# Hydrogen Purification Methods

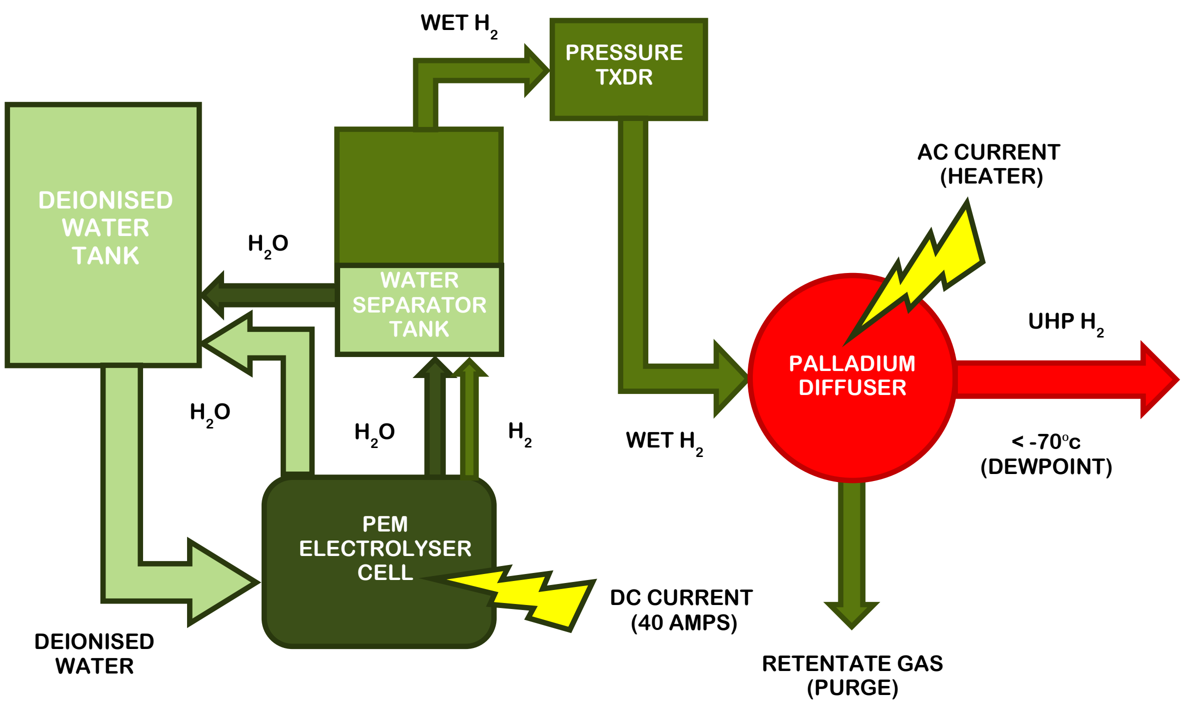
## Technology Considerations on Hydrogen Generation Technology

**Hydrogen Generators that are utilised to provide Carrier Gas for GC and GC/MS applications employ many technologies to provide high purity hydrogen.  Here were look at the various methods used to purify hydrogen. Three using PEM (Proton Exchange Membrane), combined with various purification techniques, and the fourth using a combined Palladium Electrolyser.**

## PEM/Palladium Diffusion

Palladium membrane hydrogen purifiers operate via pressure driven diffusion across palladium membranes. Only hydrogen can diffuse through the palladium diffuser.  The palladium diffuser can take a number of forms, including an array of tubes, a coiled tube or membrane foil. It comprises a palladium and silver alloy material possessing the unique property of only allowing monatomic hydrogen to pass through its crystal lattice when it is heated above nominally 300$^{o}$C.  The hydrogen gas molecule coming into contact with the palladium membrane surface dissociates into monatomic hydrogen and passes through the membrane. On the other surface of the palladium membrane, the monatomic hydrogen is recombined into diatomic hydrogen.

**PEM / Palladium Diffusion Process**




**Features and Benefits**

- Extremely pure hydrogen gas with literally no moisture or oxygen carry over. Purity in excess of 99.99999% can be obtained.
- No routine maintenance required.

