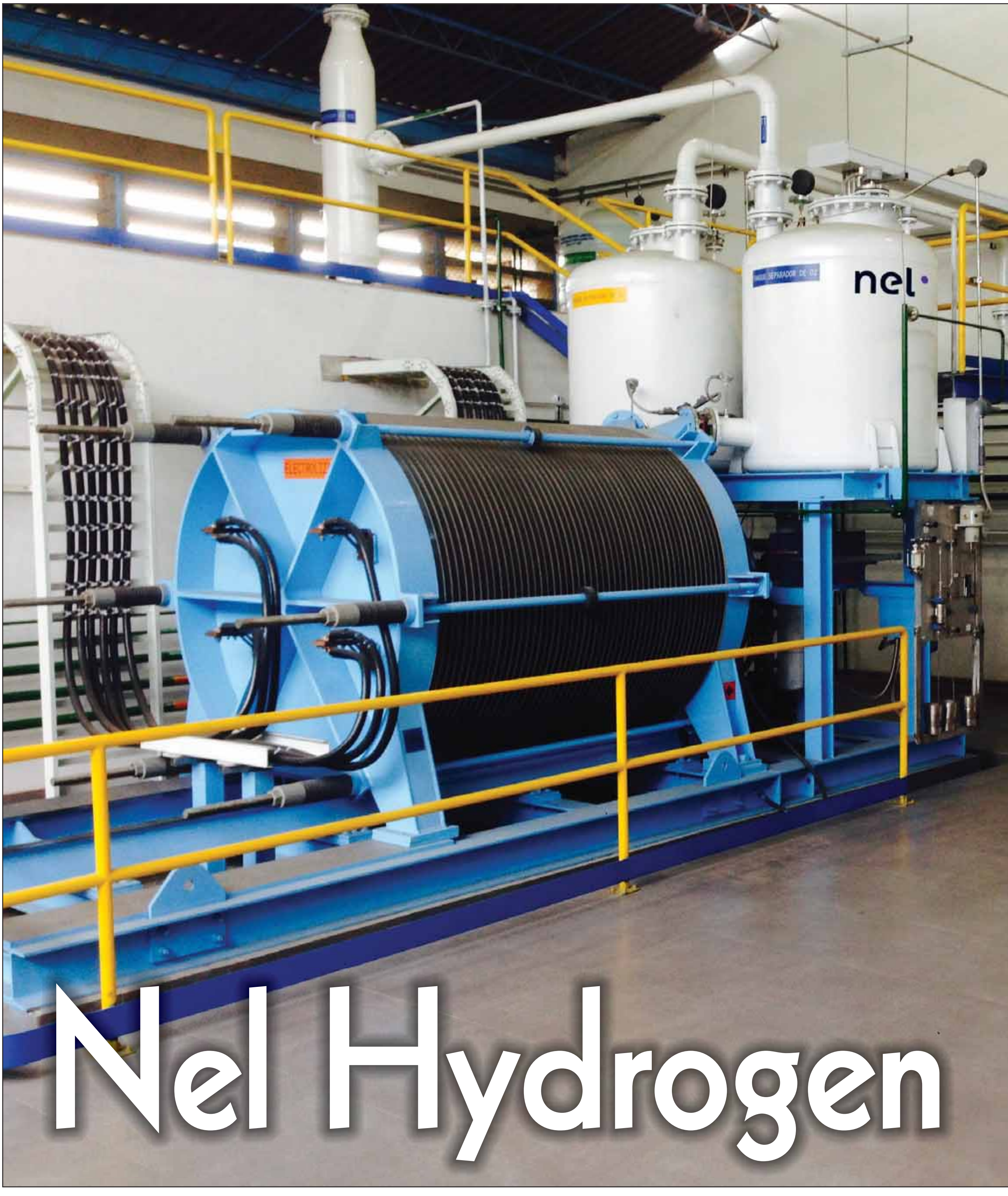


Nel Hydrogen

Nel's Alkaline Water Electrolysers (Hydrogen Generators) have been in use for decades at float glass manufacturing facilities

