

Special Edition – December 2025

Path to Sustainability

Harnessing Hydrogen

Recent developments

Curated and summarized - Industry and Patent news

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Preface

There is a major transformation taking place in the global energy landscape as countries try to reduce carbon emissions and mitigate the impact of climate change. Hydrogen, a clean and versatile energy carrier, is emerging as a promising solution for a sustainable future. Its applications are diverse, ranging from powering vehicles and generating electricity to fueling industrial processes. The hydrogen ecosystem is rapidly evolving, with innovations emerging across the entire value chain.

This monthly report is focused on **“Hydrogen as a fuel”** including applications in transportation, manufacturing industries and energy sector. This report is a free resource for anyone working in this domain including technologists, innovators, Intellectual Property (IP) managers, strategy makers, environmental enthusiasts, etc. The report contains curated insights and summaries of the latest news and key patents published in the last one month, including the latest products, business updates, collaborations, new innovations, and more.

Special Edition

This special edition report highlights the vital role of hydrogen standards in accelerating market growth and de-risking large-scale deployment. Clear, harmonized frameworks give investors confidence, support cross-border trade, and ensure that emerging hydrogen infrastructure can scale efficiently and safely. By guiding technology development and interoperability, these standards also create a more competitive and innovation-driven global hydrogen ecosystem. This month's report includes the following content:

- [Hydrogen Regulatory Landscape](#)
 - [Published Hydrogen Standards](#)
 - [Global Adoption Landscape](#)
 - [Hydrogen Standards Under Development](#)
 - [How Countries Are Expanding Beyond ISO Standards](#)
- [Industry news](#)
- [Patents of the month](#)

Key Insights this month

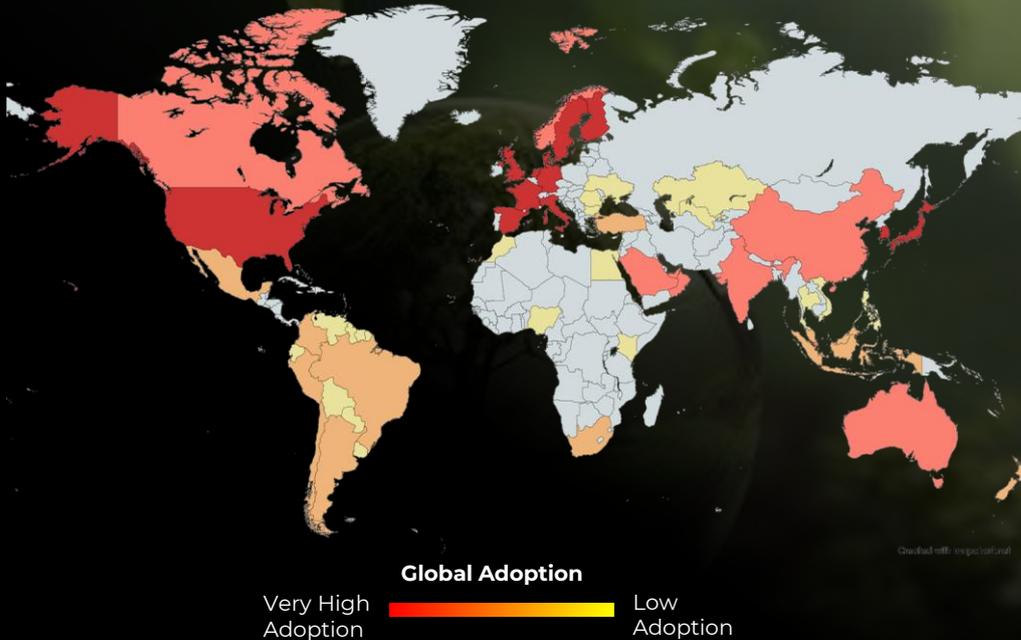
- ❑ The hydrogen regulatory landscape is expanding quickly, and the standards are becoming a crucial enabler for capital investment and accelerated commercialization. By prioritizing refuelling and operational standards, countries are laying the infrastructure backbone required to unlock large-scale mobility, cross-border hydrogen trade, and industrial adoption.
- ❑ Upcoming standards on safety, infrastructure, and GHG accountability will define future market access and competitive positioning. Proactive regulatory engagement and early alignment with draft frameworks will reduce uncertainty, de-risk capital decisions, and sets the stage for faster commercialization across transport, energy, and heavy-industry value chains.
- ❑ Reaching an €8/kg price point demonstrates that hydrogen trucking is approaching cost competitiveness with diesel, signalling a pivotal shift toward commercially viable zero-emission freight. This milestone strengthens investor confidence, accelerates fleet-level adoption, and validates the economic feasibility of hydrogen logistics infrastructure.
- ❑ Ohmium's reduction in iridium use directly lowers one of the biggest PEM stack cost drivers, as iridium typically accounts for 20–30% of stack material expense. Cutting reliance on this scarce precious metal reduces both CAPEX and supply-chain risk, making PEM electrolyzers more economically scalable. This improvement strengthens the long-term cost trajectory of green hydrogen and supports faster market adoption.
- ❑ Many inventions published last month while a few were revolving around the theme of fuel optimization. One invention maintains optimal platinum-oxide levels in the fuel cell by dynamically adjusting operating parameters to prevent degradation and ensure stable performance. The other uses an AI-based hybrid power system that switches between the fuel cell and battery for higher efficiency, reduced strain, and improved reliability.



