DEVELOPMENTS IN HYDROMET PROCESSING OF NICKEL LATERITES

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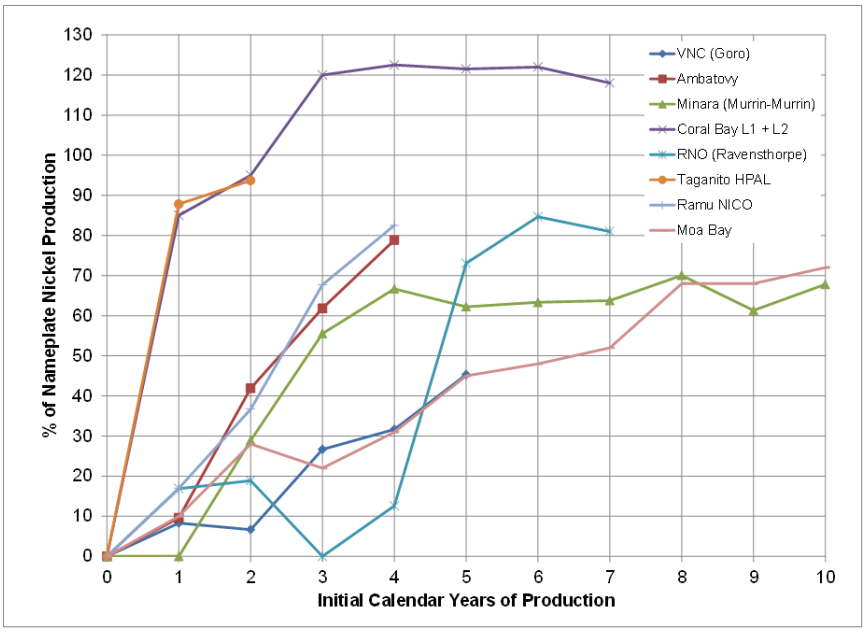
Efforts to develop lower cost and simpler hydromet alternatives to pressure acid leaching (PAL) for laterites are being made by a number of organizations. Processes retaining sulphuric acid as lixiviant include various atmospheric tank leaching concepts and heap leaching. Atmospheric leaching processes using hydrochloric and nitric acid are also being developed. Meanwhile the number of pressure acid leaching operations is increasing, with some major projects still ramping up towards full production, and by-product scandium operations are being developed.

Pressure Acid Leaching

The SNC Lavalin/Sherritt/Ambatovy presentation at ALTA 2016 on the ramp-up of the Ambatovy PAL project in Madagascar[1] included the following comparative ramp-up data for most of the operating PAL plants.



The data indicates that that small to medium scale operations making a mixed sulphide product (MSP) for off-site refining have been the most successful in achieving a short ramp-up time. This strategy is typified by Sumitomo's Coral Bay and Taganito operations in the Philippines, which have the additional advantage of existing on-site mining and stockpiled ore. Ambatovy is the best performing of the large-scale greenfield projects with on-site refining.

By-Product Scandium

Following a successful pilot plant program at their Coral Bay Nickel operation in the Philippines[2], Sumitomo Metal Mining (SMM) have decided to establish a commercial scale operation to produce an intermediate scandium oxide product at its subsidiary Taganito HPAL Nickel Corporation also in the Philippines. Processing of this intermediate product will be performed at the SMM Harima Refinery in Japan. Production capacity will be 7.5 tonnes per annum scandium oxide equivalent. Planned production start date is spring 2018. SMM have concluded a long-term sales agreement with a major US-based fuel cell manufacturer.

Meta Nikel are reported to be also developing by-product scandium recovery technology at their PAL operation in Turkey.

Laterite PAL projects with scandium as the prime product are also being developed. The most advanced include Clean TeQ's Syerston project[3] and Scandium International Mining's Nyngan project[4], in NSW, Australia. Both include an initial PAL circuit, while recovery is via resin-in-pulp (RIP) at Syerston and solvent extraction (SX) at Nyngan.

Inverse Leaching Process[5]

The process was invented by Dr. Jiang Kaixi of BGRIMM in China for the treatment of both limonite and saprolite lateritic ores. It comprises an initial atmospheric tank leach with sulphuric acid followed by relatively low pressure autoclave leaching at 150°C. Limonite ore is fed to the first stage. Saprolite ore together with the first stage discharge are leached in the autoclave while iron is precipitated and acid regenerated. Bench and pilot scale testwork carried out from 2013 have shown that a total nickel and cobalt recovery of 93% can be achieved. A bankable feasibility study for a Philippine laterite mine indicated lower capex and opex than separate processing with atmospheric tank leaching and PAL.

