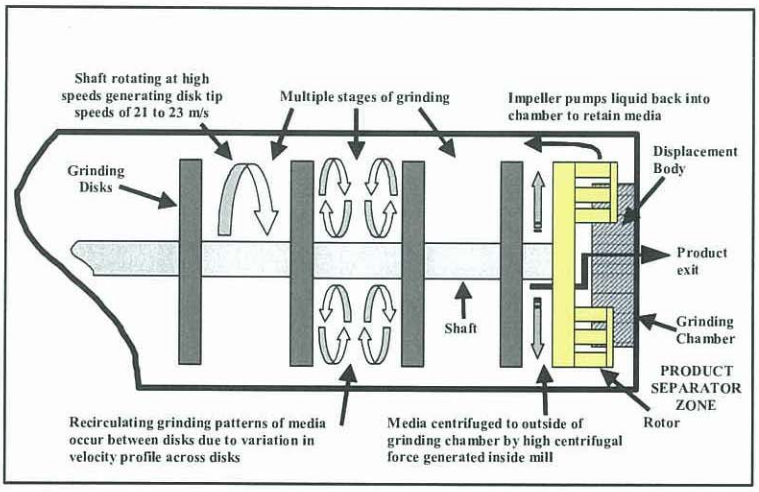

Figure 2: IsaMill™ Grinding Mechanism

In operation, the mill is filled with grinding media between each disc, each one of these segments acting as an individual grinding chamber. When 8 discs are used in the mill, it effectively acts as 8 grinding chambers in series, which also minimises any short circuiting of the mill feed to the discharge. The action of the grinding discs when rotating, radially accelerates the media towards the shell. Between the discs, where the media is not 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 by an attrition action, as a result of the agitated media, with the resulting high energy efficiency being achieved due to the high probability of media-particle collision.

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.

	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™ - M10,000	3000	10	300

Table 1: Comparative Energy Intensity of Grinding Technologies

Media

The key to the energy 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™ compared to a tower mill.

The IsaMill™ is versatile and able to use a range of media types, including low cost, locally available media such as sand or smelter slag, to 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 Magotteaux 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. The distance between the last disc and the rotor disc creates a centrifuge, so that coarse particles and media move to the outside of the mill, which are pumped back towards the feed end of the mill from the action of the rotor. Meanwhile the fine particles flow through the rotor and discharge from the mill, which means no screens or cyclones are required, and allows the mill to be operated in open circuit without cyclones, reducing capital and simplifying circuit configuration.

Product Size Distribution

In open circuit operation, the IsaMill™ is able to produce a sharp product size distribution, which reduces overgrinding and the creation of ultra fines. Typically the ratio of the P98 to the P80 is around 2.5. This is a direct result of the individual grinding chambers acting in series, preventing short circuiting, as well as 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. Also the sharp product size is beneficial in pipeline design and filtration, due to the reduction of ultra fines and oversize particles.

Inert Grinding

The operation of the IsaMill™ using sand or slag, or more often ceramic grinding media, has a big advantage over steel media in conventional grinding systems, as it greatly reduces the generation of ferric ions. These are detrimental to flotation and leaching circuits, as the ions form a coating on the mineral surface, which hinders the action of the flotation or leaching reagents, resulting in more reagents being used, and may also result in poor metallurgical performance.

Maintenance

The IsaMill™ has been designed to keep maintenance simple. The shell of the mill is simply rolled away from the mill on a set of rails, enabling the disc and internal wear surfaces to be examined and changed if required (Figure 3). The shell liner of the mill is easily replaced as the shell is designed in two pieces.

Wear within the mill is determined by the specific size reduction of the mill, as well as wear characteristics of the minerals, and it is common for IsaMills™ to be operating with availabilities 96% and higher.

Figure 3 – IsaMill™ Maintenance

COARSE GRINDING TRANSFORMATION

The IsaMill™ was developed to enable the fine grained orebodies of McArthur River and Mt Isa to be developed (Enderle et al. 1997; Pease et al, 2006). Grinding down to a P80 of 7um at high energy efficiency was a big step forward in mineral comminution, however only a small number of mine sites needed grinding down to this size.

However, the development of ceramic media and M10,000 IsaMills™ in recent years has enabled the IsaMill™ to treat coarser feed materials in tertiary and even secondary grinding duties, which has resulted in greater application of IsaMills™ in most concentrators, (Burford, 2007).

While the use of low cost natural media and slag was used in initial IsaMill™ applications, the quality variability and the certainty of supply had a big impact on IsaMill™ operation. In particular the variability of the media shape, SG and size constrained the energy efficiency of the mill when operated with sand or slag, (Curry et al 2005b)

The development of ceramic media designed for use in IsaMills™ by Magotteaux International, was a major step forward for application of IsaMills™ in coarse grinding. This was due to the media having good structural integrity, tough, high SG as well as being designed up to 3.5mm in diameter. (Anderson et al 2006)

In terms of the energy that can be provided by the media particle, the development of larger diameter media made from ceramic increases the energy available for grinding due to the increased diameter of the media, and the increased SG of the ceramic. In terms of the Keramax® MT1™, the SG of the ceramic is 3.7, over 40% higher than that of sand, (SG = 2.6). This is described by the Stress Intensity Relationship in Table 2 (Pease 2007).

$$E \, \alpha \, d^3.v^2.SG$$

E = Energy per Media Particle
d = media diameter
v = media velocity
SG = media density

Table 2 – Stress Intensity Relationship

The other development in the transformation of the IsaMill™ from fine to coarse grinding applications, was the development of the larger M10,000 IsaMill™ (Curry et al 2005a). As previously described, the WLTRP project by Anglo Platinum in South Africa required large scale grinding mills to treat 53 tph, up to a maximum of 65tph, from a P80 of 75µm down to a P90 of 25µm. This duty required 35 kWh/t, and would have involved multiple numbers of the M3000 IsaMills™. However a joint development between Anglo Platinum, and Xstrata Technology, enabled the much larger M10,000 to be developed. Not only was this mill nearly 3 times bigger in volume than the M3000, it was powered by a 2.6MW, and provided considerable more energy available for grinding, (Figure 4). Later versions were supplied with 3MW motors (Anderson 2006), such versions offering 300kW/m^3. Larger flow rates could now be treated by IsaMill™ technology.