◀ Hydrogen Regulatory Landscape

Standard Published	Description	Publication Year
ISO 22734-1	Hydrogen generators using water electrolysis - Safety requirements for on-site hydrogen production systems.	2025
ISO 14687	Hydrogen fuel quality - Product specifications defining purity requirements for hydrogen used in fuel cell applications.	2025
ISO 17268-1	Gaseous hydrogen land-vehicle refuelling connection devices - Flow capacities up to and including 120 g/s.	2025
ISO 19881	Gaseous hydrogen - Land-vehicle fuel containers (design and safety).	2025
ISO 19885-1	Gaseous hydrogen - Fuelling protocols for hydrogen-fuelled vehicles, part 1: Design & development process for fuelling protocols.	2024
ISO 16111	Transportable gas storage devices - safe handling, storage, and transport of hydrogen in metal hydride form	2024
ISO/TS 19870	Hydrogen technologies - Methodology for determining greenhouse gas emissions associated with production, conditioning, and transport of hydrogen (GHG assessment at the consumption gate)	2023
ISO 19880-1	Gaseous hydrogen - General requirements for fuelling stations, covering design, safety and operation.	2020

The hydrogen regulatory landscape is still in its early stages but is rapidly expanding. The current ISO hydrogen standards collectively signal a decisive industry shift toward global harmonization, safety-first deployment frameworks, and the scaling of mobility infrastructure such as hydrogen refuelling stations.



The map shows the global adoption of key ISO hydrogen standards

- **ISO 16111** – Transportable gas storage for hydrogen
- **ISO 17268** – Refuelling connection devices
- **ISO 14687** – Hydrogen fuel quality requirements
- **ISO 19881** – Hydrogen vehicle fuel containers

Countries are adopting safety and refuelling standards first because these create the essential foundation for safe hydrogen handling, public acceptance, and scalable mobility infrastructure enabling future expansion into production, certification, and global trade.

Standard Under Development	Description
ISO/WD TS 22734-2	Hydrogen generators using water electrolysis - testing protocols for water electrolyser systems with the focus on alkaline and PEM water electrolysers.
ISO/DIS 13985	Liquid hydrogen Land vehicle fuel storage system - construction requirements for refillable fuel tanks for liquid hydrogen used in land vehicles
ISO/DIS 19870-2	Hydrogen technologies - GHG emissions methodology for conditioning and transport of liquid hydrogen up to the consumption gate.
ISO/DIS 19870-3	Hydrogen technologies - GHG emissions from bi-directional conversion between hydrogen and ammonia (incl. transport) to consumption gate.
ISO/DIS 19870-4	Hydrogen technologies - GHG emissions for Liquid Organic Hydrogen Carrier (LOHC) conversion, conditioning & transport to consumption gate.
ISO/DIS 19884-1	Gaseous hydrogen - Pressure vessels for stationary storage; requirements for the design, manufacture and testing of pressure vessels
ISO/FDIS 13984	Liquid hydrogen - characteristics of liquid hydrogen refuelling and dispensing systems on land
ISO/TS 15916	Hydrogen technologies - Basic considerations for the safety of hydrogen systems

WD = Working Draft, DIS = Draft International Standard; FDIS = Final DIS; TS = Technical Specification

Several hydrogen standards are still under development, reflecting the sector's rapid evolution. These upcoming standards will shape future requirements for safety, infrastructure, and GHG accountability.

