ALTA 2017 PRESSURE ACID LEACHING PANEL DISCUSSION

May 2017

The panel discussion was held Wednesday 24 May, immediately following the Pressure Acid Leaching Forum during the Nickel-Copper-Cobalt Sessions at ALTA 2017 in Perth, Australia.

Panel Chair: Alan Taylor (AT), ALTA Metallurgical Services (Australia)

Panel Participants: Andrew Hawkey (AH), Aqseptence Group Srl (Diemme Filtration) (Australia); Andrew Bodley (AB), Hatch Pty Ltd (Australia); Johann Verster (JV), MOGAS Systems & Consulting LLC (USA); Dustin Pepper (DP), Andritz Pty Ltd (Australia); Daisuke Saito (DS), Coral Bay Nickel Corporation (Philippines); Kaarlo Haavanlammi (KH), Outotec (Finland) Oy (Finland); Boyd Willis (BW), Boyd Willis Hydromet Consulting (Australia); Lourdes Valle (LV), SNC-Lavalin (Australia); Mark Benz (MB), MRB Business Services, (Canada); Peter Dickson (PD), SNC-Lavalin (Australia); Peter Jolly (PJ), Highlands Pacific Pty Ltd (Australia)

***Editor's Note**: The contributions of the panel members and delegates are not presented verbatim, but rather have been paraphrased and condensed for clarity and brevity. They are not necessarily recorded in order, but are grouped into major topics. Also, it is not feasible to include all contributions made during the discussions, and they are limited to some that are representative of the key points raised and debated.*

Strategy for a Successful HPAL Project

AT (Chair,) opened the discussion by asking the panel whether we can now build a profitable HPAL plant that will be attractive to the investment community, and what is the best strategy to achieve it given the ups and downs of the HPAL industry and its negative reputation among investors. Also, how are we going to achieve commissioning and ramp-up to design capacity within a two-year time frame?

LV (panel), said that the best strategy is to ensure that the project is well managed and engineered, combined with ensuring operational excellence. This has been achieved in the past as at Coral Bay, and can be achieved again by capitalising on the lessons learnt.

MB (panel), advised that it is necessary to consider the overall business enterprise in project planning and not just the process plant. For example, Ambatovy is an incredibly complex undertaking in an extremely remote location, and the cost of the metallurgical facilities, while large, was only about one third of the total complex,

the rest being infrastructure. In such projects, it is important to avoid being seduced by the diseconomy of scale and try to reduce the cost of the infrastructure per pound of nickel by opting for a larger plant, as this also increases the complexity. The whole business enterprise should be considered in sizing the plant, not just the metallurgical portion. HPAL and the various downstream processes are well-proven metallurgical technology, but what is not entirely well proven is the running of the entire business enterprise. Project announcements typically focus on the ore grade and the mine, without including much information about the necessary sulphuric acid plants, boilers, water treatment circuits, and other support facilities. Yet the extent of these facilities, together with the distance from established infrastructure, is an important part of the decision making as to the size of the operation.

PJ (panel), added that a large integrated organization, with an in-house project team and in-house knowledge and experience, will be more confident to size a new project to take advantage the nickel market forecast. On the other hand, it will be very difficult for a non-integrated conglomerate to raise debt funding, especially in these post nickel boom market conditions. A move away from large projects, which have been largely unsuccessful, to a small low capex approach may be the best strategy.

KH (panel), said that a good way to convince investors about financial viability is to decrease project capex. From an R&D point of view, innovations such as concentrating the PLS from HPAL and recycling acid would make a big difference to the economics. For example, the application of membrane technology could be considered.

JV (panel), pointed out that these projects unfortunately carry large amounts of infrastructure, which place a strain on project economics. Besides nickel grade, the location of the project will significantly influence the decision of investors to support a project. Countries that are open and friendly to mining, such as Turkey, have a better chance of establishing new projects. Also, it is better to start off with a smaller operation and simpler flowsheet, then adding value through by-products such as cobalt and scandium.

AB (panel) and AT (Chair) added that the depletion of sulphide deposits and high-grade laterite deposits suitable for ferronickel plants will lead to a greater dependence on lower grade laterite resources and significantly affect nickel production economics.

Nick Hazen (NH), Hazen Research (USA), floor, observed that investors will come back when they can make a profit, and they will wait until the market changes as they have done throughout the past.

Mike Dry (MD), Arithmetek (Canada), floor, said the for a 20-year project, it is necessary to think beyond today's market. For example, his studies have shown that variations in nickel and acid prices tend cancel each other out over the long term.

MB (panel), agreed and added that since 1981, with the exception of cobalt which is tends to follow its own path, metal prices have actually had an advantage over the major input prices, yet this has not been reflected in profitability. Operations tend to follow the cycle rather than planning for the cycle, so that they are always just too late with measures such as hiring and firing, and tend to miss the opportunities for economic success.

Is Starting Small and Expanding the Best Strategy?

