PAPER 14

The Right Tools in the Right Place: How Xstrata Nickel Australasia Increased Ni throughput at its Cosmos Plant

Dan Curry[1], General Manager – Processing
Michael Cooper[1], Manager – Processing
Josh Rubenstein[2], Senior Process Engineer
Tom Shouldice[3], President
Michael Young[2], Principal Metallurgist

[1] Xstrata Nickel Australasia
Level 3, 24 Outram Street
West Perth, WA 6005
PH: +61 (8) 9213 1588
Email: dcurry@xstratanickel.com.au
Email: mcooper@xstratanickel.com.au

[2] Xstrata Technology
Level 5, 509 Richards Street
Vancouver, BC V6B 2Z6
PH: (604) 699-6402
Email: jrubenstein@xstratatech.com.au
Email: myoung@xstratatech.com.au

[3] G & T Metallurgical Services Ltd.
2957 Bowers Place
Kamloops, BC V1S 1W5
PH: (250) 828-6157
Email: tshouldice@gtmet.com

Key Words: IsaMill™, Jameson Cell, Wemco® SmartCell™, Nickel, Process Mineralogy

42nd Annual Meeting of the Canadian Mineral Processors

January 19 to 21, 2010
Ottawa, Ontario, Canada

ABSTRACT

Xstrata Nickel Australasia's Cosmos plant in Western Australia is currently implementing a de-bottlenecking project to increase nickel output while maintaining metallurgical performance and a low unit cost for production. Mineralogical analyses indicated that the processing bottlenecks could be removed by simply reconfiguring portions of the circuit as well as adding capacity with technical advancements – notably an IsaMill™, Jameson Cell, Wemco® SmartCell™ and Larox Filter.

The Wemco® SmartCell™, which is particularly suited for coarse mineral flotation, and Jameson Cell, which is particularly well suited for fast floating and fine minerals, combine as rougher scalpers to complete the main stream portion of the flotation circuit. Addition of the two new cells meet the required flotation capacity to handle the forecast increase in nickel feed grade and tonnage.

The addition of an IsaMill™ for regrinding allows the SAG mill to produce a coarser primary product, thus enabling increased throughput. The advantages offered by the IsaMill™ include operation in open circuit (internal classification), an inert grinding environment (ceramic media) for better downstream flotation ("clean" new surfaces), compact footprint (easy to retrofit into existing plant) and energy efficiency. With the new rougher capacity addition, the remaining original plant cells were reconfigured to suit the new regrind mill and cleaning requirements. The existing 24 m^2 Larox pressure filter was replaced with a larger 32 m^2 unit to dewater the increased concentrate output.

The paper describes the upgrade at the Cosmos concentrator with particular emphasis on the mineralogical data and metallurgical benefits associated with the changes.

INTRODUCTION

The Cosmos concentrator is located 680 km northeast of Perth in Western Australia. The deposit's development and operations were started in 1999 by Jubilee Mines NL, Cosmos' previous owner, with the first production of nickel concentrate in April 2000. The Cosmos concentrator treats a komatiite hosted high grade nickel sulphide ore, with sulphides being predominantly pentlandite and pyrrhotite with lesser amounts of pyrite and chalcopyrite.

Jubilee owned some of the most prospective and relatively under-explored nickel ground in the world thus representing an excellent expansion potential. This was well matched with Xstrata Nickel's growth strategy and in October 2007, Xstrata bid for Jubilee Mines NL. In February 2008, Xstrata assumed management control of Jubilee and established Xstrata Nickel Australasia (XNA) as a new operating unit of Xstrata Nickel.

As part of XNA's accelerated growth strategy, changes were required to accommodate increased nickel output from the Prospero mine at the Cosmos site (Figure 1). The increase in nickel production would be due to not only higher mined tonnes but also higher grades. The Cosmos concentrator was designed more than 10 years ago, and was built on the premise of approximately 3 years of operation to treat the Cosmos ore deposit. In considering the age and planned lifespan of the original concentrator and its compact footprint, one might correctly assume there would be some challenges to complete timely upgrades for improved throughputs. Indeed, in November 2008, the Cosmos concentrator had a mass flow capacity of 25tph and nickel feed capacity of 1.3tph. Achieving the 2009 budgeted nickel output meant the concentrator needed to treat up to 2.8tph of nickel in ore feed (increase of 215%), and mass flow capacity through the SAG mill needed to increase to 45tph (an increase of 180%).

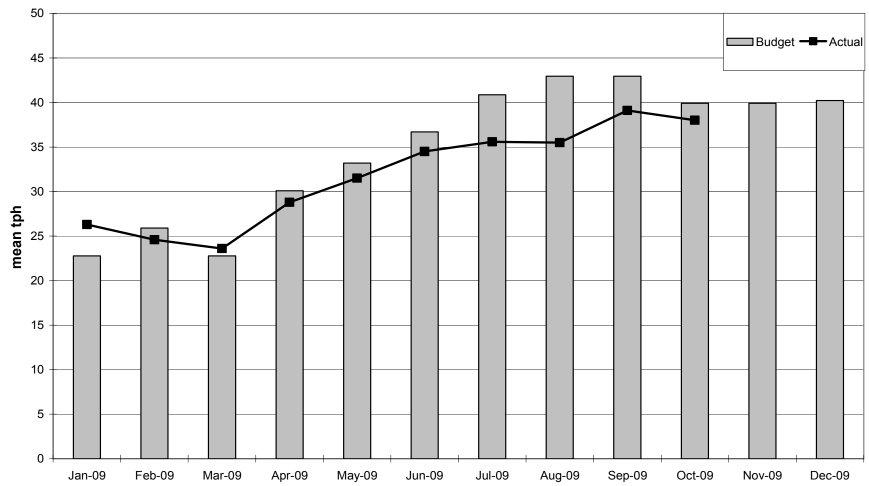

Figure 1: Cosmos SAG Mill Throughput (2009 Actual YTD vs. Budget)

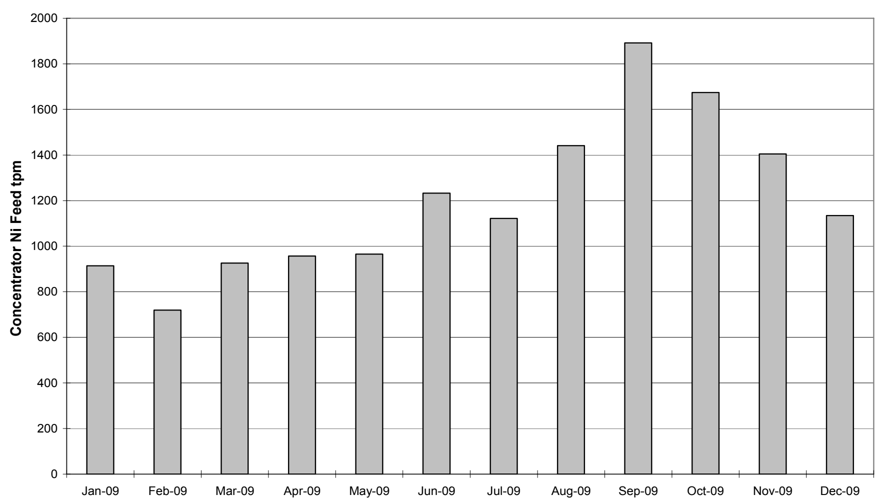

Figure 2: Cosmos Concentrator Nickel Feed Tonnes per Month Budget 2009

Mineralogical and metallurgical analyses were undertaken and the subsequent results from the various studies revealed that these ambitious targets could be achieved with the addition and rearrangement of several key pieces of equipment. Armed with this information and "the right tools" approach, a de-bottlenecking programme was initiated. While still in progress, the de-bottlenecking process has already demonstrated success and is on track to be completed within a twelve month schedule and, by industry standards, on a shoe-string budget.

Decisions and directions taken for the de-bottlenecking process have been, and continue to be, firmly based on a mineralogical approach. Size by size recovery, as well as liberation and modal analyses, have provided the scientific reasoning for the process changes being undertaken. Measurement of the size by size recovery of target minerals in key process streams was essential in determining the impact of the changes. Ensuring the "right tools" being in the "right place" included rearranging some equipment for a modified flow sheet and adding new technology, such as the IsaMill™, Jameson Cell and Wemco® SmartCell™, to help achieve the new metallurgical benchmarks.

A background description of the original flow sheet and corresponding process mineralogy is presented below, followed by a description of the de-bottlenecking project changes and impact on size by size mineral performance in the concentrator.