Atmospheric Leaching Processes

Two atmospheric tank leaching plants are reported to be operating in China - Jianxi Lithium and Yulin Wei producing 20,000 and 10,000 t/a nickel[6] respectively. Outside of China, projects using various process concepts are being developed by a number of organizations. Process developments include:

Starved Acid Leach Technology (SALT)[7]

The technology was developed and patented by Search Minerals of Canada to recover nickel and cobalt from low grade saprolite and Caron plant residues. It was subsequently purchased by InCoR Technologies of Canada. It consists of atmospheric tank leaching using a relatively small amount of sulphuric acid to selectively extract nickel and cobalt. Rather than aiming at maximizing metal extraction, the concept is based on optimizing the relationship between metal extraction and acid addition to achieve the best overall economics. After limestone neutralization and CCD, the nickel and cobalt are recovered as a mixed hydroxide, which may be refined or added directly to an on-site smelting operation. Projected benefits include simplicity, low capex and opex, and a relatively rapid ramp-up. Bench scale testwork and conceptual engineering studies have been carried out for a number of sites. For an application in Indonesia, testwork indicated optimum conditions of about 56% nickel and 65% cobalt extraction with an acid addition of 350 kg/t of dry ore for saprolite containing 1.33% Ni and 0.02% Co.

Promeca/Norilsk Process[8]

The process has been developed and patented by Promeca Consulting and Norilsk Nickel in Finland for the recovery of nickel and cobalt from limonite, saprolite and mixed ores. It is a two-stage countercurrent atmospheric leach process using sulphur dioxide and concentrated sulphuric acid. The first step involves a reducing atmospheric tank leach with sulphur dioxide and sulphuric acid solution returning from the second stage. The sulphur dioxide reduces trivalent iron, manganese and cobalt coming from the second stage to bivalent soluble sulphates. After solid liquid separation, the solids are treated in a kiln or pug mill type second stage reactor with hot concentrated sulphuric acid to complete the leaching. The temperature rises to over

200°C, and reaction time is very short. After solid-liquid separation, the resulting solution is returned to the first stage and the final residue is sent to waste disposal. Based on numerous bench scale tests, the combined leach extraction is reported to be 97-98%.

Downstream processing of the first stage leach solution varies with the type of ore feed. Typically, it includes pH adjustment, precipitation of nickel-cobalt mixed sulphide (MSP) product with H_2S, precipitation of aluminium, manganese and iron with magnesia, and evaporative crystallization of magnesium sulphate which is thermally decomposed. The resulting sulphur dioxide is utilized for acid production and in the first leaching stage, while magnesia is used in the process and can be a possible by-product. Iron oxide is also a possible by-product. Projected benefits include application to a wide range of laterite ores, possible valuable by-products, reduced waste disposal, and recycle of key reagents and water. The development program has progressed to a brief feasibility study including testwork and modelling.

Heap Leaching

Glencore's Murrin Murrin operation in Western Australia includes a satellite heap leaching circuit producing 2,000 t/a nickel from scats[9], and the Yunnan Tin Group is reported to have a small standalone operation in Yuanjiang, China, producing 1,000-2,000 t/a nickel[6]. While there has been a growing interest in atmospheric tank leaching, a number of heap leaching projects are still being developed. These include:

Piaui Project[10]

This project is under development in Brazil by Brazilian Nickel based in the UK. The proposed flowsheet comprises two-stage crushing, agglomeration, conveying, stacking, counter-current dynamic pad (on-off) leaching. Downstream processing includes iron removal and nickel production as mixed hydroxide product (MHP). Studies and testwork completed include small and large-scale column tests, pilot heaps, a demonstration nickel recovery plant, and a prefeasibility study. The column and heap tests demonstrate an extraction rate of greater than 80% Ni, with low acid consumption and short leach cycles. Target nickel production is 22,000 t/a. Demonstration heaps commenced in 2016 as part of a bankable feasibility study program.

NiWest Project[11]

The project is being developed by GME Resources in Western Australia. The proposed flowsheet consists of two stage crushing, acid/water drum agglomeration (patented). and a conveyer/radial stacking system feeding a dynamic (on/off) leach pad arrangement, followed by in-pit disposal of the leached residue. Pregnant leach solution (PLS) generated from the heap leach is directed to limestone neutralization and iron removal followed by solvent extraction and nickel electrowinning. Cobalt is separated in the SX operation and recovered as a carbonate precipitate. Residues generated in the process are co-disposed with leached residue. The heap leach solution circuit incorporates a patented iron removal/acid regeneration unit process. Preliminary studies are based on treating saprolite ore to produce 15,000 t/a nickel. GMA are undertaking a DFS program including bulk column leaching. The project is on hold as an austerity measure pending the completion of a gold project by GME.