Canada

CSA (Canadian Standards Association) develops 100+ hydrogen ecosystem standards, covering production, pipelines, refueling, and safety. Closely aligned with ISO/TC 197. Key Domains:

- Hydrogen production
- Fueling infrastructure
- High-pressure equipment
- Pipelines and transport safety

European Union

The EU is developing its own hydrogen standards; many harmonized with ISO but adapted for EU regulatory needs. The standards are underdevelopment for

- GHG accounting,
- Electrolyzer general requirements
- Built-environment safety

United States

US develops hydrogen standards through **NFPA, SAE, and CSA/ANSI**, which operate in parallel with ISO.

- NFPA 2 – Hydrogen Technologies Code
- SAE J2601 – Fueling Protocols for Light/Heavy-Duty Hydrogen Vehicles

Japan

Japan contributes heavily to ISO but also develops national hydrogen technical regulations on:

- Hydrogen fueling protocols,
- Safety regulations for vehicle fuel systems,
- Liquid hydrogen handling standards



NFPA – National Fire Protection Association
SAE – Society of Automotive Engineers

Countries are now developing their own hydrogen standards that align with ISO while reflecting national regulatory needs, creating a balance between global interoperability and domestic priorities.

◀ Industry News

H2 Motorsport Innovation

Pushing hydrogen engine technology to new heights in the super Taikyu series final race

Toyota showcased its liquid hydrogen-powered GR Corolla H2 at the ENEOS Super Taikyu Series finale, highlighting major advancements in hydrogen engine technology, including upgraded filling valves, a superconducting hydrogen pump, and real-time monitoring systems. The vehicle demonstrated impressive endurance by completing a 24-hour stint without a pump replacement, validating durability and efficiency gains from the superconducting pump which increases usable tank capacity and minimizes boil-off. Toyota also demonstrated hydrogen combustion-switching technology, allowing transitions between high-power and lean-burn modes for better performance and efficiency. Overall, the event emphasized Toyota's multi-pathway carbon-neutrality strategy and strengthened the case for hydrogen combustion in motorsport and future mobility



Zero-Emission Airlander

ZeroAvia and Hybrid Air Vehicles (HAV) sign agreement to collaborate on zero-emission Airlander

ZeroAvia and HAV are developing a hydrogen-electric Airlander 10 by installing ZeroAvia's 600 kW ZA600 powertrains in the hybrid aircraft combining aerostatic and aerodynamic lift with vectored thrust. The Airlander 10 can carry a 10-ton payload and fly 4,000 nautical miles, already cutting emissions by up to 90% in its diesel version, while the hydrogen-electric upgrade targets fully zero-emission flights for over 100 passengers. The large internal hull volume of the Airlander makes it well-suited for hydrogen storage, enabling adoption of first-generation certified hydrogen technologies. With major regulatory milestones and hundreds of ZA600 pre-orders, ZeroAvia will work with HAV on hydrogen-fuel infrastructure and future propulsion applications. Together, they aim to accelerate commercial hydrogen-powered aviation using HAV's hybrid platform and ZeroAvia's hydrogen-electric technology.



Hydrogen Cost Shift

Hylane and H2 MOBILITY enable cost-effective operation of hydrogen trucks

Hylane and H2 MOBILITY have reached a major milestone by offering hydrogen refuelling for heavy-duty trucks at around €8 per kilogram, bringing hydrogen trucking closer to cost parity with diesel. From January 2026, Hylane customers can access this reduced price at selected high-capacity H2 MOBILITY stations in Düsseldorf and the Rhine-Neckar region, supported by guaranteed offtake volumes, efficient station utilisation, and locally produced green hydrogen delivered over short distances to cut costs and emissions. These stations along key freight corridors ensure reliable daily operations and make hydrogen trucking more commercially viable, especially when combined with Germany's toll exemption for zero-emission trucks until 2031. Together, the partnership shows that hydrogen trucks can be both environmentally sound and economically practical, marking a meaningful step for low-carbon heavy-duty transport.



