Process Technology & Innovation

Process optimization for mining and aggregate industries
PTI’s particular focus is providing industry with total Process Integration and Optimization (PIO) services. Delivering integrated process solutions for the entire operation - from the mine to the processing plant.

Encapsulating mining (drill and blast), comminution, flotation / leaching and dewatering, the aim is to optimize each stage within the constraints imposed by the other operational processes. The main objectives are to reduce operating costs, increase production rates and improve overall process, energy and water efficiency.

An introduction to Metso Process Technology and Innovation

Our central office is in Brisbane, Australia with engineers also based in different regions of the world so we can better service our customers. Our offices are in Australia, Finland, Brazil, Peru, Chile, Mexico, Turkey and Russia. The Australian, Brazilian and Finnish offices also have extensive laboratory facilities. These offices have been strategically located close to major mining operations and therefore our main customers. The combination of our laboratory and consulting resources enables Metso PTI to provide customers with greenfield (design) and brownfield (optimization) services.
1. Scoping study
This step includes the collection of historical data and information to identify problems, processing bottlenecks and opportunities for improvement. Detailed analysis of this data and information is then used to produce a project proposal.

2. Benchmarking and optimization
Operational data is collected rigorously through audits and comprehensive surveys of the key processes (drill and blast, crushing, grinding, flotation, etc). PTI staff use mathematical models, ore characterization data, their database of operational data and extensive experience to identify strategies to optimize the entire process for different ore types.

3. Validation and implementation
A detailed plan is developed to implement optimization strategies which have merit based on mine and plant constraints and a cost / benefit analysis. Key performance indicators are measured during this implementation to quantify improvements and fine tune recommendations.

4. Sustaining the benefits
The recommended process changes are incorporated into managerial and site operating procedures, and operators and engineers are trained to ensure the benefits are maintained over the long term.

In over 400 projects conducted globally, we have achieved considerable increase in the production of our customers’ operations (typically ranging from 5 to 30 %) with little or no capital expenditure. This represents millions of dollars in increased revenue for our customers. In addition to increased production (throughput and metal recovery), our improvement projects can also deliver cost and energy reduction, as well as overall process efficiency increases (from the mine to the plant).
Minera Antamina, Peru

**Challenge**
Optimize the blasting, crushing and grinding processes at this copper / zinc mining operation located in the Andes in Peru.

**Scope**
Review of the current drill, blast and comminution practices, characterization of the ore, comprehensive mine audit and surveying of the crushing and grinding circuits, modelling and simulation.

**Results**
PTI recommended a number of changes and assisted in their implementation. A 20% increase in production was achieved and maintained when the mine was processing hard ore.

Barrick Osborne, Australia

**Challenge**
Optimize the comminution and flotation processes at Barrick’s copper / gold operation to remove bottlenecks and enable processing of ore at higher tonnage rates.

**Scope**
Simultaneous surveys of the crushing, grinding and flotation circuits were performed in combination with ore liberation, hardness and floatability measures. Integrated models of both the grinding and flotation circuits were developed to enable optimization of the total process.

**Results**
PTI provided a range of recommendations for Barrick Osborne to operate at higher tonnage rates and to improve metallurgical grade and recovery.

“An interesting exercise of combining both the comminution / grinding and flotation processes together which should be a pre-requisite to both the understanding and improving of any processing circuit.”

Michelle Korte
Metallurgist
Barrick

Newmont Boddington, Australia

**Challenge**
Assist the Newmont Boddington operation with circuit commissioning and optimization of their drill and blast, crushing, HPGR, ball mill and flotation circuits.

**Scope**
Newmont engaged the services of PTI on a two year service contract. This included a full Mine-to-Mill Process Integration and Optimization project, assistance with an expansion study and development of a throughput forecast and geometallurgical model.

PTI was chosen to provide this assistance due to its previous successful optimization of many large mining operations (including Cerro Verde) and its long running association with Newmont where it has provided invaluable consulting services to its other operations (e.g. Batu Hijau, KCGM, Ahafo, Yanacocha, Phoenix and Carlin).

**Results**
To date, PTI has provided support and helped to identify process limitations and provided recommendations to eliminate them to achieve grinding throughput targets.

“The personnel of PTI are highly capable, organized and effective. They provide a service that clearly provides benefits to the industry - Antamina is testament to this statement”

Chris Dechert
VP Corporate Development
Minera Antamina

“An interesting exercise of combining both the comminution / grinding and flotation processes together which should be a pre-requisite to both the understanding and improving of any processing circuit.”

