IsaMill Advantages

1. Proven Technology
   Specifically developed for rugged metalliferous applications. Every installation operating to design.

2. Improved Flotation/Leach Recovery
   Inert grinding media produces clean, polished mineral surfaces that provide improved downstream performance. A steep particle size distribution is produced, even in open circuit configuration.

3. High Intensity
   The highest intensity ultra fine grinding technology (>300 kW/m³), meaning it is also the most compact.

4. No Screens
   The centripetal classification of the Product Separator removes the need for troublesome fine screens to separate the media and product.

5. Large Size Reduction
   The possible reduction ratio of IsaMills is far greater than other types of grinding mills at fine sizes. Reduction ratios for full scale IsaMills range from 2:1 to over 16:1.

6. The Mill Size You Need
   Available in three sizes to meet the needs of your concentrate stream. Take advantage of capital and operating cost savings by minimizing the number of UFG mills in your flow sheet.

7. Simple, Fast Maintenance
   Uses a fully sealed, disposable rubber lining with simple inspection access. A shutdown for inspection and replacement of internal wear parts takes less than 8 hours. Availability of 99% and utilization of 96% are typical of IsaMills.

8. Horizontal Design
   The horizontal layout was selected for its plug-flow type design. This avoids short circuiting and makes the mill far less sensitive to process disturbances. IsaMills have a proven 1:1 direct scale-up that reduces your project risk.

About Xstrata Technology

Xstrata Technology is part of Xstrata Queensland, and is an operating division of the diversified international mining company Xstrata Plc. The company’s world class operations use the latest technologies to create shareholder value.

The Xstrata group has operations in Queensland and the Northern Territory in Australia, the United Kingdom, Germany, Spain, South Africa, Chile and Argentina, with around 22,000 employees worldwide. Major products are copper, lead, zinc, silver, coal, ferrochrome and ferrovanadium. In addition to these commodities, an integral part of the Xstrata group of operations is their process technology capabilities.

Xstrata has a long record of developing processing technologies for inhouse use and for sale to external clients. The company develops and markets key strategic technologies, both as a means of maintaining technical leadership and as a technology marketing business. These technologies encompass a large part of the process route and are developed, tested and marketed around the world by Xstrata Technology.

About IsaMill

IsaMill is a large-scale, proven, high intensity, compact, continuous ultra fine grinding technology, with demonstrated direct (1:1) scale-up.

The use of inert grinding media produces clean mineral surfaces that improves flotation and leach recoveries compared to grinding with steel media.

A steep particle size distribution is produced in open circuit operation, without the use of troublesome fine separating screens.

The plug-flow design prohibits short circuiting, and provides for a robust, forgiving and easy to operate technology.

Replacement of worn components is simple and quick and can be performed without removal of the shaft, gearbox or motor.

IsaMill is available in three models (named according to net grinding volume in litres):
- M1000 (375 kW)
- M3000 (1,120 kW)
- M10000 (2,600 kW)

IsaMills are installed in more than two-thirds of the world’s ultra fine grinding metalliferous applications.

Xstrata Technology directly supports and markets IsaMill technology through its head office in Brisbane, Australia, and it’s subsidiary company in South Africa.
As little as 15 years ago, the concept of grinding ores to around 10 microns in large-scale mineral processing plants was considered fanciful thinking.

Size reduction of materials to 10 microns or less has been done for decades in other industries such as pigments and pharmaceuticals. The equipment used in these applications was very small scale and the cost of media and power represented a much smaller component of overall process operating costs. The actual process of grinding minerals to 10 microns was therefore well established. The translation of this knowledge to the mining industry just required a lot of effort, time and of course money.

In 1990, the decision was made to develop, in partnership with Netzsch-Feinmahltechnik GmbH (NFT) of Germany, a process using fine grinding that would make the McArthur River zinc deposit (which was very fine grained) economical to mine. This commitment to spend the time, effort and money resulted in over 7 years and A$13 million being spent to develop what is now known as the IsaMill technology.