With the developments of ceramic media and M10,000 IsaMills™, energy efficiency and other benefits that were common in fine grinding circuits, were now transferred to coarse grinding applications.

Figure 4 – M10,000 IsaMill™

IsaMills™ AND THE POTENTIAL OF MAGNETITE GRINDING

The increasing worldwide demand for iron ore has triggered the development of Australia's magnetite resources. While once regarded as uneconomic to process, they are now being seriously considered as a potential iron source at the current iron ore prices, driven by high demand from the China.

Magnetite has been regarded as uneconomic to process in Australia due to the infrastructure requirements to produce an iron concentrate, as well as the high energy requirements to grind the ore. Haematite deposits in the Pilbara region of Western Australia have always been the preferred source of iron ore in Australia, due to its relatively low cost mining and processing methods, and its high quality and abundance. However, the surging iron ore price and the high demand for iron, has resulted in many magnetite projects, that were once regarded as marginal, being regarded as commercial propositions.

To date, there are approximately 5 projects planning to treat magnetite ore, scheduled to be started up over the next 5 years, with many others being considered. By 2014 this would mean approximately 40MT of ore will need to be processed yearly (Gardner-Bond, 2008; Australian Resources, 2008).

Magnetite is also a key source of iron in many countries where haematite resources are not present, and regions such as Northern Africa, Central Europe, China, and North America have operations mining and treating magnetite. In these operations, traditional comminution technology such as ball mills and tower mills are common practice, and the large tonnages treated in these plants results in large amounts of power being used for grinding the ore.

However, with the development of IsaMill™ technology for coarse grinding applications in base metals, there is also significant potential for the IsaMill™ to be used in magnetite operations. More energy efficient grinding in these plants with IsaMill™ technology, could result in less installed power being required, compared to traditional plant design utilizing ball mills and tower mills, with less infrastructure required such as cyclones and pumps.

MAGNETITE TESTWORK

The objective of the test was to do a side by side comparison for a magnetite sample being ground by an IsaMill™ and a tower mill to determine the signature plot of each mill. Both mills were to be run in open circuit. Davis tube testing was also undertaken on the samples after grinding.

The testwork was undertaken at the CSIRO facilities at Pullenvale, Queensland. At this site there is a M4 IsaMill™ lab scale unit, as well as a small scale tower mill.

Magnetite ore for the testwork was sourced from Ernest Henry Mine tailings (EHM). This mine is a copper mine in North West Queensland, with the host rock being a breccia, which is comprised of strongly altered and replaced felsic volcanic fragments in a matrix assemblage of predominantly magnetite, chalcopyrite and carbonate minerals. Post flotation, the majority of the chalcopyrite and some other sulfides have been separated from the gangue stream, leaving it rich in magnetite.

The M4 IsaMill™ is a 4 litre mill, containing 7 discs for this testwork, operating with 3.5mm ceramic Keramax® - MT1™ media. The tower mill is 40L capacity and operates using 12mm steel media. These are displayed in Figure 5.

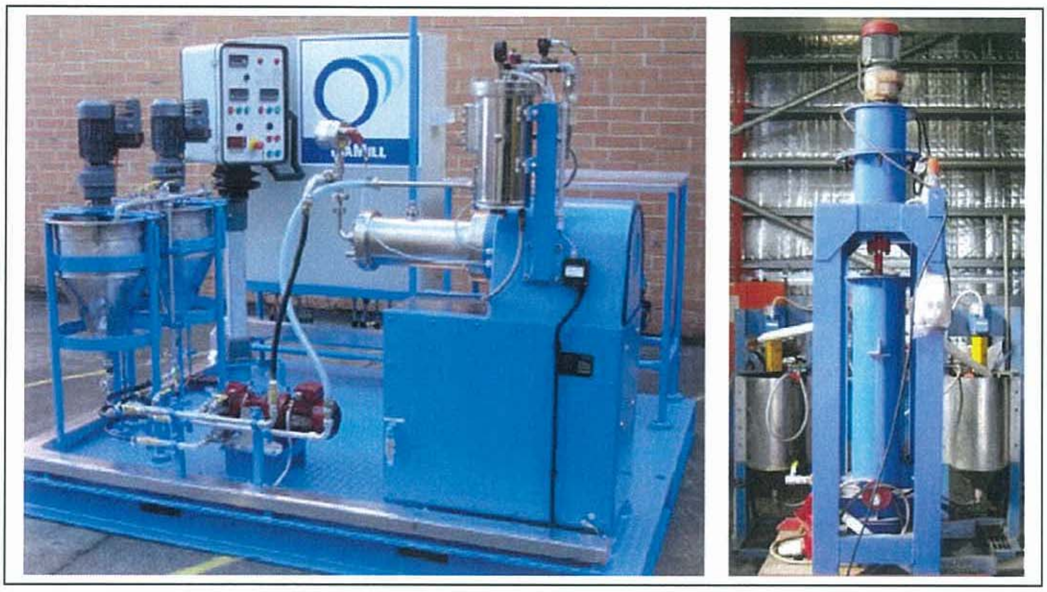

Figure 5: M4 IsaMill and small scale Tower Mill

For the tests, the as received sample under went sample preparation and preliminary grinding to reduce the feed size from 163um to 113um to eliminate oversize particles blocking the test rigs.

