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H2 FINAL FILTER® Extends PEM Fuel Cell Life

Sulfur compounds (primarily hydrogen sulfide, H_2S) can quickly ruin the PEM (polymer exchange membrane) fuel cells used to power buses, trucks, forklifts, and more. A few parts per billion of sulfur can make the difference between a fuel cell stack running reliably for years and one that fails catastrophically in hours.

Why is sulfur a problem?

In a PEM fuel cell, hydrogen is split into protons and electrons on the surface of the anode catalyst, usually platinum supported on carbon. Sulfur compounds like H_2S strongly adsorb on platinum, poisoning the active sites that normally split hydrogen. Even at very low levels (a few parts per billion, ppb), sulfur can block catalytic sites, causing a rapid drop in performance (current at a fixed voltage) and lead to irreversible deactivation. Commercially available 'high purity' H_2 typically contains about 10 ppb of H_2S. And sulfur absorbs weakly on the surface of most metals, so that the 'pure' H_2 often picks up more sulfur from contaminated pipes, valves, and fittings as it travels from the source to the fuel cell stack.

While other impurities like carbon monoxide (CO) or ammonia (NH_3) also impact PEM performance, sulfur is "the most important and most challenging specification to meet"[1]. To make matters worse, H_2S magnifies the effect of CO to damage fuel cell performance. Because of this, PEM fuel cells typically require extremely low sulfur levels in the fuel. Without adequate cleanup, fuels containing even traces of H_2S can reduce fuel cell output from normal operation to zero in a short time, as was observed in this test when the filter was bypassed.

[1] https://cordis.europa.eu/project/id/256773/reporting accessed 31-dec-2025

A Life-Extending New Solution: The H2 FINAL FILTER®

A new invention called the H2 FINAL FILTER, packed with the SULFUR MAGNET® changes everything. It's a simple filter cartridge that is put near the end of the feed pipe that quietly grabs the last traces of sulfur —down to less than **200 parts per trillion** (that's like two drops in a billion swimming pools). At that level, even the most advanced sensors can't detect the H_2S.

The SULFUR MAGNET is a regenerable, non-hazardous, high-capacity sorbent media packed into stainless-steel filter housings (the H2 FINAL FILTER® systems). It operates passively at near ambient conditions with negligible pressure drop and no utilities. Key advantages:

- Capacity up to ~55% by weight sulfur uptake.
- Removes all volatile sulfur species (H_2S, COS, mercaptans, thiophenes) plus NOx.
- Non-hazardous either before or after exposure to sulfur
- Regenerable or recyclable, with spent media forming stable, landfill-safe compounds.
- Proven in fuel-cell and SMR testing to outperform even pure bottled hydrogen by eliminating the final traces of H_2S left in the gas.

The Sulfur Challenge

The goal of the test was to see whether the H2 Final Filter could protect a small PEM fuel cell from H_2S in the hydrogen fuel stream. The test apparatus included a standard commercially available 5 cm² Ion Power PEM membrane electrode assembly operated at 80 °C and 80% humidity (typical conditions). The H2 Final Filter was placed in the hydrogen feed line upstream of the mixing point with humidified H_2. A switch valve allowed rapid switching of the fuel between (1) 'Clean' hydrogen (commercial high purity H_2 that typically contains 1-10 ppb H_2S), (2) 'Dirty' hydrogen with 5 ppm H_2S filtered by the Final Filter, and (3) 'Dirty' hydrogen with 5 ppm H_2S fed directly into the fuel cell.

The cell was first tested by feeding 'Clean' H_2 fuel to the anode and air to the cathode. The fuel was then replaced with a mixture of 5 ppm H_2S in H_2. This setup allowed a direct comparison: the same cell, same temperature, same humidity, with and without the filter under otherwise identical conditions.

