IMPROVING CONCENTRATE GRADE THROUGH SMART DESIGN AND PILOTING

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ABSTRACT

Selectively recovering pentlandite from high levels of pyrrhotite presents a technical and operational challenge. The liberation characteristics and also the chemical environment is critical to performing a successful separation. Reviewing the mineralogy to understand the characteristics of the ore and the plant flotation behavior is fundamental to designing a successful improvement program.

At Savannah Nickel the challenges presented by a falling nickel price required a rethink of the flowsheet to improve the project economics through improving the concentrate grade and recoveries. Glencore Technology reviewed the plant performance and proposed and tested solutions to improve the grade performance of the concentrator with the support of the plant team. A pilot plant comprising a M20 Isamill™ followed by an L500/1 Jameson Cell was operated on various plant streams. In addition to the pilot plant, flotation surveys and a plant based laboratory program was used to supplement the plant understanding and within two weeks significant improvements were identified and demonstrated. The combination of the pilot operation and the plant based laboratory program was able to quickly demonstrate the improvements and test with equipment that is fully scaleable from pilot plant to full scale.

KEYWORDS

Pentlandite, Pyrrhotite, Isamill™, Jameson Cell, Cu/Ni separation, Mineralogy

INTRODUCTION

Panoramic Resources Limited is a Western Australian mining company formed in 2001 for the purpose of developing the Savannah Nickel Project in the East Kimberley region of Western Australia. Panoramic successfully commissioned the $65 million Savannah Project in late 2004. The process plant at Savannah comprises a single stage crusher, SAG mill, flotation, thickening and filtering stages to produce a bulk nickel, copper, cobalt concentrate. Metallurgical recoveries average 86-89% for nickel, 94-97% for copper and 89-92% for cobalt. The plant was originally designed for a throughput of 750,000 tonnes per annum, but has consistently outperformed the design specifications.

Due to low nickel prices the Savannah Nickel mine and processing plant were placed into care and maintenance in May 2016. Prior to suspending production Glencore Technology was engaged to investigate options to improve the concentrate grade. With the discovery of Savannah North in 2014 and the Savannah North Scoping Study demonstrating LoM ~8 years and Mining Inventory of 6.07Mt @ 1.26% Ni, 0.64% Cu and 0.09% Co significant future potential exists. By completing pilot plant studies prior to shutting down, the plant engineering studies can be completed and the plant readied for restart by the time the nickel price improves.

Background

The Savannah Nickel deposit is located in the Kimberley region of Western Australia south west of Kununurra (Figure 1). The project operates as a fly-in fly-out operation with the majority of its workforce sourced from Perth.

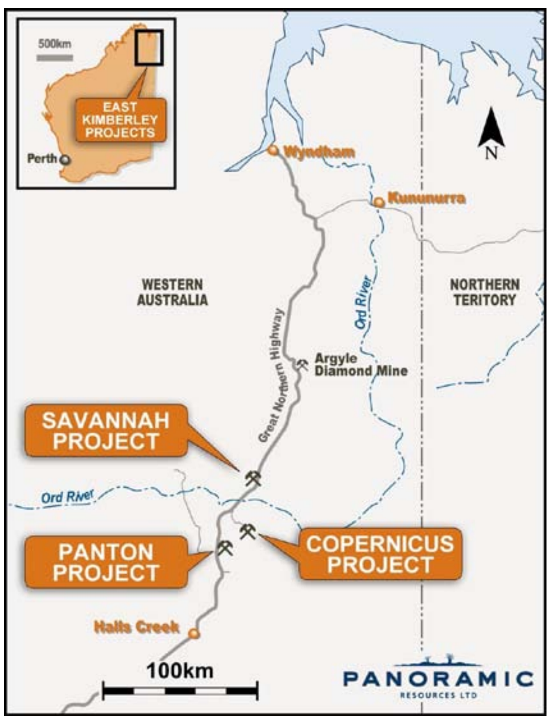

Figure 1 – Savannah Nickel Project

Figure 2 – Savannah Nickel Processing Plant

The current processing plant is shown in Figure 2 and Figure 3. The main features include the flash flotation cell and the rougher 1 concentrate that are in open circuit while the rougher 2 concentrate and scavenger concentrate are cleaned through a single stage rougher cleaner (RCC) and scavenger cleaner(SCC). The plant produces a low grade Cu-Ni concentrate at high nickel recoveries.

