Design of a Hydrogen Electrolysis System and Fuel Cell for Vehicle Applications

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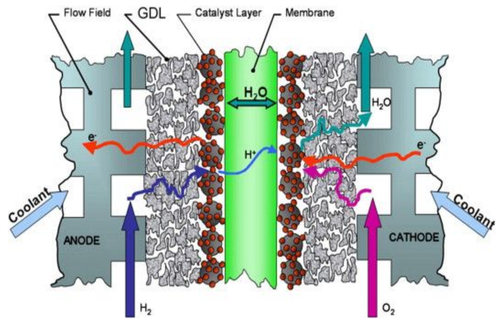
Background

- **Gasoline Engines**
  - Burn fuel ➡ emit CO_2, CO, NO_2
  - ⚠ Source of greenhouse gases
- **Electric Vehicles**
  - ✓ No tailpipe emissions
  - ⚠ But power comes from fossil fuels ➡ net emissions
- **Hydrogen Fuel Cells**
  - ✓ Zero emissions at the engine
  - ✓ H_2 can be produced cleanly

H_2 Fuel Cell Mechanism



Owejan, J., Gagliardo, J., Sergi, J., Kandlikar, S., & Trabold, T. (n.d.). Water management studies in PEM fuel cells, part I: Fuel cell design and in situ water distributions. Retrieved February 14, 2025

Anode Reaction: $\mathbf{H_2 \rightarrow 2H^+ + 2e^-}$

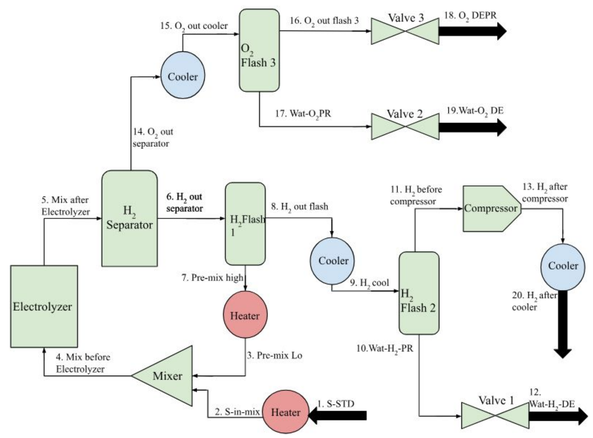
Cathode Reaction: $\mathbf{½O_2 + 2H^+ + 2e^- \rightarrow H_2O}$

- Protons travel through the membrane and meet O_2 flowing over the cathode
- e^- travel through an external circuit, generating electricity

Safety risks

- **Highly flammable, low ignition energy, and prone to leaks**; proper ventilation is critical.
- **Stored in high-pressure or cryogenic systems**; safety governed by OSHA and NFPA.

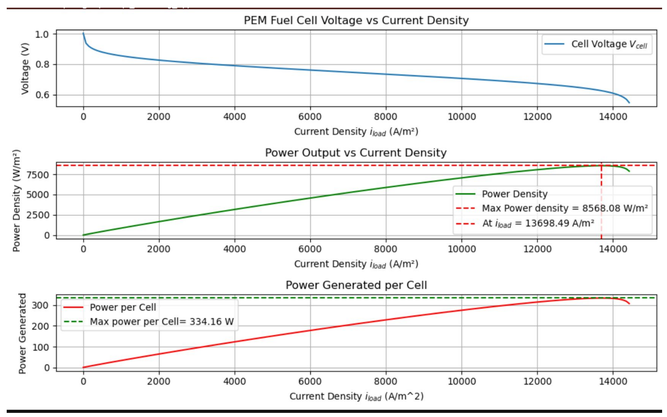
Clean H_2 Production

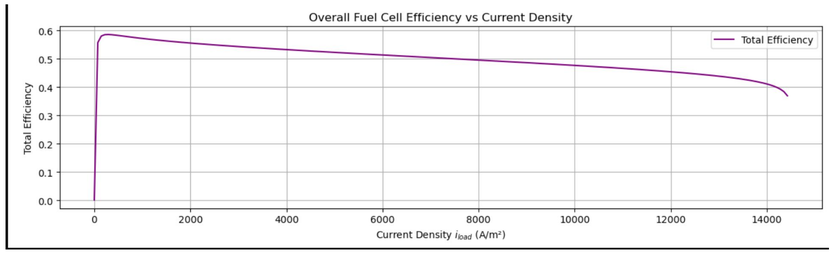


Electrolysis, powered by solar energy, splits H_2O into H_2 and O_2 with zero emissions

Input: KOH (catalyst) + H_2O + **48,400 W**
Output: 99.5% pure streams of H_2 and O_2

Data Graphs



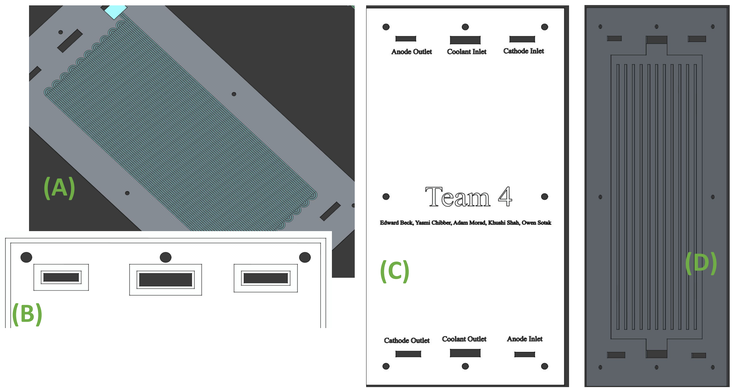


Results

- It was estimated that **4.678 kg/hr H_2** is produced, enough for a full tank
- **345 cells** are required for power production
- **Efficiency:** PEM Fuel Cell Stack: 50-60%; H_2 production: 55 %

-**Overall cost:** solar cell system, H_2 production, and fuel cell stacks = 1,033,453.74 $/345 cells
-**Pay back period:** It will take **11 years 6 months** to generate profit for selling 4 fuel stacks/yr.

Fuel Cell Design



(A): Serpentine channels distribute gas reactants evenly across the surface.
(B): The manifolds allow for gasses and fluids to flow throughout the entire system
(C): The endplates perform inlet and outlet functions
(D): The cooling system pumps coolant both around the cell and in between the two bipolar plates

Acknowledgements

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