AT (chair), posed the question whether it is best to start with a single stream HPAL plant and add a second stream later. For example, Sumitomo adopted this approach at Coral Bay with an initial single stream to produce 10,000 tpa nickel followed by a second to increase to 20,000 tpa.

Fumio Iwamoto (FI), Sumitomo Metal Mining Co. Ltd (Japan), floor, responded that any size of HPAL plant over the range of 10,000-40,000 tpa should be viable from the technical and operating cost points of view. However, the cost of infrastructure can become too high with increasing plant size. The economics of new projects depend on a number of factors including ore resources, the need for new mining, site area, location, available infrastructure, and environmental considerations. The Coral Bay project benefitted from existing ore stockpiles from the mining of saprolite ore. Other benefits include an in-house source of acid, and no on-site refining which resulted in a relatively small site area and reduced power consumption. The MSP product is shipped to an in-house refinery in Japan.

JV (panel), said that adopting a modular type of approach starting with one autoclave is a good way to build up in-house experience and knowledge, and will be less risky for investors. This approach can be seen in the gold industry where companies have been able to successfully progress to large autoclaves because they had prior experience and background knowledge with smaller operations. Similarly, Sumitomo learnt from the former single stream Bulong HPAL operation before successfully adopting a modular approach at Coral Bay, followed by a larger scale project at Taganito.

AB (panel), added that the site and its potential environmental footprint is a major factor. A site that has already been disturbed, such as at Coral Bay, benefits from existing environmental permits and a community used to mining. This may result in a significant reduction in the project development timeline, which will be attractive to investors.

BW (panel), stated that there is great opportunity to make small PAL projects more financially viable. At a previous ALTA conference, Bryn Harris pointed out the many other potential products from a PAL project, such as scandium. In fact, all the current scandium projects started out as nickel/cobalt laterites, then scandium became the major product as its value became greater than the original primary products. There are at least 20 elements in PAL autoclave discharge solution and with imagination and creativity, recovering a number of valuable by-products in addition to scandium could be considered - for example high quality zinc oxide. Metsol in Adelaide have developed a proprietary hydromet process for producing high purity zinc oxide directly from zinc oxide ore, thus bypassing the traditional route of making zinc metal then oxidizing it back. The Metsol process has reduced the cost of producing zinc oxide by more than half, which indicates that recovering it from PAL discharge solution may be viable. Another possible valuable by-product is pigment grade hematite

Developing and Applying New Technology

From the floor, it was said that it is always easy to demonstrate new technology on a small scale before progressing to large scale application. There are probably incremental improvements to be made in all the different stages of HPAL, for instance recovering the acid instead of neutralising the tailings.

KH (panel) pointed out that 60-70% of nickel usage is in the stainless steel industry, so perhaps we can develop ways to utilize MHP directly in the production of stainless steel, thus by-passing the metal refining stage. Of course, separation of cobalt from the MHP would be vital as the stainless steel producers do not pay anything for cobalt and it is required by the booming battery industry. This can be achieved using proven SX technology.

PD (panel) emphasized that the main concern of investors is risk, and if the profitability of a project is reliant on a new process, it will scare them. They will ask “how well did you do last time?”

Challenges Facing New HPAL Projects

From the floor, it was noted that the capex of the Ambatovy Project was $8 billion including infrastructure, and asked that If we could turn back time and build project again, utilizing the knowledge gained from solving all the problems, what would the projected capex be?

MB (panel), said that the $8b can be roughly split into $5b for the actual capital investment and $3b incurred during the extended ramp-up. Achieving the originally planned ramp-up time would significantly reduce the $3b portion. The process facilities actually came in close to budget, and the cost overruns were mainly related to infrastructure, starting up a complex operation in remote site, and the super project cycle experienced by the industry at that time. One possible different strategy to consider, would be to start with a half size plant and consider doubling it later, which would result in an initial 60-year mine life instead of 30 years.

AT (chair) asked whether he would consider eliminating the on-site refinery, and locate it in Canada. MB advised that the original plan was to utilize an Impala refinery in South Africa, who were a project partner. The decision to include the on-site refinery was made when Impala changed their strategic direction. He agreed that off-site refining is certainly worth considering, especially as the MSP has a high nickel content which, lowers the shipping cost.

LV (panel), added that in her experience with HPAL projects, most of the capital blow-outs occur between commissioning and ramp-up, and that is where the project value destruction happens. To be on budget requires strong leadership by the owner and a competent owners team leading the operation of the plant from commissioning right through to ramp up.

Effect of Nickel Price

Goutam Das (GD), CSIRO (Australia), floor, asked If the current nickel price continues for the next 10 years, how many HPAL projects are going to survive? Also, how long will it take to recover the $8b cost of Ambatovy with interest?

MB (panel) said he is not very hopeful for a significant recovery of the nickel price in the short term. A key strategy is to stop chasing only 1% of the mass and start recovering some additional by-products such as zinc. Some of the minor metals, including cobalt, move on a different cycle than base metals.