- Normal life expectancy of a palladium diffuser in the purifier being around 5 years dependent on the application it is being used for and the level of usage (Source: http://pureguard.net/cm/Library/FAQs.html)

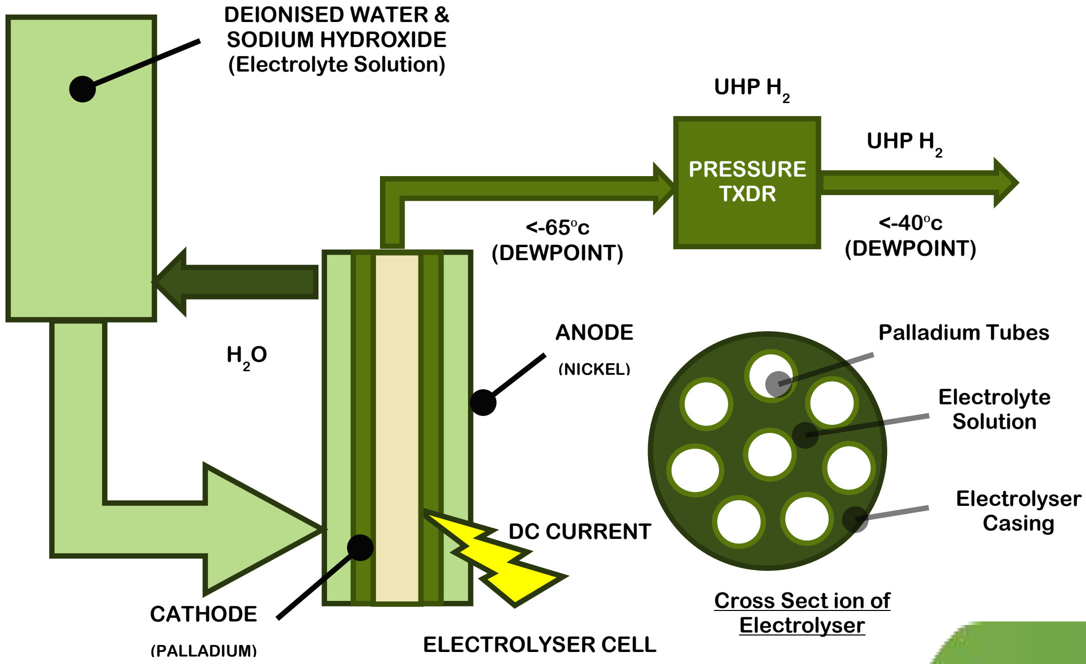
**Issues**

- When using palladium silver alloy, unexpected power outages can lead to irreversible damage to the diffuser.
- The palladium silver alloy may absorb hydrogen, increase in volume and become distorted or brittle
- If the diffuser should crack from a hole, then the cell is not financially viable for repair.
- It is essential that the palladium membrane never cools down in the presence of hydrogen ensure longer life. Durability can be compromised when the purifier operating temperature is out with the optimum range for even a short period of time.
- After the hydrogen has passed through to the 'refined' side of the diffuser, the hydrogen (still containing impurities such as oxygen and moisture) left on the 'unrefined' side has to be periodically purged from the cell. This ensures sufficient quantities of hydrogen molecules are available for transfer through the Palladium membrane, maintaining diffuser efficiency. This can be a complicated procedure and if the system is poorly designed, can cause a pulsing effect on the output pressure/flow from the diffuser.
- The reaction takes place at a very high temperature and can pose a safety concern as any source of ignition in this process is a great danger. The current used to drive the heater cartridge to this temperature is substantial and could cause a significant arc if there were any issues.
- The need to replace the palladium membrane in the purifier, which can be every 5 years.
- A spare cell may be recommended to eliminate downtime.
- Larger carbon footprint as palladium alloy requires electricity to heat the palladium alloy to the working temperature.

## Combined Palladium Electrolyser/Purifier System

A metal palladium anode is used and since water does not effectively conduct an electric current, a strong water soluble electrolyte is added, commonly 20% Sodium Hydroxide (NaOH). A bundle of palladium tubes act as a cathode and only hydrogen and its isotopes are capable of passing through the cathode producing ultra high purity hydrogen.

