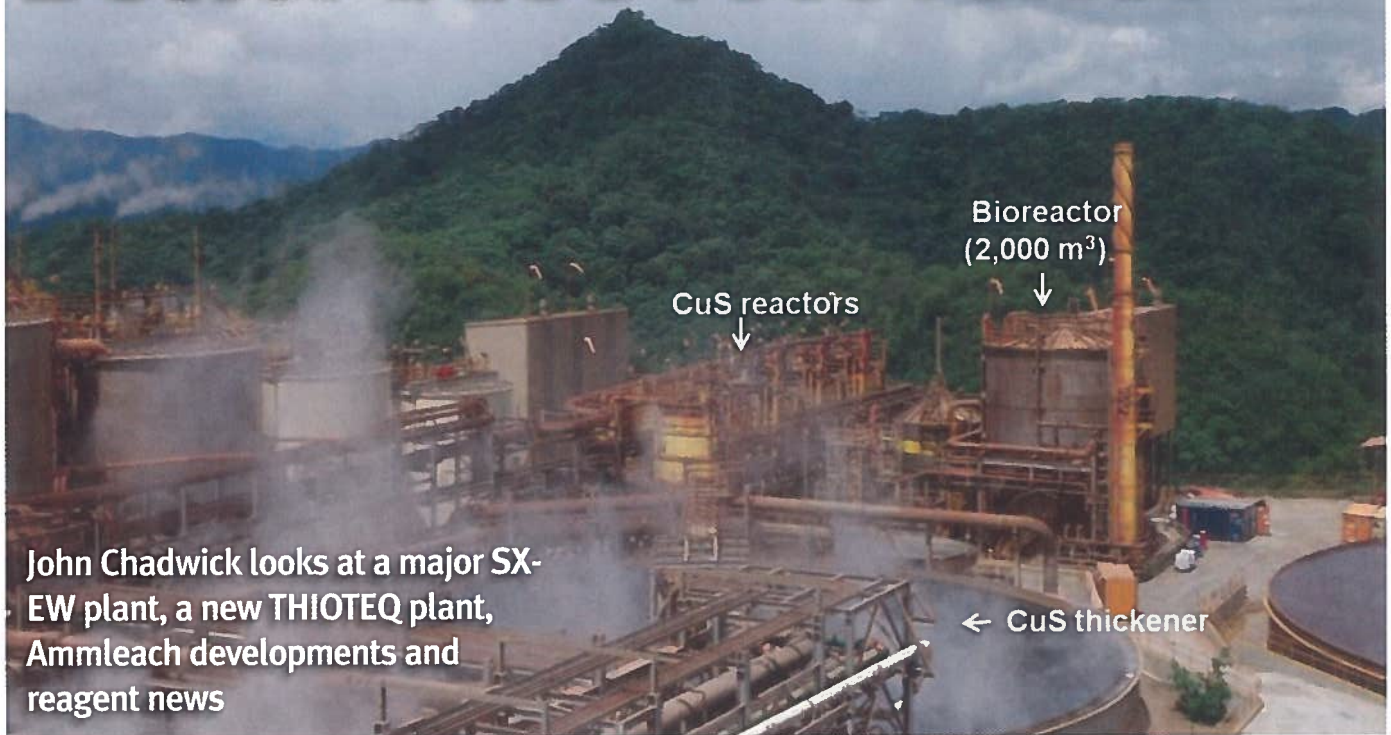


Better base recoveries



John Chadwick looks at a major SX-EW plant, a new THIOTEQ plant, Ammleach developments and reagent news

Outotec reports that its leading-edge SX-EW technology is helping to maximise return on investment (ROI) at the world's largest SX facility, Grupo México's ESDE III copper SX-EW plant in Buenavista, Mexico. The plant is located close to the town of Cananea in northern Mexico.

Prior to the ESDE III project, the Buenavista plant had two SX-EW plants, ESDE I and ESDE II, with a total annual copper cathode production capacity of 55,000 t. In early 2012 the company decided to expand the plant's capacity to produce copper cathodes via a leaching-SX-EW process. In April 2012, Grupo México signed a contract with Outotec for delivery of a copper SX-EW technology package for the ESDE III plant, with an annual copper cathode production capacity of 120,000 t. Having previously manufactured similar SX-EW equipment for other Grupo Mexico projects in the region, Outotec says it "was the natural choice to supply the technology. Furthermore, Outotec's solutions had proven to be capable of coping with the challenging process conditions at Buenavista during the testing phase."