ON-SITE TIN BATH ATMOSPHERE GENERATION IMPROVES FLOAT GLASS PRODUCTION

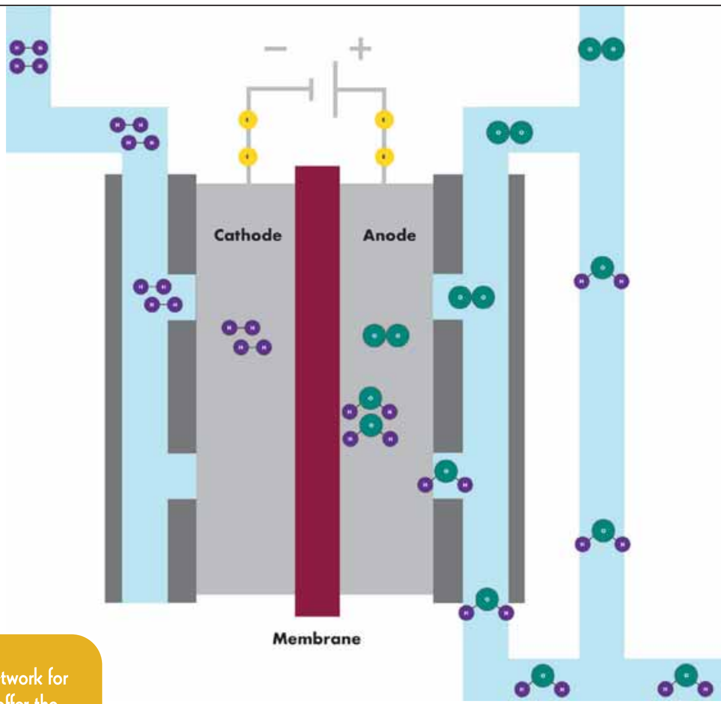
Nel is a global, dedicated hydrogen company, delivering optimal solutions to produce, store and distribute hydrogen from renewable energy. Since its foundation in 1927, Nel has a history of development and continual improvement of hydrogen plants covering the entire value chain, from hydrogen production technologies to the manufacturing of hydrogen fuelling stations, providing all fuel cell electric vehicles with the same fast fuelling and long range as conventional vehicles today.

Raymond Schmid - *VP Sales and Marketing EMEA-Oceania*
Nel Hydrogen

First developed by Sir Alistair Pilkington in 1952, the float glass process creates a specialised type of flat glass with an extremely smooth, uniform structure and superior optical qualities. Over the past 60 years, this method has not lost its relevance. Today float glass is everywhere. It is used to construct windows and doors, the glass 'skins' of modern skyscrapers, tables, shelving and display cases, solar panels, plasma, LCD and LED screens, automotive windshields and more. If you see a clear or tinted flat piece of glass, it was most likely manufactured using the float glass process.

THE PRODUCTION OF FLOAT GLASS

Float glass is produced on a continuous production line. First, raw materials such as sand, dolomite, limestone, carbonate and sodium sulfate, as well as scrap glass are heated to extreme temperatures (1,500°C/2,800°F) to form



As stand-alone units or working together in a network for greater output, Nel PEM Water Electrolysers offer the safest, most advanced technology for producing high purity hydrogen for float glass atmospheres

molten glass. This glassy liquid then moves into the tin bath chamber, which has a controlled atmosphere, where it is poured onto the surface of molten tin. As the molten glass floats on top of this tin bath, the tin acts as a level template for the glass to distribute over and then harden into high-quality flat glass.

Tin is a metal that does not react with glass, but is the forming basis for a flat surface of glass without optical defects. One of the most important tasks at this stage is to prevent the interaction of oxygen with the tin.

The oxidation of tin introduces flaws in the tin's structure, which in turn will create flaws in the surface of the glass. In order to stop this oxidation from occurring and to avoid a negative impact on the glass, a protective atmosphere is used in the tin bath chamber. This atmosphere usually consists of 90 per cent nitrogen (N_2) and 10 per cent hydrogen

(H_2). While the nitrogen remains non-reactive in the process, the hydrogen will react with any oxygen present, preventing any oxidation of the tin.