**Combined Palladium Electrolyser/Purifier System**



**Features and Benefits**

- Extremely pure hydrogen gas with literally no moisture or oxygen carry over.

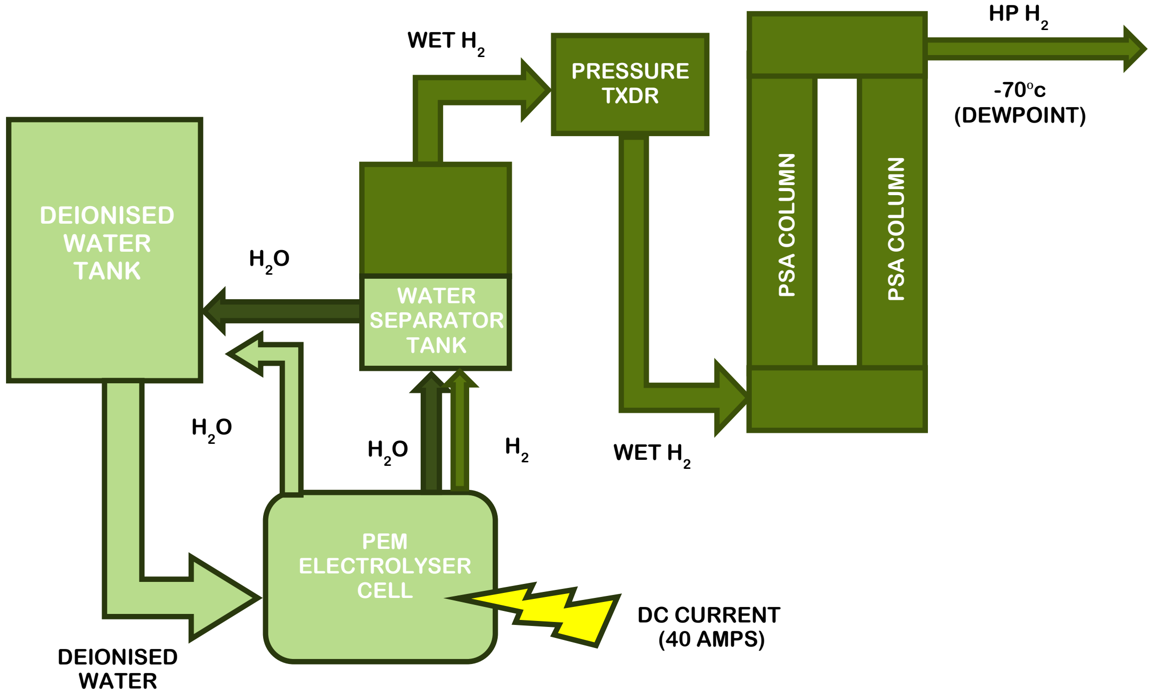
**Issues**

- Electrolyte solution in the cell must be changed every 12 months. The electrolyte used is NaOH (Sodium Hydroxide), which is a caustic substance and must be handled with care. Change procedure takes at least 8 hours with cool-down and 4 hour start-up time. All previous electrolyte solution MUST be drained beforehand.
- Sulphur-containing compounds and unsaturated hydrocarbon impair permeability.
- Sodium hydroxide can cause corrosion on equipment and over time, it can cause damage.
- Use of a poor electrolyte could lead to damage of the electrochemical assembly of the cell.
- There is a danger that electrolyte may leak and can cause burns to skin.

## PEM/Absorbent Pressure Swing Adsorption

Pressure Swing Adsorption technology works by alternating the flow through two columns which are packed with an adsorbent material (in the form of beads) which acts as a molecular sieve. While the hydrogen is being passed through one column, a small bleed taken from the dry gas is passed down the other column. No further adsorption capacity is available; at this point the adsorbent material is forced to regenerate. This action completely regenerates the adsorbent material in the column so that no replacement of the material is required. The vessel is ready for another production cycle after a small amount of the product hydrogen flushes away the waste. The hydrogen produced has a drastically removed moisture content of just 1ppm.