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The establishment of the ultra fine grinding application has allowed new process options to be explored. As with any new process step, the development required a substantial commitment of resources. The result of this development process is a body of knowledge that is more than any piece of machinery. The IsaMill Technology developed by Xstrata encompasses all aspects necessary for the incorporation of ultra fine grinding into a new process application.

Xstrata Technology has developed the Technology Partnership concept as the vehicle to transfer this body of knowledge to other companies so they can gain the benefits of ultra fine grinding in their own applications.

Whilst this approach is very different to that of traditional equipment sales, it is necessary in the area of ultra fine grinding due to the enabling knowledge that is required to ensure its success:

• Each user of IsaMill Technology benefits from the experiences of other users, with Xstrata Technology being the hub that facilitates the exchange. Xstrata itself is a significant and committed user of the technology.
• Xstrata has been using IsaMill Technology in its own operations since 1994.

The many years of operational experience combined with the latest equipment and process developments, to produce a package that allows rapid and successful implementation in a new application.

• Xstrata Technology is obligated to carry world-class technical support resources for the benefit of Xstrata’s own operations. These same resources are made available to our technology partners.
• IsaMill users are invited to participate in international technology meetings at regular intervals.

Media

The IsaMill may use a variety of media types. The major criteria in the selection of media are correct particle size, cost, consumption rates and grinding efficiency. The different types of media that may be used include granulated smelter slag, river sand, a sized portion of the ore itself or ceramics. One major benefit of using these media types, particularly in flotation applications, is that they are non-reactive. This means that compared to conventional steel media, they do not chemically or electro-chemically impact on the downstream flotation process.

Fine Particle Flotation

A common concern of those considering ultra fine grinding is the flotation of the product. This concern is generally based on historic literature that dictates that recovery of particles by flotation below 36µm is very difficult. What many potential users overlook is that a significant proportion of particles in traditional flotation circuits are already recovered at sizes finer than 10µm. The difficulties in controlling the flotation of these ultra-fines is usually caused by them being part of a very wide, and much larger, particle size distribution. With the closely sized particle distribution produced by an IsaMill, flotation kinetics of each mineral type are very similar, and whilst generally slow, can be easily controlled. Xstrata Technology also has experience in the materials handling of such fine particles, in processes such as thickening and froth pumping. This flotation and materials handling experience is passed on to the user as part of the Technology Partnership.

IsaMill Development

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>Positive flotation results from a Netzsch 0.75 mill MRM material</td>
</tr>
<tr>
<td>1989-1992</td>
<td>Prof. Bill Johnson at MIM worked with Netzsch on horizontal bead mill development</td>
</tr>
<tr>
<td>1992</td>
<td>100 litre Netzsch mill achieves 1.0 t/h from 40 µm to 7 µm at 35 kWh/t at MRM</td>
</tr>
<tr>
<td>1993-1994</td>
<td>Scale up to 3,000 litre mill at Mount Isa Mines</td>
</tr>
<tr>
<td>1998</td>
<td>Proven, and now essential at MRM and Mount Isa Mines</td>
</tr>
<tr>
<td>2003</td>
<td>Currently 18 mills in operation (22 MW)</td>
</tr>
</tbody>
</table>
Operating Principle

The IsaMill is a horizontal high speed stirred mill that operates with very high power intensities (up to 350 kW/m³). In comparison, the power intensity of a ball mill is about 20 kW/m³. 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 10 m³ in 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.

Circular 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. 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 mineral surfaces are chipped repeatedly producing very fine sized particles 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 P80. The uniform grinding mechanism and high speed are reasons why IsaMill scale-up is 100% direct from laboratory to full scale.

