Oxygen Generation Plant for Gold Leaching

PSA (Pressure Swing Adsorption) oxygen generation plant from Noxerior put into operation at the Ad Duwayhi Gold Mine of the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company)

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Fig. 1 - Installed PSA oxygen generation plant at the Ad Duwayhi Gold Mine, KSA

The company Noxerior, formerly known as IGS Italia, is a 100% privately owned Italian company and focuses on all aspects of the non-cryogenic on-site generation of nitrogen and oxygen by means of either PSA (Pressure Swing Adsorption) or hollow-fibre membrane technology.
In 2014 Noxerior supplied a custom-designed PSA oxygen generation plant to the Ad Duwayhi Gold Mine of the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company) through an EPC company from South Korea, which was commissioned and started-up successfully during the third quarter of 2015.

Principles of gold leaching

Up till now gold leaching with a cyanide solution has remained the most widely used hydrometallurgical process for the extraction of gold from ores and concentrates. During this electrochemical process oxygen will pick-up electrons from the gold at a cathodic area, whilst gold ions will be rapidly complexed by the cyanide around the anodic area to form the soluble aurocyanide complex according to the Elsner Equation:

$$4\ Au + 8\ NaCN + O_2 + 2H_2O - 4\ NaAu(CN)_2 + 4\ NaOH$$

A slurry of the ground ore is mixed with cyanide in the presence of activated carbon. The carbon has a very high affinity for the aurocyanide complex and adsorbs the gold out of solution resulting in very high loadings on the carbon (typically 1000 – 4000 g/t). At the end of the leach the loaded carbon is removed from the slurry and the adsorbed gold is stripped out at high temperature and pressure with sodium hydroxide and cyanide solutions to form a high value electrolyte solution.
Gold bullion is then recovered from the electrolyte by electrowinning.
As a deficiency in dissolved oxygen in the solutions would slow the leaching speed, gaseous oxygen is bubbled through the slurry to increase the dissolved oxygen concentration. Intimate oxygen-slurry contactors are used to increase the partial pressure of the oxygen in contact with the solution in order to raise the dissolved oxygen concentration significantly above the saturation level at atmospheric pressure.

Need for on-site oxygen generation

The open-pit Ad Duwayhi Gold Mine is situated in a very remote desert area of the Mecca Province, Saudi Arabia, approximately 440 km southwest of Riyadh.

Fig. 2 - PSA oxygen generation plant in 2 × 50% configuration

Located at latitude 22° 17' N and longitude 43° 17' E, at an elevation of 980 m a.s.l. the site is some 380 km west-northwest of the provincial capital Mecca.

Due to this location the conventional supply of oxygen by means of truck transported liquid oxygen and local cryogenic storage tanks would not be possible so that the required oxygen has to be produced on-site through an air separation process.

The oxygen production process

Considering the required rated oxygen production capacity of 2,5 t/d, Noxerior has applied its proprietary Pressure Swing Adsorption (PSA) process to separate oxygen from the other air gases by flowing compressed ambient air through a bed of Zeolite Molecular Sieve (ZMS). The applied zeolites are crystalline, highly porous materials with a strong electrostatic field on their internal surface. Due to the characteristic that nitrogen is more polarisable than oxygen, a charge induced dipole is formed when nitrogen will get in close proximity to the exposed cations of the zeolite crystal so that the nitrogen molecules present in the compressed air will be attracted into the zeolite crystal while the oxygen molecules are able to pass unrestricted.

The PSA process will take place in two adsorption vessels filled with ZMS, which will be alternatively loaded with clean compressed air in order to obtain a continuous oxygen flow. The flow direction through the ZMS bed in each adsorption vessel is from bottom to top, but the air supply will be interrupted just before the equilibrium load is reached at the top of the ZMS bed in order to prevent a nitrogen-break-through. After a subsequent pressure equalization between the two adsorption vessels, the ZMS bed of the closed adsorption vessel will be regenerated (desorbed) by means of a pressure decrease (depressurization), which is obtained by venting through the bottom of the adsorption vessel to the atmosphere. The process is then cyclically repeated.

The gas produced by means of the PSA process has an oxygen content of 95% vol. and the balance is mainly made up by argon. The capacity of the PSA oxygen plant, however, has been corrected by the purity in order to guarantee the requested flow rate of contained oxygen (= pure oxygen) to supply a sufficient oxygen mass flow to the downstream leaching process.

Fig. 3 - Close-up of PSA oxygen generation plant

Specific solutions for the PSA oxygen plant

Considering the criticality of the oxygen for the leaching process and the remote location of the mine, it was decided to design the PSA oxygen generation plant in a 2 × 50% configuration. Because of the high ambient temperatures with maximum values up to 55 °C, a special cooling system was designed for the air compressor station in order to keep the temperature of the feed air to the PSA oxygen generation plant below 45 °C under all operating circumstances.

The combination of both gas expansion and a reduced adsorption efficiency of the ZMS at increasing temperatures causes a significant drop of performance compared to the standard operating condition of 20 °C. The aforementioned maximum feed air temperature of 45 °C allowed a limited size increase of the PSA oxygen generation plant, necessary to compensate this temperature effect in order to guarantee the required rated oxygen mass flow even at the highest ambient temperature on-site. As a consequence, the PSA adsorption vessels had to be insulated to avoid external heating by the ambient air.

Due to the extreme ambient conditions and the outdoor

installation, the PSA oxygen generation plant is controlled remotely by an Unit Control Panel (UCP) located at the mine's central control room for fully automatic and unattended operation. The UCP was designed and manufactured by Noxerior as well.

First experience and current situation

The PSA oxygen generation plant was commissioned and started-up successfully by Noxerior's technical staff during the third quarter of 2015 and shortly afterwards the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company) announced the start of trial production at Ad Duwayhi gold mine. This new mine is Ma'aden's largest and is a key part of the company's strategy to develop several new gold mine facilities in the central western region of Saudi Arabia, which contains much of the Kingdom's gold ore deposits.

At full capacity, Ad Duwayhi is expected to produce 180,000 ounces of gold annually (≈ 5.6 t/y). Commercial production is scheduled to begin in the first quarter of 2016. The PSA oxygen generation plant from Noxerior has been operating flawlessly so far.

Oscar de Groen

Oscar graduated in Mechanical Engineering at the Delft University of Technology, the Netherlands, with Heavy Diesel Engines and Gas Turbines as specialization.

He started his career as Project Engineer Advanced Engineering Engines for DAF Trucks N.V. in the Netherlands in 1991, but switched to the industrial gases industry in 1995, where he worked initially as Market Developer Floxal Membrane Systems and successively as Product Manager Membrane Systems Germany for Air Liquide GmbH, Germany.

In 1998 he became Managing Director of Noxerior in Grosseto, Italy, and has developed the company from a local workshop to an international player for the supply of non-cryogenic nitrogen and oxygen generation plants. He is (co)inventor of eleven international patents and three international patent applications owned by Noxerior.