Iridium Usage Milestone

Ohmium Breaks Barriers: Exceeds 2030 industry targets of 10 GW/ton to achieve 18 GW/ton iridium utilization

Ohmium International Inc. announced that it has surpassed the electrolyzer industry's 2030 target of 10 GW per ton by achieving an impressive 18 GW per ton iridium utilization rate, enabled by a 50% reduction in iridium use in its Lotus Mark 2 PEM electrolyzer. This breakthrough significantly enhances the cost-competitiveness of green hydrogen production by lowering reliance on iridium, one of the most expensive materials in electrolyzer manufacturing. Ohmium also highlighted its high system efficiency of 48 kWh/kg, contributing further to reduced green hydrogen costs. The company aims to push utilization efficiency to 36 GW/ton within a year and move toward near-zero iridium usage within a decade, marking a major milestone for scalable PEM electrolyzer technology. This progress supports wider adoption of green hydrogen solutions and advances the global shift to a low-carbon energy system.

Source: [Ohmium](#)



PowerCell Portfolio Launch

PowerCell launches first products in its new power generation portfolio

PowerCell has launched the first products in its new Power Generation portfolio, marking the company's largest product introduction to date and aiming to meet growing demand for reliable, zero-emission power across data centers, distributed energy systems, backup power, and other mission-critical applications. The portfolio integrates Bosch's industrial fuel-cell platform with PowerCell's system-integration expertise and Distributed Master Controller to deliver high-efficiency, scalable solutions. It includes two product families: PowerSystem solutions for OEMs and EPCs such as the PowerSystem 190, PowerSystem 225 (including liquid-hydrogen capability), and M2PowerSystem 250 methanol-to-power module, and PowerPod solutions, which are fully integrated, containerised, plug-and-play fuel-cell units designed for rapid deployment and dependable zero-emission power in off-grid, mobile, or backup applications.



The editor's shortlist



◀ Patents of the month



Patents of the month

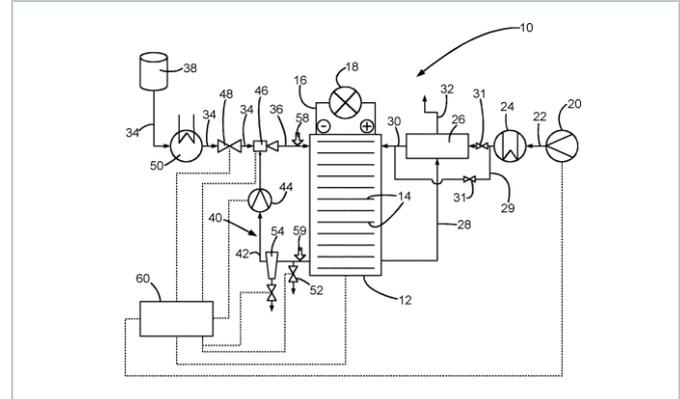
Published in Nov 2025

Shortlisted and summarized by our analyst

- [US12469867B2](#) - Method for controlling the platinum oxide content in a fuel cell and fuel cell system for a motor vehicle
Assignee: Audi AG (Germany)
- [US12463450B2](#) - Backup power supply for emergency communication in a fully discharged fuel cell electric vehicle
Assignee: Hyundai Motor Company, Kia Corp (Korea)
- [US2025360803A1](#) - System and method for optimizing performance in fuel cell electric vehicles
Assignee: Jio Platforms Ltd (India)
- [US2025357496A1](#) - Electrochemical device suitable to work both as electrolyser and fuel cell
Assignee: National Research Council, Miprons SRL (Italy)
- [EP4649184A1](#) – Electrolyser and method for its operation
Assignee: Stiesdahl Hydrogen AS (Denmark)
- [EP4650486A1](#) - Membrane-electrode-frame-assembly for ion exchange membrane electrolyser, electrolyser cell stack and method of manufacturing
Assignee: AVL Fuel Cell Canada Inc (Canada), AVL List GMBH (Austria)
- [EP4647534A1](#) - Plate assembly, electrolyser and method for producing a plate assembly
Assignee: Schaeffler Technologies AG (Germany)
- [IN202441081692A](#) - Agri-composite polymer liner material for high-pressure gas storage vessels and its manufacturing process
Assignee: Gudlyf Mobility Pvt Ltd (India)
- [JP7770354B2](#) - Separation System
Assignee: Honda Motor Co Ltd (Japan)
- [CN119022220B](#) - Liquid hydrogen pressurizing gasification type liquid hydrogen hydrogenation station and operation control method
Assignee: Tongji University (China)

