M.M.I.

Vallex
GROUP

www.mmi.am

MINING AND
METALLURGY
INSTITUTE

LME Week

October, 2022

MINING AND METALLURGY INSTITUTE

The “Mining and Metallurgy Institute" Closed Joint Stock Company (MMI) plays an important role in the mining industry of the Republic of Armenia. Historically, the Institute has been the backbone of mining engineering and laboratory services in Armenia, serving both national and regional customers. MMI has extensive experience in process R&D, engineering, geological exploration and civil engineering, and provides comprehensive geotechnical and geological services. Our lead shareholder is the Vallex Group of companies.

WHO WE ARE

MMI was established in 1952 by scientists and specialists from leading universities, who joined forces 70 years ago to create what is today a capable research organization and a leading engineering consulting services provider in Armenia. Over the decades, the Institute has nurtured several generations of scientists and skilled specialists who have established partnership networks well beyond the region, and these now include a wide range of international experts.

WHAT WE DO

Currently the Institute provides the following services:

- A full spectrum of geological exploration and documentation services, including surveying, drilling, sample preparation and assaying, plus geological model development and resource estimation.
- Process optimization for all aspects of mining and processing operations. Our innovative solutions have provided improved metal recoveries for our clients, often associated with tangible cost-saving.
- Specific focus on increasing the recoveries of molybdenum and precious metals.
- Development of dust suppression systems to mitigate and prevent respiratory issues to improve operational working conditions.
- Development and optimization of mineral processing flow diagrams for existing and green field ore processing plants. We are the established system integrators for most mining companies with a presence in Armenia.

PROJECTS

Over the past 20 years the Institute has conducted geological exploration, resource estimation and the required approval stages. Integrated designs have included social facilities and housing, power supply infrastructure, water pumping stations and hundreds of kilometers of roads. A selection of construction and commissioning of green field projects in Armenia is shown below:

- two new open pit mines and their processing plants with a total capacity of 21 mtpy, based on two different copper porphyry deposits (Cu, Mo).
- one underground deposit (Cu, Au, Ag) and a corresponding processing plant with a capacity of more than 1000 tons of ore per day.

Kashen mining complex

In addition, the Institute has recommissioned the only copper smelter in Armenia and we are proud to be amongst the largest taxpayers in Armenia. Today we have a team of 370 experts in all aspects of mining and minerals processing and are always ready to solve the most complex problems for our customers.

RESEARCH AND DEVELOPMENT

The Institute is also active in research and development work, especially for applications relating to copper porphyry deposits (CPD). Our goal is the constant optimization of mineral recovery and the optimization of the "end-to-end" economic efficiency of the entire value chain, from mining to ore processing and the production of cathode copper. Based on our experience and vision, we have developed a proprietary "Atmospheric Poly-Mineral Leaching" technology which will enable sulphur rich copper concentrates to be processed directly to cathode copper at the mine site with the obvious commercial and environmental benefits.

In general, all CPD systems have a similar vertically-layered structure: overburden on top, a layer of previously mineralized weathered barren rock below, followed by oxidized ore. Then comes the supergene ore (consisting of secondary copper sulfides and chalcopyrite), followed by the concluding hypogene layer.

While this structure is similar for all mines, the composition, thickness, and directional development of these layers are unique for each deposit. Even the properties of similar layers at two different mines vary significantly. However, they all have one important similarity: all these layers, apart from hypogene layer, have been under the influence of oxidative and weathering processes for millions of years. Naturally, the closer to the surface, the greater the effects of these processes, with uppermost layers having been simply "scoured" of most any mineralization. To put things into perspective, Earth's surface at the time of formation of deposits (150-200 million years ago) was hundreds of meters higher than today.

APL allows to utilize and build on the massive amounts of energy that our planet and natural processes have already "invested" in mineralization and weathering processes.