Michelle Korte
Metallurgist
Barrick

PTI offices and reference projects

PTI offices worldwide

9

Projects completed

400+
Integrated process consulting services

Ore characterization
In-situ ore properties govern the ultimate performance achievable in all mining operations. PTI can implement or advise customers of appropriate testing programs to establish an ore’s blastability, grindability and floatability.

Ore tracking from mine to mill
The SmartTag™ system (page 9) allows parcels of ore to be tracked from the mine, through crushing and finally into the grinding mills. This is an essential tool in Process Integration and Optimization (PIO). It allows tracking and correlation of the ore characteristics with important operating parameters in the mine and processing plant; which are then adjusted and optimized for different ore types.

Blasting optimization
Blasting is the first stage of comminution in most mining operations and should not be seen solely as a means of reducing rock size sufficiently for load and haul activities. The Run-of-Mine (ROM) size distribution has a large impact on the performance of downstream crushing and grinding processes.

The in-situ ore properties, drill blast pattern and properties of the explosive govern the size distribution of rocks produced from a blast and energy efficiency of the blast. PTI’s blast fragmentation model and SmartTag system can be used to assess the optimum blast conditions required for a particular ore type. The aim is to produce a consistent ROM size distribution that will maximize throughput and the efficiency of comminution in the subsequent crushing and grinding operations.

Comminution circuit design and optimization
A change in comminution circuit design or operational philosophy can often result in increased throughput or reduced energy consumption. PTI has vast experience in comminution circuit design and optimization of operating and control strategies. This includes traditional equipment and circuits such as staged crushing, SAG / AG mills, pebble crushers, rod and ball mills, closed or open circuits with screens or hydrocyclones, as well as alternative flowsheets and technologies such as HPGR, VRM, stirred mills, fine screening and dry classification.

In optimization projects, PTI uses ore characterization data, comprehensive plant surveys, and historical operational data to develop site specific models for the comminution processes. PTI’s extensive database of operational data is used for benchmarking existing operations and also to develop Greenfield or expansion projects.

Comminution models are used in simulation studies along with extensive industrial and consulting experience to assess comminution processes. This allows debottlenecking and optimization of existing circuits, evaluation of expansion options, design of new circuits, and evaluation of different flowsheets and equipment options (including equipment from within and outside of the Metso portfolio).

The performance of a comminution circuit is often strongly influenced by the ore hardness and the feed size distribution received from blasting. Additionally, changes to the comminution product size can affect downstream processes such as flotation. PTI conducts comminution design and optimization with a fundamental understanding of these upstream and downstream interactions to provide solutions that deliver the best outcome for the overall operation.
Flotation circuit design and optimization
Lost recovery in the flotation circuit results in lost revenue. PTI has expertise in flotation circuit operation, characterization, modelling and simulation techniques. Characteristics such as bubble size, bubble load, superficial gas rate (Jg), froth stability, froth transportation and froth depth can be measured to identify possible avenues for improving cell performance. This information, along with detailed surveys and historical operating data are used in modelling and simulation techniques. These techniques, together with extensive industrial and consulting experience and database are used to evaluate existing or new operations, and highlight opportunities for improvement in performance.
PTI can identify relationships between grind size and the flotation grade-recovery performance. This enables integrated optimization of the blasting, comminution and flotation operations. Economic balance and trade-off between grind size (throughput) and flotation recovery can be determined using this holistic approach.

Optimization of Coal Preparation Plants (CPP)
The processes and challenges in coal preparation are quite different to those of metalliferous operations. PTI has expertise in optimizing dense medium circuits, coal flotation, and gravity separation processes such as spirals and teetered bed separators. Equipment performance data (e.g. RD50 and Ep), coal washability data, survey and historical data are used to model each of the processes. The models are integrated for total plant simulation and optimization.

Optimization of water use
Most current mineral processing plants rely on wet processing and consequently consume water. It is possible to significantly reduce water consumption by evaluating water reticulation circuits, the available water sources, and dewatering equipment. PTI can assist with the establishment and estimation of the current site water balance, and based on this, identify opportunities to reduce water consumption.

Support during commissioning
There is often a considerable delay between mechanical commissioning of a plant and when it achieves design metallurgical performance; this represents lost revenue. PTI can provide the process expertise and support required to rapidly achieve process targets during comminution and flotation circuit commissioning. This support can be provided on site or remotely (by accessing the mine’s DCS systems).