The cell was conditioned and then challenged with H_2S in a controlled way. The experimental procedure included a standard break-in period where the cell was cycled between open circuit voltage (no load) and constant voltages of 0.6 V and 0.3 V. After conditioning, in step (1) the cell was held at 0.6 V for 5 hours on 'clean' hydrogen fuel while monitoring the current to establish a stable baseline and confirm that the cell behaved normally with clean gas. With the cell still at 0.6 V, in step (2) the fuel was switched to hydrogen containing 5 ppm H_2S, but with the H2 Final Filter in place. It was operated under these 'filtered dirty fuel' conditions for 25 hours, and the current output (with voltage fixed at 0.6 V) was monitored. After 25 hours, in step (3) the cell was switched from filtered fuel to unfiltered 5 ppm H_2S (bypass line, no filter) and the current was again monitored at the same 0.6 V, to see how quickly the cell degraded when sulfur reached the anode.

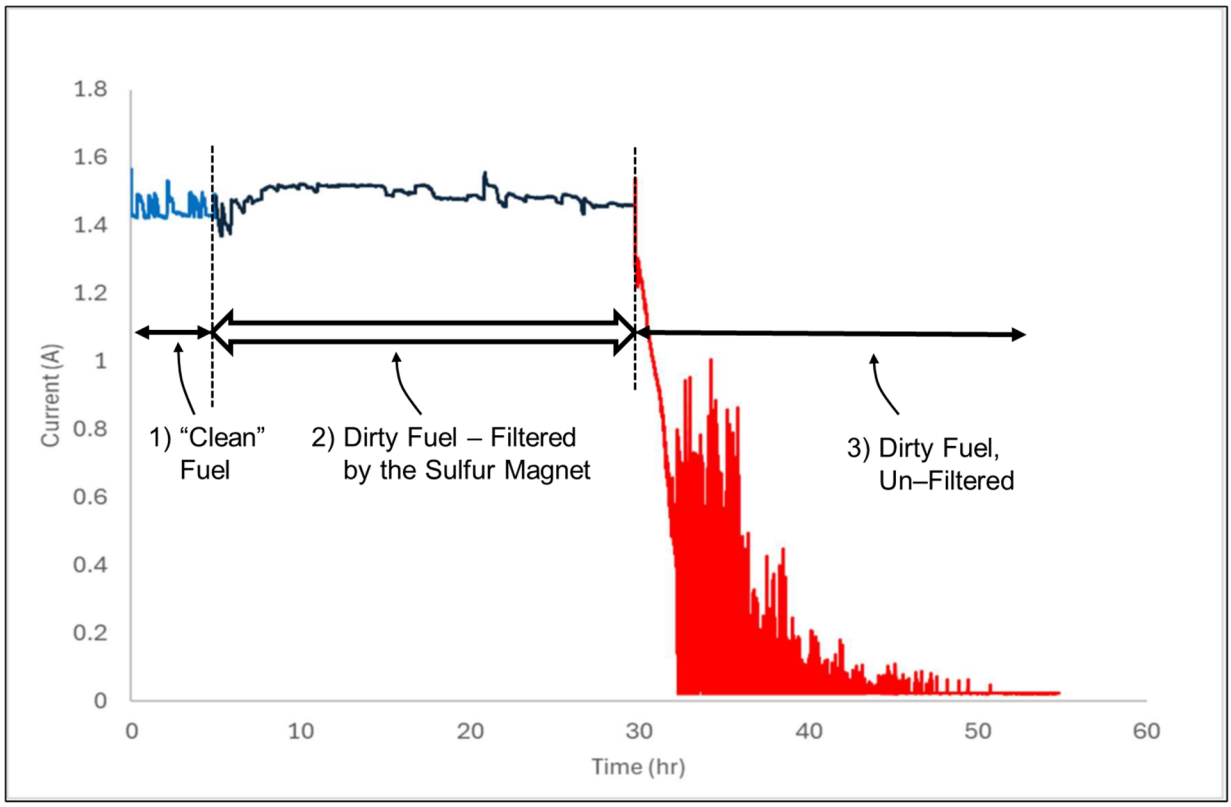

Figure 1. PEM fuel cell performance with 1) 'clean' fuel, 2) dirty fuel filtered with the H2 Final Filter, and 3) dirty fuel unfiltered.