### Machine Type

<table>
<thead>
<tr>
<th></th>
<th>M1000</th>
<th>M3000</th>
<th>M10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding chamber volume (litres)</td>
<td>1,000</td>
<td>3,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Drive capacity (kW)</td>
<td>355</td>
<td>1,120</td>
<td>2,600</td>
</tr>
<tr>
<td>Total unladen mass¹ (t)</td>
<td>15</td>
<td>23</td>
<td>62</td>
</tr>
<tr>
<td>Dimension A (mm)</td>
<td>2,400</td>
<td>2,400</td>
<td>3,450</td>
</tr>
<tr>
<td>Dimension B (mm)</td>
<td>6,415</td>
<td>16,600</td>
<td>20,000</td>
</tr>
<tr>
<td>Dimension C² (mm)</td>
<td>1,500</td>
<td>2,960</td>
<td>3,290</td>
</tr>
</tbody>
</table>

¹ Excluding gearbox and motor
² Dependent upon motor type
Testing

Laboratory and pilot scale test procedures are well established to determine full scale IsaMill performance. The one-to-one scale up procedure based on energy requirement for a specified product size has been consistently proven at all full-scale operating sites. For the benefit of existing and potential clients, Xstrata Technology retains access to a number of laboratory and pilot test-rigs to enable accurate determination of equipment requirements.

Initial batch laboratory testing is conducted using an M1 or M4 IsaMill. With this test procedure a relationship between specific power draw and product size is produced. If continuous pilot scale testing is preferred, an M20 or M100 IsaMill allows accurate confirmation of power draw requirements whilst investigating other parameters such as media load, throughput rates and media consumption. A complete self contained pilot unit is available for on-site testing.

Net Energy Consumption

A primary focus of any testwork is to determine the expected Net Energy Consumption (NEC) for a particular material to be ground to a certain size. In general, NEC is the primary operating cost for ultra fine grind applications and is naturally the first set of data that is needed for any feasibility study. For IsaMills the key variable, other than the material itself, is the size and type of media to be used. All efforts are made to test against known media materials that are used as benchmarks for NEC determination, followed by tests on local or client preferred media types.

Progression of Testwork

Generally, and from a client perspective, appropriate testing involves an initial brief laboratory investigation followed by media screening trials and eventually to larger scale pilot testing to secure confidence by usage either at site or at an independent commercial test facility.

Initial laboratory testwork is recommended for evaluating the suitability of the client's material for IsaMill grindability and determination of the energy (kW/hr) required for producing a certain target product size. Initial testwork may also be used to determine a preferred circuit configuration, either open or closed circuit (with cyclones). This is usually dependent on the total span of size reduction.

Total IsaMill testing has the objective of identifying the media type and cost, and the NEC, for a particular duty. From knowledge of these values it is possible to infer the number of mills, and total operating cost ($/yr, $/t).

Particle Size Measurement

In the business of fine and ultra fine grinding, the determination of the particle size distribution is far from trivial. Xstrata Technology has expended significant resources to arrive at a reliable methodology for this important measurement. Part of this methodology requires the use of a reliable laser-sizing device and Xstrata Technology can supply a unit of the Malvern type for this purpose. When using other machines for sizing, Xstrata Technology will conduct the required calibration and “comparison with standards” as required.

M4 Laboratory Testwork Procedure

Depending upon the sample size available, M4 (4 litre) IsaMill laboratory testwork is generally the first stage in evaluating the IsaMill Technology. The testwork is conducted in a continuous pass-by-pass mode with product samples taken at time intervals throughout the duration of the test to allow generation of IsaMill Signature Plots (P80 vs Energy plots).

A three-phase power meter or energy accumulator is used for recording the active power draw of the mill motor during the test. This method is used and recommended for determining the energy requirement, since the meter measures the electricity consumption directly from the main power input. The no load power of the motor is then subtracted to yield the absorbed power. This method of power measurement has proved accurate in scaling up the IsaMills. The milled products are sized with a Malvern Laser Sizer.

The M100 IsaMill pilot plant being unloaded from its container.

Size Reduction

In addition to energy efficiency, the term size reduction is important in comparing grinding technologies. Size reduction is the ratio of feed particle size (F80) to product size (P80). The IsaMill technology has already demonstrated its ability for very powerful efficient grinding to less than 10 microns. The IsaMill is now proving its ability as a technology that can be used to achieve size reduction ratios previously unheard of in the mineral processing industry.