◀ **US12469867B2** Green

Method for controlling the platinum oxide content in a fuel cell and fuel cell system for a motor vehicle



This invention focuses on keeping the platinum oxide level in a fuel cell at the right balance, so the fuel cell lasts longer and performs well during different driving conditions. During vehicle operation, platinum oxide can either build up too much, causing fast aging when moisture is high or drop too low, which makes the fuel cell produce excessive power that is hard to manage in real driving situations. To address this, the invention continuously calculates the current platinum oxide level using a control model and adjusts it by changing factors like voltage, air supply, power output, battery use, load transitions, and humidity. By making these targeted adjustments, it helps prevent platinum loss, avoids early degradation, and ensures stable, efficient operation of the fuel cell in a motor vehicle.

Company name Audi AG (Germany)

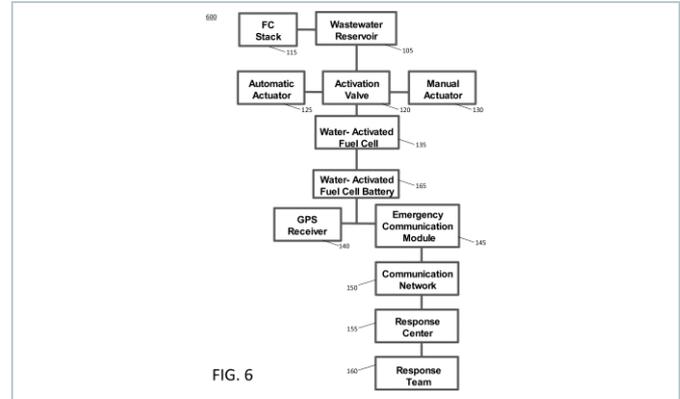
Inventors Ruf Markus,
Staub Hannah

Priority date 07-Oct-2020

Publication date 11-Nov-2025

US12463450B2 Green

Backup power supply for emergency communication in a fully discharged fuel cell electric vehicle



The invention provides a safety feature for fuel cell electric vehicles that become fully drained of hydrogen and battery power, leaving drivers unable to call for help. It introduces a backup setup that stores wastewater from the main fuel cell and uses it to activate special water-powered fuel cells when the vehicle has no remaining energy. By opening an activation valve, automatically or manually, the wastewater flows into these auxiliary fuel cells, generating enough electricity to run a GPS tracker and a communication unit. This allows the stranded vehicle to send its coordinates and an emergency message to rescue services through available networks. The design ensures a reliable way to request help even when the vehicle has zero charge, no fuel, and no working personal phone.

Company name Hyundai Motor Company, Kia Corp (Korea)

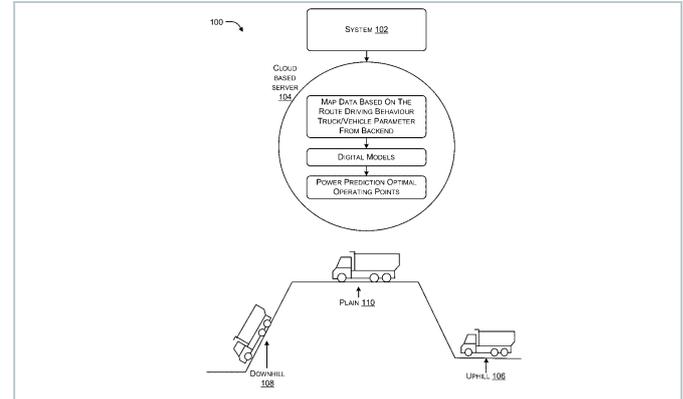
Inventors Delker Victoria,
Christiana Amanda,
Molnar John