DETERMINING WHICH TECHNOLOGY IS BEST – USING THE RIGHT GAS

In order to determine which technology is the best to produce protective atmospheres, there are several factors to considered:

- High purity requirements for process gases
- Large volume of gas demand (average: 800 Nm^3/h nitrogen and 90 Nm^3/h hydrogen)
- Sourcing gas supply
- Environmental impact of generating the gasses

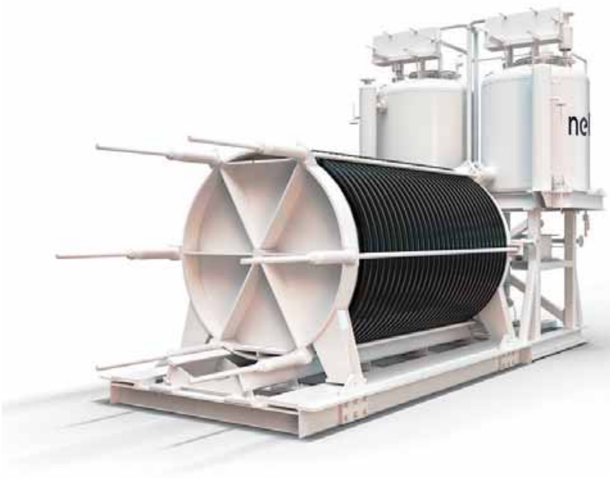
Traditionally, industries that require high volumes of these gasses for production purposes have used compressed gas or liquid forms of nitrogen and hydrogen, which are supplied by pipeline from a nearby producer, or by trucks in tanks or tube trailers. However, this is not without its problems.

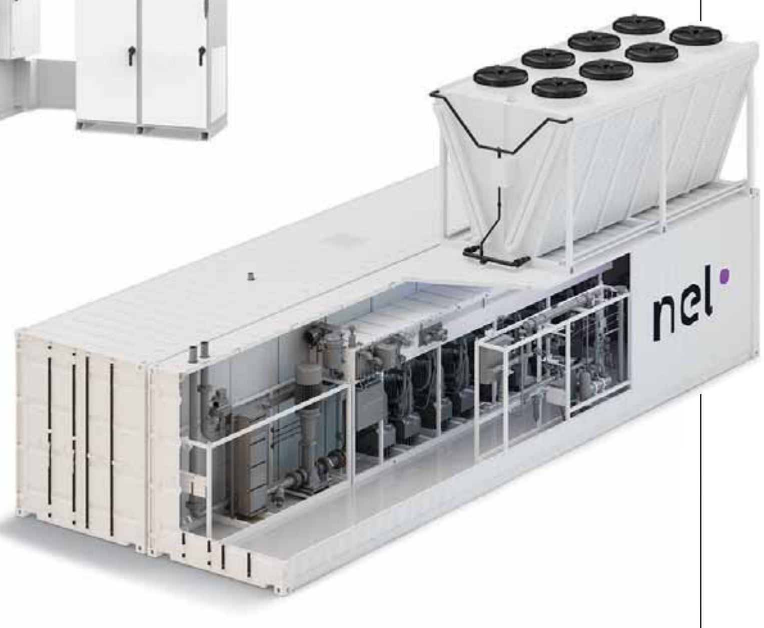
Nitrogen

Nitrogen is typically produced with air separation units using pressure swing absorption technologies. This method provides the highest purity of nitrogen available, and can be cooled and compressed into liquid form and stored cryogenic containers. However, whether as a compressed gas or liquid, nitrogen is a dangerous element to store. If it escapes into an enclosed space, there is a high risk of asphyxiation, or if pressure builds up there is a high risk of explosion. Given the high volume of nitrogen required in the float glass process, the logistics of transporting the nitrogen to the glass plant can also present a problem. Any disruption to the supply chain, whether from a strike, natural disaster or global pandemic can cut off the flow of nitrogen to the plant causing a shutdown of production. To help keep glass production operating at peak efficiency and safety, plant managers should consider installing air separation units on-site to replace, or at least supplement delivered nitrogen.

