

# ISAMILL FINE GRINDING TECHNOLOGY AND ITS INDUSTRIAL APPLICATIONS AT MOUNT ISA MINES

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## **ABSTRACT**

Tough economical conditions and high grade but fine-grained ore processing have forced the mining industry to look for more efficient processes. IsaMill Technology for ultra-fine and fine grinding is one such process employed at several mining operations in Australia including Mount Isa Mines Limited in Australia. Mount Isa Mines is a business unit of MIM Holdings Limited. MIM is an Australian-based international mining and mineral processing company with around 8000 employees worldwide. Major products include copper, gold, zinc-lead-silver, coal and technology sales.

The IsaMill is a horizontal stirred mill with sizes up to 3 m<sup>3</sup> chamber net volume and 1120 kW installed motor. It was jointly invented by Mount Isa Mines of Australia and Netzsch Feinmahltechnik GmbH of Germany for ultra-fine and fine grinding duties in the minerals industry. IsaMill operations started in 1994 at the Mount Isa Mines Lead/Zinc Concentrator and then at MIM's McArthur River Mine in 1995. These IsaMills have been used to liberate sphalerite and galena at Mount Isa and silica at McArthur River by grinding to less than 7 micron.

This paper discusses the IsaMill Technology and reports on the metallurgical performance of the IsaMills at Mount Isa Mines, including work done over the last 9 years to improve mill design, process efficiency and maintenance, which has resulted in the current state-of-the-art IsaMill Technology.

## **INTRODUCTION**

The current lead/zinc deposits at Mount Isa Mines (George Fisher, Hilton and Isa) have an average grade of 10.5% of zinc, 7.2% of lead and 165g/t of silver. Fine grinding, in particular in the zinc retreatment circuit requiring a milled product P<sub>80</sub> of 7 micron, is essential to treat the ores from the Mount Isa Mines deposits. Every one micron size reduction in the zinc retreatment circuit below a P<sub>80</sub> of 10 micron improves the overall plant zinc recovery by 1%, resulting in an increase in revenue of about 1 million dollars per annum.

Eight IsaMills operate in the Lead/Zinc Concentrator at Mount Isa Mines, with two installed in 1994 and six commenced operation at the end of 1999. (Enderle et al, 1997; Johnson et al, 1998; Young et al, 2000). These are required for ultra-fine grinding to achieve liberation of fine-grained minerals, which improves separation of the minerals in the flotation circuits.

The process parameters and IsaMill designs have been continuously improved to increase the IsaMill grinding performance and the component life between maintenance periods. This paper reports the latest progresses in developing the IsaMill process and discusses the new features of the mills that have enhanced their performance.

## **THE ISAMILL TECHNOLOGY**

IsaMill is a major development in grinding technology jointly invented by Mount Isa Mines of Australia and Netzsch Feinmahltechnik GmbH of Germany for ultra-fine and fine grinding duties in the minerals industry. The IsaMill was introduced by MIM over a period of 9 years, as there

was no existing ultra-fine grinding technology that could be used or modified for use in the minerals industry. The IsaMill technology demonstrated its ability for very power efficient grinding to less than 10 micron. The major hurdles that required extensive investment in time and money were the high wear rates, characteristic of this type of technology, and the separation of media from the product. Other technologies use exotic materials in construction and screens for these purposes but they are not consistent with a low cost, large scale and reliable grinding technology. The result of MIM's development is a combination of smart component design and careful selection of rubber and polyurethane compounds to give long wear lives with relatively cheap materials.

IsaMills are currently operating in three mining operations in Australia. Namely, Mount Isa Mines, McArthur River Mine and Kalgoorlie Consolidated Gold Mines. A total of 15 IsaMills are in use at these operations. Figure 1 shows the eight IsaMills at the Mount Isa Mines Lead/Zinc Concentrator.



**Figure 1: IsaMills in the Regrind Circuits at the Mount Isa Mines Lead/Zinc Concentrator**

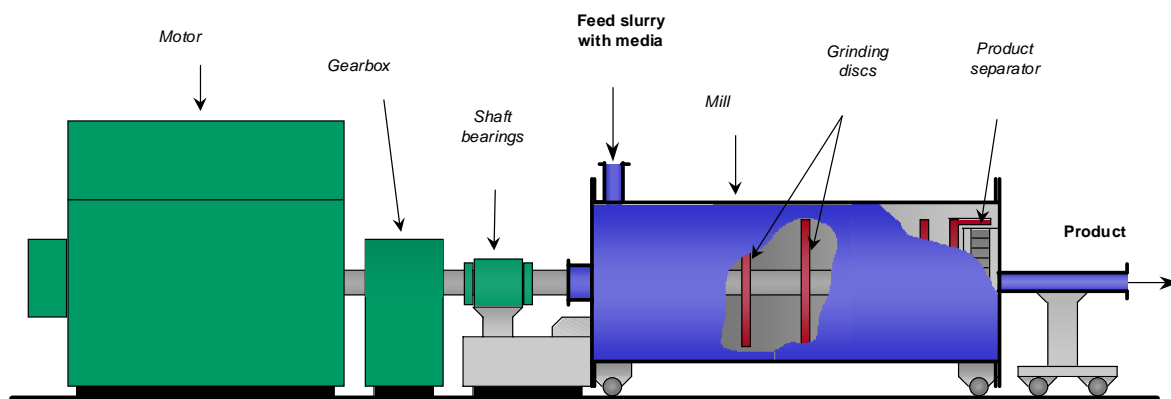
The IsaMill is a horizontal high speed stirred mill that operates with very high power intensities (up to  $350 \text{ kW/m}^3$ ). In comparison, the power intensity of a ball mill is about  $20 \text{ kW/m}^3$ . The high power intensity enables the IsaMill to process fine particles at a high throughput that is essential for the economics of the minerals industry. The largest IsaMill currently available has a horizontally mounted grinding chamber shell of about  $4 \text{ m}^3$  in total volume (or approximately  $3 \text{ m}^3$  working volume). Inside the shell are rotating grinding discs mounted on a shaft which is coupled to a motor and gearbox. To allow quick and simple removal of the grinding chamber to expose the mill internals for maintenance purposes, the shaft is counter-levelled at the feed inlet end. The grinding discs agitate the media and ore particles in a slurry that is continuously fed into the feed port. A patented product separator keeps the media inside the mill allowing only the product to exit and simple control strategies based on power draw enable the IsaMill to produce a constant target product size. The invention of the product separator eliminates screens from ultra-fine grinding which delivers a process with the robustness required by the mining industry. The