Priority date 26-Sep-2023

Publication date 04-Nov-2025

US2025360803A1

System and method for optimizing performance in fuel cell electric vehicles



The invention describes an intelligent hybrid power setup for vehicles that improves energy use by switching between a hydrogen fuel cell and a battery based on real-time driving conditions. An onboard AI engine collects information from many sensors such as road slope, braking, speed, battery charge, fuel level, weather, and vehicle load and uses this data to understand the vehicle's current state. It then selects the most efficient power source at any moment, helping the vehicle save fuel and reduce strain on components. The AI also predicts potential failures by analyzing patterns related to wear or heavy usage, allowing problems to be identified before they cause breakdowns. This approach ensures smoother performance, better efficiency, and more reliable operation across different driving scenarios.

Company name Jio Platforms Ltd (India)

Inventors Rajesh Booravalli Seetharama Sastry,
Satya Prakash Pandey,
Bipul Kumar,
Gulprit Singh

Priority date 25-May-2024

Publication date 27-Nov-2025

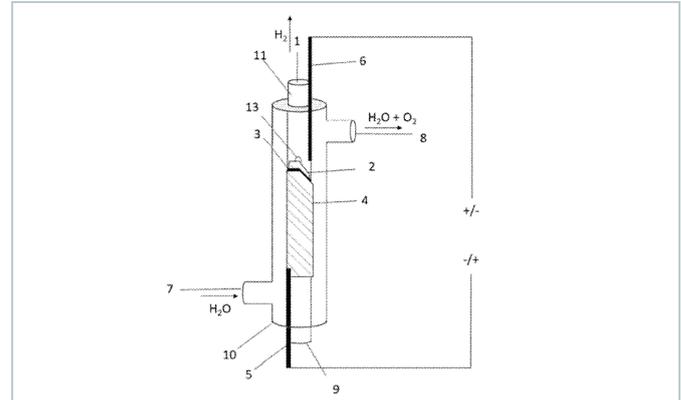




US2025357496A1

Green

Electrochemical device suitable to work both as electrolyser and fuel cell



The invention describes a reversible electrochemical device that can operate both as an electrolyzer to produce hydrogen from water and as a fuel cell to generate electricity from hydrogen, combining two separate functions into one unit. It features a tubular central electrode with openings for gas and fluid flow, surrounded by a gas diffusion layer (GDL) and a catalyst-coated membrane arranged in a wound structure to support efficient ion exchange. This design uses materials and configurations that allow smooth switching between modes while maintaining performance and minimizing wear over repeated cycles. By integrating both processes into a single device, the invention increases versatility and reduces the need for separate equipment, lowering overall complexity and cost.

Company name National Research Council, Miprons SRL (Italy)

Inventors Figoli Alberto,
Jansen Johannes Carolus,
Fontananova Enrica,
Esposito Elisa, Jerace Roberto, Longo
Mariagiulia, Minotti Angelo

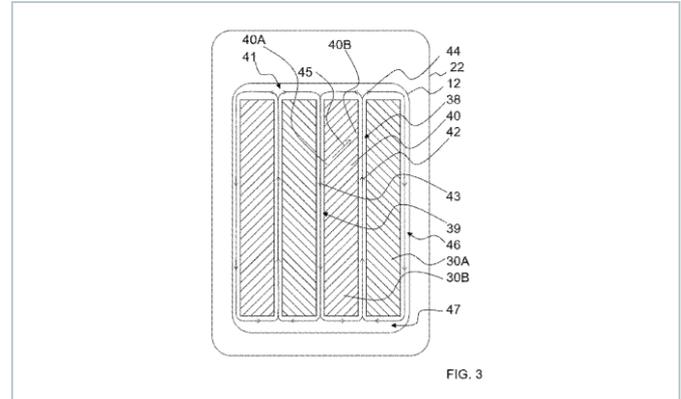
Priority date 07-Jun-2022

Publication date 20-Nov-2025



EP4649184A1 Green

Electrolyser and method for its operation



The patent addresses issues in alkaline electrolyser where high electrolyte flow rates are needed for heat removal and uniformity, forcing large conduits that create shunt currents and limit stack voltage. The invention introduces an electrolyser stack with bipolar metal separator plates embossed to form raised minor gas channels within major channels in a herringbone pattern, enabling bubble-driven internal electrolyte circulation inside electrode chambers without external pumping. Gas bubbles rising through the inclined minor channels entrain electrolyte into vertical major channels, providing effective mixing and cooling while allowing lower external flow rates. This design reduces shunt currents, supports smaller feed conduits, and enables higher stack voltages to improve efficiency and system cost.