In each test, 20 to 21kg of sample was made into slurry of 50% solids and pumped through each mill for a number of runs. The power used for each run is recorded, and a small sample of the discharge is taken for laser sizing. This procedure is carried out through each mill for a minimum of 12 times, or until there is no significant reduction in the sizing, i.e. the mill cannot reduce the sample any further. The data is then used to draw a signature plot (a log-log graph of P80 size versus the specific energy to obtain that size), as displayed in Figure 6.

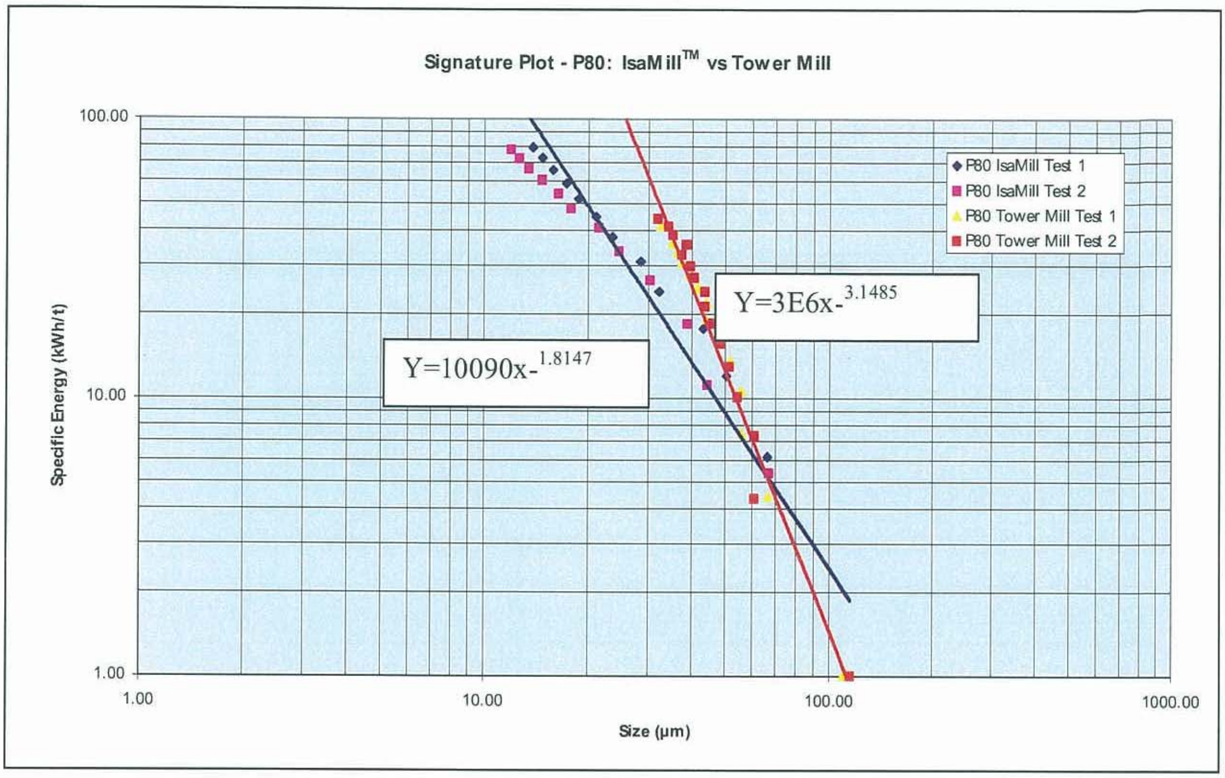

Figure 6 – Size versus Specific Energy - M4 IsaMill™ and Tower Mill

Grinding Results

The signature plot for the two tests, for each grinding technology, shows a good level of reproducibility.

The IsaMill™ was able to reduce the top size of the feed, at a F80 of 113µm, down to a P80 of 13µm. The tower mill also treated the same feed size, however couldn't produce grind sizes down any further than 31µm. For the testwork, a charge similar to what a full scale grinding unit would use was used. In the case of the IsaMill™, 3.5mm ceramic media (Magotteaux Keramax® MT1™) was used, while in the tower mill, 12mm steel media was used. As expected, the smaller media in the IsaMill™ enables finer grind sizes to be achieved, while the 12mm balls in the tower mill limits how fine the tower mill can grind.

The flatter curve for the IsaMill™ signature plot indicates less energy required to achieve grind size, than the steeper curve that was obtained with the tower mill. This difference has a big impact on the energy needed to grind down to the required product sizes. For instance, to reduce a theoretical sample with a P80 from 100 µm to 30µm, using the tower mill will take approximately 39 kWh/t. However to do the same size reduction with an IsaMill™ will take only 13 kWh/t, only a third of the tower mill power. The key to the signature plots is that for the coarser sizes, there is only a small power requirement to grind the coarse sizes. However as the size required becomes smaller, there is an exponential increase in the power required. Therefore while the tower mill may be more power efficient at sizes greater than 65µm, a reduction in particle size less than 65µm for this sample will result in the IsaMill™ being more efficient.

One scenario that was not tested was using the tower mill in a closed circuit, as is often the case in practice. However setting up such an experiment is difficult due to recirculating loads and ensuring the cyclones cut efficiently. This is one of the practical drawbacks of closed circuits, in that cyclones never operate efficiently, and are often poorly maintained, and small diameter cyclones required for fine cuts, are prone to blockages. Also the associated power of pumping at a reasonable pressure for the cyclone to operate needs to be taken into account in the energy use in these circuits.