product separator uses the high centrifugal forces generated to retain the media inside the grinding chamber.

The IsaMill uses fine media, stirring it with very high disc rotation speed, which increases the probability and energy of media/particle collisions. The mill has been designed to break particles using the attrition/abrasion mode of breakage where particle surfaces are chipped repeatedly producing very fine sized progenies at relatively low power consumption.

The compact IsaMill operates under pressure with "stage-by-stage" grinding occurring between the high speed rotating discs, which ensures grinding events are evenly distributed throughout the grinding chamber. This homogeneous grinding mechanism results in significant improvements to the particle size distributions from the feed to the product. The IsaMill Technology grinds the particles requiring size reduction, without over-grinding material at or below the required  $P_{80}$ . The uniform grinding mechanism is also the reason why IsaMill scale-up is 100% direct from laboratory to pilot to full scale (Weller et al 1999).

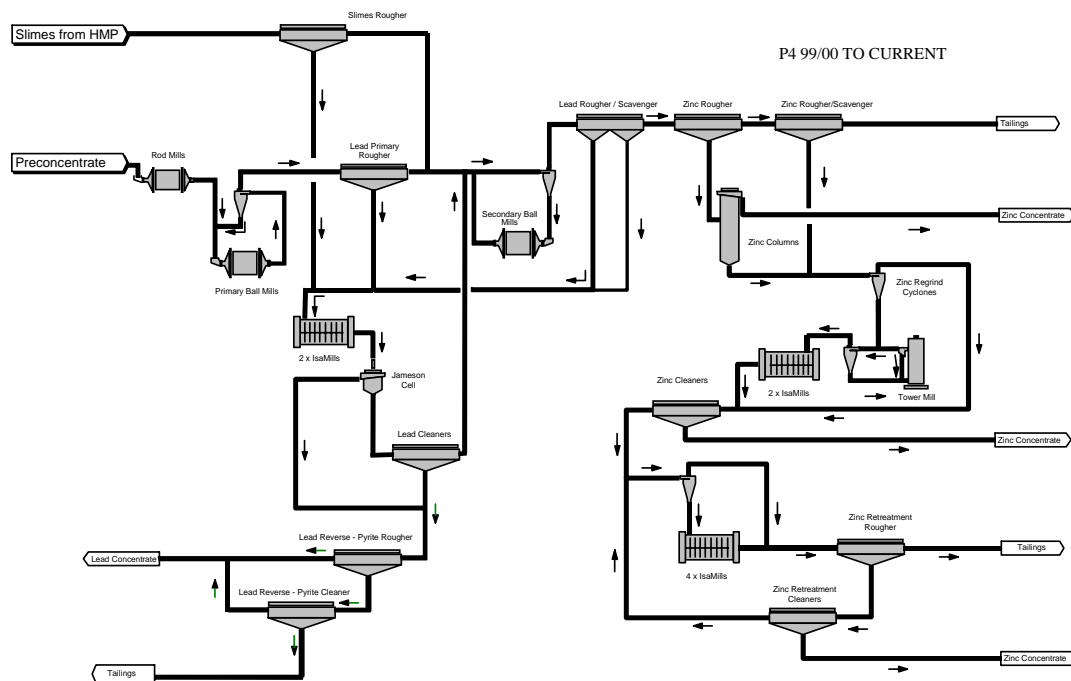
Currently, all operating IsaMills are installed with 1120 kW (1500 hp) motors and a grinding chamber with a net volume of 3 m<sup>3</sup>. A range of different size IsaMills below the 1120 kW motor model are also available. The schematic of the mill is shown in Figure 2.



**Figure 2: IsaMill Schematic indicating Major Components**

## **MOUNT ISA LEAD/ZINC CONCENTRATOR FLOWSHEET**

The process flowsheet of the Mount Isa Mines Lead/Zinc Concentrator is shown in Figure 3. The circuit has been through various stages of modifications to address the declining ore qualities in the last ten years (Young et al 1997). It contains three IsaMills in the lead circuit and five IsaMills in the zinc regrind and retreatment circuits.



**Figure 3: Mount Isa Mines Lead/Zinc Concentrator Flowsheet**

The designed specifications of the IsaMills in the lead and zinc circuits are listed in Table 1. The product  $P_{80}$  sizing of 12 micron for the lead and zinc regrind IsaMills was required to liberate the galena and sphalerite from the gangue materials in the lead rougher concentrate, zinc column cleaner tailings and zinc rougher/scavenger concentrate. The zinc cleaner tailings were further reduced to a product  $P_{80}$  of 7.5 micron in the zinc retreatment circuit.