ORIGINAL FLOW SHEET AND PERFORMANCE (JULY 2008 SURVEY)

This section focuses on the plant design, flotation feed characteristics, flotation performance, final concentrate composition and tailing losses from before the de-bottlenecking process - the last two items being very important considerations. That is, what is present in the concentrate that should not be there and conversely, what in the tailings should not be present? Figure 3 is the original flow sheet of the Cosmos concentrator.

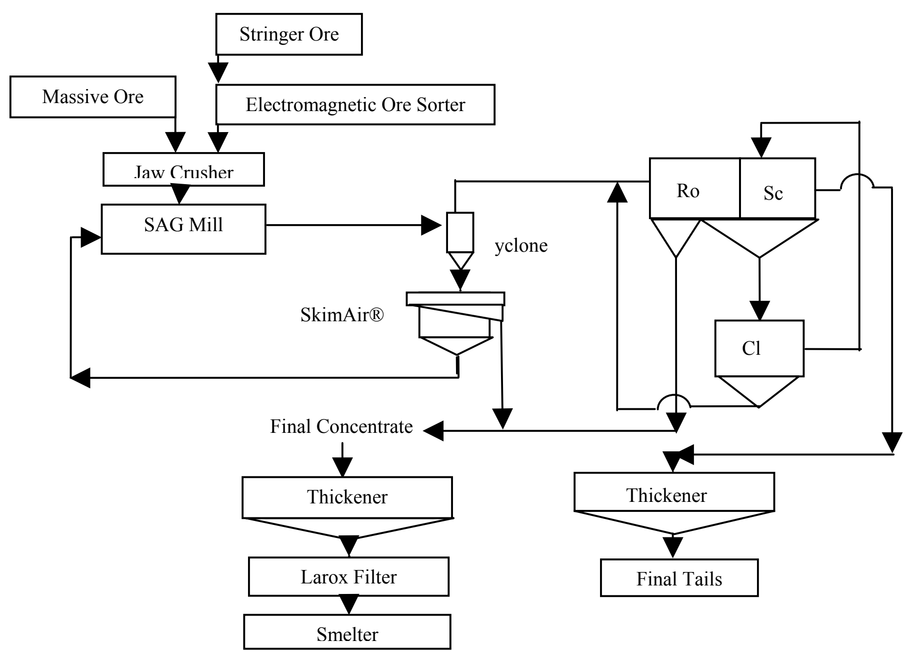

Figure 3: Original Flowsheet

The comminution circuit comprised a single jaw crusher feeding directly into a single stage SAG mill in closed circuit with one pair of 400 mm Cavex cyclones. The classification design was inflexible and inefficient resulting in a significant amount of liberated pentlandite reporting to the cyclone underflow. Consequently the SkimAir® flotation cell performance was excellent, but characteristic of poor grinding circuit efficiency rather than good plant design as these liberated particles should have reported to the cyclone overflow. The SkimAir® recovered the majority of the nickel (61%) at a concentrate grade of 20%. The remaining flotation circuit produced a concentrate grade of 16% nickel and a further 30% recovery. The overall circuit achieved 92% nickel recovery at a concentrate grade of 19% (Table 1).

The flotation circuit used two stages of roughing and three of scavenging in the main stream to treat the flotation feed (Table 2 and Table 3). The first rougher concentrate reported to final concentrate along with the SkimAir® product. Unusually, the cleaner concentrate and tail were in closed circuit with the rougher/scavenger circuit. This resulted in every flotation stream having a mixture of all flotation reagents; all competing simultaneously to activate, collect and depress. Apparently this made the circuit easier to operate but the large re-circulating loads, difficulties in controlling reagent dosages and continual dilution of the cleaner concentrate with rougher feed suggested simple and significant improvements could be made.

As further evidence of over-grinding, the cyclone overflow had pentlandite that was 86% liberated and non-sulphide gangue (NSG) 97% liberated. This degree of liberation was more suitable for a cleaner feed than a rougher circuit and suggested that the SAG mill throughput could be increased and a coarser cyclone overflow produced without compromising rougher recovery.

Table 1: Overall Metallurgical Balance – July 2008

Product	Mass	Assays - %					Distribution - %				
	%	Ni	Cu	Fe	S	As	Ni	Cu	Fe	S	As
Recalculated Feed	100	4.61	0.17	12.2	8.69	0.08	100	100	100	100	100
Skim Con	13.8	20.6	0.68	34.5	30.6	0.24	61	54	39	49	43
Rougher 1 Con	8.5	16.4	0.77	27.7	26.1	0.13	30	37	19	25	15
Final Con	**22.2**	**19.0**	**0.70**	**31.9**	**28.9**	**0.21**	**92**	**91**	**58**	**74**	**58**
Final Tailings	77.8	0.5	0.02	6.5	2.9	0.04	8	9	42	26	42

Table 2: Flotation Feed – July 2008

Mineral	Symbol	Composition (%)
Pentlandite	Pe	13.5
Chalcoyprite	Cp	0.5
Pyrrhotite	Po	9.7
Pyrite	Py	1.0
Non-Sulphide Gangue	Gn	75.3

Table 3: Fragmentation of Flotation Feed Minerals – July 2008

Mineral Status	Flotation Feed 104µm K_{80}		
	Pe	Po	Gn
Liberated	85.9	77.4	97.0
Binary with Pe	-	6.0	1.1
Binary with Po	3.2	-	0.6
Binary with Gn	6.9	9.4	-
Binary with Other	0.7	0.6	0.3
Multiphase	3.3	6.6	1.0

Figure 4 shows the recovery by size in the SkimAir® circuit. Coarse particle recovery is excellent and gangue entrainment low (particularly considering the relatively high pulp density required in this circuit to manage the SAG water balance). Recovery of finer (<50µm) particles was poor however, these were recovered later in the main flotation circuit as shown in Figure 5. Approximately 30% of the liberated pyrrhotite in the cyclone overflow was recovered into the rougher 1 concentrate (maximum recovery occurred for particles sized between 10 and 50µm in diameter). NSG entrainment into the Rougher 1 concentrate was more extensive than with skim concentrate.

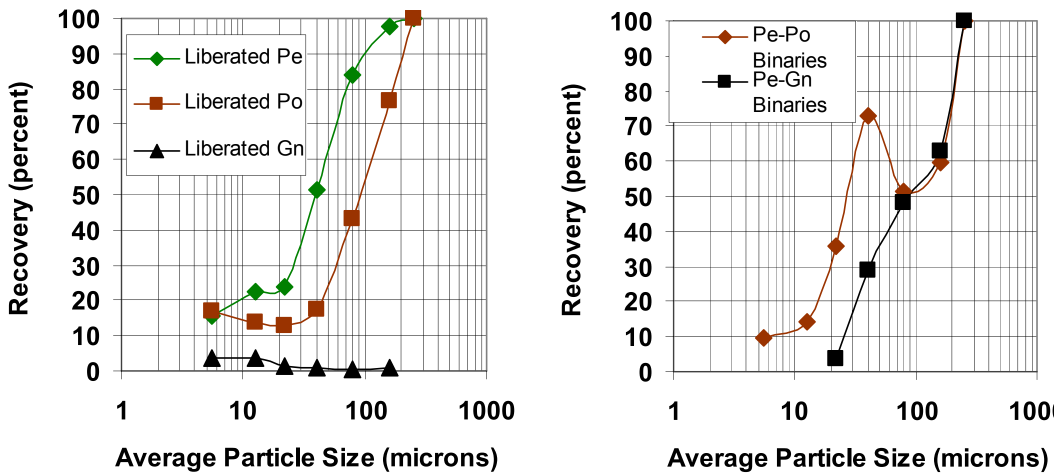

Figure 4: Recovery by size and class into the SkimAir® concentrate

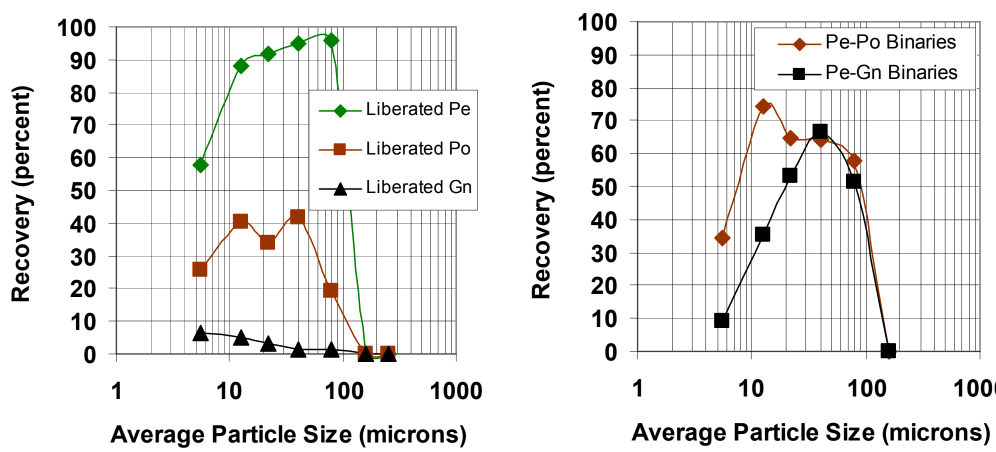

Figure 5: Recovery by size and class into the Rougher 1 concentrate

As shown in Figure 6, the two main diluents for the SkimAir® concentrate were pyrrhotite and NSG. Respectively, these represented 21% and 12% of the concentrate mass. The rougher 1 concentrate had approximately double the amount of NSG but about the same amount of pyrrhotite as the SkimAir® concentrate (Figure 7). Most of the major diluents were present as liberated grains. The theoretical grade-recovery curve shown in Figure 8 emphasizes that if more of these liberated diluents were rejected, a higher concentrate grade would be achievable.