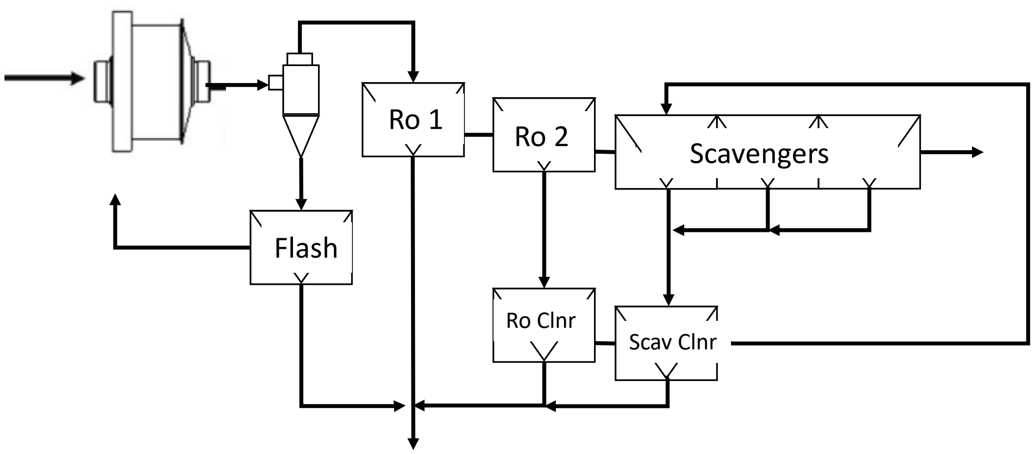

Figure 3 – Savannah Nickel Flowsheet

Historical Data Review

To understand the requirements for improving the concentrate grade at Savannah Ni, an historical review of plant data was undertaken by Glencore Technologies. This review included previous survey work, daily and monthly balances and where available mineralogy of selected streams. The plant had been successfully operating in a high recovery, low concentrate grade scenario. The incentive for the review was to investigate whether the concentrate grade could be improved to improve project economics through reduction in transportation and smelting costs at the historically low nickel prices.

The composition of the nickel concentrate was reviewed by size to determine the source and composition of the diluents. These data are given in Figure 4. The valuable minerals are distributed across all sizes while the non sulphide gangue (NSG) is in the finest fractions and pyrrhotite (Po), the most dominant diluent, is in the intermediate fractions although it is diluting the concentrate across all fractions. The source of the pyrrhotite needed to be identified across the four streams that combine to make the final concentrate.

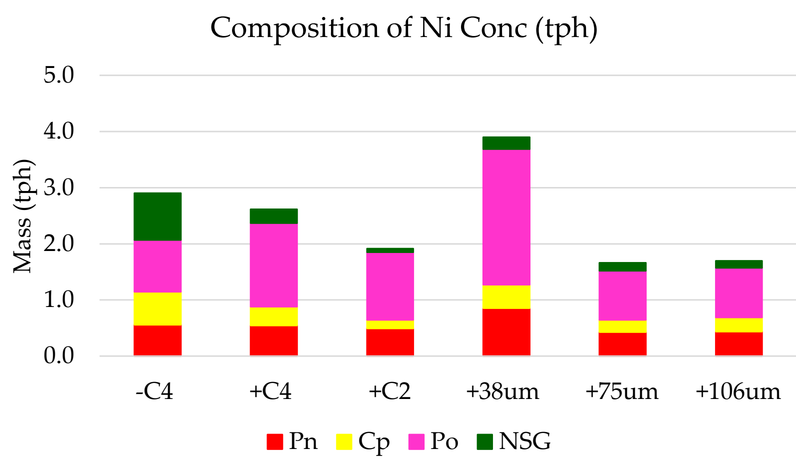

Figure 4 – Composition of the concentrate

By reviewing the diluents by size and by stream (Figure 5) it was determined that the non-sulphide gangue dilution was distributed across the various concentrate streams with the rougher 1 concentrate and rougher 2 concentrate being the major sources. The pyrrhotite was also distributed across all streams however the major source was the flash concentrate in the particle sizes greater than 38 micron. The remaining pyrrhotite was in the floatable fractions between C4 (approximately 15 micron) and 38 micron mainly in the rougher 1 and 2 concentrates.