**Table 1: Design Specifications of the IsaMills**

	<b>Lead Regrind</b>	<b>Zinc Regrind</b>	<b>Zinc Retreat</b>
Feed $F_{80}$ , micron	25	25	20
Product $P_{80}$ , micron	12	12	7.5
Net Energy, kWh/t	10	25	45

The ores from lead/zinc deposits in Mount Isa Mines contain minerals with a range of textural associations (Bojcevski et al, 1998). These textural associations allow a portion of the minerals to be liberated at coarse grind sizings ( $P_{80} = 37$  micron), a portion to be liberated at fine grind sizings ( $P_{80} = 12$  micron), while the remainder require ultra-fine grind sizings ( $P_{80} = 7.5$  micron) for liberation.

This range of textural associations allows the use of a flowsheet using staged grinding and staged flotation to remove liberated valuable minerals with a coarse grind, while composite particles are reground for further liberation. This reduces the overall grinding energy consumption of the

flowsheet and decreases the flotation capacity required, as coarse particles have faster flotation kinetics than fine particles.

## THE ISAMILL PERFORMANCE

### Lead Regrind Circuit

The original lead regrind circuit was part of the bulk lead/zinc retreatment circuit that consisted of a tower mill operating in closed circuit configuration with 6 inch Krieb cyclones as shown in Figure 4. The cyclone overflow was processed by Agitair flotation cells. This circuit had problems of over-grinding the galena-bearing minerals as the cyclones returned the smaller but heavier galena particles and coarser but lighter gangue particles to the underflow for further grinding. The effect of this phenomenon is illustrated in Figure 5.

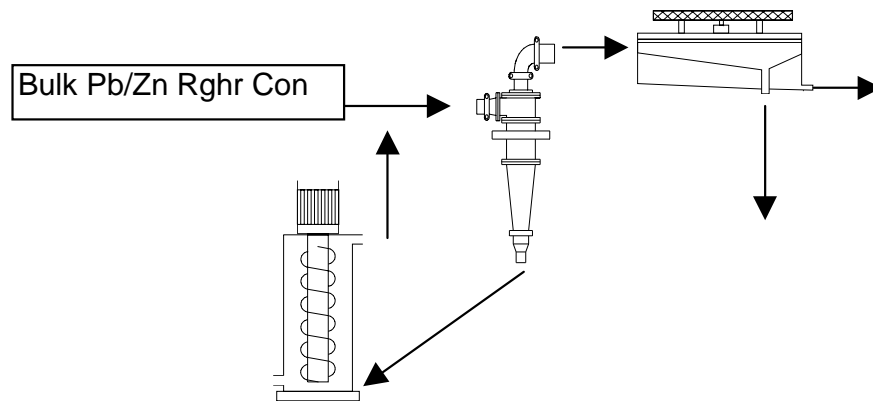


Figure 4: Closed-Circuit Tower Mill for Treating Bulk Lead/Zinc Concentrate

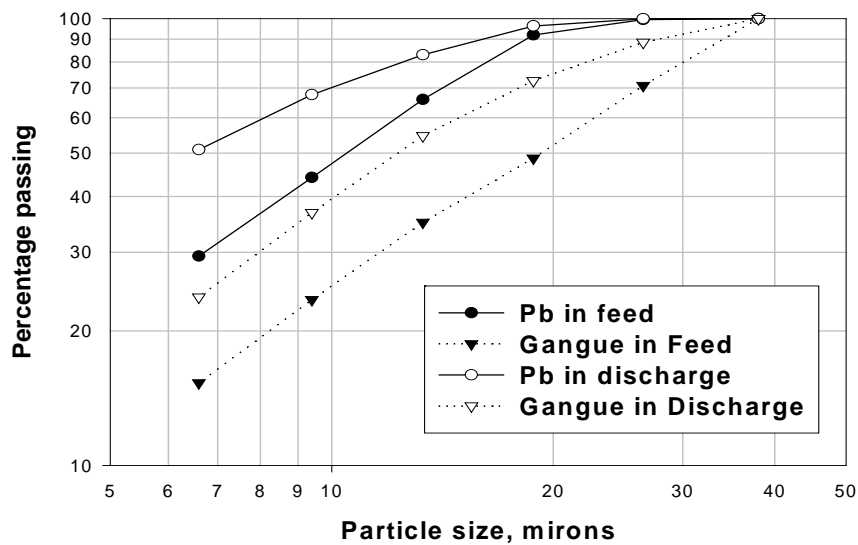
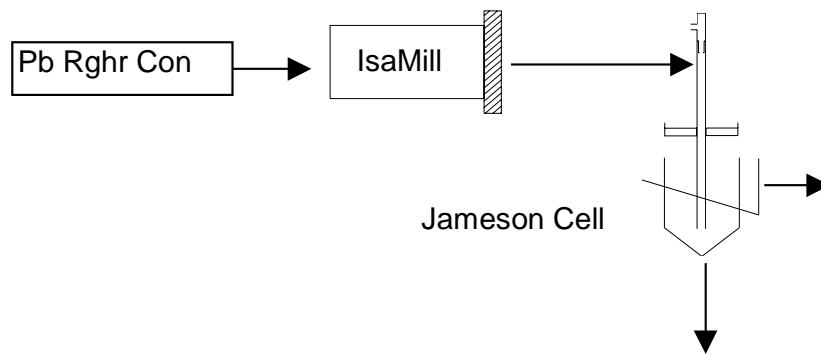


Figure 5: Component Size Distributions of Mount Isa Mines' Tower Mill Feed and Discharge

With the introduction of the IsaMills in 1994, better liberation was achieved. This eliminated the bulk lead/zinc concentrate regrind circuit (Young et al, 1997). In 1999, three IsaMills configured in open circuit were installed in the lead regrind circuit, followed by a Jameson Flotation Cell. This new circuit is shown in Figure 6.