Alternatively, a coarser grind (resulting in less liberation) would not necessarily affect the final concentrate grade. Using the cleaning circuit in a more conventional way and/or froth washing to reject liberated, entrained NSG could potentially assist in the production of higher concentrate grades.

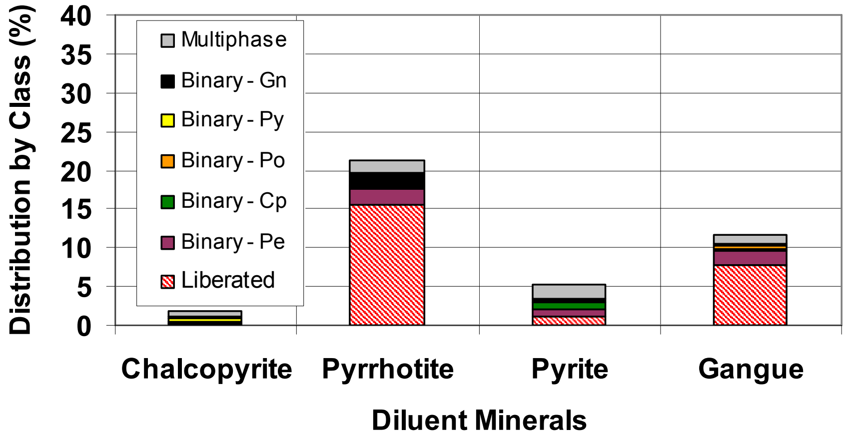

Figure 6: Distribution of Diluent Minerals in the SkimAir® Concentrate

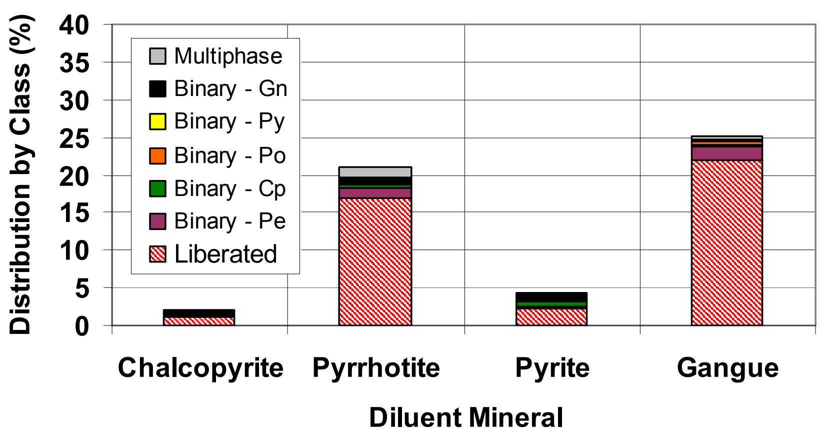

Figure 7: Weight Distribution of in the Rougher Concentrate

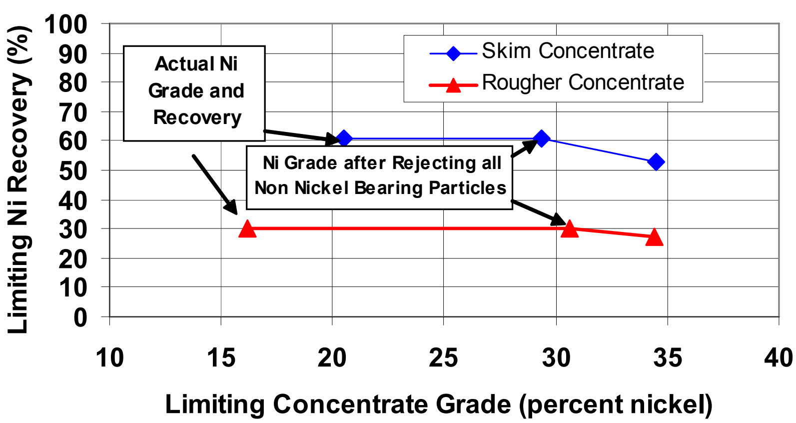

Figure 8: Mineralogical Limiting Grade Recovery Charts

Eight per cent of the nickel in the ore was lost into the final tails. 60% of this was rejection of liberated pentlandite grains (Figure 9), a significant portion of which were less than 11µm. This is not unexpected given the absence of a true cleaning circuit and the conflicting pulp chemistry.

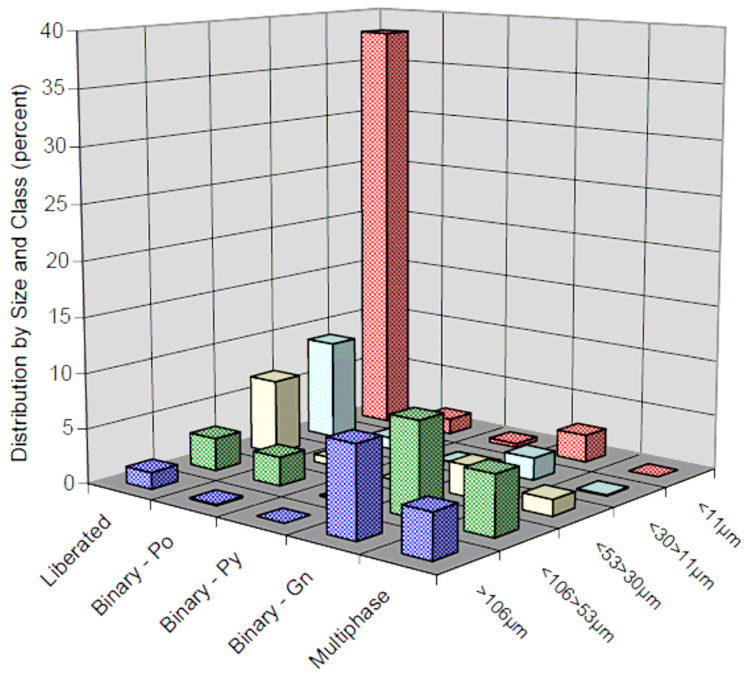

Figure 9: Distribution of nickel losses by size and class into the tailings. Expressed as a Percent of Pentlandite in the Tailings.

DE-BOTTLENECKED FLOW SHEET AND PERFORMANCE (APRIL 2009 SURVEY)

The SAG mill throughput has increased to accommodate the higher mined tonnage and as consequence produce a coarser flotation feed. Figure 10 shows the increase in SAG mill throughput. Significant changes around the SAG mill circuit included changing from a mix of 80/100/125mm balls to only 125mm balls, increasing the SAG shell lifter face angle from 15 to 20 degrees to take advantage of higher mill speed, and increasing the aperture size and open area of the discharge grates. Due to difficulties in balancing the cyclone operation over a wide range of flows with the 2 x 400mm Cavex cyclones, these were replaced with 4 x 250mm Cavex cyclones. Mineralogical analysis had shown that the flotation feed's pentlandite and NSG liberation state could be lowered with a coarser grind size without harming rougher/scavenger flotation recovery. This would result in the recovery of a larger percentage of composite particles. If the final concentrate grade was to remain constant, then regrinding of these composites would be required prior to cleaner flotation. An IsaMill™ was added to the circuit for regrinding purposes.