APL CONCEPT AND RATIONALE

Sulfide concentrates obtained from supergene ores may have properties that allow them to be at least partially (most importantly - inexpensively) leached. Our early experiments confirmed this, thereby shaping the concept behind APL, namely:

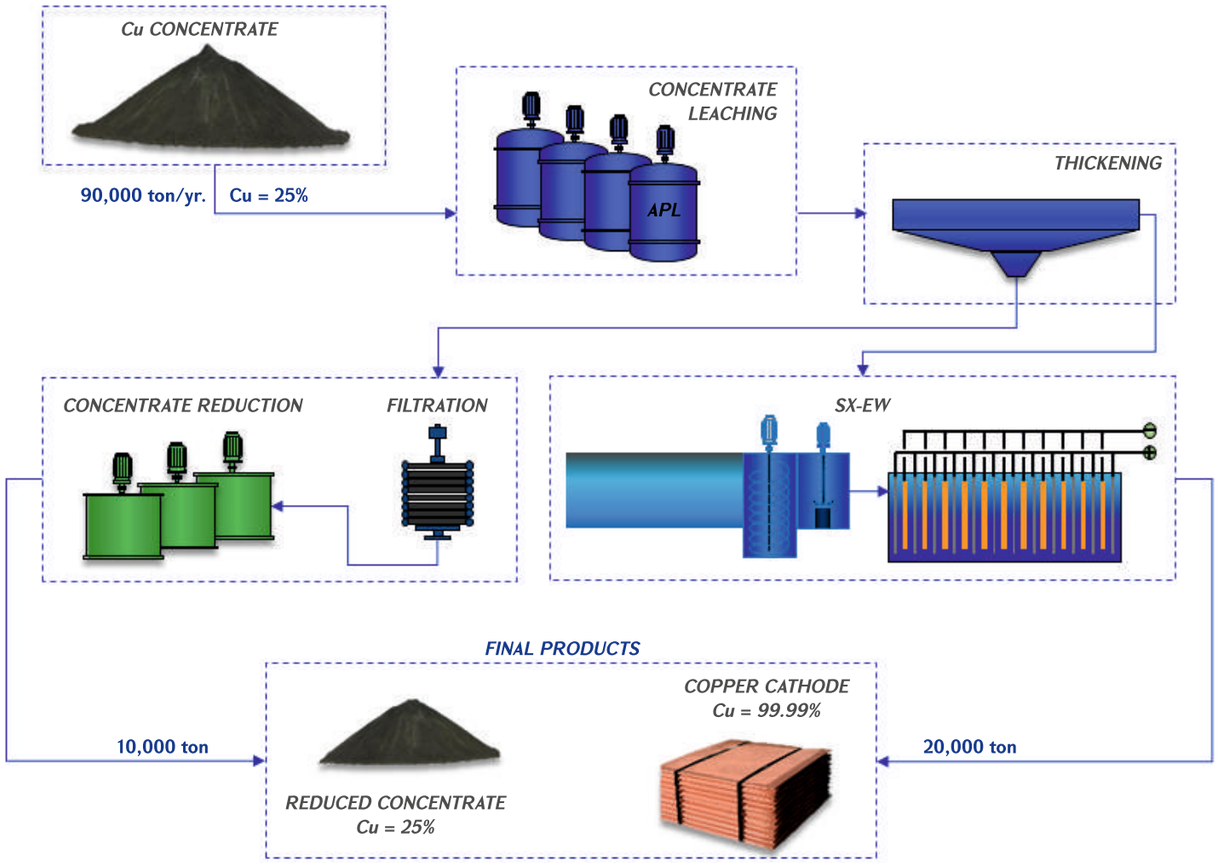
- for selected concentrates, metal recoveries, and therefore end-to-end economic efficiencies are significantly better in the **ore - concentrate - electrolyte - cathode copper** value chain, than in the traditional **ore - concentrate - smelting - anode copper - cathode copper** paradigm.

Our experience in copper concentrate production and process optimization has led us to develop the APL (Atmospheric Poly-mineral Leaching) technology, enabling the production of copper cathodes directly from suitable sulfide concentrates.