Neomet Process[12]

The Neomet Process is being developed by Neomet Technologies, Canada, as a potentially low capex process able to process both limonite and saprolite ores. It is an atmospheric hydrochloric acid leaching process coupled with a patented "atmospheric autoclave" system to regenerate the acid. Nickel and cobalt extractions are high (> 90% in reported testwork data). No secondary neutralization is needed to remove residual iron. Nickel and cobalt are recovered as basic chlorides which can be further processed to metals or calcined to form oxides. Iron and magnesium oxides are possible by-products. The flowsheet is a closed loop in that there are no liquid effluents and solids are environmentally benign. The process has been developed to a continuous integrated pilot plant level. As with other processes, impetus for the Neomet Process on laterites has been muted due to nickel prices. However, the overall process is not only limited to nickel, and development of the key unit operations has continued. It is expected that a decision on a laterite project will be made in late 2017[13].

A number of other chloride processes are also at various stages of development.

DNi Process[12]

The DNi process is being developed by Direct Nickel Limited, Australia, for the processing of both limonite and saprolite ores. It is an atmospheric nitric acid leaching process coupled with a patented acid regeneration system. Nickel and cobalt extractions are high (reported to be > 90%). No secondary neutralization is needed to remove residual iron. Nickel and cobalt are recovered as MHP or further processed to mixed oxide. Iron and magnesium oxides are possible by-products. The flowsheet is a closed loop in that there are no liquid effluents and solids are environmentally benign. The process has been demonstrated at a continuous integrated pilot plant level. Direct Nickel Projects Pty Ltd, the owner of the Direct Nickel Process, is now under new ownership and management. The company is actively pursuing opportunities to license the Direct Nickel Process to companies wishing to adopt a simple but elegant solution to the production of either a mixed hydroxide, a mixed oxide product or, indeed, nickel metal. The new owners are focussed on achieving the first commercial utilization of the Process in the near future[14].

BGRIMM (Beijing General Research Institute of Mining and Metallurgy), China, have developed the NAPL nitric acid pressure leaching process and have operated a pilot plant[15].

The topic for the ALTA 2017 Nickel-Cobalt-Copper Forum and Panel is Pressure Acid Leaching, which will be held 23-25 May in Perth, Australia.

For more information on PAL of laterites, attend the *Treatment of Nickel-Cobalt Laterites Short Course* scheduled for 20 May in Perth, as part of the conference. The manual is available from ALTA Publications.

Alan Taylor
Metallurgical Consultant/Managing Director
ALTA Metallurgical Services
www.altamet.com.au/MetBytes

References

1. Valle, L et al, Completing the Ambatovy Ramp-Up: The Road to Successful Financial Completion, ALTA 2016 Conference, May 2016, Perth, Australia.
2. Salanga, L.G et al, Current Plant Operation of Coral Bay Nickel Corporation, ALTA 2015 Conference, May 2015, Perth, Australia.
3. Carr, J, Syerston Scandium Project: Long Term Sustainable Scandium Supply Using Clean TeQ's Continuous Resin-in-Pulp Technology, ALTA 2016 Conference, May 2016, Perth, Australia.
4. Ricketts, N and Duyvesteyn, V, The Current Status of Scandium Supply Projects and Their Technical Challenges, ALTA 2017 Conference, May 2017, Perth, Australia.
5. Jiang, K et al, Inverse Leaching Process for Nickel Laterite Ores, ALTA 2015 Conference, May 2015, Perth, Australia.
6. Oxley, A et al, Why Heap Leach Nickel Laterites?, Minerals Engineering, 88 (2016) 53–60.
7. Dreisinger, D, The Starved Acid Leaching Technology (SALT) for Nickel Recovery from Saprolites, ALTA 2016 Conference, May 2016, Perth, Australia.
8. Saikkonen, P et al, An Atmospheric Dissolving Process for Laterites, ALTA 2015 Conference, May 2015, Perth, Australia.
9. Brown, M, Murrin Murrin Operations – Past, Present and Future, ALTA 2011 Conference, May 2011, Perth, Australia.
10. Oxley, A et al, The Piauí Nickel Heap Leach Project, Brazil, Heap Leach Solutions Conference 2015, September 2015, Reno, USA.
11. Readett, D, and Sullivan. J, GME's NiWest Nickel Project – Ongoing Development of Ni Laterite Heap Leach, SX-EW Process, ALTA 2015 Conference, May 2015, Perth, Australia.
12. Taylor, A, Technical & Cost Comparison of Laterite Treatment Processes, Part 1, ALTA 2014 Conference, May 2014, Perth, Australia.
13. Communication from B. Harris, Neomet, 30 September, 2016.
14. Communication from C. Gower, Direct Nickel Projects, 11 October, 2016.
15. Baozhong Ma et al, Pilot-scale Plant Study on The Innovative Nitric Acid Pressure Leaching Technology for Laterite Ores, Hydrometallurgy, 155:88 (2015).

MetBytes are metallurgical commentary and insights written by Alan Taylor who has 40+ years' experience in the metallurgical, mineral and chemical processing industries. He has worked in metallurgical consulting, project development, engineering/construction, plant operations, plant start-up and technology development. Projects and studies have involved copper, gold/silver, nickel/cobalt, uranium, base metals, phosphates and alumina.