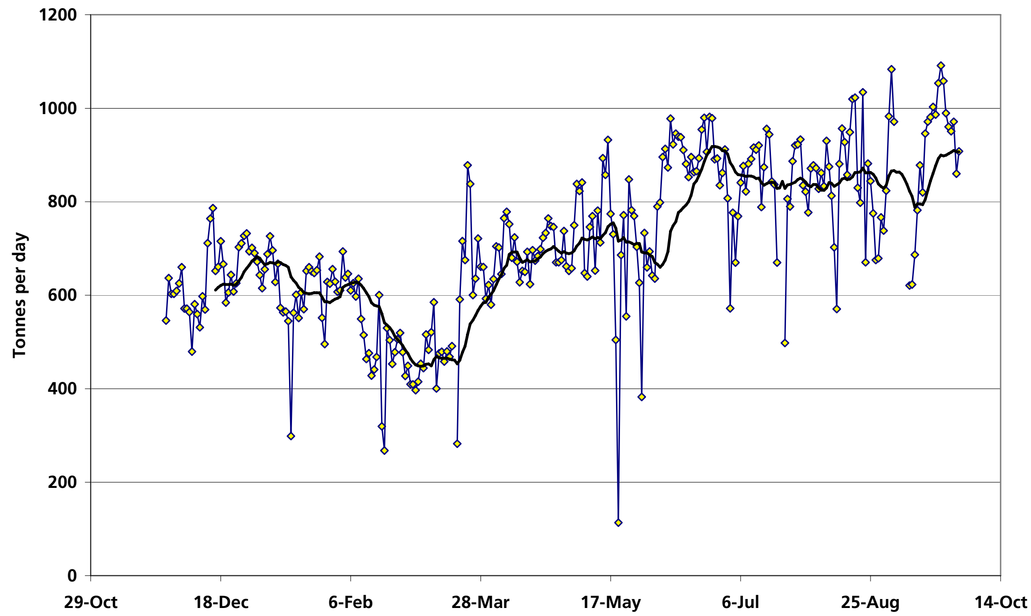

Figure 10: SAG Mill Throughput

A M500 IsaMill™ (as shown in Figure 11) was chosen for the regrind duty because of its small footprint; ideal for such a brownfield expansion. Its established ability to increase concentrate grades, use inert grinding media (clean particle surfaces), produce a narrow particle size distribution (in open circuit) and efficiently grind at low pulp density were all benefits useful to the Cosmos mineralogy and metallurgy. The fresh "clean" particle surfaces that inert media produces allow for optimised mineral separation, lower reagent consumption and higher flotation kinetics (Côté and Adante, 2009; Finch, Rao and Nesset, 2007; Huang, Grano and Skinner, 2006). The type of poorly liberated pentlandite composites that require regrinding are shown in Figure 12.

Figure 11: M500 IsaMill™ with 200 kW motor at Cosmos Concentrator

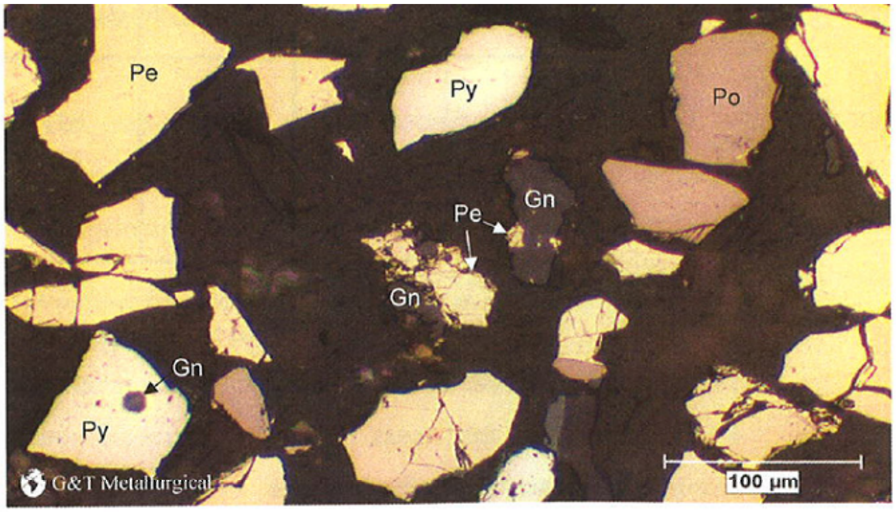

Figure 12: Photomicrograph of poorly-liberated pentlandite particles

Lab scale tests on selected concentrates were reground and floated to test the concept. With a finer flotation feed, it was found that the nickel grade/recovery curve could be shifted upwards (Figure 13). The IsaMill™ also allows for much better MgO rejection and, when chemical conditions in the cleaners are set for it, optimal As rejection.

The typical size distribution for the M500 IsaMill™ product is given in Figure 14. The F_{80} and P_{80} are around 40 and 20µm, respectively. The specific energy needed for this size reduction is around 20 kWh/t. Of particular note is that the particle size distribution of the product is sharper and steeper than that of the feed. The IsaMill™ directs the grinding energy into grinding the coarse particles, not generating more fines. This is evidenced by the minimal change in the P_{10}, P_{20} or P_{30} particle sizes. A 2mm ceramic media, Keramax® MT1™, supplied by Magotteaux, is being used for this regrind duty.

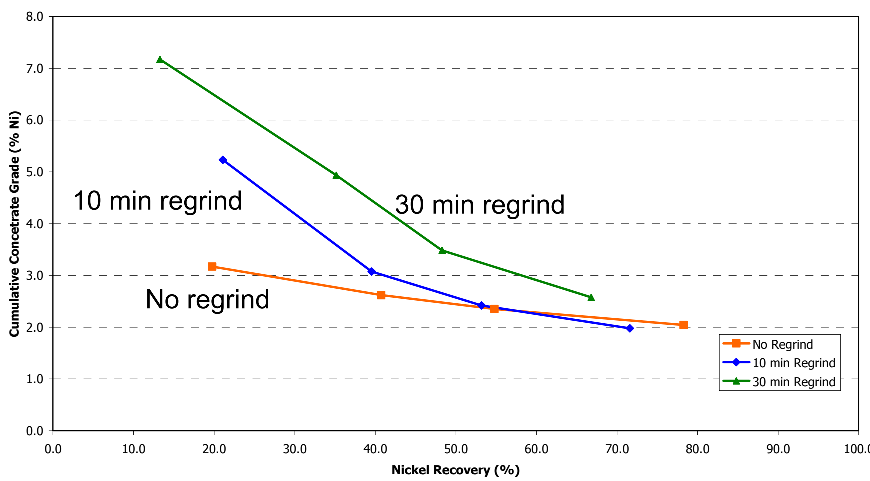

Figure 13: Example of Grade/Recovery Improvement from Regrinding

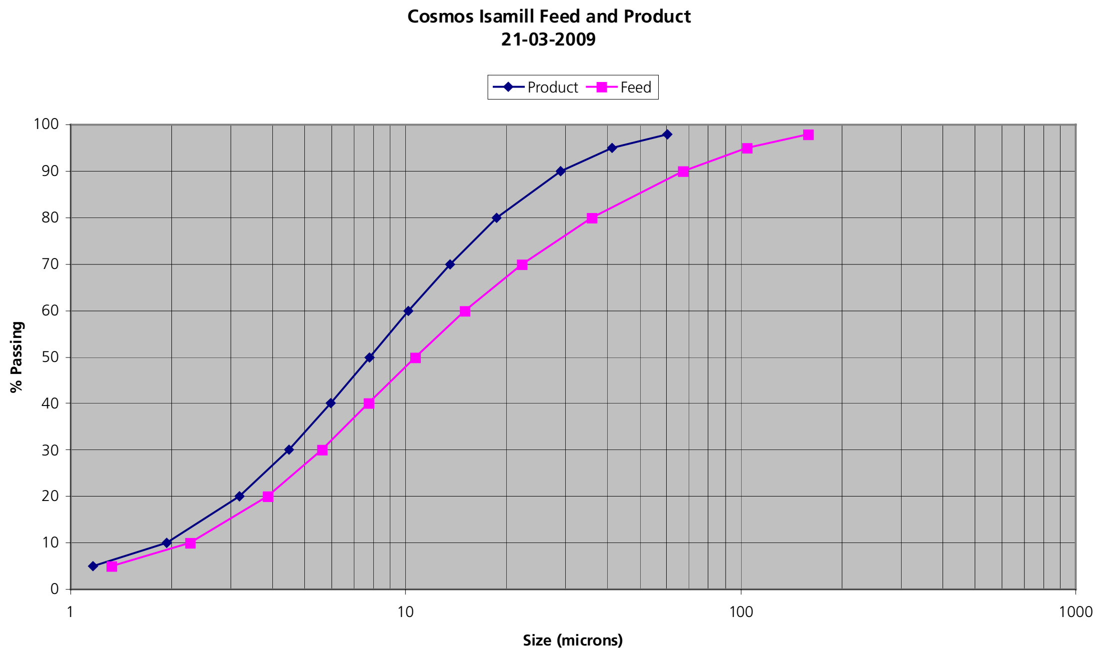

Figure 14: Typical Size Distribution for the IsaMill™ M500

Due to the higher head grade and plant throughput rates, additional flotation capacity was required. The first steps taken were to add a Z1600 Jameson Cell treating the SAG cyclone overflow as a rougher scalper and reconfigure the flotation circuit to be completely open (cleaner concentrates reconfigured to report to final concentrates and cleaner tails will report to final tails). After coarsening the SAG cyclone overflow product, the amount of liberated pentlandite in the cyclone underflow reduced and the SkimAir® recovery decreased (Figure 15). The SkimAir® was subsequently reconfigured to be fed from the cyclone overflow as a rougher.