Figure 1 presents the record of the current produced by the PEM fuel cell under the 3 conditions described above. With the 'clean' fuel (1) the current was measured at about 1.4 amps which is typical performance for this type of cell. In step (2), when the cell was fed H_2S containing fuel that had been cleaned by the H2 Final Filter, the current

remained unchanged at about 1.4 amps. ***The H2 Final Filter completely removed the sulfur and protected the platinum anode against sulfur poisoning***. When fuel containing 5 ppm H_2S was allowed to enter the cell (3) the current dropped precipitously and continued to degrade irregularly for another 25 hours. After the cell had degraded under unfiltered H_2S, the fuel was switched back to 'clean' fuel to see whether the performance would recover, but no recovery was observed, indicating irreversible damage had occurred.

Polarization curves are like 'fingerprints' of the condition of the cell. Cell polarization curves (current vs voltage) were recorded after operation for 5 hours on clean fuel and after 25 hours of operation on contaminated fuel filtered by the H2 Final Filter; they are compared in Figure 2. Polarization curves taken after operation with clean fuel and after operation with contaminated fuel cleaned by the H2 Final Filter were essentially indistinguishable. There was no measurable negative effect on cell performance attributable to gas passing through the filter over the ~30 hours tested (5 hours clean fuel + 25 hours filtered dirty fuel). A post-test polarization curve after exposure to unfiltered 5 ppm H_2S could not be obtained because the cell had degraded due to sulfur poisoning of the platinum anode to the point that it could not provide meaningful output.

