Hydrogen production for mining vehicles

Generating Hydrogen – Alkaline vs. PEM Electrolysis

Discerning the Optimal Choice for Your Mining Operation

Hydrogen Mining Truck: Nel Hydrogen provided the alkaline electrolyser that is generating renewable hydrogen for the world's largest hydrogen fuel cell electric vehicle project with ENGIE – the electrical utility providing the renewable hydrogen solution – and Anglo American. The 300-ton truck is a retrofitted Komatsu haul truck and developed at Anglo American's Mogalakwena platinum metals mine, in Limpopo. Ballard Power is the provider of the fuel cell.

By Nick Barnes

There has been much interest, and deservedly so, surrounding the world's largest hydrogen-fueled vehicle – the 300-ton mining truck delivered to Anglo American's platinum mine in South Africa last spring. More information about the day-to-day experience and decarbonization results will be announced in the coming months as all involved gather quantifiable information to share. Meanwhile, since hydrogen is at the center of South Africa's energy roadmap towards zero carbon emissions by 2050, it makes sense to have a better understanding of the two most dominant means of generating hydrogen today – alkaline electrolysis and proton exchange membrane (PEM) electrolysis.

Both types are suitable for hydrogen fuel making on-site and on-demand at mining companies. They make the appropriate hydrogen purity and dryness for operating fuel cells and provide sufficient pressure so that the vehicles' tanks can be quickly filled. However, there are some differences that are worthwhile knowing to better discern what is best for differing circumstances.

As a basic electro-chemical refresher, electrolysers use an electrochemical reaction to split water into its components of hydrogen and oxygen which yields hydrogen without a carbon byproduct. The process only emits clean, carbon-free oxygen. Like a standard fuel cell, an electrolyser has an anode and a cathode divided by an electrolyte. Electrolysers can vary in size, from the size of a household appliance to large-scale systems that might take up an acre of land. Alkaline electrolysers use a liquid electrolyte – a potassium hydroxide solution – with a porous separator between the anode and the cathode. Hydroxide ions cross the separator by the liquid solution to form oxygen and water. At the other electrode, hydrogen is generated with the hydroxide ions. Alkaline electrolysers operate at 100-degrees C to 150-degrees C.

Alternatively, PEM electrolysers use a solid polymer electrolyte membrane and an applied current to separate, with protons, hydrogen and oxygen from water. The electrons are then transported from the anode electrode to the cathode electrode by an applied electrical circuit. PEM electrolysers require temperatures ranging from 70-degrees C to 90-degrees C. The temperature ranges for both types are considered low-temperature electrolysis, or LTE.