The signature plot was restrictive in the scale that could be achieved with the IsaMill™, as the feed for each test was maintained at a P80 of 113µm. In practice, coarser grinding can take place at increased sizes between P80's of 250 to 300µm, and larger media is being developed to handle even coarser sizes.

Davis Tube Results

The samples from the grinding testwork underwent Davis Tube testing, which involved the separation of the magnetics from non magnetics using a small scale magnetic separator. The iron grade versus iron recovery obtained from this testwork is shown in Figure 7. The grade recovery relationship indicates the maximum grade for the ore type was 71% iron, at a maximum iron recovery of 90%. The assay from the magnetic separation from the Davis Tube testwork gives an indication of how the liberation of the minerals occurs as the particle size reduces.

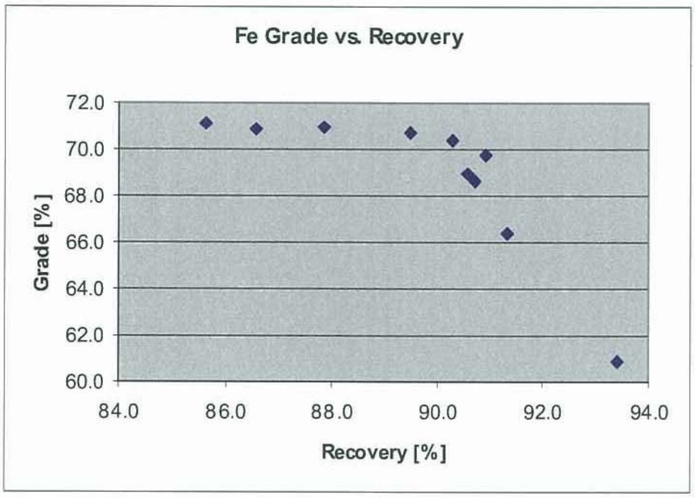

Figure 7 – Iron Grade vs. Recovery

The EHM tailing that was received and used in the test work contains 43% iron, with a P80 of 163µm. When this material under went magnetic separation without regrinding a concentrate containing 61% iron was achieved at an iron recovery of 93%. At this grade, the silica, sulfur, alumina and phosphorus levels are 9.3%, 0.34%, 2.01 and .02% respectively.

The data was also plotted to produce a grade versus size curve as shown in Figure 8.

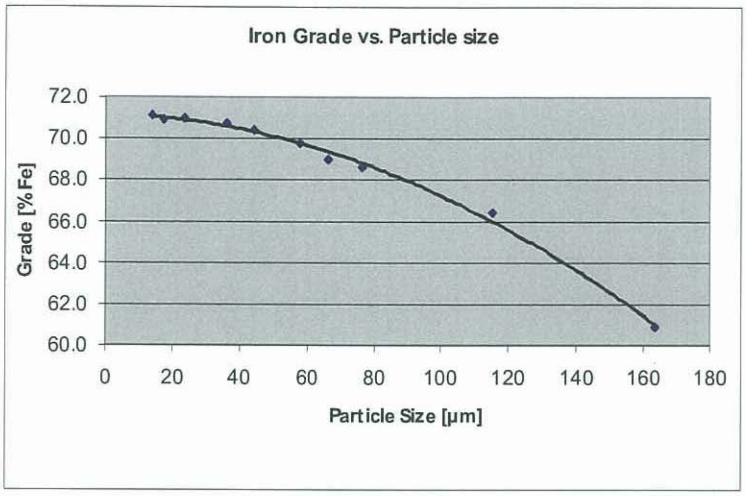

Figure 8 - Grade vs. Size Curve

Figure 8 shows that a 70% iron grade is achievable with a grind size P80 of 50 µm. Further grinding will improve the grade marginally to a 71% iron grade. As in any grinding circuit, the benefits of increased concentrate grade needs to be weighed up against the extra grinding power that is required. In cases where the grind size is quite fine, the increase in grade requires an exponential increase in grinding energy and could well require another grinding unit to achieve.

Figures 9, 10, 11 and 12 also show the particle size grade relationships of the impurity elements, silica, sulfur, alumina and phosphorus. As expected, grinding finer and separating the magentics from the non magnetics, will result in less of the non ferrous impurities reporting to the magnetics as they are liberated by finer grinding. At a grind size P80 of 50µm, silica, sulfur, alumina and phosphorus levels have dropped to 1.6%, 0.045%0.035 and .003% respectively.