Limited liberation data existed for the individual concentrates however the point counting data that was available indicated that the pentlandite (Pn) appeared to be adequately liberated as defined by Johnson (1988) with values greater than 80% while the chalcopyrite (Cp), pyrrhotite and non-sulphide gangue were only moderately liberated. The main association of chalcopyrite was with pyrrhotite while the pyrrhotite was associated with pentlandite. The major association for the non-sulphide gangue in the concentrate was with chalcopyrite.

These data when reviewed collectively suggested that to remove the diluents from the concentrate would require a combination of a moderate regrind and improvements in flotation separation to improve the concentrate grade. A proposal for an onsite pilot campaign using both an M20 Isamill™ in combination with an L500/1 Jameson cell was provided. As the separation of pentlandite from pyrrhotite is challenging and often requires an optimisation of chemistry, an accompanying laboratory campaign was proposed to be conducted on the samples from both the plant and the pilot plant to confirm the correct chemistry of separation.

EXPERIMENTAL

The pilot plants were shipped to site in April 2016. The onsite personnel arranged for set up and connection to services. In addition a laboratory proposal had sourced the required chemicals and readied all the required laboratory equipment in advance to make best use of the two week campaign. Planning also included sourcing mine supply that would best represent the future operation as any flowsheet changes would take time to implement and current ore sources were in decline. The installed pilot plants are shown in Figure 6 near the flotation feed conditioning tank.

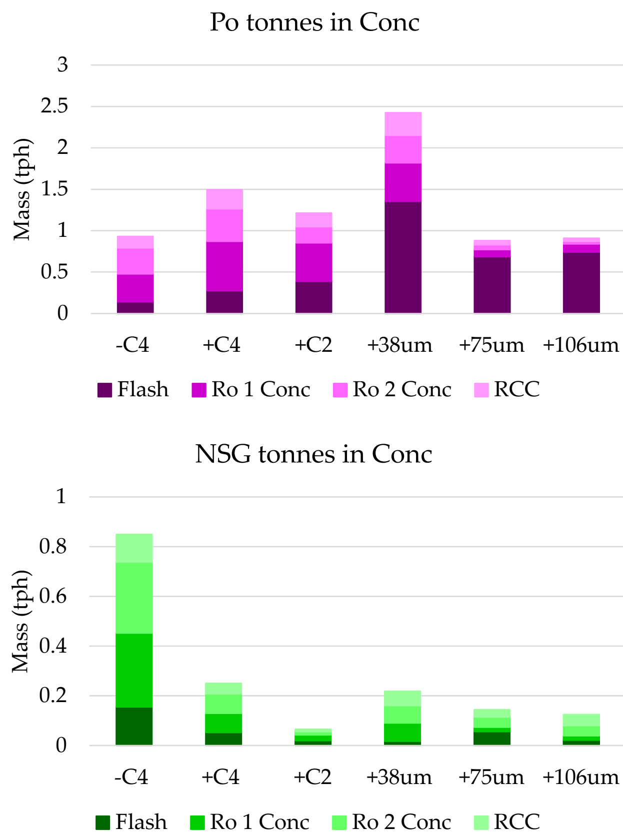

Figure 5 – Diluent by size and stream

Figure 6 – Pilot plants on site

The pilot plant consisted of an M20 Isamill™ and an L500/1 Jameson Cell. Both are highly instrumented allowing for minimal operator intervention. This enabled a single operator to run both pilot plants while a second was able to conduct flotation tests. A total of 120 pilot plant surveys and 57 flotation tests were conducted on various streams over the two weeks on site. To complement the pilot plant work a full plant survey was conducted and a series of mini circuit block surveys to allow a comparison between the current operation and the proposed circuit changes.