Advanced training
PTI experts routinely conduct advanced training for engineers and operators on site. These can be a series of courses and workshops focused and tailored to customer needs or part of the technology transfer process within an optimization project or support contract.
Throughput forecasting and geometallurgical modelling

To maintain long-term profitability, it is important to be able to predict the throughput, grind size and flotation recovery of different blocks of ore in the mine plan. This requires the development of geometallurgical models which predict the performance of each stage based on measurable in-situ ore properties. This enables throughput and metal recovery forecasting, strategic planning and optimization for different ore types in order to maximize the profitability of the operation over the Life-of-Mine (LOM).

PTI’s approach is to use the mine’s existing data and block model as the framework for developing a geometallurgical model. The process starts with ore characterization to define ore domains within the deposit that will behave similarly throughout blasting and processing. The SmartTag™ ore tracking system is used to track the characterized ore from the mine to the plant. With the ore source known, detailed audits of the blasting and processing operations are used to develop site-specific predictive models for each operation (blasting, comminution, separation).

Together, these models indicate how the whole process will respond to different ore types and operating conditions in the mine and the plant. Using these predictive models, the blast design is optimized to generate optimal Run-of-Mine (ROM) fragmentation for all ore types, and downstream processes are adjusted accordingly. The models also allow prediction of throughput and recovery performance for each ore domain, and when combined with the mine plan enable production forecast for the LOM. They can also be used to identify potential bottlenecks, process constraints and opportunities for improvement.
PTI products

1. SmartTags are placed with source ore in the mine (blastholes, muckpiles etc)

2. Tags survive the blast and travel with the ore

3. They are detected when they pass antennas at critical points before milling

4. With no internal power source they can remain in stockpiles for extended periods

5. The physical ore properties in the mine can then be linked with time-based performance data from the plant

SmartTags are robust passive radio frequency transponders (RFID tags).

SmartTag™

SmartTag™ (winner of the 2010 iAward) is an innovative system for marking and tracking ores in both open pit and underground mines.

In Mine-to-Mill applications, SmartTags™ are inserted in blastholes and/or in muckpiles, stockpiles, etc in the mine. They survive blasting, primary and secondary crushing operations. Marking and tracking ores through the mining processes enables spatially based ore characteristics in the mine such as ore hardness, fragmentation and mineral content to be linked with time-based performance in the processing plant. Measurement using SmartTag™ allows operating parameters and control strategies in the mine and processing plant to be adjusted and optimized for different ore types, thereby reducing costs and increasing profitability.

In Pit-to-Port applications, the SmartTag™ system can be used to track product through the complete supply chain, from the mine through the entire transport chain (road, rail, port) up to final delivery to the customer. This is particularly relevant for iron ore and coal operations, which often have complicated product marketing and supply logistics, with products of different quality specifications and contained value. Properties such as grade, shape, texture, moisture, ash, sulphur, phosphorus, energy content, etc can be tagged and tracked. This facilitates optimization of plant operation, sorting, blending and homogenization to maximize the value of the final product. The system also provides more accurate reconciliation, and allows monitoring and optimization of product supply and transport logistics.

SmartEar™

SmartEar™ is a robust SAG mill acoustic monitoring system designed mainly to prevent damage and minimize wear to mill liners caused by the impact of grinding balls. SmartEar™ also identifies anomalous noises and can indicate the presence of large foreign objects in the mill (feed chute plates, shovel teeth etc) or when liners or lifters have come loose. It can also be used to improve grinding circuit control; it can detect mill overload and provide an estimate of the filling level. SmartEar™ also provides a filtered audio signal from the mill to the control room, which is a popular feature with operators as they can listen to the mill from the control room without the background noise from the plant.

The system can operate standalone and/or interface to any control system. The SmartEar™ system consists of rugged microphones, a signal transducer system and software to process the data.
PTI laboratories, equipment and resources

<table>
<thead>
<tr>
<th>METALLURGICAL TESTWORK CAPABILITIES</th>
<th>BRISBANE, AUSTRALIA</th>
<th>SOROCABA, BRAZIL</th>
<th>TAMPERE, FINLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sizing</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Bond ball and rod mill index</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>JKMRC breakage test</td>
<td></td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>SMC breakage test</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Bond abrasion index</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Point load index</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pilot ball mill</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pilot jaw crusher</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pilot barmac crusher</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pilot screening equipment</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Laboratory flotation testwork</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Laboratory batch ball/ rod milling</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Laboratory continuous ball milling</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Fine grinding test unit</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Abrasivity meter</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Metso crushability index</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Pilot scale HPGR</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

PTI laboratories and pilot plants

PTI offers crushing, grinding and flotation test work on supplied ore samples using state-of-the-art laboratory and pilot plant equipment. We have laboratories and pilot plants in Brisbane (Australia), Sorocaba (Brazil) and Tampere (Finland). The PTI head office in Brisbane is co-located at the Queensland Centre for Advanced Technologies (QCAT), providing access to Commonwealth Scientific and Industrial Research Organization (CSIRO) laboratory and pilot plant facilities.