As part of the new circuit the recycle stream in the milling stage was eliminated to ease the problem of over-grinding the galena minerals. The new circuit also incorporated a Jameson Flotation Cell that generates finer bubbles to process the IsaMill product that has a P80 sizing finer than 12 micron. The immediate benefit from this simple circuit modification was to increase the overall lead recovery by 5%.

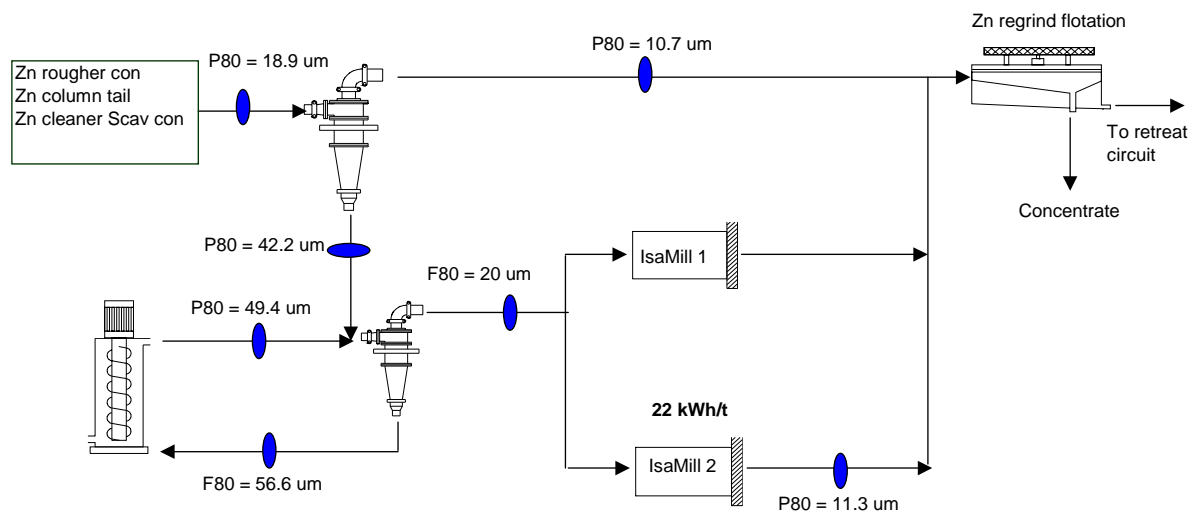
Another feature of the new circuit is the use of inert lead granulation slag as grinding media in the IsaMill. This improves the pulp chemistry and hence flotation selectivity, compared with using 12 mm steel balls in the tower mill.



**Figure 6: Lead Regrind Circuit**

### **Zinc Regrind Circuit**

Figure 7 shows the flowsheet of the zinc regrind circuit. It includes a pre-cycloning stage, a closed-circuit tower mill and two open-circuit IsaMills that operate in parallel. The feed to the pre-cycloning stage includes the zinc column cleaner tailings and the zinc rougher and scavenger concentrate. As well as removing particles already at or below the required P<sub>80</sub>, the pre-cycloning stage also increases the feed density to the regrind circuit.

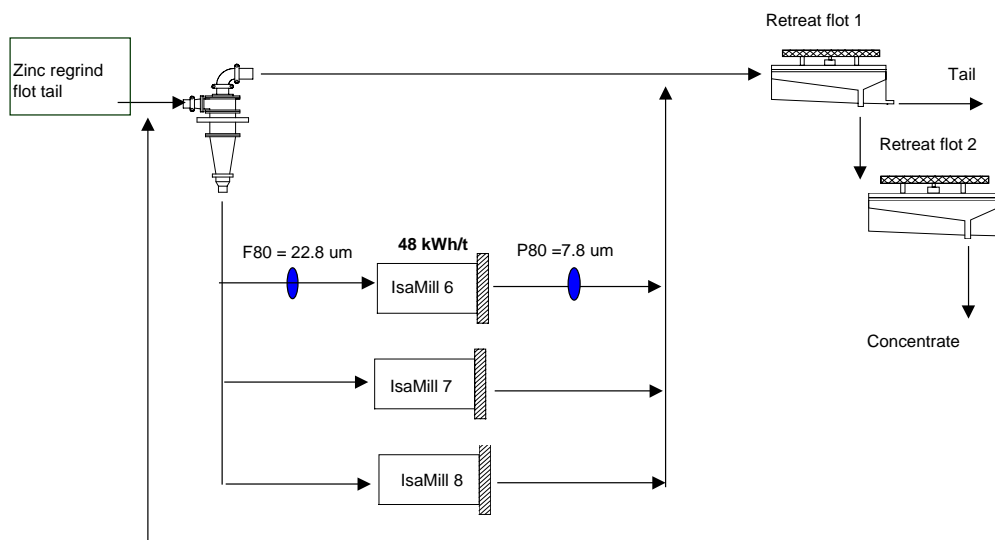


**Figure 7: Zinc Regrind Circuit**

Figure 7 shows that the IsaMills in the zinc regrind circuit reduced the feed  $F_{80}$  of 20 micron to a product  $P_{80}$  of 11.3 micron with a net energy consumption of 22 kWh/t. In comparison, the size reduction across the tower mill was only from a feed  $F_{80}$  of 56.7 micron to a product  $P_{80}$  of 49.4 micron.