Rougher 1 Concentrate

Initial testing was conducted on the rougher 1 concentrate while the remaining tie-ins were completed for the flash concentrate stream. The rougher 1 concentrate was tested with and without regrind in the pilot plant and through various pH and reagent conditions in the laboratory (Figure 7).

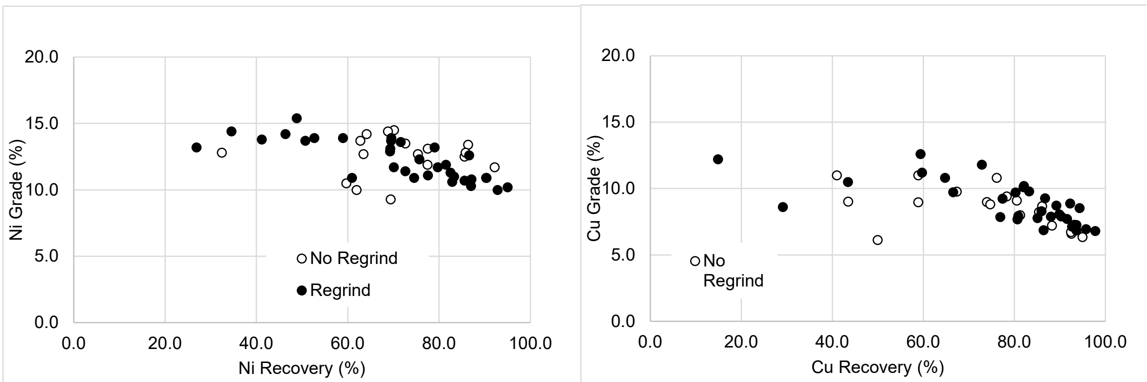

Figure 7 – Pilot Plant performance rougher 1 concentrate

The combination of the pilot plant data the laboratory flotation tests indicated that regrind had a small but significant effect on the grade recovery curve of copper with a less significant effect on nickel. Variables such as collector addition rate were evaluated and its addition was significant on improving recovery at the expense of grade in the regrind case. Diethylenediamine (DETA) and sodium sulphite (SS) were also evaluated and determined to have a significant impact on grade although testing was only conducted on the laboratory samples. Excess DETA additions resulted in almost compete depression of pentlandite and indicated it may be useful if copper nickel separation is ever considered. Optimisation of DETA dosage was conducted as the two weeks progressed to restore the recovery lost after its addition. The recovery of pyrrhotite to the rougher 1 concentrate is very high and the easier targets for pyrrhotite removal are the streams where regrinding is more effective for its removal. Neither pH nor DETA resolved the high pyrrhotite flotation in the rougher 1 concentrate at the levels tested.