Company name Stiesdahl Hydrogen AS (Denmark)

Inventors Stiesdal Henrik,
Voigt Niels Vinter,
Jensen Thomas T Ttrup

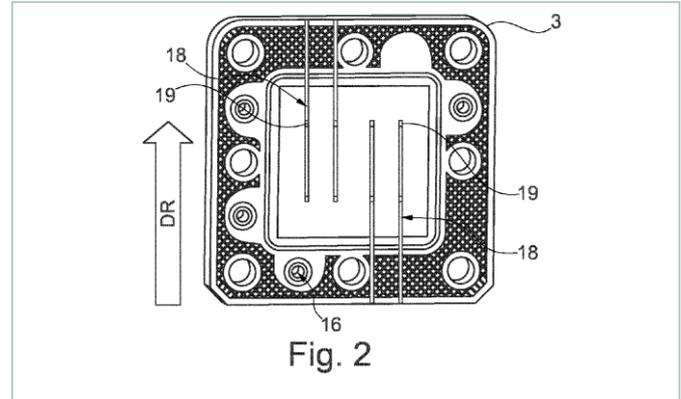
Priority date 13-Jan-2023

Publication date 19-Nov-2025



EP4647534A1 Green

Plate assembly, electrolyser and method for producing a plate assembly



The patent tackles the difficulty of accurately measuring temperature inside compact electrochemical cell stacks, where installation space for sensors is limited. It introduces a 3D-printed multilayer plate element with perforated layers of varying fineness, enabling coolant channels in coarser layers and porous transport layers near the active membrane. A temperature sensor routed through reserved recesses passes across multiple layers and sits adjacent to the finest structured layer to detect local temperatures close to reaction sites with high precision. This integrated design improves measurement accuracy, optimizes space usage, and combines multiple functional layers coolant flow, fluid transport, and sensing within a single component.

Company name Schaeffler Technologies AG (Germany)

Inventors Schaeperkoetter Claus,
De Brouwer Benno

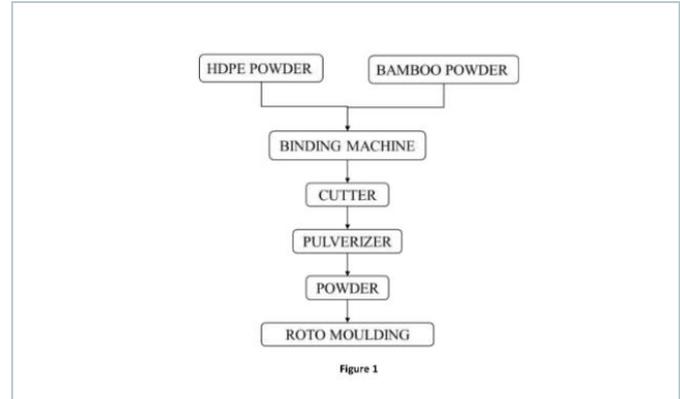
Priority date 06-May-2024

Publication date 12-Nov-2025



◀ IN202441081692A

Agri-composite polymer liner material for high-pressure gas storage vessels and its manufacturing process



The patent describes a sustainable agri-polymer composite liner for Type IV hydrogen storage cylinders, created by blending chemically treated bamboo dust with HDPE (High-density polyethylene), PA6, or PA11 to enhance bonding, strength, and hydrogen-barrier performance. The composite is compounded and rotationally moulded into seamless liners with improved gas impermeability, dimensional stability, and thermal resistance. Mechanical tests confirm strong tensile, flexural, and impact properties, while microstructural, permeation, and Raman analyses show reduced voids, higher crystallinity, low hydrogen diffusivity, and far lower permeability than pure HDPE. The material also offers better creep resistance, long-term hydrogen retention, and roughly 25% cost savings from the renewable filler.