### Zinc Retreatment Circuit

Figure 8 shows the zinc retreatment circuit. There are three IsaMills in the circuit. The feed to the pre-cyclones in the retreatment circuit includes the zinc cleaner tailings and the zinc retreatment cleaner tailings. These streams are pre-cycloned to remove material already at or below the required  $P_{80}$  and to increase the feed density to the IsaMills. The IsaMill product combines with the cyclone overflow and feeds to the zinc retreatment rougher flotation cells.



**Figure 8: Zinc Retreatment Circuit**

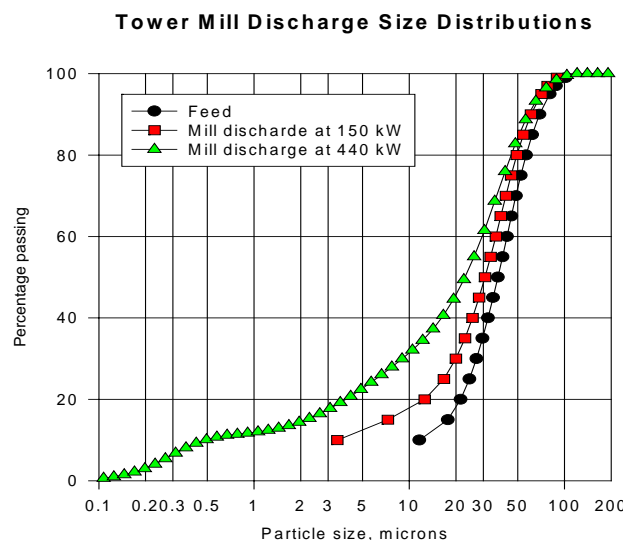


The feed to the zinc retreatment IsaMills is extremely hard to grind as it contains a large amount of composite particles with silica content as high as 30%. This is because the liberated valuable minerals have been removed in previous stages of flotation. Figure 8 shows the performance of one of the zinc retreatment IsaMills. It reduced a feed  $F_{80}$  of 22.8 micron to a product  $P_{80}$  of 7.8 micron with a net energy consumption of 48 kWh/t.

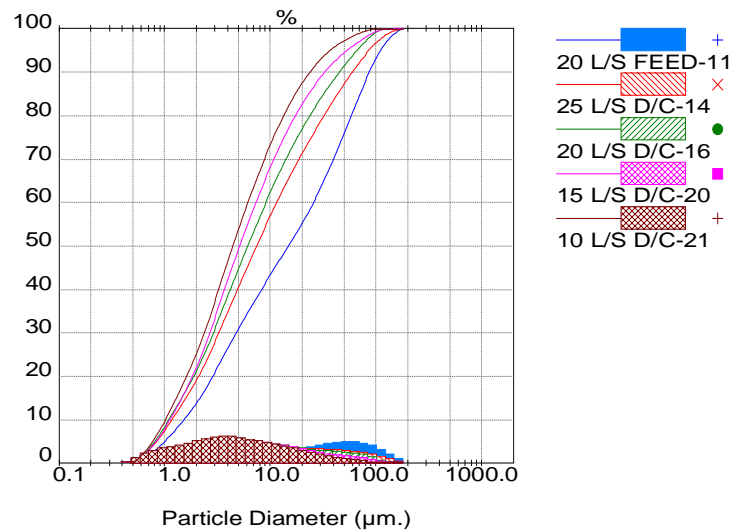
### ISAMILL VERSUS TOWER MILL

The existing tower mill was in operation since 1991, firstly in the lead/zinc bulk concentrate regrind circuit, then in the original zinc regrind circuit. It was re-located to the current zinc regrind circuit in 1999 as the first stage of zinc regrinding. The purpose the tower mill was to produce a finer IsaMill feed, so the available IsaMills could be operated in open circuit with a fine lead slag media of 1 to 2 mm. This fine media sizing achieves the best power efficiency for products below 10 micron.

Using the survey data collected from the zinc regrind circuit, a comparison of the IsaMill versus the tower mill was possible. Figure 9 shows the size distributions of the feed and products for the tower mill. The difference in the 80% passing sizings of the feed ( $F_{80}$ ) and the products ( $P_{80}$ ) was in the order of 5 micron. Many surveys of the same tower mill in previous applications have also indicated that when being fed with a feed  $F_{80}$  finer than 50 micron, the tower mill was capable of a size reduction of only 5 to 10 micron..



**Figure 9: Feed and Product Size Distributions for Zinc Regrind Tower Mill**



**Figure 10: Feed and Product Size Distributions for Zinc Regrind IsaMill**

In comparison, as shown in Figure 10, the size reduction across the zinc regrind IsaMill was from a feed  $F_{80}$  of 55 micron to a product  $P_{80}$  as fine as 12 micron, depending on the feed flow rate.

The excellent size reduction performance with the IsaMills is a result of using small media in the order of 1 to 2 mm. The advantage of operating with smaller media size is that it provides an increased number of media particles in the mill for grinding. For example, 1172 spheres of 1 mm media occupy the volume of only one 12.5 mm ball. Therefore, an IsaMill using 1 mm media will have 1172 times more media particles per mill volume available for grinding compared to a tower mill using 12.5 mm balls.

The IsaMill is also more efficient in using small media by stirring them with very high disc circumferential speed (21m/s), increasing the probability and energy of media-particle collisions. The IsaMill consists of a horizontal stationary mill chamber operating under a pressure of 100 to 200 kPa. This grinding mechanism ensures the grinding events are evenly distributed throughout the mill chamber. In comparison the tower mill is pressurised only by gravity, which results in the grinding events occurring mainly near the base of the tower mill's vertical grinding chamber.