Hydrogen

Most hydrogen is produced via coal gasification (CG) or steam methane reforming (SMR), which uses fossil fuels as the feed stock and creates carbon dioxide (CO_2) emissions, a very damaging greenhouse gas. Depending on the method used, for every ton of H_2 produced, 11 to 19 tons of CO_2 is released.
The main driver for CG and SMR applications is the low specific cost of hydrogen produced. However, the disadvantages are the high cost of equipment, costly and lengthy maintenance, and the presence of impurities in the hydrogen, which requires additional purification equipment. Add to that the changing attitudes and legislation around the world on greenhouse gas emissions, decarbonization of industries and the expense of carbon capture equipment now being required, CG and SMR are starting to fall out of favour. In addition, liquid





Nel Water Electrolysers (Hydrogen Generators) for float glass manufacturing hydrogen is highly explosive which means it must be handled very carefully, and requires a large storage area and special permitting.

Hydrogen production through traditional alkaline water electrolysis is a well-known technology to the glass market. In this process, the electrolyser uses a liquid alkaline electrolyte (NaOH or KOH) to facilitate the electrolysis. While installation of an alkaline system may require RTN and other permits as well as additional inspections and special insurance due to the caustic nature of the alkali, the system is extremely reliable and efficient. Many float glass plants have been using this technology for decades to produce the hydrogen they require for their tin bath atmospheres. Because the hydrogen produced by water electrolysis is generated by cracking water molecules (H_2O) into hydrogen (H_2) and oxygen(O_2) using only electricity and an electrolyte, no greenhouse gasses are produced. The only by-product is oxygen. When hooked up to a source of renewable energy for the electricity, true green (zero carbon) hydrogen is produced. Utilizing the water electrolysis process to generate the required hydrogen will lower a plant's carbon footprint and help the company comply with the ever-tightening carbon reduction legislation. By producing the hydrogen on-site as needed, the plants can also eliminate the safety and storage problems of delivered hydrogen.

WATER ELECTROLYSIS – THE OPTIMAL CHOICE

Given the importance of hydrogen purity for the float glass process, all the features of CG and SMR operations, and the same logistic problems for delivered hydrogen as for delivered nitrogen, the process of water electrolysis is the optimal choice for the float glass process. Today the safest, most advanced technology to produce the purest hydrogen is through Proton Exchange Membrane (PEM) water electrolysis. This process uses a caustic free solid polymer electrolyte as the catalyst to crack the water molecule (H_2O) into hydrogen (H_2) and oxygen (O_2).

In a Nel Proton® PEM electrolyser, deionized water and electricity are fed into the cell stack. Here, water splits at the anode into electrons, protons and gaseous oxygen (O_2) at a pressure of 1.5 barg. Protons then pass through the proton exchange membrane while the electrons follow an electric circuit to the cathode. At the cathode, protons and electrons combine to form hydrogen (H_2) at a pressure of 30 barg. The membrane material is gas impermeable, and the differential pressure between the hydrogen and oxygen streams ensures that there is no mixing of the gasses. This mechanism of the Proton PEM system has brought water electrolysis to a new level of safety. The high purity of hydrogen is due to using pure DI water as the only raw material. Hydrogen purification consists of drying the hydrogen through two internally installed pressure swing absorption tubes. There is no need to have additional purification and treatment equipment. The standard purity of hydrogen is guaranteed at a level of not less than 99.9995 per cent with a dew point of 72°C.

With the absence of a liquid alkaline tank and mechanical high-pressure compression on the hydrogen line, PEM systems are more compact than their Alkaline counterparts. A more important benefit that comes with the absence of alkali in the PEM systems in the lack of need for 'hazardous production facility' signs, RTN and other special permitting, additional inspections and special insurance.

Nel electrolysers operate automatically and do not require the constant presence of customer personnel. They can be set to follow the on-demand requirements of the production process, eliminating any hydrogen storage requirements. The systems constantly monitor the operation process adhering to several dozens of safety parameters.

As float glass facility managers contemplate changes or additions to their tin bath atmosphere supplies, it should be noted that each project requires a detailed technical and economic analysis, taking into account specific plant requirements. Nel Hydrogen produces hydrogen generators, both alkaline and Proton PEM technologies, and can match the needs of any float glass operation. Nel provides turnkey solutions… the implementation of all stages including production, delivery, commissioning, warranty and post-warranty service throughout the life of the equipment.