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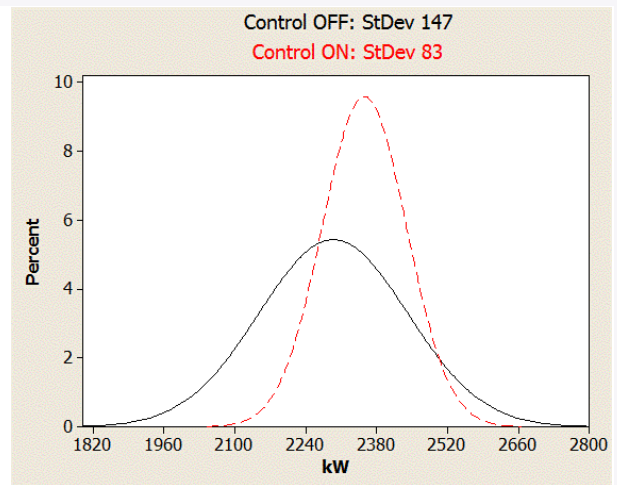
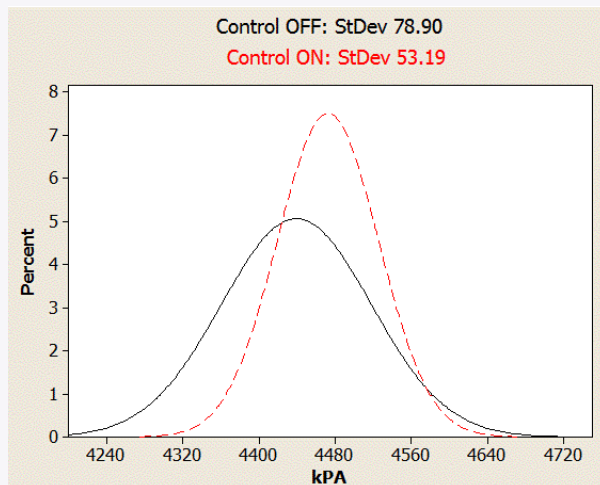
# Evolution of SAG Mill Process Control at the Xstrata Nickel Raglan Operation

The Xstrata Nickel Raglan Concentrator, located at the northern limit of Quebec's Nunavik Region has been in operation since 1997. Originally designed to process 800,000 tonnes per year of high grade nickel ore, plant capacity is currently approaching 1.2 million tonnes per year due to an Optimization Project (Fully Autogenous Grinding to SAG conversion) in 2005 and many recent process improvements.

In 2006, the Raglan Metallurgical Group with assistance from the Xstrata Process Support group decided to make SAG control one of its priorities in order to further increase throughput and improve stability. The original primary mill control logic delivered by the Optimisation Project in 2005 consisted of a simple PID loop controlling the mill charge (bearing pressure) through feed rate changes. Due to the non-

linear and disturbance dominated nature of the SAG circuit it was quickly found that this traditional PID control strategy was not able to adequately control the mill; resulting in poor stability, frequent operator interventions and less than optimum performance.

This paper describes the successful integration of advanced fields systems such as mill feed image analysis (Wipfrag) and crusher gap controller (ASRI), into a multi-variable fuzzy logic SAG mill controller. The process of how a strategy for control was developed and implemented directly in the existing control system (exploiting standard system capabilities) is discussed. It is also shown how this approach has provided mill automation which is simple, robust (despite erratic feed characteristics), and delivers both an increase in throughput and a reduction of variability.

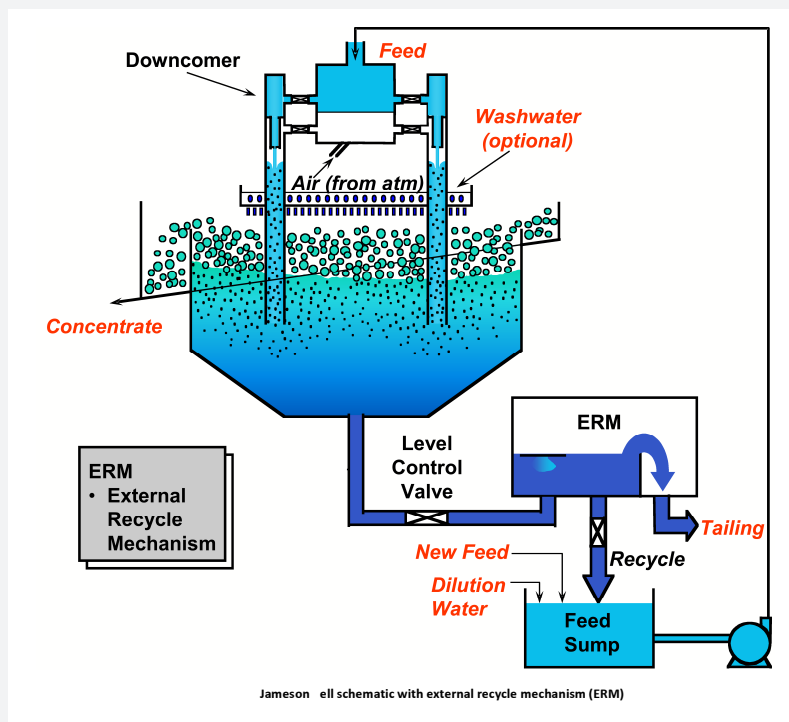


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# Removal of organic carbon with a Jameson cell at Red Dog Mine