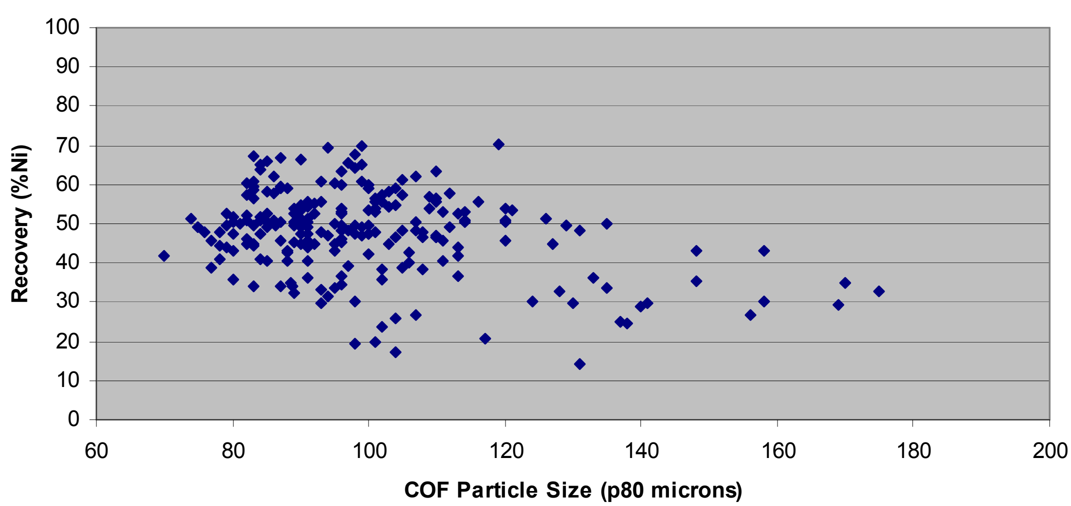

Figure 15: SkimAir® Recovery versus SAG Cyclone Overflow Size

The second step was the addition of a 40m^3 Wemco® SmartCell™ tank cell to increase the roughing capacity, initially added downstream of the Jameson Cell to provide sufficient overall roughing capacity, thereby enabling the remaining original flotation cells to be reconfigured into the appropriate cleaning circuit. Upon commissioning of the Wemco® SmartCell™, it was found that frother carry-over from upstream additions caused excessive frothing, as well as concentrate pumping issues. Piping arrangements in place readily allowed the Wemco® SmartCell™ to be placed ahead of the Jameson Cell, which is the current configuration.

The Jameson Cell was selected for the Cosmos project because it is a small, high-throughput device. A picture of the Jameson Cell installed at Cosmos is given in Figure 16. Like the IsaMill™, the compact design makes it easy to retrofit into existing plants.

Figure 16: Z1600 Jameson Cell at the Cosmos Concentrator

The Jameson cell was commissioned in late March 2009 which coincided with a 2 unit increase in nickel concentrate grade while recovery was maintained at 90% (Table 4). As shown in Figure 17, the Jameson Cell concentrate grade is consistently above that of the final concentrate. Further, froth washing is used to reduce the entrainment of NSG as shown in Figure 18. It should be noted that the Jameson Cell was commissioned on cyclone overflow; several weeks before the SkimAir® was reconfigured.

Table 4: Metallurgical Balances for Various Months

Month	Final Prod	Mass %	Assays - %					Distribution - %				
			Ni	Cu	Fe	S	As	Ni	Cu	Fe	S	As
July 08	Con	22.2	19.0	0.71	31.9	28.9	0.2	92	91	58	74	58
	Tails	77.8	0.5	0.02	6.5	2.9	0.04	8	9	42	26	42
Aug 08	Con	18.7	18.7	0.74	29.9	29.6	0.28	91	92	56	76	77
	Tails	81.3	0.4	0.01	5.4	2.2	0.02	9	8	44	24	23
Dec 08	Con	19.9	19.6	0.65	25.7	24.5	0.25	90	87	50	67	46
	Tails	80.1	0.5	0.02	6.4	3.0	0.07	10	13	50	33	54
Feb 09	Con	22.8	19.9	0.68	24.8	23.5	0.19	90	81	44	60	45
	Tails	77.2	0.7	0.05	9.3	4.6	0.07	10	19	56	40	55
April 09	Con	22.5	21.8	0.75	30.6	27.6	0.11	90	88	36	50	44
	Tails	77.5	0.7	0.03	15.5	8.0	0.04	10	12	34	50	56