In conventional base and precious metal concentrators, ball mills have historically, and are still predominantly, used for regrinding applications. When a ball mill is used with cyclones in closed circuit operation, size reduction ratios of around 2:1 are typical. That is, for a F80 of 150 micron, a ball mill operating in closed circuit configuration would achieve a P80 of around 75 micron at a reasonable kWhr figure. While a ball mill operating in closed circuit can achieve higher size reduction ratios by employing higher recirculating rates, the power consumption generally becomes prohibitive.

The IsaMill was developed because existing ball mill technology was not able to achieve the very fine grind sizes required in many flotation and leaching applications.

Kalgoorlie Consolidated Gold Mines (KCGM)

KCGM is Australia’s largest gold producer with an annual production of approximately 800,000 ounces. In February 2001, KCGM commissioned its first full-scale ultra fine grinding (UFG) plant at their Gidji site to supplement existing roaster concentrate treatment capacity. Following this a second similar UFG circuit was later installed and commissioned in February 2002 at the Finniston mine site. These UFG processes involve the fine grinding of refractory pyritic concentrate to approximately 10 micron, followed by direct cyanide leaching for the recovery of gold. By this method, gold is successfully extracted from the concentrate without the need to first oxidise the host pyrite.

The diagram opposite shows the IsaMill circuit configuration at both the Gidji and Finniston operations. A single M3000 IsaMill together with 4 inch cyclones, treats approximately 10 t/h. A size reduction ratio of 14:1 has been achieved using 4-6 mm inert sand media.

About IsaMill

IsaMill CIRCUIT CONFIGURATION

Example

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The diagram opposite shows the IsaMill circuit configuration at both the Gidji and Finniston operations. A single M3000 IsaMill together with 4 inch cyclones, treats approximately 10 t/h. A size reduction ratio of 14:1 has been achieved using 4-6 mm inert sand media.
Fine grinding to a P80 of 7 microns in the zinc retreatment circuit was one of the key features for developing George Fisher deposit, which contains on average 9% zinc, 6% lead and 130 g/t silver. Every one micron size reduction in the zinc retreatment circuit below a P80 of 10 microns improves the overall plant zinc recovery by 1%, which is equal to an increase in revenue of about $1 million.

Ore from Xstrata’s George Fisher mine is processed through the Mount Isa lead/zinc concentrator. Ore is trucked 20 km from the George Fisher mine site to the concentrator, which has been modified to suit the new ore type. Currently, ore from the Mount Isa and Hilton deposits is processed as a blend with the George Fisher ore. Over time however the Mount Isa and then Hilton deposits will be depleted, and then the Mount Isa concentrator will treat ore entirely from the George Fisher mine.

To achieve the designed size reduction of the George Fisher ore, six IsaMills (each with 1.12 MW motor) were installed in the Mount Isa zinc circuit in addition to the two existing IsaMills on the lead circuit. The installation of the IsaMills in the zinc circuit, along with the zinc circuit changes, increased the liberation of sphalerite and increased the zinc recovery at the target zinc grade.

Figure 1 shows the concentrator zinc recovery performance for the months before, during and after the George Fisher flowsheet changes. It shows that the zinc recovery before the changes was 70%, then performance was reduced due to the removal of some grinding and flotation capacity for its relocation in the new flowsheet. Upon commissioning of the zinc regrind IsaMills and the first zinc retreatment regrind IsaMill in October, and the remaining zinc retreatment regrind IsaMills in November, the zinc flotation performance improved to 75% zinc recovery.

This demonstrates that the increased liberation from the IsaMill regrinding gave an instantaneous increase in zinc performance of 5% zinc recovery when processing Mount IsaHilton ore. The benefits for processing George Fisher ore are greater due to the more complex texture associations in the George Fisher deposit.

There have also been shifts and days where the recovery benefits have been much greater. By understanding how these occur and then further tuning the circuit, plant performance can be increased further.

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Xstrata operates mines throughout the world. Tough testing grounds that make our process technologies the best on earth.

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