PJ (panel) pointed out that it will be hard to obtain capital for process additions in a contained nickel market environment. He agreed that there is no short-term solution to the nickel market, but like copper, the market will eventually turn around. Major players in the energy storage and battery sectors are forecasting that by 2022 an extra 400,000 tpa nickel will be needed. This would be a significant boost to the present market which is about 2m tpa, and could encourage new nickel projects.

The Largest Operating HPAL Autoclave

Goutam Das (GD), CSIRO (Australia), floor, asked what is the biggest operating HPAL autoclave, with may be relevant to sizing autoclaves for the aluminium industry?

MB (panel) said that the Ambatovy autoclaves are likely the largest for HPAL at about 5.2 m diameter (see note below), but he agreed with comments that there are bigger autoclaves in the gold industry. He said that while the alumina industry uses large high temperature and pressure vessels, there is not a direct analogy with HPAL because of the different chemistry and conditions of the Bayer Process, which involves a caustic leach.

JV (panel), agreed that the Ambatovy autoclaves are the largest, and that there are bigger autoclaves in the gold and uranium industries. He added that the Meta Nikel autoclave is of similar size to Ambatovy, but the discharge valves are larger (16 inch) due to higher flow. While the industry seems to have reached a standardized clave design, the size of supporting equipment can vary.

PD (panel) explained that in the design of autoclaves, a certain diameter is reached where the shell thickness becomes 125 mm, at which point rolling becomes difficult. Bigger vessels can be made by increasing length but not diameter. For example, increasing to 9 compartments would result in a vessel 50% bigger than Ambatovy. Then comes the questions “how big are the flash vessels and heaters?” We have currently reached a proven size which can be reliably repeated, and to suddenly go to twice the size, for example, would involve big risk. So, if you want to go bigger, why not add a second train?

Note: Sumitomo commented that the Taganito autoclaves are larger than Ambatovy. This was confirmed by the following data kindly supplied by panel member Lourdes Valle after the conference:

PROJECT	LOCATION	PLANT CAPACITY, Ni tpa	QTY	SIZE, m	*Vessel Volume, m3*
Taganito HPAL	Philippines	30,000	2	5.67 ID (inside steel) x 36.11 L (tan-tan)	*1,008*
Ambatovy Nickel	Madagascar	60,000	5	5.23 ID (inside steel) x 37.0 L (tan-tan)	*870*

Summary of Key Points

- The Coral Bay Project proved that a successful HPAL project can be achieved with good project management, sound engineering and operating excellence.

- HPAL and the various downstream processes are well proven metallurgical technology, but what is not entirely well proven is the running of the entire business enterprise for large plants, especially in remote locations
- The economics of new projects depend on a number of factors including ore resources, the need for new mining, site area, location, available infrastructure, and environmental considerations. The Coral Bay project benefitted from existing ore stockpiles, in-house source of acid, and an in-house refinery for the MSP in Japan.
- HPAL plants with outputs in the range of 10,000-40,000 tpa, should be viable from the technical and operating cost points of view. However the cost of infrastructure can become too high with increasing plant size.
- It is important to avoid opting for a large plant based on reducing the cost of infrastructure per pound of nickel, as this also increases the project complexity.
- For organizations with limited HPAL experience, starting small and adopting a modular low capex approach will likely be the best strategy, and will be easier to finance due to decreased risk. For example, Sumitomo adopted a two-step strategy starting with a single stream and adding a second stream based on operating experience with the first stream.
- A large integrated organization, with an in-house project team and in-house experience, will be more confident in sizing a new project to take full advantage the nickel market. For example, Sumitomo opted for an initial two-stream 30,000 tpa plant for the Taganito Project after gaining experience at Coral Bay.
- A site that has already been disturbed, such as at Coral Bay, benefits from existing environmental permits and a community used to mining. This may result in a significant reduction in the project development timeline, which will be attractive to investors.
- Eliminating on-site refining, or delaying it for later implementation, will significantly reduce project cost and risk.
- There is an opportunity to improve project viability by developing valuable new by-products such as scandium, zinc and hematite, especially for small plants where the additional cost and risk is relatively low.
- Development of innovations to the basic HPAL process, such as using membranes to concentrate PLS and recycle acid, could be a way to improve economics.
- A turnaround of the current nickel market will be needed to justify new PAL projects. Investors will wait until the market changes as they have done in the past. One possible driver for increased nickel consumption could be the bullish forecasts for the energy storage and battery manufacturing sectors.
- The HPAL industry appears to have reached a manufacturing limit for the diameter of autoclaves. While larger flash tanks and heaters could be manufactured, increasing above currently proven designs would involve risk.

Alan Taylor: Panel discussion close

We acknowledge the efforts of the student volunteer from Curtin University, Lia Cherico, for providing detailed notes on the discussion.

Hydromet Processing of Copper, Nickel & Cobalt Sulphides is the featured the topic for the ALTA 2018 Nickel-Cobalt-Copper Forum and Panel, which will be held 21-23 May in Perth, Australia.

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