"Due to the metal content of the PLS, it was important to select technology that would allow us to minimise the mechanical and chemical entrainment of the PLS in the organic phase, in order to keep control of the electrolyte quality," says Ramon Bustamante, ESDE III project manager, Grupo México. "With Outotec's VSF SX technology, Buenavista has achieved good control over entrainment at the ESDE III plant,

leading to good copper cathode chemical characteristics and appearance."

Excellent cooperation between the project partners ensured fast implementation and start-up, with the plant coming online in June 2014, just over two years after the contract was signed. Achieved benefits:

- Maximised ROI resulting from low CAPEX and OPEX, and high plant availability
- Optimised plant ergonomics for safe, comfortable working conditions
- Short project lead time with equipment readily available
- Sustainable environmental performance.

Power and water availability are increasingly an issue for the mining industry. Additionally, every bit of soluble metal that ends up in the sulphate rich process water can become a liability by impacting the surrounding environment of the mine.

In 1992, Paques commissioned its first SULFATEQ™ plant to remove sulphate and recover zinc as zinc sulphide at Nyrstar's zinc refinery in the Netherlands. In 2000 a second SULFATEQ plant transformed the Nyrstar site into the world's first gypsum free zinc refinery.

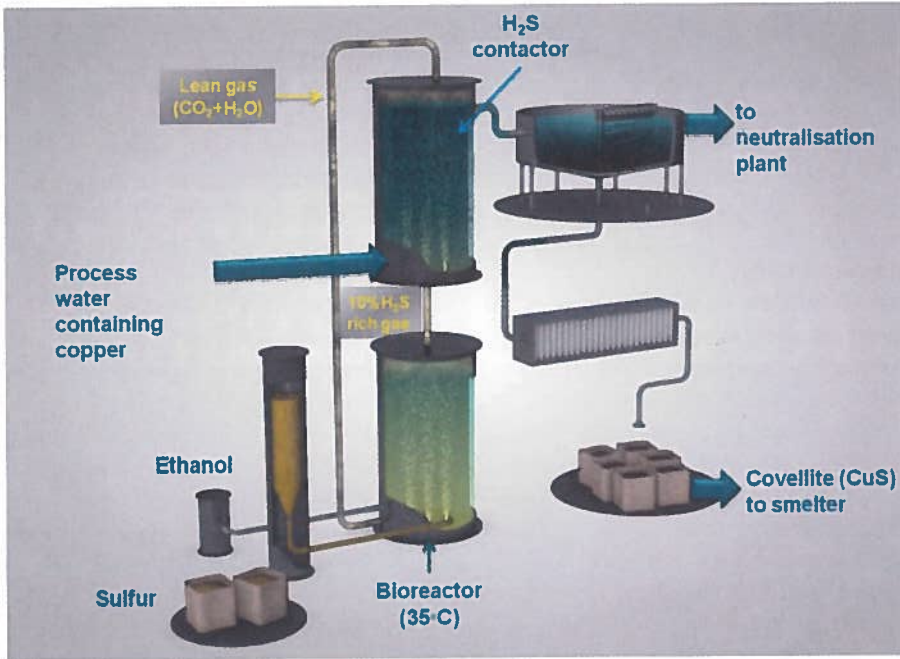
When sulphate removal is not required another technology can be applied in order to reduce the cost for sulphide. Between 1996 and 2003, Paques piloted several metal recovery plants on a small scale (< 0.5 t/d H₂S) to demonstrate the biological production of H₂S from elemental sulphur; nowadays, this technology is known as the THIOTEQ™ process.

Paques's first THIOTEQ at a very large scale was commissioned in 2014 at the Pueblo Viejo mine

The first such installation at a very large scale was commissioned in 2014 at the new Pueblo Viejo gold mine.

Pueblo Viejo mine is located in the Dominican Republic and is operated by the Pueblo Viejo Dominicana Corp (PVDC) - a joint venture between Barrick (60%) and Goldcorp (40%). PVDC mines ores containing gold, silver and copper and recovers them by conventional crushing, grinding and pressure oxidation in autoclaves, cyanidation and refining. After autoclaving, a thickener separates the slurry from the clarified liquid. The slurry continues to the gold/silver circuit while the remaining liquid contains soluble copper at concentrations between 100 and 400 mg/litre. This stream is neutralised before being recycled to the wash thickener. The soluble copper would normally be precipitated during the neutralisation stage and lost in tailings with the disposed gypsum. However, in 2014 Paques commissioned a THIOTEQ plant to recover the copper upstream of the neutralisation plant.