Another major difference in the performance of the IsaMill and the tower mill is the profile of the product size distributions as indicated in Figures 9 and 10. The tower mill product has a long tail at the finer end of the particle size distribution due to over-grinding of the fines. The IsaMill on the other hand grinds mainly the coarser part of the feed size distribution and produces a minimum amount of new fines. This ability of selectively grinding coarser particles in the feed is ideal to liberate the valuable minerals from the inter-locked particles and maximise their recovery in the down stream beneficiation processes. The tighter size distributions produced by the IsaMill allow the flotation circuit to operate more efficiently, since the flotation feed is more uniform. Optimising the flotation circuit is also made easier with a feed having a consistent particle size

distribution. The IsaMill Technology efficiently grinds the particles requiring size reduction, without over-grinding material at or below the required P80.

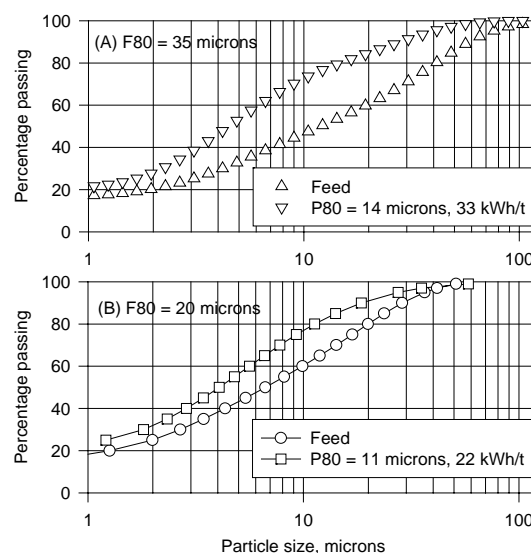
### EFFECT OF SLURRY FEED SIZING

Over the years of operating the IsaMills at Mount Isa Mines, it has been found that the slurry feed size distribution is important for the IsaMill performance when using local smelter slag as the grinding media. A finer feed size would normally help to reduce the energy consumption for a finer product when operated in open circuit. When the feed size becomes coarser the media sizing should be increased to provide the momentum and media-particle size ratio needed for breaking larger particles.

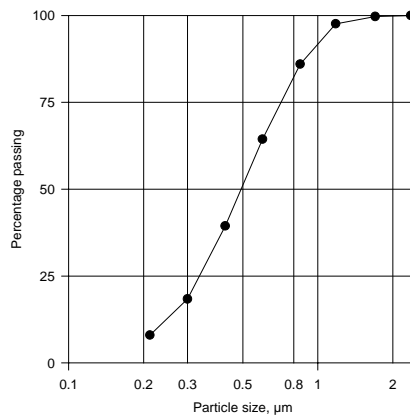
To demonstrate the effect of feed size, the IsaMill performance with feed  $F_{80}$ s of 35 and 20 micron are compared in Figure 11. Reducing the IsaMill feed  $F_{80}$  from 35 to 20 micron enabled the IsaMill to produce a finer product  $P_{80}$  of 11.3 micron compared to 14.4 micron for the coarser feed. Also the net energy consumption was reduced by about 30% from 33 to 22 kWh/t.

The less efficient grinding when processing the coarser feed was due to the size of the fine slag media. Figure 12 shows the size distribution of the slag media collected during the survey. It contained about 50% fines below 0.5 mm, which is at the lower limit of media size for effective grinding in the IsaMill. A finer media normally helps to produce a finer product but has limited ability to cope with a coarser feed.

For an IsaMill operating in open circuit configuration with a fine grinding media, the feed size needs to be controlled operationally to achieve target grind sizes at maximum power efficiency.



**Figure 11: Effect of Feed Size on Zinc Regrind IsaMill**

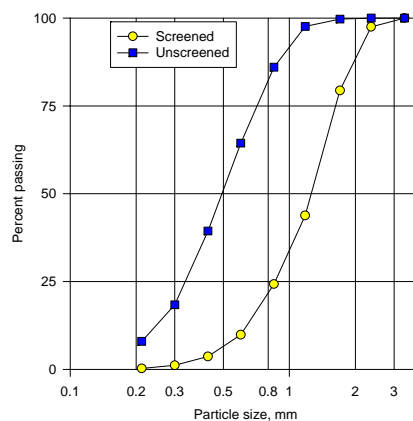


**Figure 12: Size Distribution of Fine Lead Slag Media**

### EFFECT OF MEDIA SIZING

The tower mill circuit prior to the zinc regrind IsaMills is required to maintain the IsaMill performance when the feed size becomes coarser. Another option is to coarsen the slag media size used in the IsaMill to process the coarser feed. If an ultra-fine product is required with both coarse feed and coarse grinding media then the IsaMill should be operated in closed circuit to maintain power efficiency.

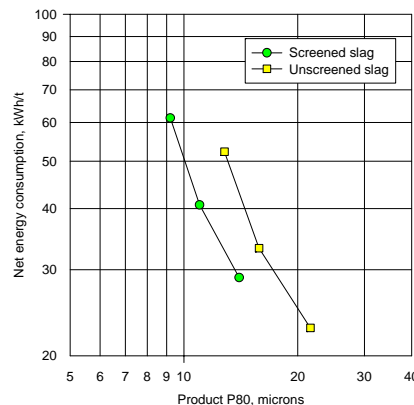
Trials with different lead slag media sizes were conducted in one of the zinc regrind IsaMills, with unscreened slag containing about 50% fines below 0.5 mm and screened slag containing about 8% fines below 0.5 mm. Figure 13 shows the size distributions of the screened and unscreened slag.