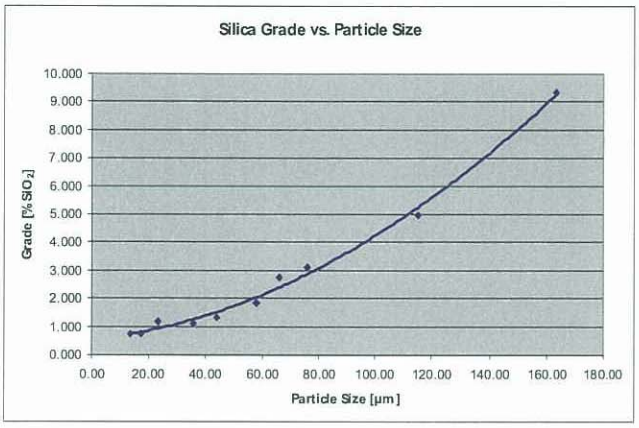

Figure 9 – Size vs. Silica Grade

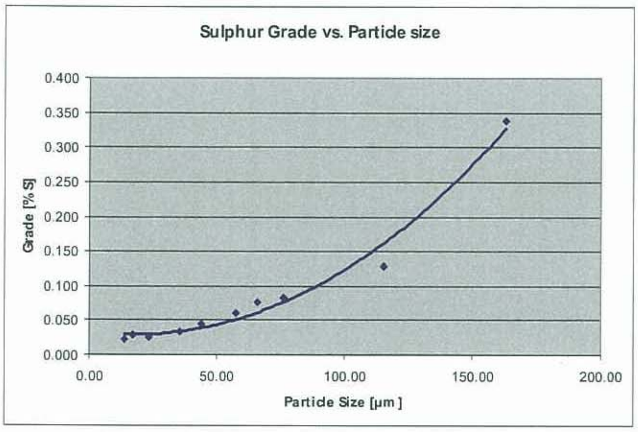

Figure 10 – Size vs. Sulfur Grade

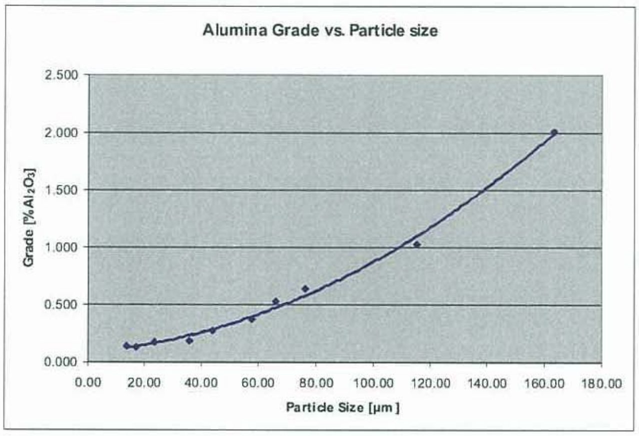

Figure 11 – Size vs. Alumina Grade

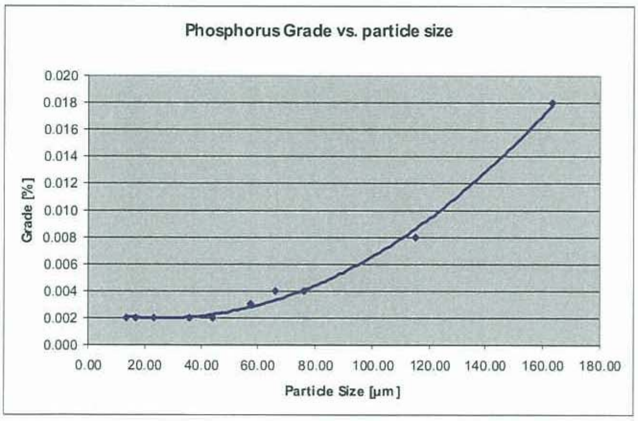

Figure 12 – Size vs. Phosphorus Grade

	Size (µm)	%Fe	$\%SiO_2$	%S	$\%Al_2O_3$	%P	%Cu	%As	%Co
As Received	163.30	60.890	9.340	0.339	2.010	0.018	0.083	0.007	0.009
Ground Feed	115.35	66.440	4.980	0.128	1.030	0.008	0.037	0.004	0.006
Ground Sample 1	76.20	68.620	3.090	0.082	0.640	0.004	0.022	0.003	0.005
Ground Sample 2	66.20	69.000	2.730	0.076	0.530	0.004	0.020	0.003	0.005
Ground Sample 3	57.83	69.780	1.840	0.060	0.370	0.003	0.016	0.002	0.005
Ground Sample 4	44.14	70.420	1.330	0.045	0.270	0.002	0.015	0.002	0.005
Ground Sample 5	36.04	70.690	1.080	0.033	0.180	0.002	0.012	0.002	0.005
Ground Sample 6	23.46	70.980	1.150	0.026	0.170	0.002	0.010	0.000	0.004
Ground Sample 7	17.27	70.900	0.720	0.028	0.130	0.002	0.011	0.000	0.004
Ground Sample 8	13.82	71.120	0.730	0.022	0.140	0.002	0.010	0.002	0.004

Table 2 – Assay per Size Fraction – Magnetic Concentrate

In relation to other magnetite ores, there have been several M4 IsaMill™ tests conducted on other deposits, although not as many as undertaken on base metal deposits. The magnetite samples come from deposits in the Yilgarn Craton in Western Australia, and Central Europe

The M4 IsaMill™ on the magnetite material to date, indicate that it is in the middle of the range in terms of the power required to reduce the size of the sample. Magnetite, copper and PGM (Platinum Group Minerals) signature plots using an M4 IsaMill™ have been plotted on Figure 13, as well as in Table 3, for the power required to grind samples from an F80 of 45 µm, to a product size P80 of 25µm. This range was chosen as the majority of magnetite samples that have been tested have been in this range. However, as observed in Table 2, the IsaMill™ could treat much coarser magnetite feed sizes than these.