THIOTEQ technology recovers dissolved metals from liquids by the formation of high purity metal sulphides. The required sulphide for this process is generated on-site and on-demand in the form of H₂S gas, avoiding the addition of sodium, which could hamper the neutralisation plant performance. The H₂S is generated from elemental sulphur in a high rate



The recovery capacity of the plant at PVDC is 12,000 t/y of copper, requiring around 20 t/d H₂S, making this system the world's largest operating biological H₂S generator, according to Paques

bioreactor operated at ambient temperature and pressure. Because the bioreactor is operated offline, i.e. bacteria are not in direct contact with the metal-containing process stream, the technology can be applied to other metallurgical

streams at different pH and temperatures. This feature enables applications such as metal precipitation from electrolyte bleeds or from acid leaching operation streams. Recovery of zinc and removal of arsenic can also be achieved using the technology.

The copper plant at PVDC was designed for the recovery of 12,000 t/y of copper requiring around 20 t/d H₂S, making this system the largest biological H₂S generator in operation

worldwide. The THIOTEQ technology operates at 10% H₂S concentration in the rich gas. The H₂S gas is contacted with the copper containing process stream, resulting in a recovery of 99% of the metal. A high grade copper concentrate of up to 60% copper is produced equivalent to covellite concentrates.

The Pueblo Viejo plant represents the introduction of an innovative technology at a large industrial scale. Using THIOTEQ technology, mining companies can capture the maximum value of metals in ore and minimise impact on the environment through the use of sustainable methods.

Paques says THIOTEQ technology has the following benefits:

- Payback time around three years for copper recovery for large systems (< 5 t/d)
- No sodium addition to water streams; i.e., allowing effective removal of sulphate in (existing) lime neutralisation plants
- Production of H₂S over large turndown ratios. No storage or transport of hazardous chemicals
- Guaranteed high-grade copper concentrate as covellite (CuS) to be sold at copper market price (concentrate containing 60% copper)
- Potential metal/contaminants removal from process streams such as arsenic removal from electrolyte bleeds or zinc recovery
- Proven technology at a scale of 20 t/d H₂S. This is the largest bioreactor of its type operating worldwide

- Easy to operate and robust system. Bioreactor fully productive in less than two days after a two-month shutdown
- Designed based on Paques extensive expertise on H₂S processes with 200 industrial references. These include refinery and natural gas applications through a joint venture with Shell Global Solutions.

Dealing with arsenic

In December 2015, FLSmidth and BASF signed a joint development agreement to expedite the commercialisation of the FLSmidth® Rapid Oxidative Leach process targeting difficult-to-process copper concentrates, such as primary sulphides and concentrates containing high levels of arsenic.

In May Rapid Oxidative Leach was announced as “a technological breakthrough that will enable the copper industry to dissolve copper from low to mid-grade concentrates at 80°C. This will maximise the use of existing capacity during the transition from oxide to sulphide ore. The technology allows extraction of copper as an alternative to selling concentrate to smelters and metal production at the mine site.”

Now, with the joint development agreement, BASF will bring additional funding, resources and new novel chemical reagents and processes to more rapidly commercialise FLSmidth's leaching technology. In particular, BASF will incorporate innovative SX reagents, which exhibit high resistance to degradation and a step change in copper selectivity.

The decline of copper ore grades in Chile and Peru, home to the world's largest copper reserves, has driven companies towards new higher-copper-grade ore deposits containing arsenic. This requires costly cleaning, as arsenic is a health and safety risk for copper smelters with smelters limiting arsenic content to a maximum of 0.5% arsenic in the concentrate.

According to BASF, the hydrometallurgical processing of primary copper sulphide concentrates and concentrates containing high levels of arsenic, offers an exciting opportunity. “Several years ago, we focused on developing chemicals that would support the industry' inevitable move towards mine more complex ores, chemicals that required a new leaching technology. We believe that the FLSmidth Rapid Oxidative Leach process combined with BASF's novel reagents is the game changer that will enable the copper industry to process such ores,” states Christian Lach, Vice President Strategic Marketing and Innovation for Water, Oilfield and Mining Solutions at BASF.

Vice President R&D, FLSmidth Minerals Division, Gary Roy describes the partnership as a way to economically sustain copper production and maintain profitability: “This is a powerful development-partnership; BASF is the industry

leader within chemical inventions for the copper industry and we have the leading equipment and process technology. By combining our strengths, we can more rapidly commercialise the Rapid Oxidative Leach technology to make it possible for the industry to economically process arsenic-laden high grade copper ore in the future.”