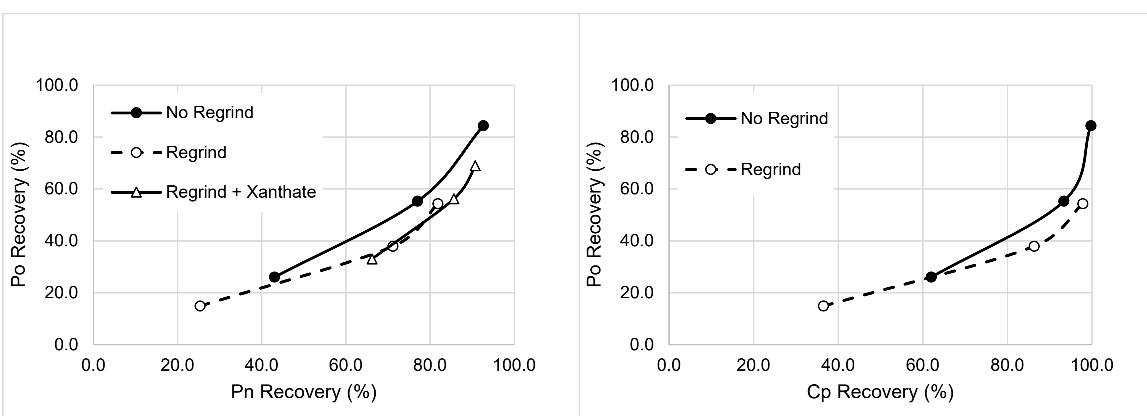

Figure 8 – Laboratory flotation of rougher 1 concentrate

Flash Concentrate

The next stream to be tested was the flash concentrate. The sample was found to be very coarse and the lines sanded on occasion. Due to this materials handling challenge, all the pilot tests were conducted with regrinding while some laboratory tests were conducted without regrind. Analysis of the laboratory tests determined that regrinding had a significant impact on the cleaner grade recovery curve of the flash concentrate and the work continued with regrinding only tests in the pilot plant. Three stage laboratory cleaning of the flash concentrate at low solids density (referred to as dilution cleaning) resulted in no separation from pyrrhotite nor did modification of the pulp pH in the case with no regrind. Optimum conditions for the flash concentrate were regrinding with the addition of DETA/SS at a pH of 9.5. It is expected that regrinding with DETA/SS and Jameson Cell flotation will provide a superior grade recovery curve. In all cases the grade of the flash concentrate could be significantly improved and as this stream represents over a third of the final concentrate this will result in a significant shift in the grade recovery curve for Savannah Nickel.

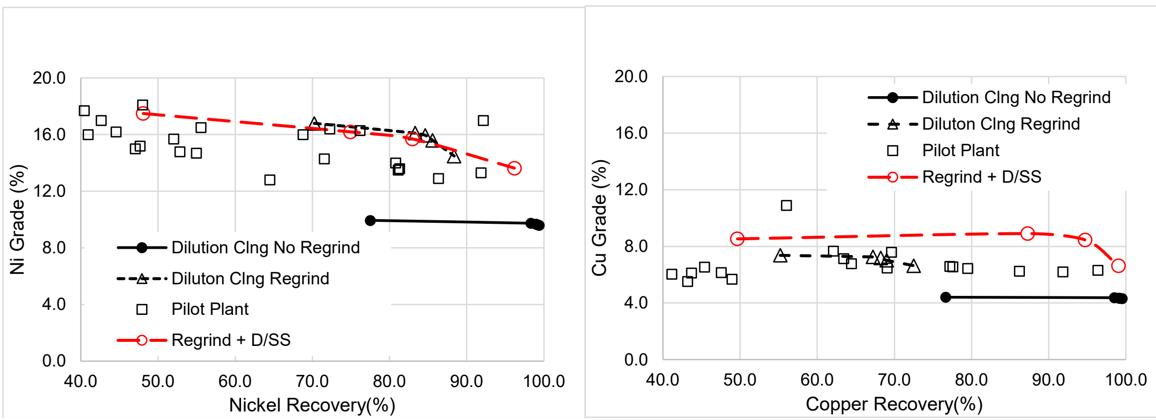

Figure 9 – Laboratory and pilot plant testing on flash concentrate

Rougher 2 Concentrate

Laboratory tests on the rougher 2 concentrate with and without regrind clearly showed the improved grade recovery curve position following regrind. For this reason this stream was tested with regrind for all pilot tests. In conjunction with the pilot plant operation plant block surveys were conducted to measure the performance of the existing plant cleaner.