PTI can conduct commercial laboratory breakage test work such as the internationally recognized and industry standard JKMRC and SMC breakage tests as well as many other ore characterization tests and measurements. These are important inputs for modelling and simulation. Results of any test work can be supplied directly to the client for in-house analysis or alternatively interpreted by PTI engineers, providing a report of recommendations.

PTI transportable flotation rig

It is difficult to measure the effect of operational and design changes in industrial flotation circuits due to the size and complexity of industrial plants and variability in the feed. Therefore, PTI developed a portable, fully instrumented 3m³ test cell to enable flotation testing of key parameters (air rate, froth depth, feed flowrate, impeller speed, impeller size, reagent scheme, froth launder configuration) at a realistic scale. The cell is controlled by a Programmable Logic Controller (PLC) to enable stable operation and has been designed so representative samples of all key process streams can easily be collected in a safe manner.

The test cell is available for hire to mine sites, and PTI can provide assistance with the development of the experimental program and specialists to perform the test work. Recent consulting and research projects that have been undertaken include: evaluation of reagents, investigation of circuit configuration options, exploration of different launder configurations, energy studies, and examination of the effect of density and turbulence.

Software tools

Throughout most process optimization projects, computer software is used to analyze data and perform mathematical modelling and simulation. PTI uses industry best practice software to perform these tasks: Split desktop to analyze rock fragmentation images, JKSimBlast to design the drill hole patterns, FracSIS to visualize the 3D spatial data in the mine, JKSimMet and JKSimFloat to model and simulate the grinding and flotation processes, Limn to model and simulate non-conventional processes and Bilmat to mass balance. We also develop our own software and applications.
PTI has a strong focus on customer driven research and development, conducting internal and collaborative projects to tailor and develop services and equipment to best meet customer and industry needs. We sponsor and collaborate with a number of research organizations and universities globally.

There is a strong need for improved sustainability and efficiency in the mining industry. This is why one of PTI’s main research projects is the “Development of a Resource and Eco-Efficient Mining Process”. This project investigates alternative technologies and practices in mining and minerals processing that reduce energy and water consumption and greenhouse gas emissions, while minimizing waste and maximizing value. The focus is on improving resource efficiency - creating more value with less impact to generate better economic returns from the available resource. This might incorporate some or all of the following alternatives:

- High intensity selective blasting (HISB) to improve fragmentation and reduce energy consumption in downstream comminution processes.
- In-pit crushing and conveying (IPCC) is a more efficient transportation method than conventional truck and shovel operation.
- Pre-concentration using screening and/or bulk ore sorting to discard barren material prior to downstream processing.
- Alternative energy efficient and dry comminution technologies such as vertical roller mills (VRM) or high pressure grinding rolls (HPGR) and air classifiers may be incorporated in new plants. While, in existing operations with wet grinding circuits, fine screens may be used to improve efficiency.
- Enhance coarse particle flotation to reduce energy requirements in previous grinding stages (by providing a coarser product to flotation).
- Finally, filtration and dry stacking of tailings can be implemented to reduce water consumption and reduce reclamation and closure costs (due to reduced footprint, easier construction, and the possibility to rehabilitate progressively).

Conservatively, energy use could be reduced by more than 35%, with a similar reduction in GHG emissions, and water savings in excess of 40% compared to a conventional process. Additionally, the footprint of dry stacked tailings could be more than 80% smaller than a traditional tailings dam.

Savings:

<table>
<thead>
<tr>
<th></th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption</td>
<td>35%</td>
</tr>
<tr>
<td>GHG emissions</td>
<td>35%</td>
</tr>
<tr>
<td>Water consumption</td>
<td>40%</td>
</tr>
<tr>
<td>Tailings footprint</td>
<td>80%</td>
</tr>
</tbody>
</table>

PTI has strategic alliances and collaborations worldwide with: The University of Queensland, McGill, Amira International, Hacettepe University, CSIRO, UFRGS, IBM, UBC, Grupo IASA and CEEC.
Expect results

“Expect results” is our promise to our customers and the essence of our strategy. It is the attitude we share globally. Our business is to deliver results to our customers, to help them reach their goals.