Swiss Re
Corporate Solutions

Risk Engineering Services

Sustainability series: “Green” Hydrogen

Companies and nations around the world strive to decrease their carbon footprint and meet aggressive reduction targets. As a result, demand is increasing for green energy, specifically wind and solar power. These forms of electrical generation have supply limitations (lack of wind, cloudy days, etc.), giving rise to the need for energy storage systems. “Green” hydrogen is increasingly explored as a medium for energy storage. With green hydrogen, firms can accumulate energy in a more environmentally friendly manner.

Hydrogen can be an energy carrier, either for combustion or more likely, to produce electricity. Fuel cells convert hydrogen into electricity and produce water as its only byproduct. This allows hydrogen to be used as a means of energy storage or a way to move energy from one place to another more easily. This can help smooth supply disruptions from wind and solar installations.

The hydrogen production process

Traditional industrial-scale hydrogen production comes from steam-methane reforming, a process that heats natural gas and steam in a large furnace to produce syngas (a mixture of primarily H2, CO_2, CO) that is later purified into hydrogen. This is considered “gray” hydrogen because it requires consuming and burning a large amount of fossil fuel.

In our earlier article “In 6 charts: De-risking the hydrogen economy”, we outlined the hydrogen pathways and process further.

“Blue” hydrogen takes this process one step further and uses carbon capture and storage (CCS) to trap the carbon emitted from the furnace and by doing so, reduces the net carbon output of the plant. By contrast, “green” hydrogen is derived from electrolyzers.

Electrolyzers are devices that utilize electricity to break water into its constituent components hydrogen and oxygen. If the electrolyzer’s power source is renewable, perhaps from solar panels or wind farms, then the result is hydrogen without carbon emissions.

All three types of electrolyzers require water which must be contaminant-free. Impurities can clog or damage membranes creating off-spec product, plant outage, and possible business interruption. High-level water purification may increase the cost of water as a utility. It may also require additional infrastructure for the hydrogen plant in the form of an additional purification system.

Like any piece of technical equipment, electrolyzers require preventative maintenance including replacing membranes, cathodes, and anodes on a regular basis. This can be accomplished by a well-trained in-house staff. However, it is also common for maintenance services to be provided by manufacturers on a contract basis.

The low-tolerance operation of electrolyzers raises the need for regular maintenance and high-quality water. Combined with flammability of the hydrogen product, it is critical that the operation is closely monitored for safety and performance.

New users of hydrogen

Less experienced companies are exploring this space and need guidance as they take on new technology. As an example on the consumption side, municipalities (or other organizations) with large vehicle fleets may want to use fuel-cell vehicles and need a small hydrogen infrastructure to supply them. Producers and consumers who are new to hydrogen must consider the distinctive characteristics of the gas and the unique risk factors it poses.

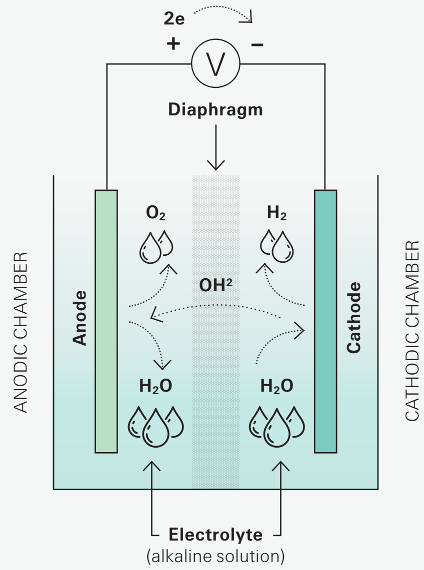
Usage of electrolyzers

There are three main types of electrolyzers currently in use.

Proton-exchange membranes
- Sometimes called polymer-electrolyte membranes
- Use of electricity to separate the oxygen and hydrogen atoms in water.

Alkaline electrolyzers
- Cells containing cathodes and anodes separated by a diaphragm.
- Potassium hydroxide (KOH) or sodium hydroxide (NaOH)-filled cells allow electrons to flow to the cathode, causing water molecules to separate into hydroxide ions and hydrogen gas.
- The hydroxide ions migrate to the anode where they are separated further into oxygen, hydrogen, and electrons.