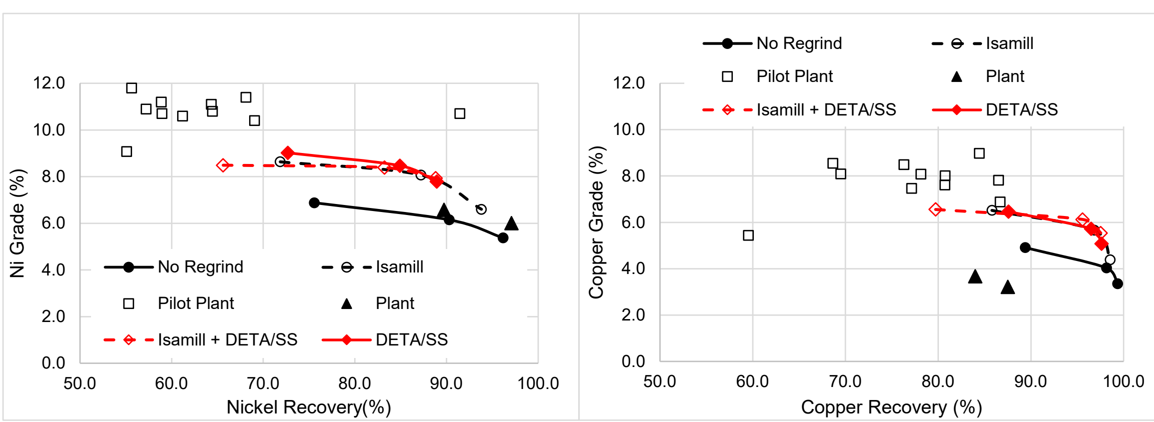

Figure 10 – Grade recovery curves for rougher 2 concentrate with and without Isamilling

The demonstration in the pilot plant of the improvement in grade recovery position with regrind is shown in Figure 10. The pilot plant produced a superior grade recovery curve for both copper and nickel compared to the laboratory. The difference is likely the result of the superior cleaning efficiency of the Jameson Cell compared to the laboratory single stage cleaner flotation. DETA/SS was able to achieve a similar response to regrind alone however the regrinding in combination with the Jameson Cell without DETA/SS produced the highest grade.

Scavenger Concentrate

The final stream tested was the scavenger concentrate. As the scavenger concentrate consisted of the highest pyrrhotite content additional laboratory tests were conducted to try to understand the behaviour of pyrrhotite. The pilot plant was only operated for one day on this stream and a single plant survey was also conducted. The impact of various parameters investigated in the laboratory are given in Figure 11 and are compared to the performance of the pilot plant.

The laboratory testing showed that the grade of the scavenger concentrate could be improved by regrinding. The best performance was indicated by the dilution cleaning test after regrinding suggesting that the small number of pilot tests hadn't achieved the optimum performance in the Jameson Cell that is indicated by the laboratory simulation. A significant level of entrainment after regrinding for the scavenger concentrate requires optimisation of wash water addition and air rates in the pilot tests. Increases in concentrate grade by a factor of 2 are possible by Isamill™ regrinding and cleaning.