**Figure 13: Comparison of Screened and Unscreened Media Size Distributions**

Figure 14 shows the plant survey data using the same feed material, but with screened and unscreened slag as the media. The feed  $F_{80}$  was 30 micron in both cases. The figure shows that screened slag media achieved a  $P_{80}$  of 15 micron using less than 30 kWh/t, compared to unscreened slag which required more than 40 kWh/t for the same product size.

Selection of the grinding media size is undoubtedly one of the key criteria for achieving the maximum IsaMill power efficiency.



**Figure 14: IsaMill Performance with Screened and Unscreened Lead Slag Media**

## NEW DESIGN FEATURES OF THE ISAMILL

The initial prototype IsaMill installed at Mount Isa Mines in 1993 had a grinding chamber volume of 1500 litres and operated with 5 grinding discs. The purpose of this mill installation was to aid in the design of the full-scale production IsaMills. The first production mills installed at MIM's Mount Isa and McArthur River mines operated initially with 6 discs. Subsequently the number of grinding discs was expanded to seven and then to the current standard of eight discs. The net mill volume of the production mills with eight discs was 3000 litres.

Continuous development and improvement of the IsaMills from 1994 to the present has lead to a design providing superior grinding performance, increased component life, and decreased downtime during routine maintenance periods.

With the developmental focus of the IsaMill being minimum operating costs and maximum availability, the equipment has been designed for fast and straightforward maintenance. Locating all major components at ground level with the shell components on rails results in very easy access to the wear items. The major mechanical items such as motor and bearings are standard components with typical maintenance programs and life expectancy.

## Internal Wear Components

The materials of construction and design, and method of fabrication of all IsaMill internal wear components have improved since the first installation. Over 20 different types of wear materials

have been tested. These tests determined the characteristics that components need for long wear life.

The internal steel surfaces on the original production IsaMill grinding chambers and end flanges were cold rubber lined. These wear components were required to be sent to the nearest rubber lining workshop after a certain amount of operating time for relining. This meant that a spare set of these steel components had to be held in stock.

To avoid this requirement components of the feed and discharge end flanges were redesigned, so that only a replaceable rubber wear component had to be held in stock. These rubber components simply slide on to the steel surfaces and then are bolted in place. This allowed improvements in the fabrication technique of these rubber components, which lead to an improvement in wear life.

The final challenge in terms of wear components was the IsaMill grinding chamber. The latest IsaMills were designed with a split shell (Figure 15), in which a replaceable slip-in liner could be installed. The IsaMill shell can be unbolted, opened into two halves and the worn shell slip-in liner removed and a new one installed. This removes the need to send the shell away to be cold rubber lined and the need to have spare shells to install when one is worn. All wear components are fabricated off-site then stored on-site until required. All components are steel backed with rubber or similar coating. These are relatively low cost, light and easy to handle and store, but still provide long wear lives.



**Figure 15: IsaMill with a Split Shell Design**

### **Shaft Sealing System**

In addition to the internal wear components of the IsaMill, the shaft sealing system also requires routine maintenance. This system prevents slurry and grinding media discharging from the point where the rotating shaft enters the grinding chamber. The gland sealing system can be adjusted

externally while operating, similar to a slurry pump, and can be maintained when the discs are removed from the shaft during scheduled maintenance.

The commercial full-scale IsaMills use gland packing and gland water sealing for sealing the shaft. The design of this gland sealing system was a great improvement over several of versions trialed during the scale-up phase of the IsaMill development program. The gland life of these trial systems was shorter than desired, especially since the life of the internal wear components (grinding discs and shell liners) had been extended.

Improvements were made to install an independent gland water supply system that increased the gland life. The new design for the gland system also includes an increased bearing spacing to decrease the deflection of the shaft at the gland, and introduces water flushing on the slurry side of the gland to reduce the amount of slurry and media in this area. The new gland system has been working well since installed about 2 years ago.

### **Mill Access**

Figure 16 shows the support system for the IsaMill. The mill grinding chamber shell and discharge end flange are both fixed to trolleys which are mounted on four wheels that sit on rails. The IsaMill has hydraulic rams on the rails under the wheels. These rams are used to move the grinding chamber and discharge end flange along the support rails so that the internal components of the mill are exposed for maintenance. The original installations had fixed hydraulic power packs on each IsaMill, which tended to get covered in dust and other debris, thus requiring more than expected maintenance. The new IsaMill design has a portable hydraulic power pack that plugs into the rams on the mill when maintenance is required and is then stored in a clean area after maintenance has been completed.

This quick and simple system to access the mills is achievable since the internal shaft is counter-levelled at the feed inlet end. In other words there are only bearings at the feed inlet end of the mill and at the discharge end the shaft is free and does not protrude through the end flange.



**Figure 16: IsaMill Support System**

## **MAINTENANCE PROGRAM**

Maintenance of the IsaMill is as simple as routine maintenance for a slurry pump. As previously mentioned the internal rotating shaft is counter-levered at the feed inlet end. This means that the discharge end flange and grinding chamber can be removed to expose the mill internals without having to remove bearings, shaft etc. The discharge end flange is firstly unbolted from the grinding chamber and the trolley fixed to the flange is then connected to the hydraulic ram and driven out along the rails. Next the chamber shell is unbolted from the feed inlet flange and is also moved along the rails using the hydraulic ram to fully expose the mill internals, including shaft, grinding discs and product separator.