The lead and zinc flotation circuits at Red Dog Mine are preceded by a preflotation circuit which recovers naturally-floating organic carbon contained in the ore. Organic carbon is a potential contaminant in the lead concentrate and is detrimental to lead-zinc selectivity. Prior to 2007, the Red Dog preflotation circuit consisted of a single stage bank of tank cells which floated the organic carbon. The preflotation concentrate was discarded directly to tailings. However, this stream contained significant amounts of lead and zinc. Zinc loss to preflotation ranged from 2% to 6%, relative to the zinc in the mill feed and was proportional to the amount of organic carbon in the ore. The main mechanism of the zinc loss was entrainment.

Pilot plant and modeling testwork were conducted to examine the use of a Jameson Cell to clean the preflotation concentrate. Results indicated that up to 90% of the zinc deporting to preflotation concentrate could be returned to the flotation circuit for recovery. The installation of a 5.4 m Ø Jameson Cell with 18 downcomers was initiated in June 2006. The new preflotation cleaning circuit was commissioned in March 2007. Conservatively, preflotation cleaning has resulted in zinc and lead absolute recovery gains of 1.0% and 1.5%, respectively. The \$9.1M project has a payback period of approximately 1 year at current metal prices.



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## Process Improvement Update at Brunswick Mine

The Brunswick Mine Concentrator (Xstrata Zinc Canada) is located near Bathurst, New Brunswick and is one of the world's largest lead/zinc mines. The concentrator has been in operation since 1964 and utilizes selective flotation to produce zinc, lead, copper, and bulk lead/zinc concentrates. The ore is a complex massive sulphide, consisting of approximately 20% valuable minerals, 60% pyrite and 20% silicates.

A pilot plant study performed in 1990 to evaluate autogenous grinding and potential impacts on copper-lead and zinc circuits demonstrated that baseline plant operation was significantly less than ideal, and this disparity between the pilot plant study and plant operation initiated the course of improvements.

Since 2001, process optimization has been achieved through the application of Six Sigma methodology and this paper provides an update on the process improvement initiatives that have taken place in the concentrator since 2004 using that methodology. Despite the fact that ore feed to the concentrator has become increasingly more difficult to

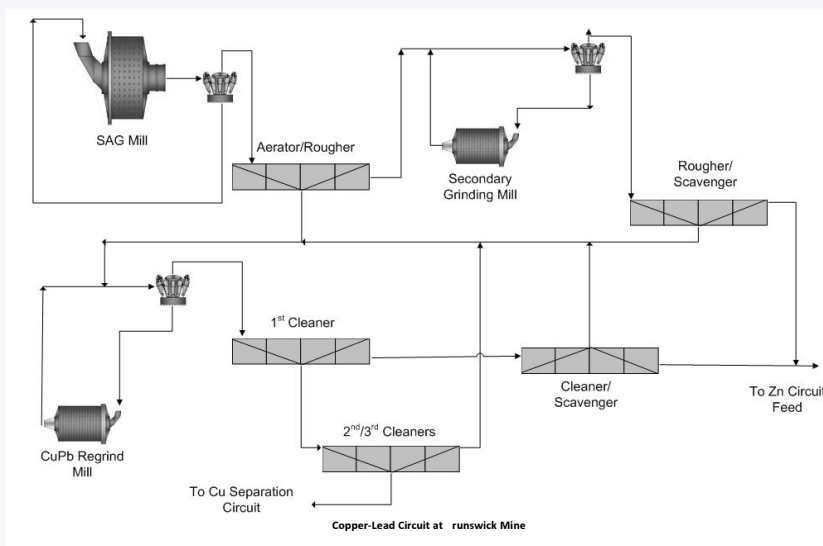
process, increased revenue and cost savings have materialized with minimal capital investment as a result of projects which have been completed in all areas of the concentrator.

The first project implemented recirculation of warm water to the flotation circuit as a cost-saving measure. The Brunswick flotation process requires steam produced in a Bunker 'C' fired boiler to heat the various circuits. Recirculation of the zinc thickener overflow to the zinc and bulk cleaners, recirculation of the paste plant waste return water to the external reclaim water system and the use of the compressor cooling heat exchanger to heat the fresh water used for flotation spray water reduced the Bunker 'C' consumption significantly.