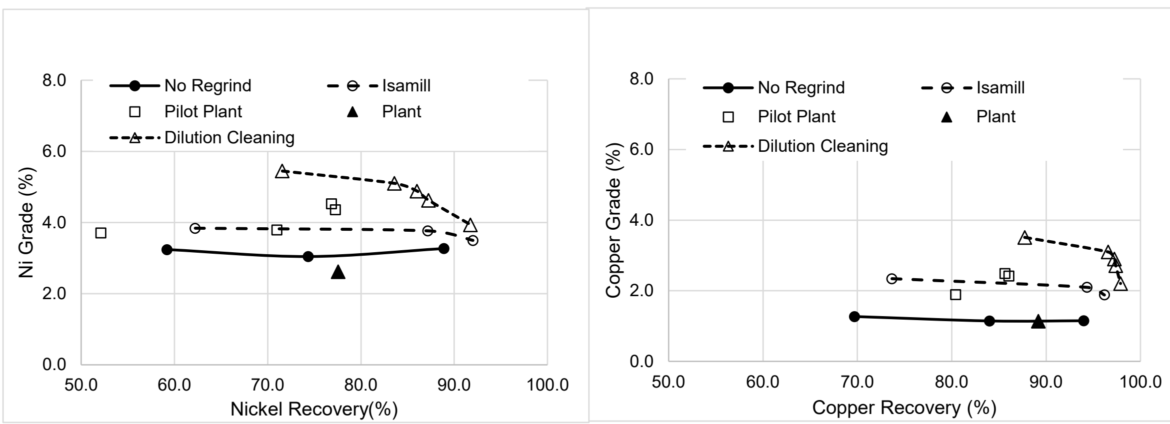

Figure 11 – Grade recovery curves from testing of scavenger concentrate

To determine the impact of conditioning on the selectivity of pentlandite from pyrrhotite, Isamilled scavenger concentrate was conditioned with nitrogen or air or combinations of the two. The closed nature of the Isamill™ means that the discharge slurry is often devoid of oxygen when highly reactive sulphides such as pyrrhotite are ground as any oxygen present in the pulp is consumed as new surfaces are created. The Isamilled sample conditioned with nitrogen only remains at the low Eh level of -200 mV. The oxygen level was not measured but the rise in Eh is assumed to be associated with an increase of oxygen in the pulp as the pulp is conditioned with air. As the air is introduced the recovery of pyrrhotite decreases relative to the pentlandite improving the grade of the concentrate. This has implications for plant and pilot plant practice suggesting that conditioning will be required after and optimisation of air rates to achieve optimised concentrate grades.

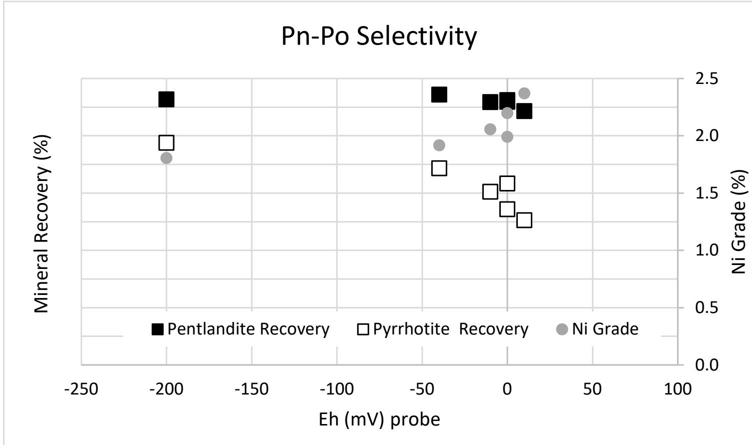

Figure 12 – Pentlandite-Pyrrhotite selectivity vs flotation Eh

ENGINEERING DESIGN

To enable engineering design on the preferred flowsheet a full plant survey was conducted in order to be able to accurately predict the required mass flows for sizing the Isamill™ and Jameson Cells. The full plant survey confirmed the distribution of masses from earlier work supporting the high mass from the flash concentrate. Any improvements in concentrate grade or recovery would rely on being able to shift the position of the flash concentrate grade recovery curve. The mass splits are provided in Table 1.

Table 1 – Full Plant Survey Balance

Stream	tph	%Solids	Ni	Cu	Co	Mass	Ni	Cu	Co
Flash	5.6	33.4	12.0	5.3	0.7	4.0	30.8	29.1	35.1
Ro 1 Conc	4.9	44.5	11.4	7.4	0.6	3.5	25.9	35.9	29.0
Ro 2 Conc	8.8	34.1	6.45	3.31	0.31	6.3	26.2	28.7	25.4
Scav Conc	9.8	27.5	1.57	0.52	0.07	7.0	7.1	5.0	6.1
Ro Clnr Conc	6.5	37.4	8.1	4.3	0.4	4.7	24.6	27.6	24.1
Scav Clnr Conc	2.5	31.8	4.3	2.0	0.2	1.8	4.9	5.0	5.3
Final Conc	19.6	28.0	9.5	5.1	0.5	14.0	86.3	97.6	93.5

Based on the results of the piloting a flowsheet was proposed to improve the grade and recovery at Savannah Nickel. Using the mass splits from the full plant survey in conjunction with the laboratory results a simulation of the expected plant benefit was completed. It is proposed that the installation of the Isamill™ and Jameson Cell modified circuit will improve the concentrate grade to 10.5% Ni at the same recovery. This represents a 1% grade improvement compared to the full plant survey and a 2% grade improvement compared to the operating data for the remainder of the time on site.