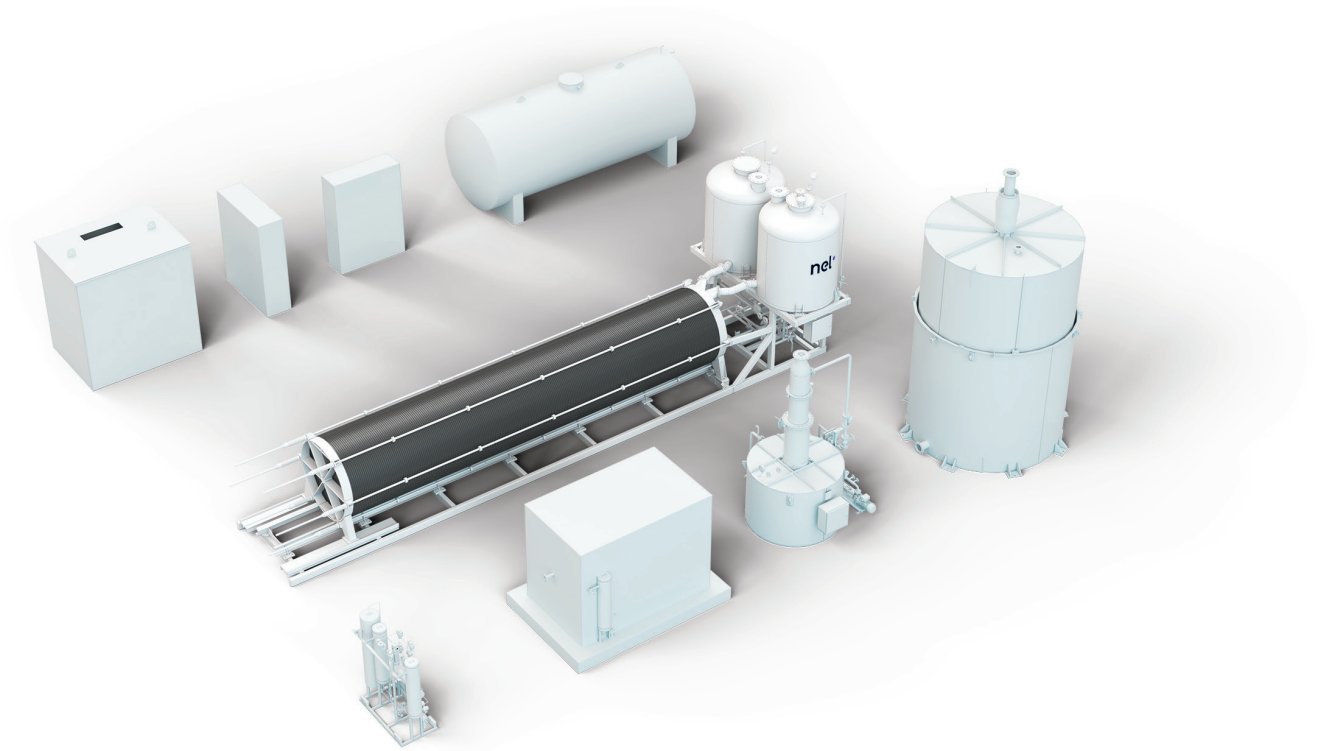
The choice for Alkaline vs. PEM electrolyser technologies comes down to the application and other parameters. Scale, input power characteristics, electricity cost, and rate of technology development are likely factors that may play into the decision. In reviewing the differences, alkaline electrolysis is the more mature technology track record. Around 1890 Charles Renard constructed a water electrolysis unit to generate hydrogen for French military airships. It is estimated that around 1900 more than 400 industrial alkaline water electrolysers were in operation worldwide and large-scale deployment of the process started. Its long history comes with a sense of comfort. Hence, alkaline electrolysers may be familiar to maintenance personnel, and the alkaline types are inherently more simply engineered than PEM types. This characteristic also makes alkaline electrolysers less expensive than PEM electrolysers. The PEM types feature a more novel membrane technology and catalyst compositions. However, it's those attributes – the membrane and the catalysts – that can provide the compelling reasons to choose PEM electrolysers for certain projects. For instance, they are more compact. If an alkaline electrolyser and a PEM electrolyser are side by side, and both are producing the same amount of hydrogen, the alkaline system will be substantially larger in footprint than the PEM. Choosing a smaller "box" could be reason enough to go with PEM if land is at a premium, or the mine encroaches on a residential area. PEM types use pure water rather than the liquid caustic solution that alkaline electrolysers do. Further, since the PEM technology is comparably newer, there is potential for further development lower cost and improve power efficiency.

According to Nel Hydrogen, the world's largest hydrogen electrolyser manufacturer with more than 3,800 units delivered in 80+ countries since 1927, both types are far from reaching the end point for improvement. The company's vision for the future comprises a balance of continually improving and further developing both technologies. In fact, the latest research on electrolysers focuses on overcoming various challenges, including the capital cost of electrolysers, improving energy efficiency, and adding compression to increase pressure for optimal hydrogen storage.

Nel provided the alkaline electrolyser that is generating renewable hydrogen for the world's largest hydrogen fuel cell electric vehicle project with ENGIE – the electrical utility providing the renewable hydrogen solution – and Anglo American. The 300-ton truck is a retrofitted Komatsu haul truck and developed at Anglo American's Mogalakwena platinum metals mine, in Limpopo. Ballard Power is the provider of the fuel cell. The adjustments to the truck consisted of swapping the diesel tank for hydrogen tanks and exchanging the diesel engine for a battery and hydrogen fuel cells. The electricity for the electrolysis process is supplied by a solar power system at the mining location.

In operation at Anglo American, the Nel 3.5 MW alkaline electrolyser splits water into hydrogen and oxygen, and the excess hydrogen is stored for use at night or when solar radiation is poor. Anglo American's long-term target is to convert the entire fleet of haul trucks at Mogalakwena to hydrogen and to also introduce decarbonized hydrogen mobility at other Anglo American mining locations. This is a key initiative of the company's larger sustainable mining efforts. According to the company's official website, a sustainable mining plan promotes innovation and produces benefits across the entire value chain.