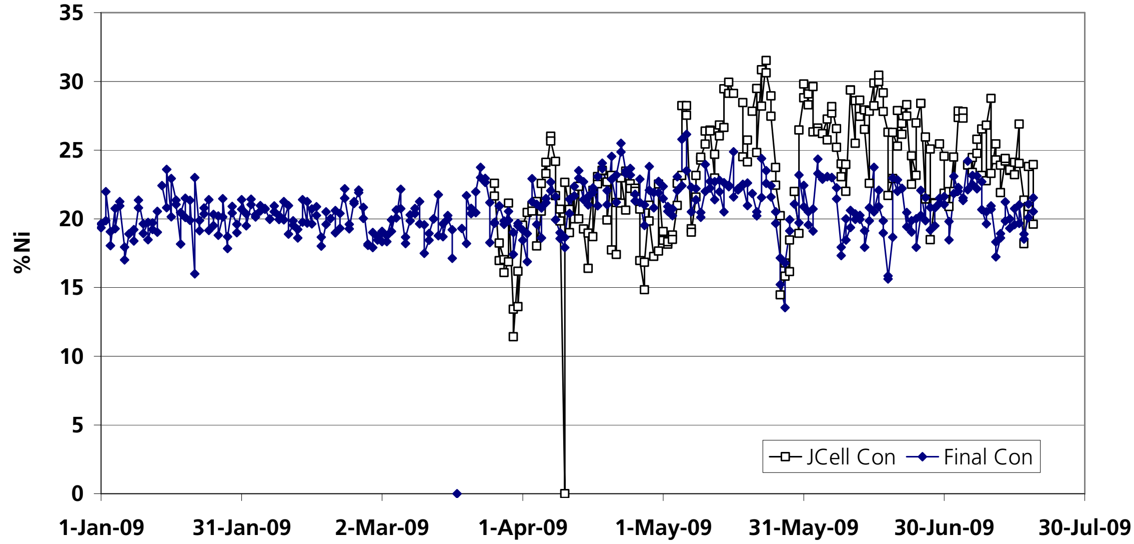

Figure 17: Jameson Cell versus Final Concentrate Grade

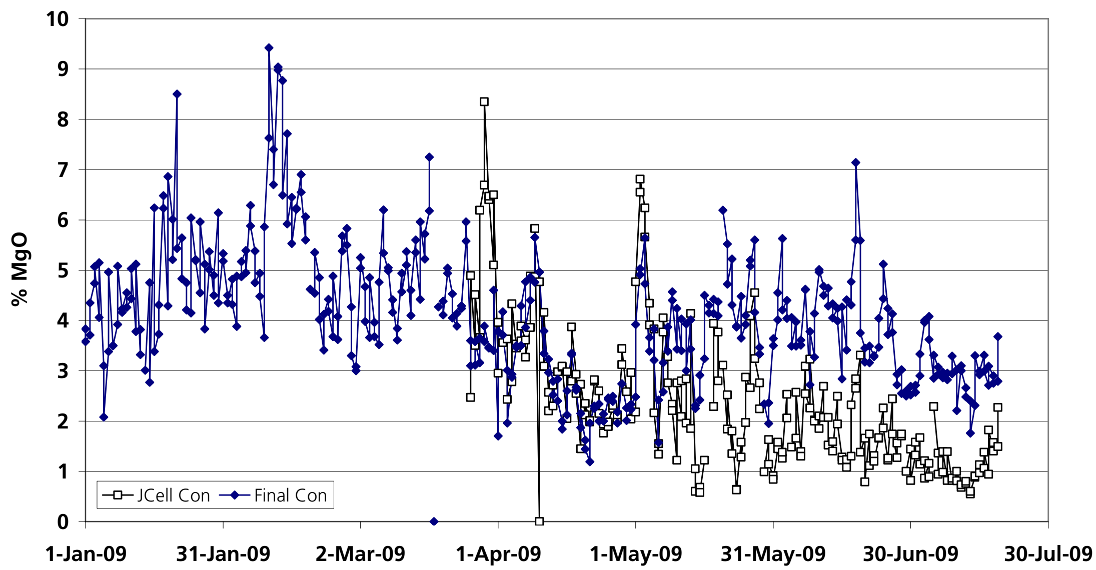

Figure 18: MgO content of Jameson Cell versus Final Concentrate

The final flow sheet change was the reconfiguration of the original rougher/scavenger flotation cells into the cleaning circuit. In making the flotation circuit open, the sequential flotation stages are now more clearly defined. A diagram of the three main components of the circuit is shown in Figure 19. In this strategy the rougher and scavenger cells are designed to maximize nickel recovery. The cleaning section depresses and removes the NSG minerals via regrinding, washing/dilute cleaning and depressants. The re-cleaning stage can be employed when necessary for selective arsenic removal via pH control and cyanide addition.

The advantages of this strategy are three-fold. Sequential reagent addition ensures that reagents are only introduced at the intended stage and not upstream via a recycled stream. For example, previous studies have shown that cyanide and copper sulphate addition can slow the kinetics of pentlandite. Secondly, the circuit is easier to operate with the various functions defined. Thirdly, the larger residence times allow higher throughput of ore and nickel units.

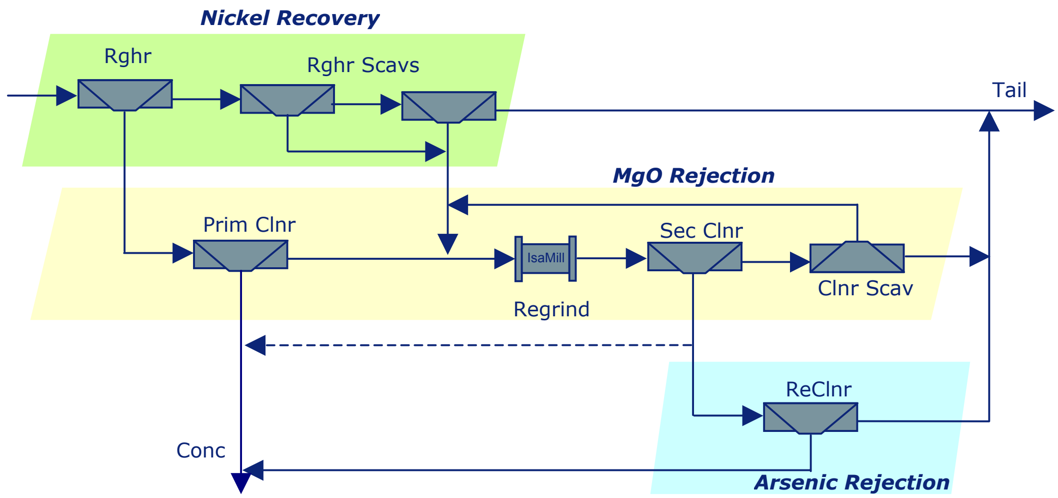

Figure 19: Sequential Flotation Stages

Size by size recovery analysis of the final concentrate after de-bottlenecking shows good recovery of liberated pentlandite by the flotation circuit (Figure 20), although there are still substantial losses of the sub 10 micron material. At the time of the April 2009 survey, the cleaner changes were not complete so residence times were achieved with high pulp densities. Dilution cleaning in the ultimate circuit should recover additional valuable fines and reduce entrainment of liberated NSG. Recovery of unliberated pentlandite had also improved (Figure 21). The new flotation circuit also showed an improvement in rejecting liberated pyrrhotite. As shown in Figure 22, liberated pyrrhotite made up less than 9% of final concentrate - a significant change from the 15% measured in July 2008 with the previous circuit.

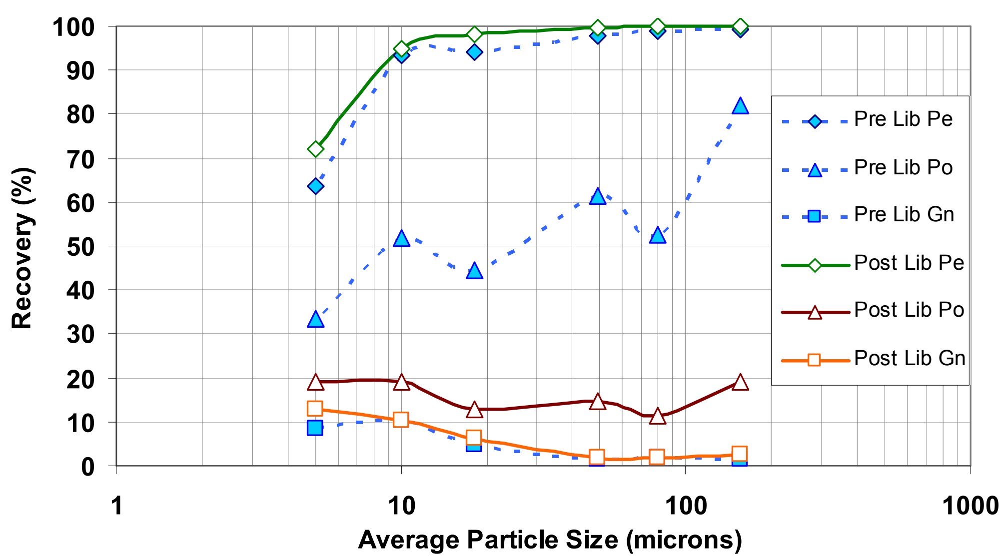

Figure 20: Recovery by Size and Class into the Final Concentrate

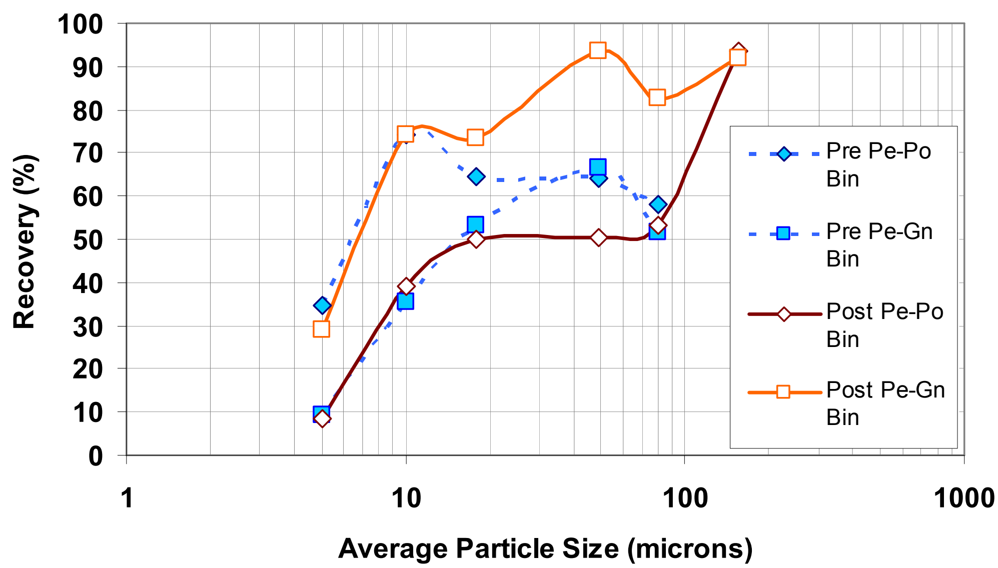

Figure 21: Recovery of Pentlandite Binaries into the Final Concentrate

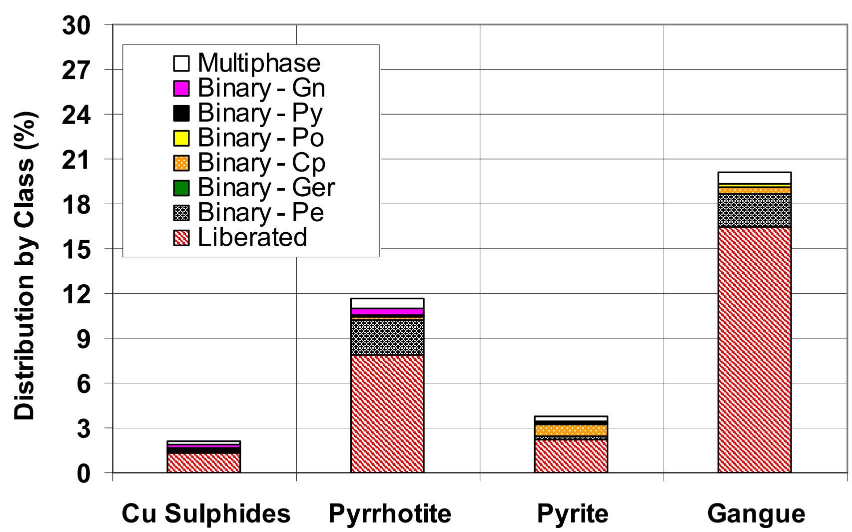

Figure 22: Distribution of Diluent Minerals in the Final Concentrate – April 2009

In considering the theoretical grade-recovery curve given in Figure 23, it can be seen that despite some improvement from the original data, there remains opportunities to increase the concentrate grade without sacrificing nickel recovery.