The second initiative was the installation of a direct contact condensate heat recuperation tower to recover the heat lost from the zinc dryers. After 8 months of operation it was determined that the project decreased steam consumption by 11,600 pounds per hour for a value of Can\$850,000 per year.

The third project was the installation of an extra row of cleaner-scavenger cells for the copper-lead circuit which led to a 2.0% increase in total lead recovery for the three-month time period following the project resulting in almost \$600,000 in additional revenue. A modification of the reagent scheme in the Copper Separation circuit which generated additional revenue of US\$5.6 million per year was the fourth project.

New methods for monitoring and sustaining the gains achieved through these process improvement initiatives are detailed. These methods include providing visual displays of information and assigning accountability to the owners for the individual processes.



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# Comparison of ore hardness measurements for grinding mill design for the Tenke Project

As part of the ongoing project development for the Tenke Fungurume Copper-Cobalt Project in the Democratic Republic of Congo, Phelps Dodge Corporation (now FMI) has examined methodologies for determining the size of grinding mills to support a 7,000 mtpd operation. Six samples were tested by Hazen Research, Inc. to obtain the JK parameters using the JK Drop Weight Test, standard Bond crushing, and rod mill work indices, abrasion indices, and by Dawson Metallurgical Laboratories, Inc. for Bond Ball Mill Work Index tests using crushed feed, and SAGDesign Tests, patented by Outotec.

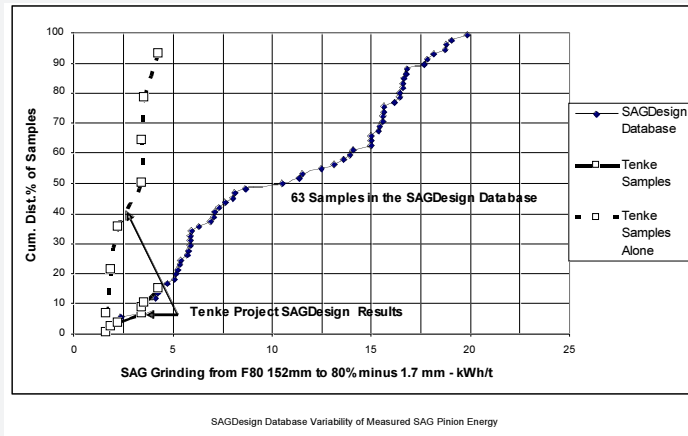
The comparison of these six results gives context to how the various measurements relate to each other and how they can be used to obtain an accurate design for the grinding mills required for the Tenke Project. This is the first published direct comparison between JK Drop Weight, standard Bond work indices, and SAGDesign test results. The SAGDesign test includes a SAG test followed by a Bond BM Wi test done on SAG ground material.

The test work was done in a normal and standard manner at each of the laboratories noted above. In addition, unconfined compressive strength measurements were made at the Advanced Terra Testing, Inc. laboratories and specific gravity measurements of the six samples was done at Terra, Hazen, and Dawson (as part of the SAGDesign tests).

The following graph (Figure 3) shows the relative position on the SAGDesign database, for the Tenke samples. They were soft, with the majority of them falling at or below the 10<sup>th</sup> percentile of hardness variability and the hardest, at the 15<sup>th</sup> percentile. Similar trends were observed for the standard crushed Bond Wi, the SAGDesign Bond Wi on SAG ground ore and the JK Tech database. In short, each of the methods used correctly identified the hardness level when compared to previous measurements made on other ores using the same test method.

The SAGDesign test data was judged to give the same relative hardness as any of the other methods tested. Since the reproducibility of the SAGDesign tests is excellent, these results were used for the mill design. SAGDesign results have the added advantage of giving the required pinion energy to grind the ore to 80% passing 1.7 mm (SAG test) and the energy to grind from T80 1.7 mm to 80% passing 200 microns, the selected grind.

Hardest measurements were used to allow any blend of feed to be treated at design t/h. A total of 9 kWh/t of grinding energy was indicated and this could be provided either in



a single stage SAG mill to produce the P80 200 micron product, or a two stage circuit with equal power on the SAG and ball mills using the design Bond Wi of 11.5 kWh/t.

A number of conclusions were drawn from this work. Some are presented here.

The SAG part of the SAGDesign test measures much more than impact breakage energy. It measures the design energy needed to grind from F80 152 mm to T80 1.7 mm.

The lack of reproducibility in many comminution test measurements is a problem that demands many more measurements be made for good design. The best and most cost effective way is to use the most accurate test. That test is the SAGDesign test.

High testwork costs and lack of samples for testing have, and will in the future discourage the use of more samples and 'usual' grinding tests, especially for small mining companies.

The use of Bond equations to calculate pinion energies in ranges where the mill feed size exceeds normal rod mill feed is a mistake and leads to lower than required SAG pinion energy. Fred Bond did not envision the use of these equations for other sizes than he had data to support.

It is important that we all understand the fundamentals of SAG mill design. Otherwise mistakes will continue to happen.

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