Company name Gudlyf Mobility Pvt Ltd (India)

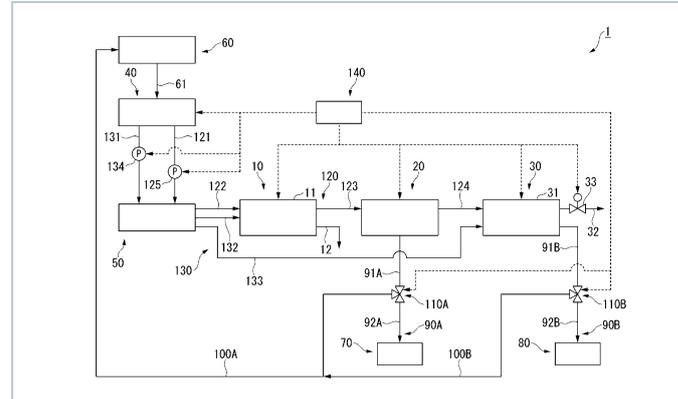
Inventors Dr Ajeet Babu Kumar Parasumanna,
Kumar P S,
Dr Kamal Kishore Vora

Priority date 26-Oct-2024

Publication date 14-Nov-2025

JP7770354B2 Green

Separation System



This patent describes a hydrogen-isotope separation system used with water electrolyzers and fuel-cell-type separators, designed to prevent unreacted or partially separated fluids from leaking during shutdown. It prevents unreacted or partially separated isotope-containing fluid from leaking during shutdown. The setup includes an electrochemical first separator, a gas-liquid separator, a second fuel-cell-like separator, and return paths that send remaining liquid back into internal storage. A control unit handles valve switching, pressure balancing, and membrane sealing so all fluids stay contained. Cooling controls prevent freezing and maintain separation performance. Overall, the invention enables safe, leak-free shutdown of isotope-separation systems integrated with electrolyzer and fuel-cell components.

Company name Honda Motor Co Ltd (Japan)

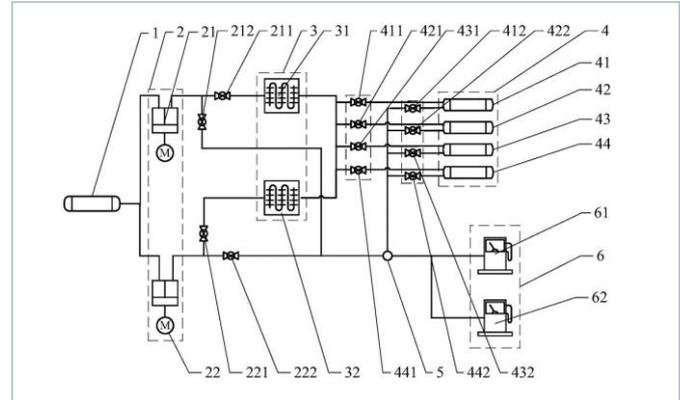
Inventors Furusawa Koichiro,
Murata Naotaka,
Takahashi Kazuyuki,
Uenodai Asao

Priority date 30-Mar-2023

Publication date 14-Nov-2025

◀ **CN119022220B** Green

Liquid hydrogen pressurizing gasification type liquid hydrogen hydrogenation station and operation control method



The patent describes a liquid hydrogen refueling setup that improves the efficiency, speed, and safety of filling fuel cell vehicles at very high pressures. It integrates a liquid hydrogen source with booster pumps, gasifiers, graded high-pressure storage bottles, a temperature-mixing tank, and a hydrogenation unit, all coordinated by a central controller. The setup allows liquid hydrogen to be pressurized, gasified when needed, stored at varying pressures, and blended at controlled temperatures before reaching the vehicle. By dynamically switching connections among pumps, storage bottles, and gasifiers, it supports flexible filling modes for different vehicle pressures while improving storage bottle use and reducing station size and cost. This enables faster, continuous high-flow fueling and more reliable operation than existing stations.

Company name Tongji University (China)

Inventors Ue Mingzhe,
Yang Jingcheng,
Zhang Cunman,
Wu Hao

Priority date 23-Aug-2024

Publication date 18-Nov-2025

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