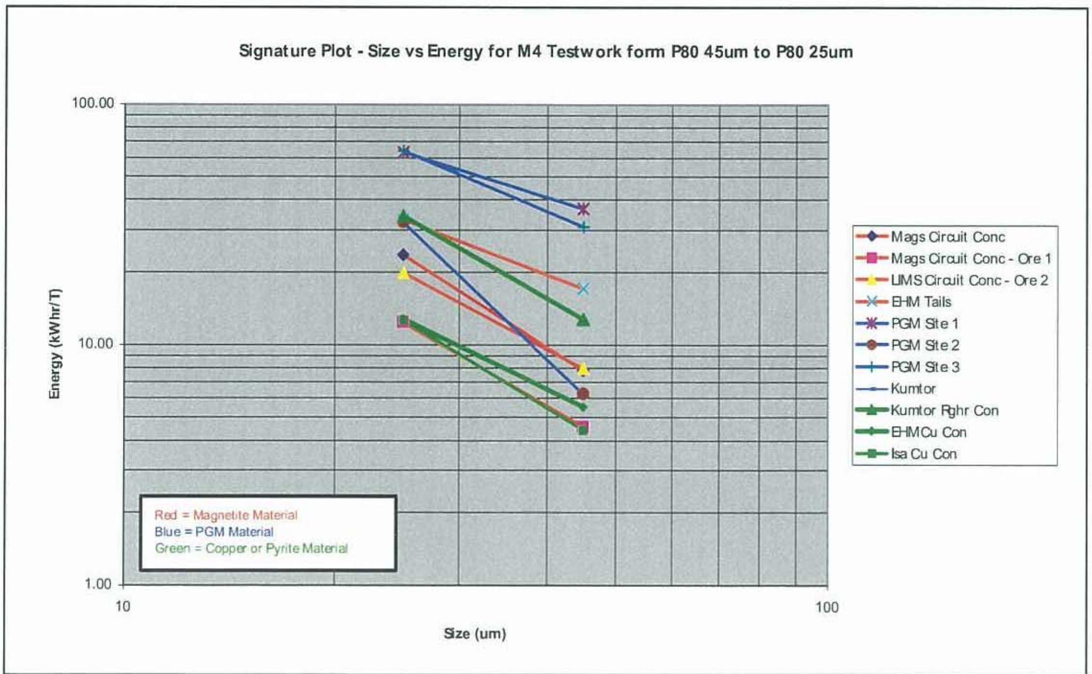

Figure 13 – Signature Plots of Different Materials

Material	Circuit	kWh/t
Magnetitie Material	Mags Circuit Conc	15.8
Magnetitie Material	Mags Circuit Conc - Ore 1	7.8
Magnetitie Material	LIMS Circuit Conc - Ore 2	12.0
Magnetitie Material	EHM Tails	16.0
PGM Material	PGM Site 1	26.2
PGM Material	PGM Site 2	26.1
PGM Material	PGM Site 3	33.1
Pyrite Material	Kumtor Rghr Con	21.5
Copper Material	EHM Cu Con	7.3
Copper Material	Isa Cu Con	8.2

Table 3 – Power Requirement for Grinding from 45μm to 25μm

The information from Table 3 and Figure 13 indicates that the 4 magnetite samples required 8 to 16 kWh/t to achieve the grind required. The hardest of the magnetite material was the EHM tail sample. In comparison to the EHM copper concentrate sample, EHM Cu Con, which is floated off before the tailing, and contains mainly chalcopyrite and other sulfides with low levels of magnetite, required less than half the energy compared to energy required to do a similar size reduction for the EHM Tails sample.

The PGM Material came from several sites across the Bushveld in South Africa. The power required for the grinding duty ranged from 26 to 33 kWh/T, and was significantly higher than the energy to grind the magnetite sample, which ranged in energy from 8 to 16 kWh/t. Both PGM Site 2 and PGM Site 3 have M10,000 IsaMills operating, treating the PGM minerals which are associated with the hard chromite host rock. The other site in the list where a M10,000 IsaMill™ operates is the Kumtor mine in Kyrgyzstan, which treats a pyrite concentrate at 21.5 kWh/t.

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 mineralization: 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. Feed to the concentrator will consist of 12MT on average, with planned annual output from this mine being over 200,000 tonnes 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 106μm to a P80 of 38μm, before further flotation. The grinding media for the operation will be MT1. The Phu Kham Copper-Gold operation is planned for start-up in mid 2008.

Prominent Hill Project

Oxiana Limited owns 100% of the Prominent Hill copper-gold project located 650 kilometers north west of Adelaide, and 130 kilometers north west of BHP Billiton's Olympic Dam in South Australia.

The ore body consisting of a copper gold breccia, 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 tpa, peaking at 230,000 tpa 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 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 125μm to a P80 of 24μm 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

In 2007, Anglo Platinum had ordered five, M10,000 IsaMills™, following the successful installation and operation of the first M10,000 IsaMill™ at their Western Limb Tailings Retreatment Project in 2003. The typical duty of these installations is from 75-100 μm feed size down to 53 μm product size.

Installations have been successfully commissioned at Potgietersrust Platinum mine (C-Section), Potgietersrust A and B Sections (2 mills), and two more at the Rustenburg Watervaal UG2 operation.

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 14 illustrates the simplified C section flowsheet using an IsaMill™.

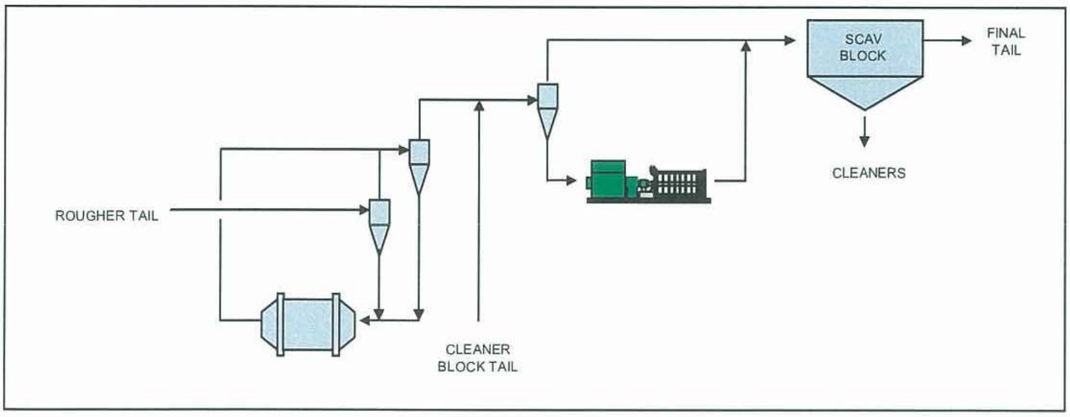

Figure 14: Simplified PPL C Section Flowsheet with a M10,000 IsaMill™

McArthur River Mines (MRM)