It is well established that the mining industry alone accounts for up to 7% of all global emissions, so decarbonizing mining equipment can yield dramatic results since diesel trucks can make up to 30% to 50% of their mines' total energy use. Just one of these standard diesel engine trucks consumes over 900,000 liters of diesel fuel and coughs out enormous carbon emissions. For example, there is an estimated 28,000 of these types of open-pit mining trucks

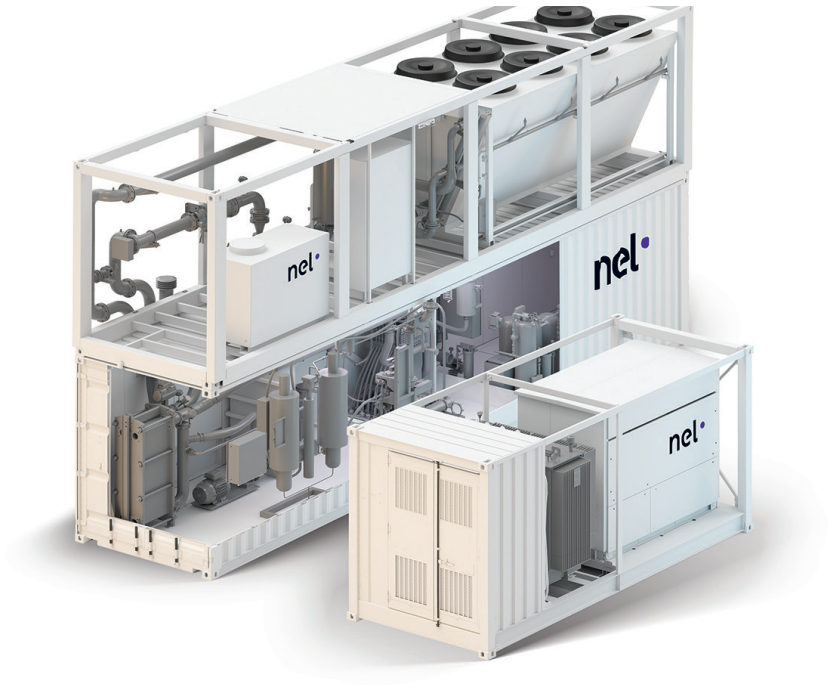


Alkaline Electrolyser: Alkaline electrolysers comprise a more mature technology – the first one was developed in the late 1800s. As such, alkaline electrolysers may be familiar to maintenance personnel, and the alkaline types are inherently more simply engineered than PEM types. This characteristic also makes alkaline electrolysers less expensive than PEM electrolysers.

working around the globe. In a recent published blog by Ballard, that number of trucks emits 68 million tons of CO2 (MtCO2) each year, the same as certain countries such as New Zealand or Finland. Decarbonizing all those trucks would be like removing the impact of 150-million gasoline-powered cars off the roads.

If you are considering fuel cell vehicles, there are considerable benefits for mining's off-road vehicles, according to Ballard. There are fewer regulatory requirements and certifications compared to on-road vehicles. Larger mining and construction companies may be able to reduce costs by ordering in quantity and leveraging economies of scale. Centralized hydrogen refueling can be built on site, and potentially renewable hydrogen can be leveraged on site to generate green hydrogen to be used as fuel for vehicles.

Certainly, those of us who are stakeholders in Africa's mining industry can appreciate such efforts surrounding Africa's hydrogen roadmap, and we look forward to hearing more about the hydrogen fueled haul truck as Anglo American's experience with it can be relayed. In the meantime, as you may be contemplating just how hydrogen can play a role at your operation, it's clear that the electrolyser choice is an important place to begin.



PEM Electrolyser: The PEM electrolysers are more compact than alkaline types. Choosing a smaller "box" could be a wise choice if land is at a premium, or the mine encroaches on a residential area. PEM types use pure water rather than the liquid chemical solution that alkaline electrolysers do. This technology is newer than the alkaline process; it was developed in the 1960s. Both electrolyser types are far from their end point for further development and improvements, according to Nel Hydrogen, which invests heavily in ongoing electrolysis research and development.

Reduce your carbon footprint...

With green hydrogen generated on demand

Nel Hydrogen is leading the global decarbonization revolution and can help reduce your carbon footprint, increase mine and plant safety, streamline operations
and increase your bottom line.

- Alkaline and PEM water electrolysers
- Safe, clean and cost effective
- Consistent purity and pressure
- Eliminate hydrogen delivery and storage
- Scale to match any application

nel

Visit us on-line or call for a consult with one of our sales engineers today!
+1.203.949.8697
www.nelhydrogen.com