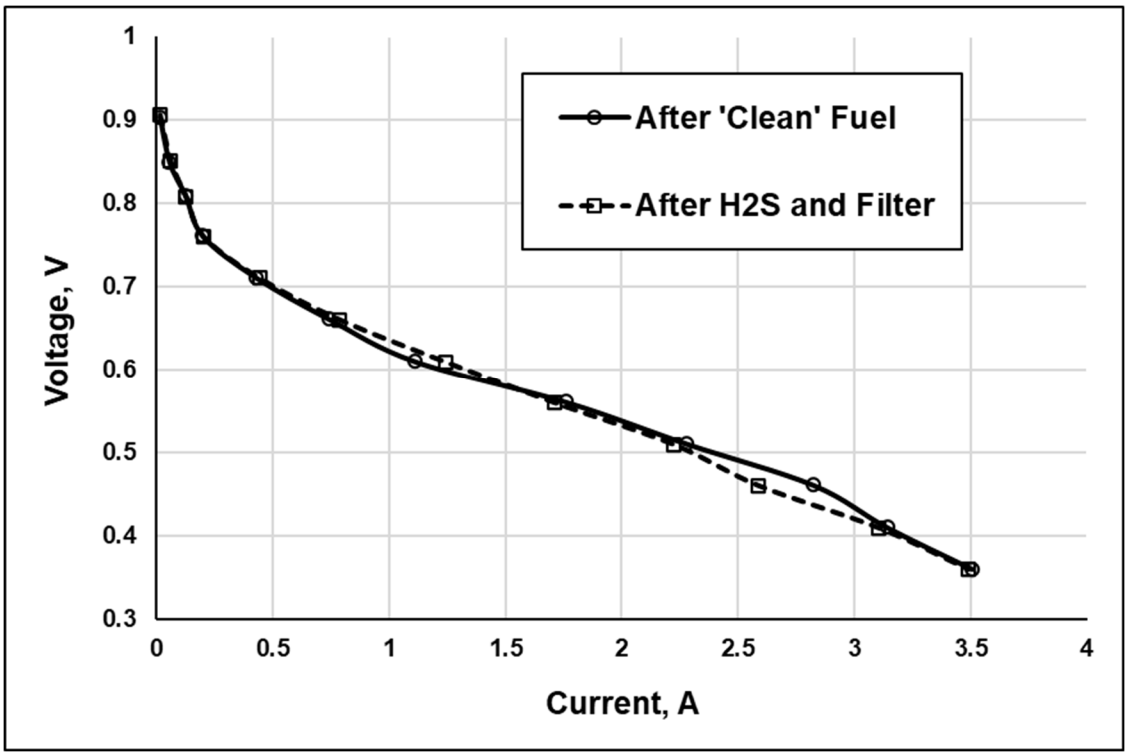

Figure 2. Comparison of polarization with 'clean' fuel vs filtered dirty fuel.

Significance for PEM fuel cell applications

1. **Protection from low-level sulfur is essential.**

The fact that 5 ppm unfiltered H_2S completely killed the cell, with no recovery, highlights that typical PEM fuel cells cannot tolerate even a few ppm of sulfur in their fuel. Any real-world system using fuel that may contain sulfur (from reformers, industrial gas sources, pipeline gas, etc.) will require effective sulfur cleanup.

2. **The Final Filter can provide robust protection**

During 25 hours of continuous feed with 5 ppm H_2S in the H_2 fuel that is cleaned by the H2 Final Filter, the cell performance was indistinguishable from operation on 'clean' hydrogen. This proves that the H2 Final Filter can remove sulfur to levels that are harmless to the PEM anode.

Where this matters in practice

The implications of these results differ by application and by fuel quality.

1. **Fuel-cell systems using high-purity hydrogen** (e.g., cylinders, well-controlled industrial sources), that are typically already low in sulfur (1-10 ppb), can be protected against poor quality gas and can have their useful lives extended. The benefits include risk reduction and cost savings.
2. **Systems that use hydrogen from reformers or mixed-fuel** processing (SMR, ATR, gasifiers) often contain 100+ ppm of sulfur that conventional desulfurization may reduce to the ppm range. The H2 FINAL FILTER could be placed downstream of the primary cleanup system to ensure that the fuel entering the PEM stack is effectively sulfur-free, greatly extending stack life.
3. **Backup power and stationary systems intended for remote or industrial sites** see more variable fuel quality. A robust sulfur filter provides resilience against fuel quality swings. The H2 Final Filter is a relatively simple hardware addition that prevents sudden stack loss due to unanticipated sulfur spikes.
4. **High-value, high-uptime applications** (data centers, telecom, critical infrastructure, semiconductor manufacture) where the cost of losing a stack or batch of product is very high would be protected by the H2 Final Filter.

This test included a real, commercially relevant PEM fuel cell generating electricity from hydrogen and air that showed no impact of sulfur in the feed when the H2 FINAL FILTER was in place; that is the difference between normal operation and a total stack replacement.

H2 FINALFILTER® Enables Clean Energy

The H2 FINAL FILTER with the SULFUR MAGNET technology represents a step-change for PEM fuel cell users. The H2 Final Filter:

- Completely prevents sulfur poisoning of a PEM fuel cell even when the incoming fuel contains significant concentrations of H_2S.
- Allows the safe processing of opportunity feedstocks with higher or variable sulfur content, such as biogas
- Delivers hydrogen meeting the most stringent fuel-cell purity specifications (ISO 14687 Type D/E) without additional purification steps

By eliminating trace sulfur — the primary life-limiting factor in a PEM fuel cell — the H2 FINAL FILTER has the potential to accelerate *The Hydrogen Economy* while maximizing the value and sustainability of PEM fuel cell vehicles already in service and enabling further adoption of fuel cell technology. PEM fuel cells will be fueling vehicles for decades to come, and the SULFUR MAGNET is helping to pave the way to a low-carbon, clean-energy future.

H_2 Final Filter®

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