McArthur River Mine (MRM) is a zinc/lead mine in the Northern Territory, Australia, and is operated by Xstrata Zinc. It was commissioned in 1995, and was where the IsaMill™ was developed to regrind streams down to a P80 of 7 µm, which 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 IsaMills™ with a combined installed power of 6.7MW. The current plant flowsheet is shown in Figure 15.

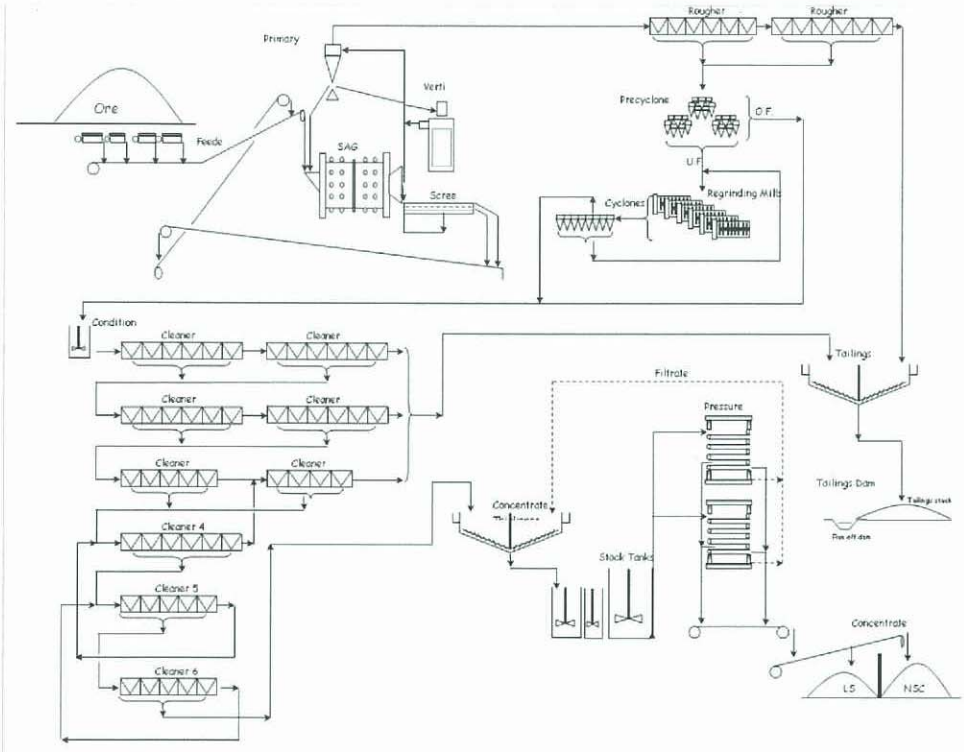

Figure 15: McArthur River Flowsheet

MRM have a need to increase milling capacity from 230tph to 305tph to account for decreased head grades as the operation shifts from underground to open cut. Flotation feed size is also to be reduced from the current P80 of 75µm, back to the original size of a P80 of 45 µm. 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.

Testwork has been undertaken using a M4 and M20 IsaMills™ treating SAG mill cyclone underflow (Anderson 2006, Burford 2006), with further testwork using a M20 IsaMill™ in late 2006 designed to overcome the presence of scats which caused problems in the earlier testwork. Figure 12 displays the flowsheet that was used for this testwork that incorporated a magnetic separator to remove steel scats in the cyclone underflow. Feed to the mill was also screened at 1mm.

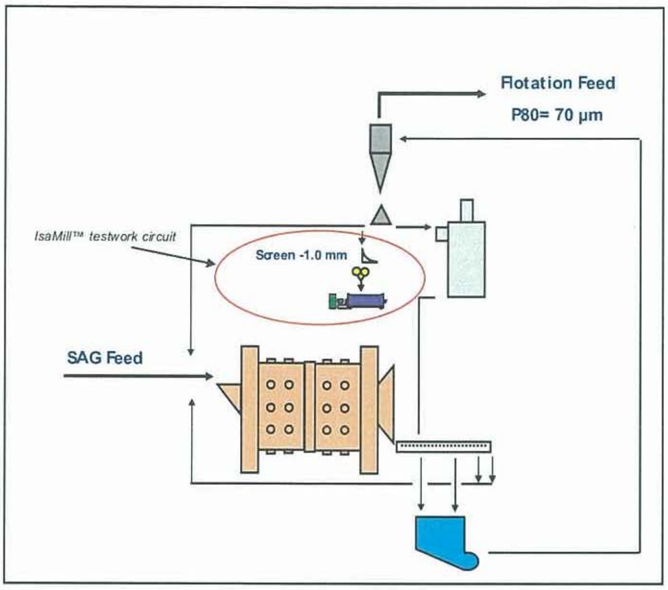

Figure 16: Site Testwork at MRM Using M20 IsaMill™ with a Magnetic Separator on Feed

The M20 IsaMill™ was able to treat material from a feed sizing of 300um, down to a product sizing of 20 to 25 um, (finer than the 40 µm target), in a single pass 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.