**PEM / Adsorbent PSA Process**



# Hydrogen Purification Methods

**Features and Benefits**

- Robust and regenerative technology.
- No high temperatures or associated high electrical currents.
- A continuous flow of hydrogen with no pressure fluctuations or pulsing effects.
- Maintenance requirements limited to replacement of de- ionizer cartridge.  No replacement of desiccants or hazardous caustics required.
- Short and easy start-up and shut-down procedures.
- Simplicity and reliability of operation.
- Minimal energy consumption and therefore lower operating costs compared to other hydrogen purification methods.
- Industry research suggest that use of palladium technology will produce the driest possible hydrogen, however PSA will adequately meet requirements for GC/MS MS as per purity recommendations quoted by Agilent technology.

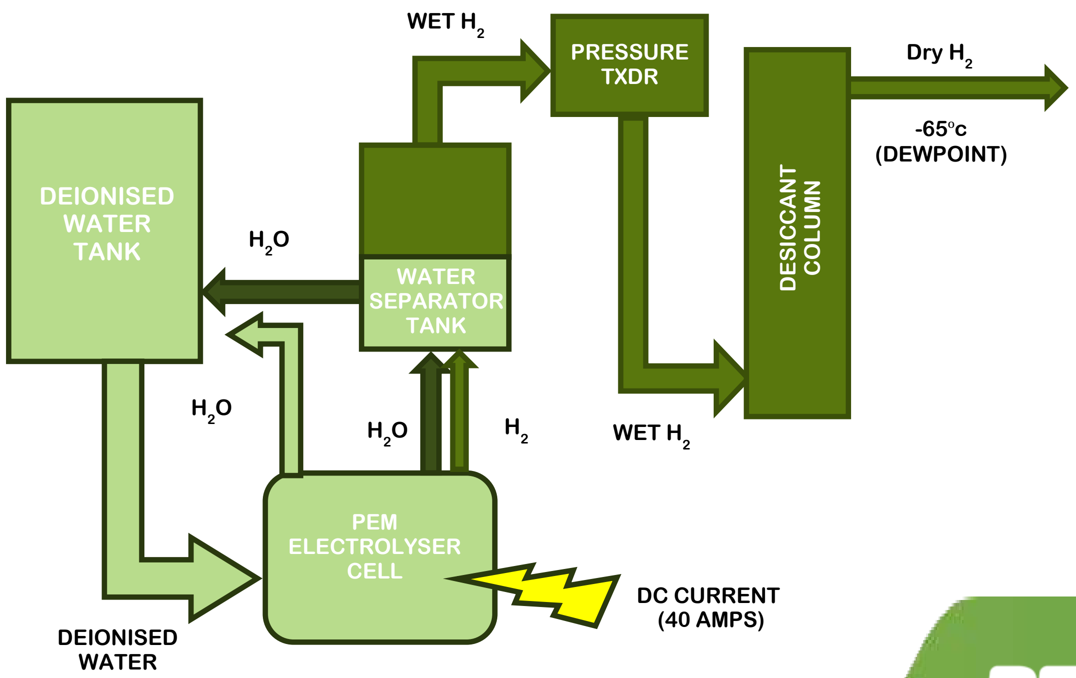
**Issues**

- Larger cell replacement cost may be involved.
- The hydrogen gas used to regenerate the molecular sieve is vented into the atmosphere.  Although there are a selection of hydrogen gas generators on the market that will pass the vented hydrogen through a catalyst, to eliminate hydrogen being vented into the atmosphere.

## PEM/Silica Desiccant System

The use of silica desiccant columns is another common purification method and popular due to its simplicity.  The Hydrogen that is produced using PEM technology then flows through a stainless steel desiccant cartridge for moisture removal.  The desiccant column is most commonly made up of silica gel beads which act as a drying agent in hydrogen to produce high purity hydrogen, meeting industry purity requirements.

**PEM / Silica Desiccant Process**



**Features and Benefits**

- Easy replacement of desiccant (silica gel) and de- ionizer cartridge.
- Meets common requirements of purity required for GC.
- Cost effective in comparison to other purification methods.

**Issues**

- Some moisture or oxygen carry over will often still exist.
- The desiccant (silica gel) needs to be monitored constantly and replaced periodically dependent on the level of use of the system. For high levels of usage this could be weekly replacement of desiccant cartridge.