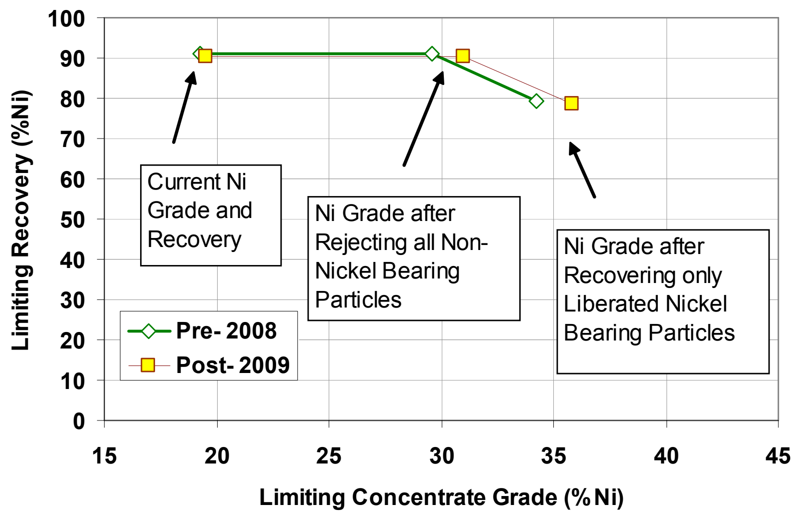

Figure 23: Mineralogically Limiting Grade-Recovery Curve – Before and After

As shown in Figure 24 and Table 5, nickel losses to the final tailings remained similar for the month of April as compared to the previous survey (Figure 9).

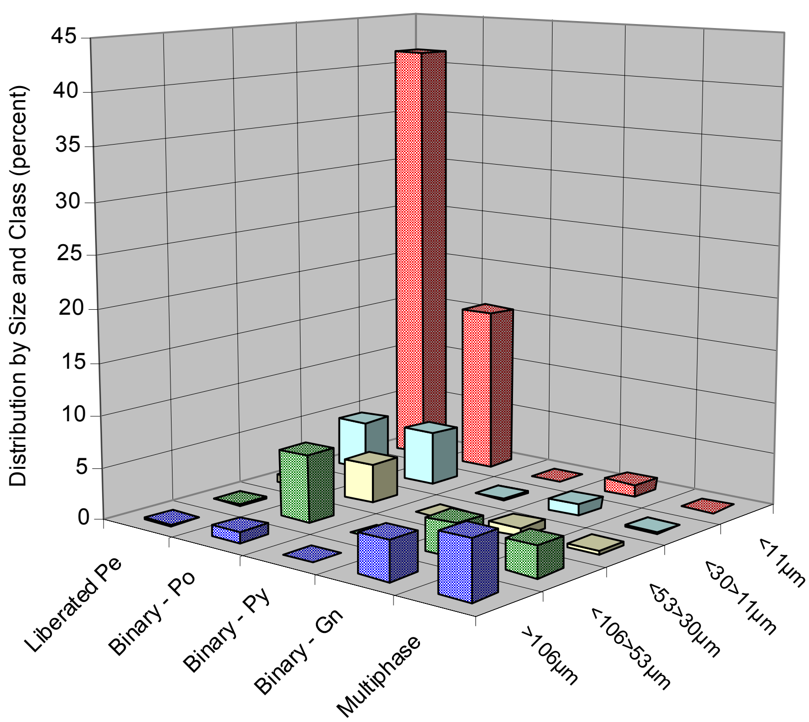

Figure 24: Distribution of Nickel Losses by Size and Class into the Tailings – April 2009

Table 5: Overall Distribution of Nickel Losses into the Final Tailings Stream

Mineral Class	Distribution by Size Range and by Class					Losses by class
	>106µm	<106>53µm	<53>30µm	<30>11µm	<11µm	
2008 Average						
Liberated	0.1	0.2	0.4	1.0	3.1	4.8
Binary – Po	0.0	0.2	0.2	0.1	0.2	0.7
Binary – Py	0.0	0.0	0.0	0.0	0.0	0.0
Binary - Gn	0.7	0.8	0.2	0.3	0.3	2.3
Multiphase	0.4	0.4	0.1	0.1	0.0	1.0
Losses by Size	1.2	1.6	0.9	1.5	3.6	8.8
April 2009						
Liberated	0.0	0.0	0.1	0.5	4.0	4.5
Binary – Po	0.1	0.6	0.4	0.5	1.5	3.1
Binary – Py	0.0	0.0	0.0	0.0	0.0	0.0
Binary - Gn	0.4	0.3	0.1	0.1	0.1	1.0
Multiphase	0.5	0.3	0.0	0.0	0.0	0.9
Losses by Size	1.0	1.2	0.5	1.1	5.6	9.4

FINAL FLOWSHEET

The envisioned final flowsheet is shown in Figure 25. These changes will complete the plans for increased nickel output and lower production costs.

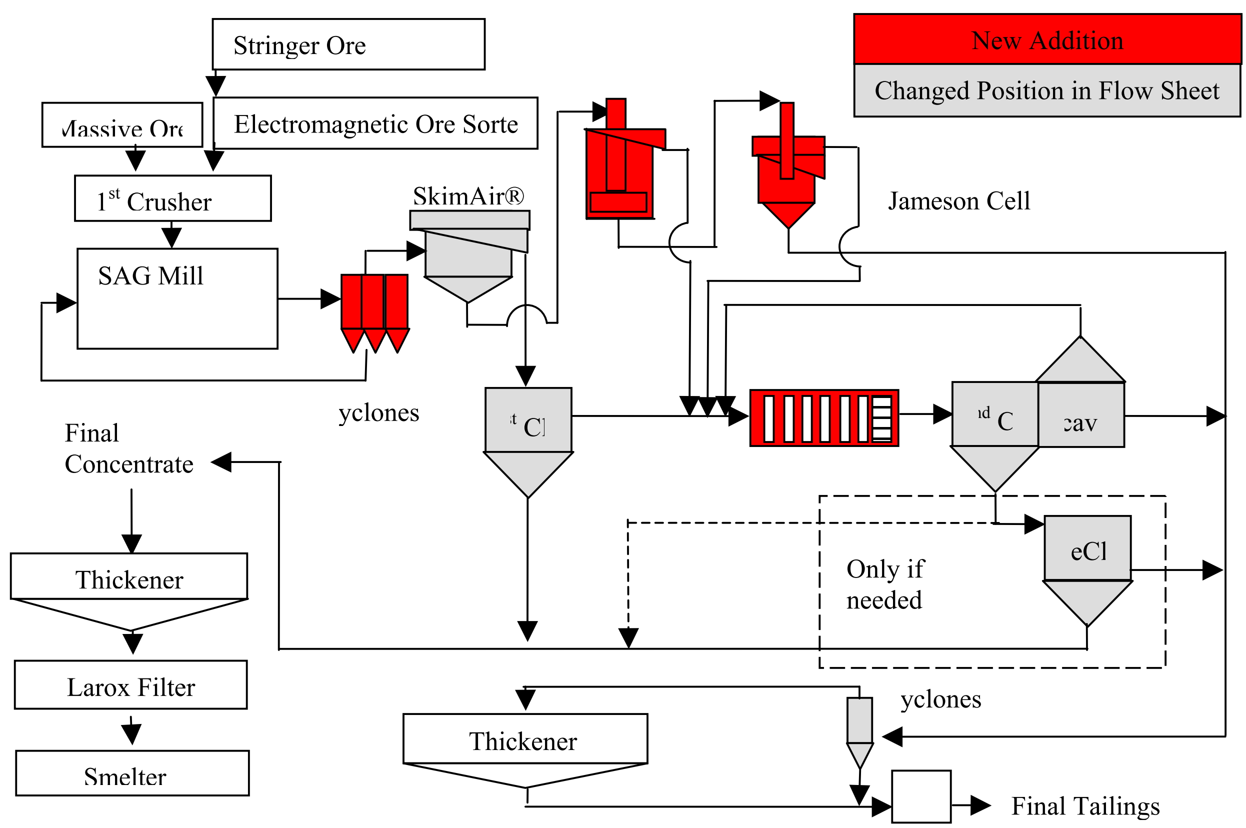

Figure 25: New Flowsheet Layout

CONCLUDING REMARKS

Performance from the Cosmos concentrator has broadly met targets with respect to the changes made to date through the de-bottlenecking process. Overall concentrate grade and plant recovery have been maintained with respect to more difficult ore treated (nickel grades in feed have decreased, nickel to arsenic ratios in feed have increased and the ratio of massive to more disseminated ore has decreased - all negatively impacting nickel recovery) at increased plant throughput.