Hydrometallurgy

Last year Alexander Mining continued to line up patents around the world, including *Method of Oxidative leaching of Sulphide Ores and/or Concentrates* through the African Regional Intellectual Property Organisation; *Method of Oxidative Leaching of Molybdenum - Rhenium Sulphide Ores and/or Concentrates in the USA*; *Method For Leaching Cobalt from Oxidised Cobalt Ores in France and Method for Ammoniacal Leaching in Morocco*. The latter patent forms part of MetaLeach's family of core AmmLeach® technologies. All these add to the wide global spread of patents that is in place.

At the time of the Moroccan award, Martin Rosser, CEO, said: “The grant of our Morocco patent for ammoniacal Leaching is gratifying given the potential for its use to process amenable copper and zinc deposits. The patent is the overarching AmmLeach patent in our intellectual property portfolio and underpins all applications of the AmmLeach technology.”

The granted patent encompasses methods for leaching one or more target metals from an ore, the methods comprising the steps of: curing the ore to be leached through the application of an aqueous solution of a curing agent, producing a cured ore; leaching the cured ore at atmospheric pressure through the application of an ammonium carbonate solution containing free ammonia, producing a pregnant leach solution; and passing the pregnant leach solution to a means for metals recovery.

A hydrometallurgical process such as this has major benefits, as detailed by Alexander Mining:

- Higher returns by increasing mine site metal product value
- Can make uneconomic orebodies economic
- No associated concentrate costs, i.e. transport, smelter & refinery charges
- Concentrate producers not paid for valuable metal byproducts
- Concentrate charges and costs can be > 40% of contained metal value.

The company has maintained its focus on executing a clearly defined commercialisation plan. Amongst a range of global opportunities, the company has selected initiatives which it is working on in Australia, Turkey and Mexico.

Recovery chemistry

As a reagent developer and supplier, Axis House says it “has the unique ability to adapt to the

ever-changing requirements of mining. From fluctuating commodity prices to variations in ore type, Axis House sees change as an opportunity for the development of new technologies and established technologies with new applications.”

This adaptability is evident in the development of the patented, base-metal oxide flotation reagents: originally produced as a paste but now available as a liquid. The original AM-technology paste was effective but, as to be expected, difficult to dose. Axis House's new liquid hydroxamate-based reagent is fully neutralised and easy to use and dose. The AM-technology can be tailored to fit a client's needs by altering chain lengths, among other factors, to affect its collecting power and selectivity. These base-metal oxide collectors have found widespread use on several mines with varying mineral content.

These types of Axis House reagents' application have now widened to include the flotation of rare earth elements (REE) from rare earth oxide (REO) ores. Their ability to float other industrial minerals, like fluorspar and phosphates, are currently being implemented.

Axis House has, in conjunction with their base-metal oxide flotation reagents, a wide range of other chemicals and reagents available. These include diluents, depressants and flocculants. This list also includes a range of base-metal- and PGM-sulphide collectors. These sulphide collectors vary in functional group, as well as chain length, allowing the selection of a collector with the appropriate pulling strength and selectivity.

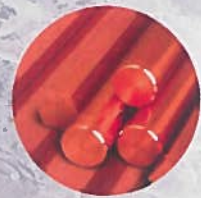
Another example of new technologies finding new applications is the screening methodology of the flocculent-range. Based on a reagent matrix, which groups the broad range of polymeric substances by molecular weight and other physiochemical properties, the laboratory can select the best flocculent for the specific client depending on what is required (free settling velocity, turbidity/clarity etc.). Axis House has a mobile laboratory for their flocculation testing that allows for this type of flocculent screening to be done on site.

The research and development of an optimised reagent suite, for all current and prospective clients, is accomplished at the Axis House metallurgical laboratory in Cape Town. The laboratory boasts qualified chemists, metallurgist and sophisticated analytical technologies. Complimentary flotation testing, and other reagent screening, is done on received samples from clients. The laboratory aims to achieve the client's set objectives by determining the optimum reagent suite and optimising the dosages.

Clariant recently launched its revolutionary new Hostaflo® products for copper mining. These Hostaflo collectors are effective alternatives to hazardous xanthate collectors.

“This is groundbreaking new collector

Profitable metal recovery and water treatment for sustainable mining



Copper Recovery



Zinc Recovery



Arsenic Immobilisation



Bio Sulphur Production from sulfate

Proven biobased technologies to recover valuable resources from process and bleed streams:

THIOTEQ™

Biological H₂S on-site and on demand production for metal recovery

SULFATEQ™

Biological sulfate removal with zero gypsum generation

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