To remove the grinding discs the locking nut at the end of the shaft is undone so that discs can be slid off the shaft. New discs are then slid on the shaft. The bolt-on wear components on the feed and discharge end flanges and the shell liner can then be replaced, if required. After replacing any worn components the chamber shell is moved back into position using the hydraulic ram and rebolted to the feed inlet flange. The discharge end flange is then wheeled up and bolted against the chamber shell. The IsaMill is now ready for to be put back into service.

The maintenance schedule is built around the grinding discs. The average life of a set of discs at Mount Isa is about 4000 hours. The other components last several cycles of disc replacement. The lives of all the components are continually being improved to decrease downtime and maintenance costs.

The maintenance program at Mount Isa Mines is currently based upon a 1,500 hour operating cycle. At the end of each cycle the IsaMill is shutdown and opened for inspection and replacement of wear parts if required. The shutdown has a total duration of 8 hours.

The inspection has the following procedure:

- Shutdown of mill
- Flushing of mill followed by dumping of mill contents
- Removal of end flange bolts
- Removal of Shell
- Inspection of discs, shell liner, product separator and gland seal for wear
- Replacement of any worn discs
- Replacement of gland seal if required
- Re-assembly of shaft, discs and spacers
- Replacement of shell and end-flange
- Recommencement of operation

On each third operating cycle a 16-hour shutdown is undertaken for detailed inspection of bearings and tolerances etc.

At Mount Isa Mines the shell liner, product separator and end-plate linings have typical wear lives of 18 months. The shaft sleeves (disc spacers) are low wear items and their life significantly exceeds that of the other mill internals.



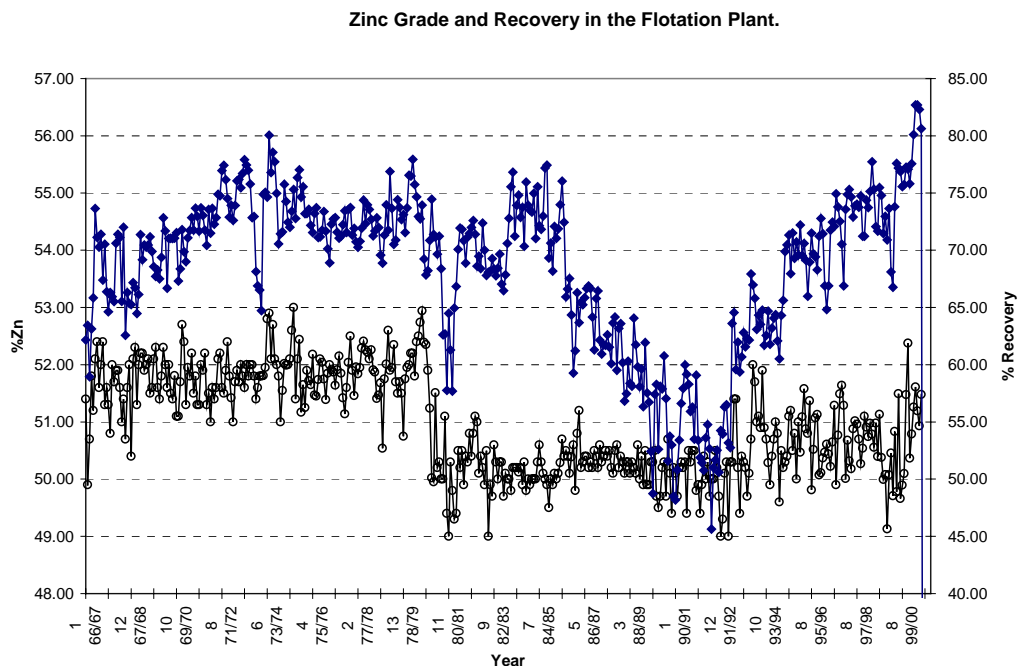
The gland seal packing is comparable to that used in slurry pumps and can be expected to have a similar life. Clean and consistent water supply will ensure maximum life. Recent design changes as mentioned above has increased gland life by at least a factor of two. Gland packing life is estimated to be at least 6 months.

At Mount Isa Mines the overall IsaMill availability on an annual basis is 99%.

## BENEFITS TO PLANT METALLURGY

The installation of eight IsaMills since 1994 in the Mount Isa Mines Lead/Zinc Concentrator, along with other circuit modifications, has increased the liberation of galena and sphalerite and increased the metal recoveries at the target grades.

Figure 17 shows the concentrator zinc recovery performance for the last twenty years with recent operation reaching the highest zinc recoveries. Significant liberation of valuable minerals as a result of using the IsaMill technology is one of the most important technical breakthroughs that has contributed to the improved plant metal recoveries.



**Figure 17: Lead Recovery at Mount Isa Mines' Lead/Zinc Concentrator since 1980**

## SUMMARY

IsaMill technology was successfully developed and operated at Mount Isa Mines over the last nine years. Currently 15 full-scale IsaMills operate in three mining locations in Australia, economically producing products as fine as 7 micron.

Compared to other fine grinding technologies, the IsaMill has high power input per mill volume (up to 350 kW/m<sup>3</sup>) and operates under pressure (100 to 200 kPa). These two features enable the small grinding media of a few millimetres to work effectively to process a wide range of feed sizes and to produce the required fine products.

Media selection is important for the IsaMill operation. Mill scale-up data can be obtained from laboratory data but design of IsaMill circuits needs to be conducted carefully. Feed size and media size effects as well as variations in the circuit need to be appreciated.

The new IsaMill design has increased the grinding performance and improved the maintenance cycle giving greater component life and ease of maintenance.

#### **ACKNOWLEDGMENT**

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