Mineralogically, Figures 27 to 29 demonstrate improved pentlandite recoveries across all size fractions, and similarly reduced pyrrhotite recoveries across all size fractions. NSG recovery has remained largely unchanged, but this will be the focus of the upcoming modifications to the cleaning portion of the new flow sheet.

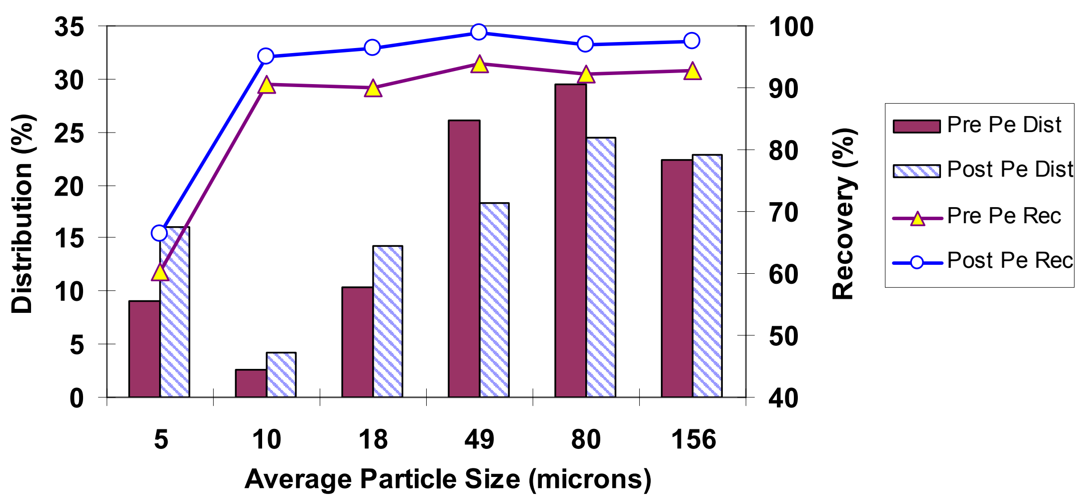

Figure 26: Pentlandite Recovery Comparison

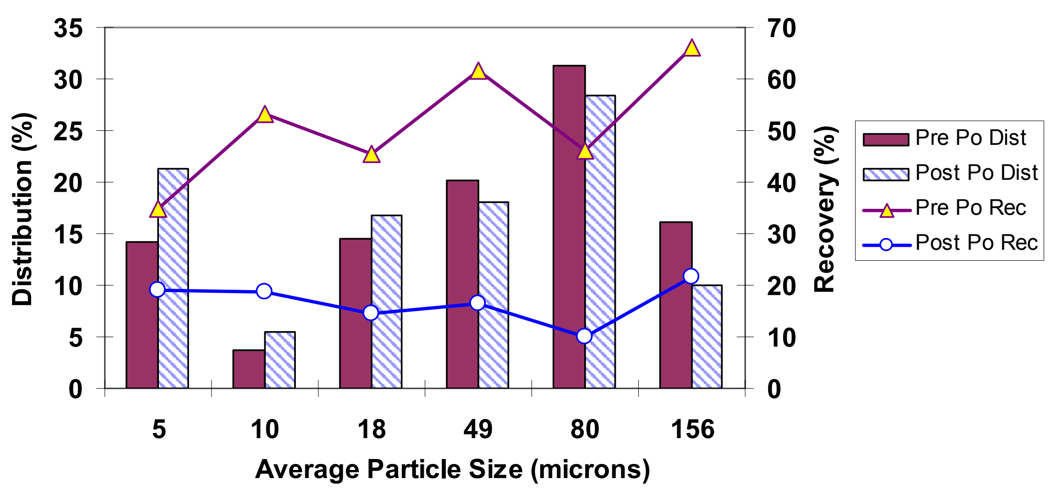

Figure 27: Pyrrhotite Recovery Comparison

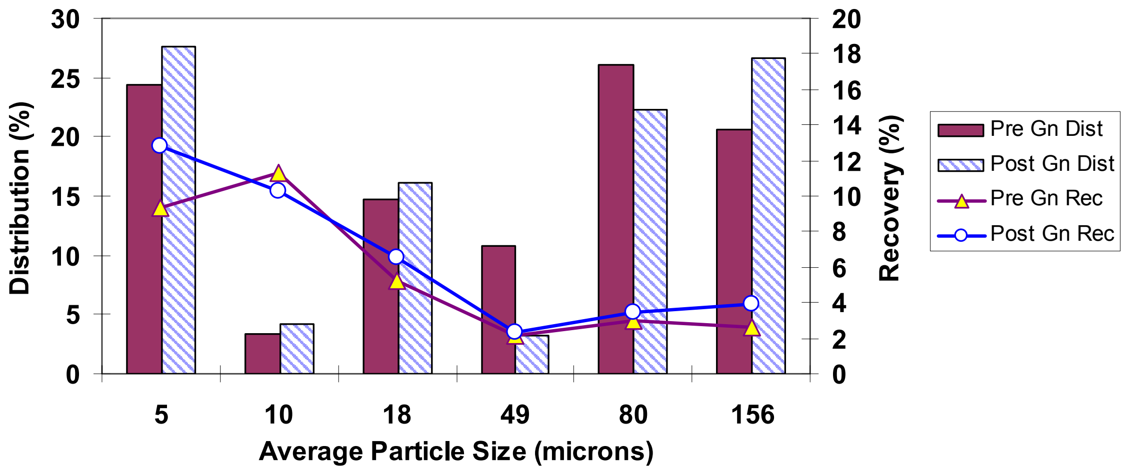

Figure 28: NSG Recovery Comparison

Most of the de-bottlenecking plant design completed to date has focused on modifications to existing equipment and installations of several key additions such as the M500 IsaMill™, Z1600 Jameson Cell and Wemco® SmartCell™, with the primary objective of increased plant throughput capacity. As demonstrated in Figures 27 to 29, this has been achieved without sacrificing the plant performance.

Final modifications in the cleaning circuit will complete having the "right tools in the right place" to enable enhanced metallurgical performance. Analytical tools such as modal analyses and size by size recovery determinations were and will continue to be essential in identifying how best to use the processing tools installed for optimal mineral separations. The new circuit is key to enabling the Cosmos operation to be a low cost nickel producer into the future.

ACKNOWLEDGEMENTS

The authors would like to thank Xstrata Nickel Australasia for their permission to publish this paper.

REFERENCES

Shouldice, T. and Lafreniere, T. (2008) G&T Metallurgical Report of the July 2008 Survey of the Cosmos Concentrator (Internal)

Côté, l and Adante, J (2009) Design, Start-up and Optimization of Pb & Zn Flotation Circuits Utilizing Ultra-Fine Grinding Technology, *41st Annual Meeting of the Canadian Mineral Processors*, Ottawa, Canada, January 20 to 22.

Huang, G., Grano, S. and Skinner, W (2006) Galvanic Interaction between Grinding Media and Arsenopyrite and its Effect on Flotation: Part II. Effect of Grinding on Flotation, *Int. J. Miner. Process.* 78, pp. 198– 213.

Finch, J., Rao, S., and Nesset, J. (2007) Iron Control in Mineral Processing, *39th Annual Meeting of the Canadian Mineral Processors*, Ottawa, Canada, January 23 to 25

Shouldice, T. and Ma, W. (2009) G&T Metallurgical Report of the April 2009 Survey of the Cosmos Concentrator (Internal)