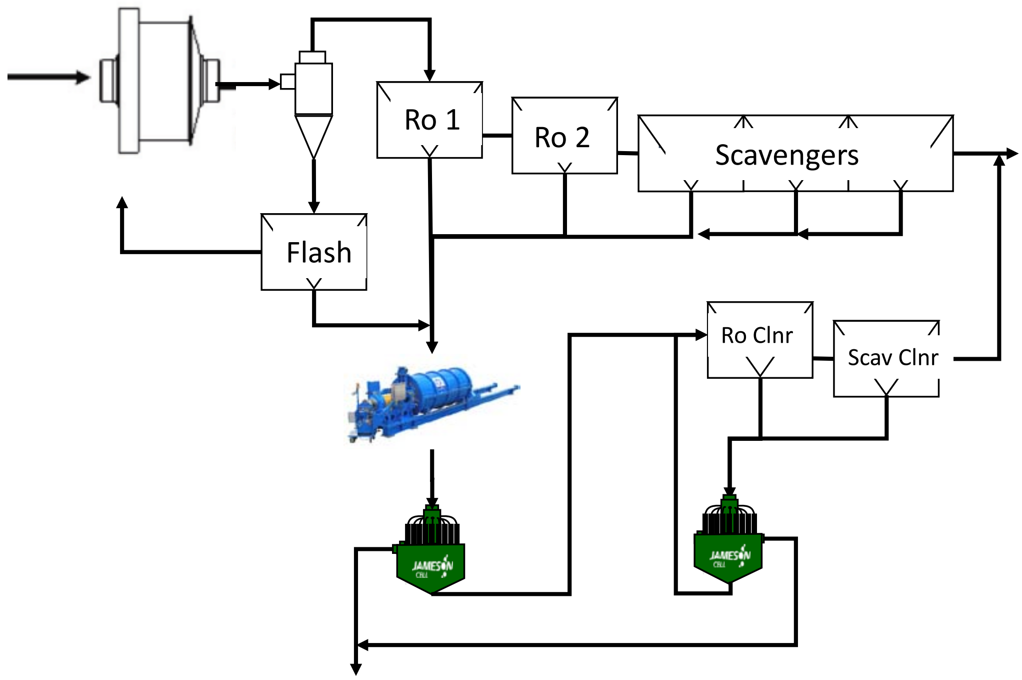

Figure 13 – Proposed Flowsheet

The proposed Isamill™ was based on the design throughput and an energy consumption determined from both onsite testing and from an independent signature plot. The proposed Isamill™ was an M1000 with 500 kW of power. Following regrinding the functions of grade and recovery are separated by including a Jameson Cell in open circuit followed by a Jameson Cell and the existing cleaner circuit in closed circuit. This cleaner flowsheet has been published previously by Huynh et al (2014). The benefit of the flowsheet is the immediate removal of over half the final concentrate at high grade while the remainder is floated to a discard tailings grade to reject liberated sulphide and non sulphide gangue. The final step is also to achieve final concentrate grade in a second Jameson at moderate stage recovery in closed circuit. This allows the separation of the grade and recovery to different flotation cells making the circuit easier to operate. This circuit has been employed in several base metal concentrators with great success. The Jameson Cells would be an E2532/6 and an E2514/3 cell representing rectangular cells of dimensions 2.5 x 3.2 m with 6 downcomers for the cleaner scalper and 2.5 x 1.4 m with 3 downcomers for the recleaner cell.

CONCLUSIONS

Pilot and laboratory plant testing in an intensive two week campaign enabled identification of opportunities to increase the grade and recovery of the Savannah Nickel operation in Western Australia. In combination with plant surveys a complete understanding of the behaviour of each stream when subjected to regrinding and laboratory flotation cleaning was achieved. The flowsheet could then be redesigned with the identified improvements. These improvements have been presented to develop a business case for the flowsheet to position the plant for higher grades and recoveries when the nickel price improves.

Regrinding was able to significantly shift the grade recovery performance of the flash, rougher 2 concentrate and scavenger concentrate. The rougher 1 concentrate showed limited benefit from regrinding however and pyrrhotite flotation levels were high in this stream. The addition of the Jameson Cell on the Isamill™ discharge increased the grade compared to single stage laboratory cleaning demonstrating that entrainment remained a factor in the recovery of pyrrhotite. The combination of Isamilling and Jameson Cell flotation provided the best improvement and a flowsheet has been suggested that allows easy control of grade and recovery. A concentrate grade of 10.5 % Ni at the same recovery can be achieved.

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