This certainly begs the questions: what is considered as "suitable," and how many such deposits are there? We are confident that the quantity of ore in deposits generating such concentrates is quite comparable to the volume of oxide ores processed by SX-EW (i.e., 5.5 Mt of cathodes per annum). Thus, of the more than 16 Mt of cathodes produced from sulfide concentrates per year, a significant proportion (perhaps around 5 Mt) can be efficiently processed with APL.*

*- ***A study is in progress, and more standard experiments are required for statistically valid and conclusive results.***

APL PROCESS FLOWSHEET



APL KEY BENEFITS

Up to 98 % copper recovery from concentrates

APL allows the recovery of up to 98% of copper from concentrates in less than 8 hours with selected concentrates. This is confirmed by detailed testing on one of the Armenian copper porphyry deposits. Tests on several other Armenian copper concentrates and foreign copper concentrates, have indicated typical leaching recoveries between 67% and 90% without process optimization. As an overview, the APL process has indicated recoveries in the range of 67% to 98% for a wide selection of copper concentrates.

We are convinced that the application of the APL process will provide a very effective and cost-efficient technology for the extraction industries.*

Atmospheric pressure

APL does not require high pressures and consequently there is no need for expensive autoclaves with their associated high operating and maintenance costs.

Low temperature process

The leaching process takes place at 95 degrees Celsius. Therefore, the process requires no high temperatures or complex and expensive external heating systems.

High grade cathode production

APL incorporates several expert processes plus a standard SX-EW technology stage, which allows the production of 99.99% copper cathodes.

Tangible cost savings

APL will enable mines to drastically reduce transportation costs by shipping copper cathode instead of copper concentrates typically containing 25% copper, 8% moisture and DLC in the range of 80 - 90%. Transportation costs will be reduced by 62 -70%.

Low environmental footprint

This low-temperature process avoids the generation of liquid or gaseous contaminants. Installed in the immediate vicinity of the process plants, the APL technology allows miners to deliver cathode quality copper with a drastically reduced Zero Discharge policy which does not need a smelting stage.

**- A study is in progress, and more standard experiments are required for statistically valid and conclusive results.*

The APL process removes the environmental risks posed by copper smelters and pyrometallurgical processes, such as harmful dust; greenhouse gas emissions; sulfuric acid or elemental sulfur generation; problematic elements including arsenic, antimony and other metals. A mine with an APL process will produce 80-95% of all copper from its concentrate at site and with minimal environmental risks. APL implementation will:

- relieve our planet from greenhouse gases that would otherwise be released during the smelting process.
- allow the monetization of "saved" GHG emissions though potential "green" funds.*
- enable a more sustainable balance between the supply and demand of sulfuric acid (or elemental sulfur), therefore positively affecting market conditions.*

Increased copper recovery from concentrates

One of the most important effects of APL is its systemic impact on the entire copper processing value chain. Let us consider a plant with an integrated APL process as a single economic unit. Acceptable increases in operating costs with the inexpensive APL technology would enable the processing of low-grade concentrates, as opposed to the standard high grades required by smelters. Naturally, this will result in both improved copper recoveries in primary processing, and subsequently an increase in overall copper recoveries of more than 5%. Certainly, the return on "additional copper" recovery would exceed any small increase in operating costs.

Deposit's reserves growth

Taking APL's economic rationale a step further, we can conclude that mines working with near cut-off grade material would now be able to process mineralized material at below cut-off grade copper content, thereby increasing the economic reserves of their deposit.*

Increase in gold and silver concentrations

Generally, gold and silver are payable in concentrates provided they are above a given threshold level. Applying the APL technology should enable unrestricted economic recovery of gold and silver values and boost overall mine revenues.*

**- A study is in progress, and more standard experiments are required for statistically valid and conclusive results.*

CONCLUSION

Our team has been working on the APL project for over 5 years with a vision to provide an enhanced, economic process route to deliver copper cathodes from copper concentrate at the mine site without the need for a smelting stage.

In a short period of time, the APL technology was scaled up from laboratory testing to a pilot stage, with a capacity to process larger volumes of different concentrates. This provided a much clearer understanding of the leaching process and its associated economic viability.

After hundreds of trials and experiments, the APL approach can be considered a sustainable and economic solution as an efficient leaching process that will allow global copper mining companies to produce and ship high quality copper cathodes direct to the market instead of delivering conventional copper concentrates to smelting facilities.

ARMENIA
2022