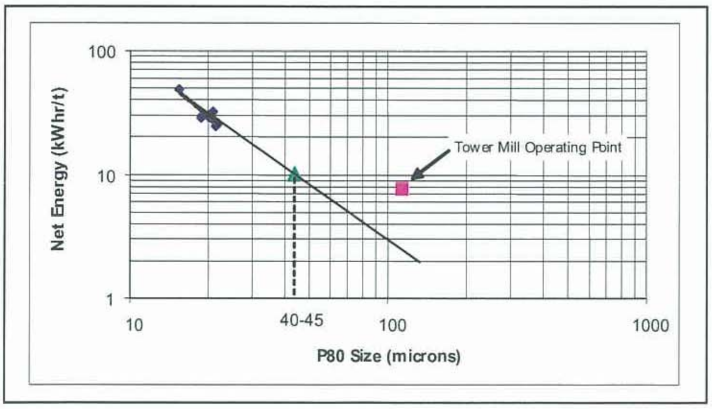

Figure 17: Size versus Net Energy Comparison for IsaMill™ and Tower Mill

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 produce a P80 size of 45 µm to 50 µm, while the tower mill could produce a P80 of 100 µm using a similar amount of energy.

However the flowsheet was not the most efficient use of both of the technologies, especially the IsaMill™, as IsaMill™ operation was hampered by the need to operate the mill to control the coarse particles, rather than achieve target grind size. Simulations followed the testwork with different circuit configurations, which lead to a much better circuit design based on the main advantage of the IsaMill™, open circuit operation.

MRM is planning to use IsaMills™ to treat the flotation feed instead of cyclone underflow, with the eventual circuit designed to eliminate cyclones and the tower mill. The eventual circuit configuration is displayed in Figure 18.

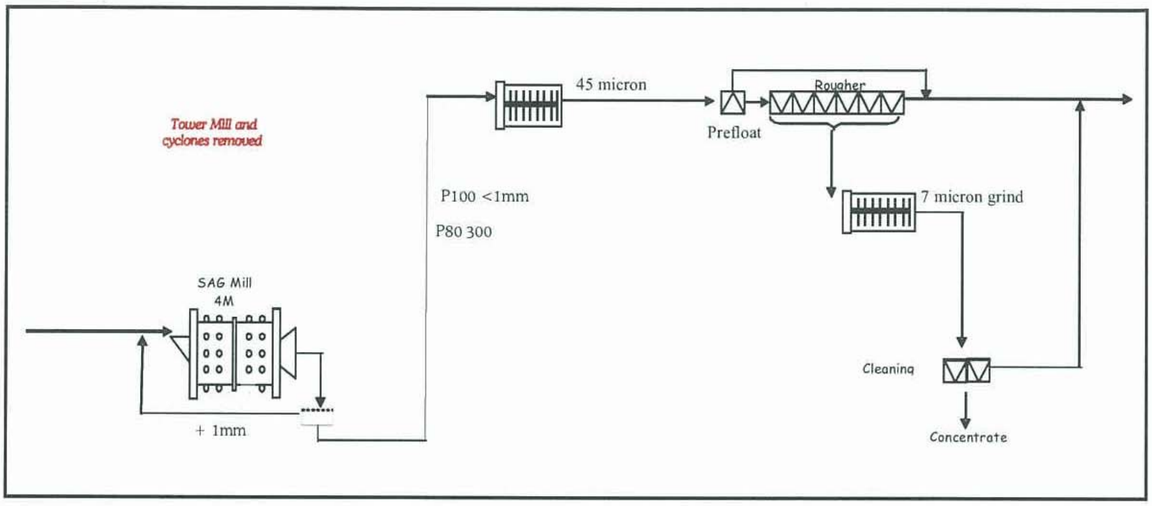

Figure 18 – IsaMill™ in MRM Grinding Circuit

This benefit of this circuit is that it allows the IsaMills™ to concentrate on the particles that it is ideally suited to, with an estimated F80 of 300μm, to produce the P80 of 45μm.

To date, testwork is being undertaken with one M3000, 1.1MW IsaMill™ continuously operating in this circuit with different grinding media, wear materials and feed sizing being trialed by the mill. Later in 2008, two M10,000 IsaMills™ powered with 3MW motors will be installed in the primary grinding circuit, with the rated capacity of the primary grinding circuit to be increased from 1.9 Mtpa to 2.5 Mtpa.

It is expected that the introduction of open circuit IsaMilling™ on the flotation feed using inert media will improve metallurgy as has been observed at other lead/zinc circuits (Pease *et al* 2005, Young *et al* 1997), such as improving the selectivity of fines, improving flotation rates, and reducing circulating loads and flotation reagents.

CONCLUSION

IsaMill™ technology is becoming a realistic alternative in coarse grinding applications since the development of ceramic media as well as the large scale M10,000 IsaMill™. These developments have enabled coarse grinding to be undertaken at a number of mineral processing sites, where energy efficient grinding is required.

The application of IsaMill™ technology to new applications, such as grinding in magnetite concentrators, offers magnetite operators an exciting alternative to conventional ball mill and tower mill technologies. Magnetite ore was found to be amenable to grinding with IsaMills™, in much the same manner as base metal ore is, with several of the magnetite samples being softer than base metal oretypes that are treated using IsaMill™ technology.

With the pressure being applied to all industries today for improved sustainability and the potential cost implications of carbon emission in the future, the need for increased energy efficiency in grinding is as important as ever.

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AMMENDMENT

Figure 6 - Size versus Specific Energy – M4 IsaMill™ and Tower Mill

Equations updated with more data post publishing of original paper.