Solid oxide units
- Use of high-temperature electrolysis to break water into hydrogen and oxygen.
- Water molecules combine with electrons to release hydrogen gas and create oxygen ions.
- The oxygen ions pass through a solid membrane to the anode portion of the cell, where the ions release extra electrons.
- The resulting oxygen gas is removed from the system and the electrons are used on the cathode side of the unit to continue the process by reacting with water.



Electrolyzers have been in place for decades, and manufacturers have well-established histories with the technology. However, as demand for green hydrogen increases, the number and size of electrolyzer installations will increase accordingly. This increase could be at 5-6% per year over the next 5 years, according to some estimates.

Manufacturers will have to quickly ramp up production capacity to meet increased demand for electrolyzer installations. Rapid scaling should be closely managed to avoid product quality problems.

Many of the companies and governments installing this capacity will be first-time users. More than just buying an off-the-shelf electrolyzer as a plug and play appliance, these users will need full installations. Such installations could include interconnecting piping, storage, specialized utility supplies, and other things more consistent with a traditional chemical plant installation.

Hydrogen – Risk considerations

In our recently published "Manufacturing Trends: Hydrogen as an alternative fuel" article, we had outlined leaks, flammability, and hydrogen embrittlement as some of the risks associated with hydrogen. Beyond these risks, there are other risk considerations to note:

- **High-temperature hydrogen attack (HTHA):** Hydrogen is most often stored and transported in carbon steel pipes and vessels. While this can be done safely, hydrogen at elevated temperatures and pressures can cause what is known as high-temperature hydrogen attack (HTHA). In this process, carbon and carbides are leached from the steel. Consequently, its mechanical properties are changed, creating the potential for structural failure.

- **Exposure to third parties:** Hydrogen generation units present an exposure to third parties such as end users or industrial neighbors in proximity. This is a special concern for any type of on-site or distributed hydrogen network intended to locate generation close to the consumer. Similarly, damaged equipment would cause business interruption.

However, if the hydrogen is provided to a customer, the failure to supply could give contractual penalties or subrogated losses.

It's worth noting that oxygen is generated as a by-product of the three electrolyzer types listed above. A general process failure that allows the hydrogen and oxygen streams to mix could lead to a much larger fire or explosion. This is in comparison to a hydrogen only induced fire or explosion.

Fire and explosion are hardly the only liability risk presented by green hydrogen. Unless a contractual agreement addresses supply quality, off-spec product that damages a customer's fuel cell could potentially be subrogated to the hydrogen provider.

Hydrogen safeguards and mitigation

Some common incident prevention measures from the process industry can help reduce the likelihood or impact of a hydrogen-based fire or explosion. These include hydrogen-specific gas detection, ventilation, damage limiting construction, siting, and safety management programs.

Machinery breakdown can be mitigated with robust maintenance and inspection programs. Other mitigation measures include careful consideration of material compatibility and effective change management. A comprehensive blast study can help define site exposure and identify steps to reduce potential impact. Software such as Swiss Re's ExTool quickly provides such insights. Process safety management is a well-established methodology in the chemical industry to carefully consider process risks and mitigate potential problems.

Even with these standards in place, wide-spread, large capacity electrolysis is a new concept on the horizon. Care should be taken to ensure all necessary safety measures are considered. For the sake of process safety, reviewing new installations and new applications is a must. That process is best done with an iterative approach. Engaging risk experts at each stage, and as details change, will help prevent surprises down the road.

Conclusion

Hydrogen is quickly becoming a significant option for companies looking to provide alternative, greener energy solutions, both for themselves and customers. With some thought and care put towards installation and operations, green hydrogen can be a safe and beneficial energy carrier that helps advance sustainable operations.

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Resources

- AIChE Center for Hydrogen Safety
- Hydrogen Tools

Specific codes and standards relevant to hydrogen systems:

- **CGA G-5**
  Compressed Gas Association (CGA) – Hydrogen
- **CGA G-5.4**
  Compressed Gas Association (CGA) – Standard for Hydrogen Piping Systems at User Locations
- **ASME B31.12**
  Hydrogen Piping and Pipelines
- **ISO/TR 15916**
  Basic Considerations for the Safety of Hydrogen Systems
- **NFPA 2**
  Hydrogen Technologies Code